European Tree Technician

STUDY GUIDE

Edited by Bregt Roobroeck

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Tree
Technician

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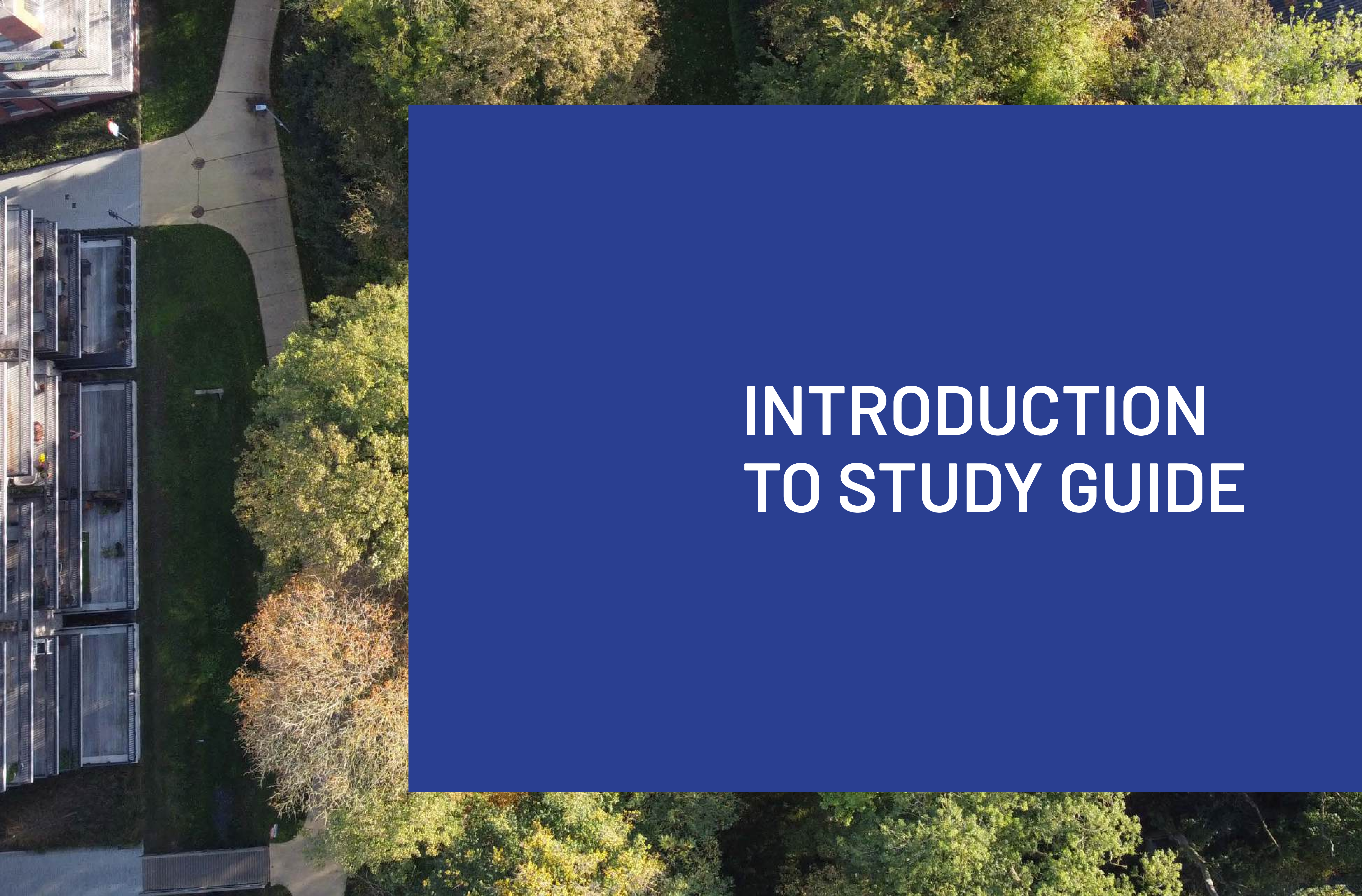


INTRODUCTION TO STUDY GUIDE

WHAT IS THE STUDY GUIDE ALL ABOUT

Bregt Roobroeck

This study guide on arboriculture provides a comprehensive pathway for learning about the captivating world of trees. Arboriculture, the science and art of managing trees, opens a doorway to understanding, among other things, how tree ecosystems function, how trees grow, and how they interact with the environment.

The study guide has been developed by a highly specialist pan-European arborist group, which has decades of experience in all arboricultural – and some urban forestry – disciplines. The knowledge they lay out in the following chapters is supported by scientific research and is presented together with practical information on how specific tasks should be carried out.

We are careful to underpin the texts we have written because knowledge should be verified through the scientific method and not by a single guru or solely on best practices. This means we want to bring that philosophy of respecting peer-reviewed information to you by encouraging you to always justify your conclusions or advice on tree-related matters.

Note that this study guide is not a practical handbook like the ETW handbook, as here we focus more on the *why* than the *how*. Be aware, too, that this study guide is not an all-inclusive summary of knowledge on state-of-the-art arboriculture. That would be too ambitious project, as the information on this field of study is vast, scattered, and already set down in very good standard textbooks.

So, what then is the added value of this study guide? Well, we have tried to bring true meaning to the word 'guide' as this study guide is not your average textbook on trees or arboriculture. First of all, in a world in which overwhelming amounts of data are available at the touch of a keyboard or swipe of a screen, this guide can help you discern what is trustworthy information and what is not. Moreover, as this guide is structured according to the ETT curriculum of the European Arboricultural Council (EAC), it means that we elaborate on all the chapters of the ETT curriculum as we lead you through the relevant topics. This is, therefore, good material for studying for the ETT exam.

Secondly, at the beginning of each chapter, we state the essence of the topic to be covered. This is a crucial part of finding your way through the vast maze of arboricultural information. It helps set the compass for each chapter by stating what is truly essential and what is not, thereby helping you filter out irrelevant information.

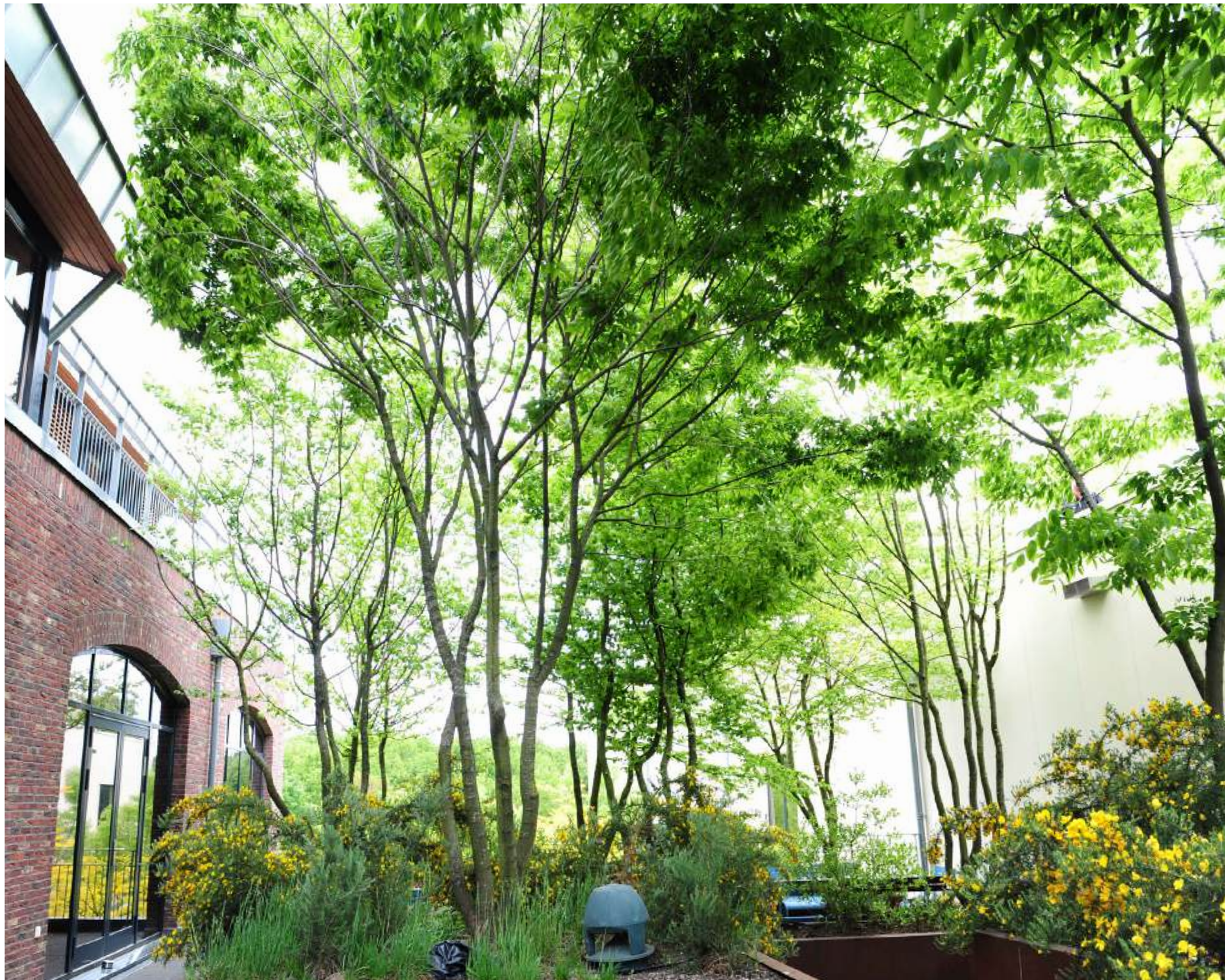
Thirdly, in order to bring the material to life, we have attempted to create a storyline within each chapter. This not only helps anchor the information within a narrative, but it also helps you, the reader, get inside the heads of experienced arborists to see how they think about various tree-related scenarios.

Finally, we have summarised the essential information in each chapter and included additional references, together with extra information that will assist you should you be inspired to delve deeper into the topics.

To conclude, the study guide will benefit you due to the:

- structured chapters that follow the ETT curriculum;
- clear overviews of the essence of each chapter;
- comprehensive storylines that bring the material to life; and
- a summary of the essential information, together with additional references.

For these reasons, we believe this guide is the best way for you to begin your journey towards your ETT certificate.



THE ROLE OF AN ETT IN MODERN ARBORICULTURE

What is Modern Arboriculture?

Bregt Roobroeck

WHAT IS MODERN ABORICULTURE?

Modern arboriculture is based on informed and structured management according to certain data, visions, objectives, and plans. All this is framed in the larger context of urban development and/or landscape management. This means that when it comes to tree care, shared goals are achieved through multidisciplinary consultation and cooperation. Sustainable tree care, seen from a human perspective, attempts to facilitate and maintain the associated natural processes throughout the tree's various life stages, bringing true meaning to the words "sustainable arboriculture". A balance is, therefore, sought that both improves the quality of life of the individual and benefits future generations of people and trees.

Investments are made with the aim of maximising returns based on set objectives. Therefore, objective data based on precisely measurable parameters and a thorough analysis are essential in the future arboriculture. To summarise in a philosophical vein, an ETT is a stakeholder who interprets the voice of the trees to help them live in a sustainable way through all the natural processes in our society in which trees are involved. To be able to do this, an ETT has to understand the tree.

WHAT ARE THE CHALLENGES OF MODERN ARBORICULTURE?

There are numerous challenges facing people working in the field of modern arboriculture, but the most important ones are discussed below:

Climate Change:
Rising temperatures and changes in the amount of available water require a lot of adaptability from trees. Not every tree in every location is able to adapt to this. Also, we need to maximise tree ecosystem services to create liveable cities that can mitigate the harmful effects of climate change.

Biodiversity Loss:
Animals and plants naturally live in association with each other according to a balanced eco-system. Due to our human influence on our urban environment, the number of associated organisms belonging to the tree's own ecosystem has greatly diminished. The more diverse the ecosystem, the easier it is to adapt and the less vulnerable it is. Trees can function as anchor points or hot spots for biodiversity.

WHAT ABOUT THE ETT IN URBAN FORESTRY?

Although arboriculture and urban forestry are related fields that focus on the care, management, and study of trees in urban environments, they have distinct emphases and goals. Arboriculture is more about managing an individual tree or a small group of trees and the surrounding ecosystem. Urban forestry, or urban forest management, is the science, technology, and skill set required to manage trees and their ecosystem services in an urban environment. So urban forestry, in contrast to arboriculture, takes a broader perspective by considering the entire urban forest ecosystem, which includes not only individual trees but also the interactions between trees, other vegetation, wildlife, humans, and the built-up environment. Urban forestry, therefore, is concerned with the planning, management, and maintenance of trees and green spaces on a larger scale. It aims to create sustainable and healthy urban environments by addressing issues like air and water quality, energy conservation, carbon sequestration, biodiversity, and community engagement. Urban foresters work to develop comprehensive strategies and policies for managing urban forests, often collaborating with various stakeholders to enhance the overall quality of life in cities and towns.

In summary, the main difference between arboriculture and urban forestry lies in their scope and focus. Arboriculture centres on the care of individual trees, while urban forestry encompasses a holistic approach to managing the urban forest ecosystem for the benefit of both human and environmental well-being. As you will intuitively figure out, arboriculture and urban forestry are, in practice, closely tied together and will need to work more closely together in the future as both disciplines naturally converge with one another. In this Study Guide, we strive to bring this merger about.

Integration into Urban Infrastructure:
As mentioned earlier, the aim is to maximise return on investment. When planting or integrating trees into cities, one should look at how the ecosystem services provided by the tree are maximised and utilised. Trees should be integrated into the green, blue, and grey sectors. For instance, by integrating water supply and buffering into the habitat. This means looking at and thinking about trees differently.

Strengthen their Importance in Policy and Management:
By using objective and easily measurable parameters to determine the ecosystem services and benefits, the importance of trees in our environment can be better substantiated. This will allow tree management to be placed clearly and correctly on the political agenda.

Data Management & New Technology:
The amount of available data related to tree management will increase. Policymakers and management look to make data-driven decisions to better measure the impact of their chosen policies. Proper interpretation and analysis will help determine future policy management. New techniques and methodologies, such as artificial intelligence, drone technology, remote sensing, the internet of trees, etc., will provide us with data that is unknown today due to it not being measurable or being too labour-intensive and expensive to follow up systematically.

WHAT IS AN ETT?

The definition of the ETT in modern arboriculture is explained and elaborated on below.

Definition
European Tree Technicians are skilled in operations on and in amenity trees with the aim of keeping them healthy and safe whilst bearing in mind the demands of biodiversity. In particular, they act on the basis of current best practices within arboriculture, conservation, environmental protection, and work safety. They work as an intermediary, communicating with all the involved stakeholders and the practical people in the field while keeping an overview of the whole process of practical tree work. Their field of competence will also include technical knowledge as well as organisational, communication, and supervisory skills.

Clarification
A European Tree Technician is the person who works in a preparatory, guiding, investigative, or supervisory role within tree care. The ETT is often the intermediary between the client and the executing parties in the public space for projects that take place in the vicinity of trees. An ETT understands how the processes work and under which conditions the parties must work together. The ETT also has the knowledge and skills required to organise (tree) projects and supervise their correct implementation. To do these tasks well, the ETT must have good reporting and advisory skills. He or she must be able to conduct conversations with and give presentations to various stakeholders in the public space and be able to describe and, if necessary, defend the role and importance of trees in public and private spaces.

Collecting and analysing data is an important part of the work. This is essential in order to be able to draw the correct conclusions and then substantiate them properly to the client. The ETT can advise clients at a strategic and tactical level on how to make the right choices for their tree policy and management in the future. Due to the increasing awareness that trees represent an important opportunity to dampen the negative effects of urbanisation and climate change, the ETT has an important role to play. Together with workers from other technical disciplines, such as civil engineers, cable layers, and constructors, he/she must sometimes be able to develop technically complex solutions for growth sites.

In short, trees make an important contribution to biodiversity and ecosystem services. An ETT can advise clients on making the right choices in their tree management with regard to these topics.

WHAT IS THE ROLE OF THE ETT?

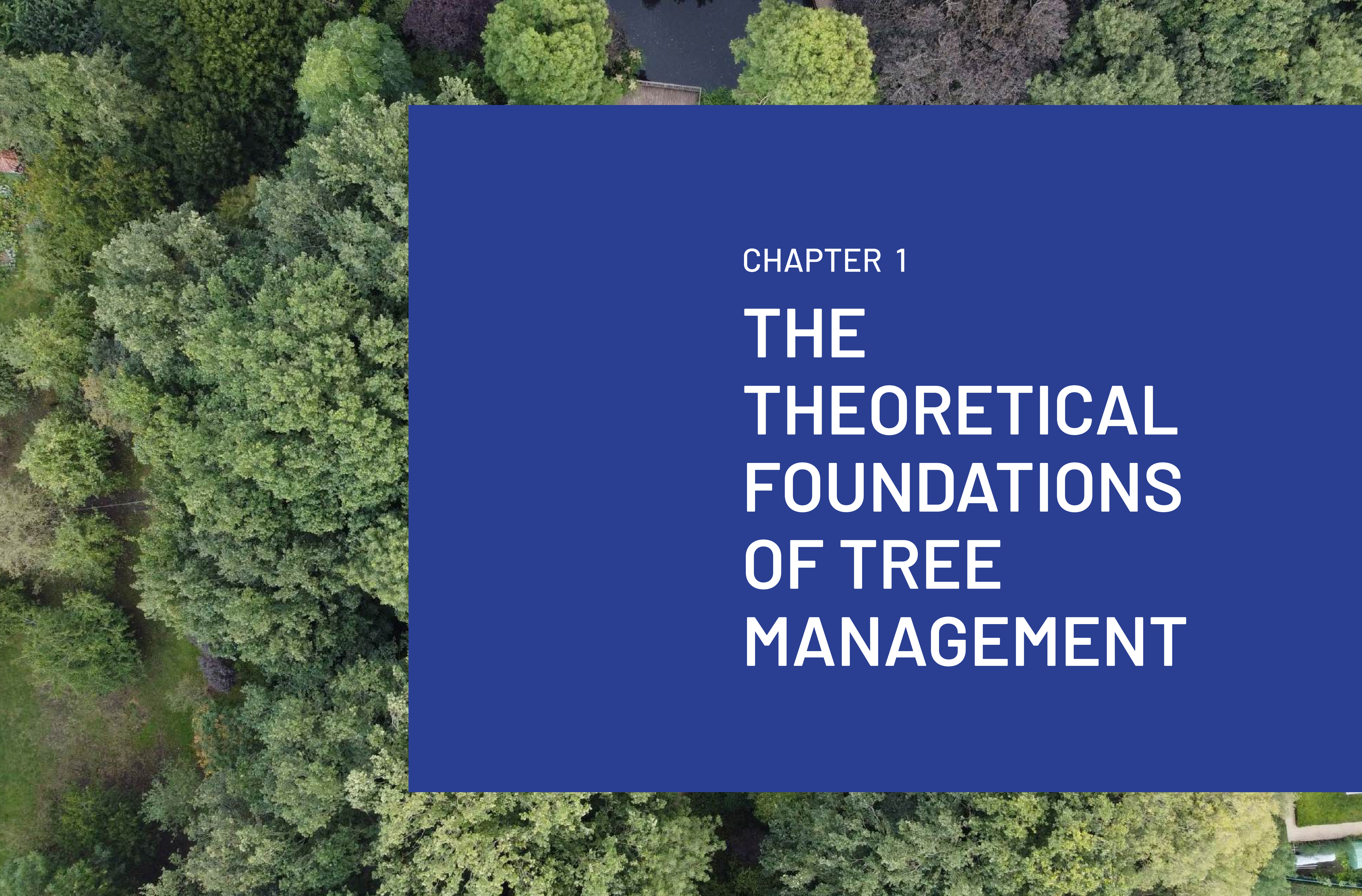
The above description of a European Tree Technician assumes, in essence, a triple role and is illustrated in the figure on the next page. This doesn't mean that an ETT is an expert in all these disciplines, but he/she should be aware of everything that concerns trees. The ETT should be a spokesperson for the tree and put the tree at the centre.

An ETT is a Tree Expert
The ETT has an extensive knowledge of trees, especially the technical part: anatomy, physiology, diseases, pests, the different life stages, and the specific properties of different species. An ETT also knows how the tree can react to internal and external processes, what happens when something goes wrong, and how to remedy the issue. He/she has the knowledge to determine the impact of the environment on the tree. In essence, the ETT is a technical expert on how trees work and what their needs are.

An ETT is an Organiser and Supervisor
For projects that take place in the vicinity of trees, the ETT, being an intermediary between the client and the parties executing the work, works together with all the stakeholders and is aware of what can happen in the vicinity of the tree and what preconditions and solutions are necessary for the tree to be able to develop properly. The ETT has the competencies to integrate trees sustainably, both in design and in practice. In essence, the ETT is aware of the considerations that need to be kept in mind when designing, constructing, managing, and planning in and around the tree.

An ETT is a Consultant or Advisor
The third role is that of a consultant or advisor working with different stakeholders in a multidisciplinary team, in which adaptive communication and reporting skills are required.

Figure 1 (P. Sanecka). The three main areas of ETT involvment – individual trees (1), trees in the context of project implementation in their surroundings (2) and consultation work and reporting (3). (Based on the concept Willem van Delft)



CHAPTER 1

THE THEORETICAL FOUNDATIONS OF TREE MANAGEMENT

INTRODUCTION

The theoretical foundations of arboriculture form the bedrock upon which effective and sustainable arboricultural practices are built. We went deeper into the topic of modern and sustainable arboriculture in the Introduction to Study Guide “The Role of an ETT in Modern Arboriculture”. These principles provide a deep understanding of the complex interactions between trees, their environment, and human interventions.

At the heart of the theory underpinning the discipline of arboriculture lies a comprehensive grasp of tree biology and physiology. This entails an exploration of how trees grow, obtain nutrients, and respond to various stressors. Understanding the inner workings of tree systems allows practitioners to diagnose issues, implement appropriate treatments, and ensure the well-being of individual trees or entire populations. So, basically, Part 1 is all about the physics and natural processes that you should master in order to understand trees. We attempt to show the many complex connections between the topics covered in the chapters by integrating this theoretical knowledge into four case studies.

Note that the information found in the following chapters of Part 1 sometimes differs from the common, widespread information you might be familiar with. But as science advances, so new insights are discovered, which we have tried to describe here. Capturing knowledge is a never-ending, dynamic process, and so we humbly point out that the material in this section, too, will need to be updated in the coming decades.

1.1.
THE FUNCTION, STRUCTURE, DEVELOPMENT, GROWTH STAGES AND PHYSIOLOGICAL PROCESSES OF TREES

1.1.1. Tree Function and Structure

Aino Mölder & Robert Oetjen

GENERAL OBJECTIVE

To get acquainted with the visible parts of a tree and its functions, allowing to understand the inherent internal and external structures of the tree based on the genetics and growing environment. This is the basis for choosing the right tree care techniques to ensure sustainable good health. Or in other simple words – to be able to explain what we see when we look at the tree.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- understand the basics of tree biology and their relevance to modern arboricultural practice;
- recognise the external features (morphology) of trees;
- identify and describe the anatomical and physiological features and functions of the tree;
- give a detailed account of the lateral branch to trunk union and describe how pruning techniques must be adapted to this feature;
- describe the processes of callus and woundwood production as a response to injury;
- describe the main defence mechanisms of the tree with reference to injury, including compartmentalisation;
- highlight the influence of environmental factors on tree physiological processes;
- show a basic understanding of root plate architecture and morphology and how it affects the stability of trees;
- form an image of the rooting pattern;
- show an understanding of crown structure, wind-sail factors and crown balance; and
- explain the positive and negative impact of co-dominant stems and multiple stem attachments.

KEY TERMS

Tree morphology: tree architecture, stem, crown, habit, roots, plasticity, leaves, branch, twig, branch union, branch collar, branch bark ridge, included bark, central leader, co-dominant stem, apical bud, axillary bud, adventitious shoots, absorbing roots, root hairs, root tip, root cap

Tree anatomy: cell, tissue, bark, cork cambium, phloem, xylem, sapwood, heartwood, pith, medullary rays (pith rays, radial rays), primary meristem, secondary meristem, annual growth, annual ring, adventitious bud

Tree physiology: photosynthesis, respiration, transpiration, assimilates, energy, phytohormones, defence system of a tree

SEE TOGETHER WITH:

Tree Development and Growth Stages

ESSENCE OF THE TOPIC

Trees are plants that are distinguished from other plants by the ability, developed during evolution, to continue growing for many years. This characteristic comes from the tree's ability to produce wood, giving it its height and strength. Their crowns, extending above the ground, allow them to gather more light in order to produce carbohydrates (sugars), enabling them to grow efficiently and survive amongst other competing plants. Like every living creature, this tree design or architecture has internal and external *building blocks* that, on the one hand, are predetermined by genetics, and on the other hand by their specific growing environment. The internal building blocks are meristems and the external ones are shoots and buds. Because of this, crowns, stems and roots of different tree species have a unique - but adjustable – architecture. This duality between fixed and variable characteristics is expressed in the tree's morphology and anatomy. Tree morphology refers to how the tree appears externally; anatomy describes its internal structure. In addition, tree physiology is key to understanding how trees live, function, and grow. When managing trees, it is essential to understand all this complexity.

A. Tree Morphology

People who work with woody plants can identify them from a distance. They do this based on external appearance, which can be referred to as tree architecture. Important aspects of tree architecture are the trunk and branching patterns and the shape of the crown. All trees have their own species-specific habitus. These external features are determined both by genetics and by the environment where the tree grows. Environmental conditions influencing the external appearance of trees include light, wind, soil characteristics, etc. The ability of trees' crowns and roots to adjust their shape and size in response to their environment is called plasticity. In summary, the external appearance of a tree – tree architecture – depends on the combination of its genetics, age, and the external forces working on it. Knowledge of the morphological features of different tree species allows, on the one hand, to identify the species and, on the other hand, to choose maintenance measures that support the natural growth and development of the tree.

A.1. Tree Crown Architecture

We first zoom in on the shoots and buds, as they are the small growing units. We do not want to go into the anatomy yet. Secondly, we scale up to the branches and their hierarchy. Lastly, we look at the crown architecture itself to cover the whole picture.

A.1.1. External Building Blocks: Buds

When looking at a tree crown in temperate regions and trying to describe the growth pattern, intuitively, we end up with branching as the general pattern. The branching pattern is the key to understanding the habitus of a tree. A branch is made up of modules consisting of a shoot with its leaves and buds. The final form of the tree is the reiteration of these modules. A bud is an undeveloped or embryonic shoot (or flower) and normally occurs in or under the axis of a leaf (lateral bud) or at the tip of a stem (terminal bud). Stems and branches originate from buds. The branch developed from the lateral bud is connected to the stem pith and is firmly locked into the wood and can fork. The terminal bud normally leads to apical dominance, which means that the main stem (or branch) is dominant over its lateral twigs and branches.

An axis is a linear structure, from its origin to its end, resulting from the action of one or more successive meristems (see tree anatomy). According to this meaning, an axis can be either monopodial, made up of the linear extension from a single meristem, or sympodial, made up of a succession of branches stacked on top of each other, with dominance transferred. The simplest example of an axis is the central trunk, formed either by the extension of the terminal bud or by the succession of several twigs, each of which in turn assumes dominance. In summary, when studying tree architecture, an understanding of the structure of axes is important.

A.1.2. Branches, Forks and Hierarchy

As described, a tree is genetically programmed to grow in height. This requires branches to be dominant over other branches when building the structure. Tree trunk is the part that holds up the crown and allows it to reach large dimensions and a good position in the competition for light. The internal organisation of a tree can be strictly hierarchical when one axis dominates over another. The organization may also be polyarchical when that hierarchy may or may not be briefly absent. The simplest and best-known form of hierarchy is apical dominance in which the terminal bud suppresses the growth of the underlying buds.

When the stem or main branch grows stronger than the branch emerging from its parent branch (or stem), a branch collar forms at its base. This is clearly visible when a branch is dying – a larger collar will be formed as the difference in growth increases. On the upper side of the union, and extending down both sides, the stem- or branch bark ridge is formed. Due to the whorled structure of the wood, the bark ridge indicates a strong union (Figure 1). When the stem and branch grow nearly at the same rate, the branch collar may be absent. In some cases, there may be included bark between the joining branches (or stem and branches), which may weaken the union (Figure 2).

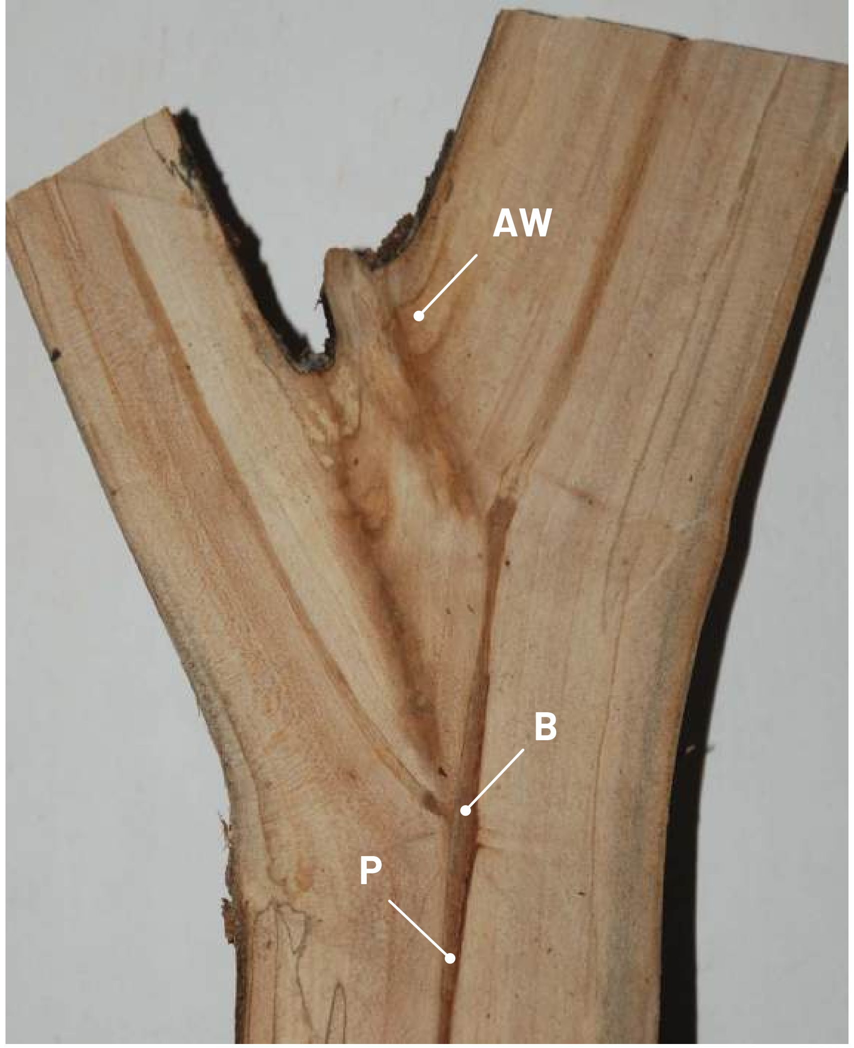


Figure 1 (W. Peeters). Anatomical features providing mechanical support to the fork. P = pith; B = bifurcation of the pith; AW = axillary wood. The union with the axillary wood is more resistant (on the left image) than the union with inclusion (on the image below).

Figure 2 (W. Peeters). However the tree was reinforcing the bifurcation with included bark, one of the leaders still failed.

UNDERSTANDING THE TREE: THE COMPROMISE OF TREE DESIGN

Tree design is the architecture of the living organism, which has a strategy for gathering light and is fine-tuned in through evolution. But this design comes with a few challenges and compromises.

It would not be wise to grow as fast as possible, outcompeting all neighbouring trees and then collapsing by the first gust of wind. In order to survive, a trade-off is needed between competitiveness and resiliency to the abiotic and biotic environment, because energy is limited. SO, every tree design is a compromise between growth, biomechanical stability and resilience to stress caused by the environment.

A.1.3. Tree Crown Design – Four Dimensions

This supporting wooden skeleton, consisting of the branches, twigs, leaves, and reproductive structures extending from the trunk or main stem, has a distinguished habitus which is not random. This forms the architecture of the tree. Presently, twenty-four architectural models for trees have been identified and described, covering almost all tree species on the planet.

As already stated, the habitus is defined by the genetic code, while the shape of each individual tree will, to some degree, be shaped by its specific growing environment. The inherent natural process of building the crown according to its architecture is explained by the theory of how the meristem of each axis functions and how hierarchical relations are established between those axes. This can be explained as follows:

As every tree grows, it has a species-specific branching pattern, which is one (1) of the basic characteristics of the tree's building plan. In the temperate climate, this growth can be continuous e.g., in *Chamaecyparis lawsoniana* or *Cupressus sempervirens* or rhythmic, meaning growing plants have a rest period in which the meristem tissue is protected in the bud (e.g., in *Quercus robur*). When the branch grows rhythmically, several growth units can be distinguished. In a cross-section of a terminal bud, the twig, and leaves for the following year can be recognized in miniature. Remember that these growth units are literally the "measuring unit" used to describe tree architecture and can be seen as the external building blocks.

Another dimension (2) of crown architecture, which needs to be understood, is the difference between monopodial and sympodial growth patterns. The first term is that the main axis – thus the trunk as we know it – is dominant and side branches are inferior (apical dominance). Sympodial growth implies that apical dominance is lacking, resulting in co-dominancy of the side branches with the main axis. The third dimension (3) is the position of the axis (read: branches). Orthotropic branches grow vertically while plagiotropic branches grow horizontally. Ageotropic means no fixed growth direction is observed. The last dimension (4) is the position of the flower. A terminal bud that forms a blossom cannot grow into a shoot to form an axis.

In summary, crown architecture is defined by observing the four dimensions as described above, resulting in one of the twenty-four defined architectural models. By asking the following questions, tree professionals can determine the model. Caution is needed because models are a simplification of reality and architecture changes during the lifetime of a tree and can be mixed.

QUESTIONS

1. Is branching present; is it sympodial or monopodial?
2. Is the growth of the stem and branches rhythmic or continuous?
3. Is the growth of the axis plagiotropic and/or orthotropic?
4. Is the position of the flowers lateral or terminal?

Tree professionals should understand tree architecture because the natural processes are the basis of sustainable tree management. Tree growth cannot be evaluated without first understanding how the wooden skeleton is structured. Without this knowledge, it is impossible to judge whether and when a co-dominant top should or should not be removed during formative pruning. Not every fork becomes a co-dominant top.

A.2. Root Architecture

The root's main functions are the absorption and transport of water and minerals when foraging the soil, storage of nutrients and anchoring the tree to

the ground. When taking management decisions like excavations, planting, and revitalisation, especially in the urban environment, it is crucial to look at the tree's perspective as to what its roots are needed. In this chapter, we first examine the two root types which form the basis of the root system. Secondly, we go into more depth about the root system, explaining the root organisation. Lastly, we look at the root architecture or design itself to cover the whole picture.

A.2.1. Fundamentals

Roots, like shoots, are dynamic branched structures originating from the seed of the plant and visually starting from the root collar. Anatomically, roots can be fundamentally classified as woody or non-woody. Together they form the root system. Woody roots are those that have undergone secondary growth, resulting in a rigid structure with a long lifespan and can regenerate. Functionally, these roots are often referred to as structural roots. Non-woody roots, often referred to as fine or absorbing roots, have their primary role in water and nutrient uptake. These roots are generally small in diameter (<2 mm) and have a high metabolic rate. Their lifespan typically ranges from a few days to some weeks, and they cannot regenerate. The newest fine roots (first-order roots at the very end of the root tip) are the most likely point for mycorrhizal colonization and consistently have higher nitrogen (N) levels than higher-order roots. These fine roots require a low amount of carbohydrates but are still energy-consuming for trees to maintain on a mass basis because of the high metabolic rate, also known as fine root turnover. Nonetheless, they provide the most plasticity for trees in responding to nutrient and water resources in the soil. Despite their diminutive stature, fine roots can account for as much as 90% of the total root system length.

As well as plasticity, roots are characterised by their opportunistic nature – meaning that they will spread and grow wherever it is suitable. This feature enables trees to survive in urban conditions. At the same time, it is not possible to easily predict where the roots are distributed around the tree. The best way to search for the roots is by digging or using high-performance technology like tree radar.

A.2.2. Tree Root System

Tree roots form a system in the sense that their components are connected in an organised network. This system is not random and will be explained in the section on tree root design. First, a classification of tree roots is needed to understand their design and strategy (Figure 3). There are two subclasses of long lignified (woody) roots – permanent and non-permanent. The first forms the main structural framework (skeleton) of the root system, the second type emerges laterally from the first and can be shed and replaced.

Permanent lignified roots consist of the following types:

- **Taproot**, is the first root of the seedling when germination occurs, mostly going straight down into the ground and anchoring the plant. It is the central root and functions as the generator and organiser of the root system. As complexity increases, multiple (additional) taproots can be formed;
- **Exploration roots**, which are formed laterally from the taproot and explore the soil in all directions.

Non-permanent lignified roots consist of the following types:

- **Colonisation roots** are formed from the exploration roots and colonise the soil laterally.
- **Exploitation roots** are short-lived and exploit the soil parallelly with the colonisation roots.

This root system gradually gains complexity as the tree grows older, until full complexity is achieved. Together with the nonlignified roots and the mycorrhiza, they form the vast network of the root system.

ROOT TYPES

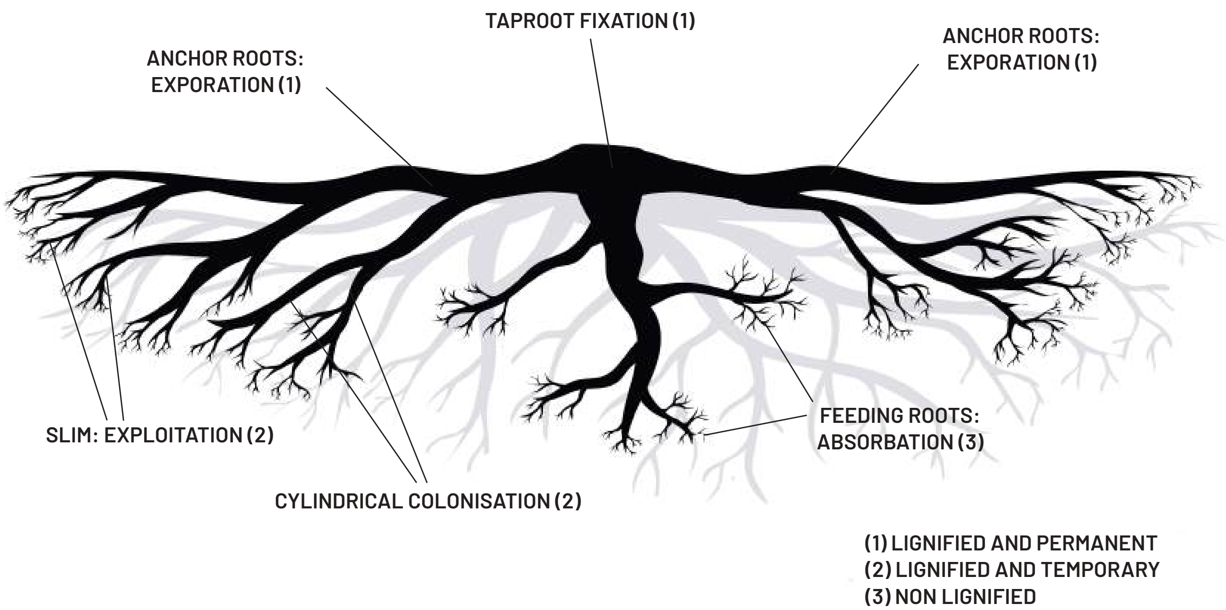


Figure 3. Classification of roots forming the root system. (Adapted from Plante & Cité by Claire Atger)

A.2.3. Tree Root Design

Similarly to the tree crown, the root system of trees also has an architecture with a clear design. Roots are like "the hidden branches of a tree" with a genetically determined pattern, based on meristems and axes acting within a hierarchical relationship. The main purpose of this design is to secure the exploitation of water and nutrients. At the same time, despite its genetic determination, the root system still has a degree of plasticity and adaptability, which is expressed in response to soil characteristics.

The non-lignified roots do not have a preferred growth orientation while lignified roots have a sense of orientation – when they deviate from their trajectory, they generally resume their original orientation as soon as they can. As the woody roots drive the exploration and exploitation of the root system, two types of strategies for building that root system are known: gigantism, which is a strong hierarchy throughout the entire life of a tree, and a second strategy which is a consecutive repetition of hierarchy and polyarchy (no hierarchy). This last strategy is a more efficient way of exploiting the soil because of the parallel colonisation of the roots. Unfortunately, a large part of the root architecture is not clear... yet.

It is, however, commonly known that the root system extends well beyond the perimeter of the crown. In terms of depth, where needed and possible, roots will grow deeper. In other cases, for example in high water table conditions, shallow roots will be formed. The intertwined larger and smaller roots, together with the soil covering and surrounding them, form a root plate, the presence of which ensures the balance and stability of the tree. The architecture of the root plate is affected by

environmental factors such as adaptation to the soil and winds. Although an impression of the root plate can be achieved when a tree has been uprooted after a storm, in reality, it extends much wider and is not accurately definable (Figure 4).

B. Tree Anatomy

Tree anatomy is focused on the inner part of a tree – that which we cannot directly see. The main internal building blocks of trees, like all living organisms, are the cells which form different tissues. Tissue is a level of organization in multicellular organisms that consists of a group of structurally and functionally similar cells and their intercellular material. Each one of them performs its specific role in the life of a tree. The tissues and their functions are briefly described below, but the most important one is called *meristem*. When moving outward, we encounter the wood structure whose primary function is to form a framework for interconnected water and nutrient flow and provide support for the organism. This can be explained by looking at the radial cross-section of trunk diameter.

B.1. Internal Building Block: Meristem

The formation of functional tissues is possible due to the presence of meristematic tissues. The meristems are built up from undifferentiated cells (meristematic cells), capable of division. Meristematic cells can develop into all the other tissues and organs that occur in plants. In the case of trees, two types of meristems are present:

1. primary or apical meristem, which is responsible for the growth in length of shoots and roots; and
2. secondary or lateral meristem (cambium), which is responsible for increasing the diameter of the tree parts.

For example, in the event of injuries (including pruning), the cambium begins to produce callus cells, from which the wound tissue forms. In cases where outer bark is damaged or lost, such as collisions, cambium can produce callus covering the wound surface. Secondary meristem activity also takes place in the roots.

Figure 4 (W. Peeters). Root plate. Destroying or disturbing the roots on the root plate area may leave the tree unable to hold itself up. The genetic and environmental factors are important as well.

B.2. Functional Tissues

When looking at the radial cross-section of a tree trunk, the tissues of the tree and their functions are well distinguished (see also Figure 5). Starting at the outer layer, the bark is the outermost tissue of the tree. It is composed of non-functional phloem and corky tissues and is responsible for protecting the tree from damage, temperature, water loss, etc. The inner layer of the bark consists of active, living cells, i.e., cork cambium and phloem. The phloem is a tissue which is responsible for the transport of soluble organic compounds made during photosynthesis into parts of the tree where they are needed. The cork cambium is responsible for producing new bark cells on the inner surface of the bark. The next tissue is the vascular cambium, which consists of undifferentiated cells (see also above in B.1). It produces new wood on the inside and phloem on the outside.

The wood is made up of vessels, parenchyma cells and fibres in hardwood species. The wood of softwood species is made up of tracheids, parenchyma cells, and resin canals. Wood, regardless of species, is divided into sapwood (xylem) and heartwood. Sapwood is the living, outermost portion of a woody stem or branch, consisting of parenchyma cells and active vessels (often called *pores*) or tracheids. Parenchyma cells are the only living cells in wood. All trees start as sapwood which forms due to the activity of cambium. In young trees all the wood in the stem is sapwood. Sapwood is where water and dissolved minerals are transported from the roots to the crown of the tree where they are needed both for photosynthesis and transpiration. When the tree gets older and its trunk increases in diameter the entire cross-section of the trunk is no longer needed for conducting water. This, combined with an increased need for structural support, causes significant changes in the wood – the cells of the annual rings nearest to the centre of the trunk start to die and become heartwood. This creates a strong structural pillar in the central part of the tree. Compared to sapwood, the moisture content of heartwood is lower. The relative amount of sapwood and heartwood depends on tree species and age. The expansion of the heartwood from the inside to the outer part of the trunk or branch takes place along the contours of the annual rings. They consist of a lighter and a darker part. The lighter part of the rings is made up of larger cells and is called the early wood. The darker part of the rings is made up of smaller cells and it is called latewood, which is formed when growth intensity has decreased.

The inner part of the cross-section has the pith and is crossed with the medullary rays (wood rays), both consisting of parenchyma cells. Medullary rays are soft-textured channels running radially in wood. Together with the parenchyma from the sapwood they form a 3D network for transportation. In summer nutrients are deposited in medullary rays, which provide the tree with energy to start growing next spring, as well as to cope with damage and injuries. The assimilates produced in the leaves are conducted horizontally through the trunk from the xylem to the direction of the pith. By forming radial barriers, the rays also prevent the spread of rot and allow gas exchange between the inside and the outside of the tree.

C. Tree Physiology

The tissues of a tree allow many different physiological processes to occur, making the growth and development of a tree possible. The most fundamental of them are photosynthesis, respiration, transpiration, taking up and use of nutrients, plant hormone functions, etc., which are described below.

C.1. Photosynthesis

All the building materials that a tree needs for growth and functioning are produced through the process of photosynthesis. Photosynthesis is a naturally occurring process in which chlorophyll in plants converts light energy from the sun into chemical energy.

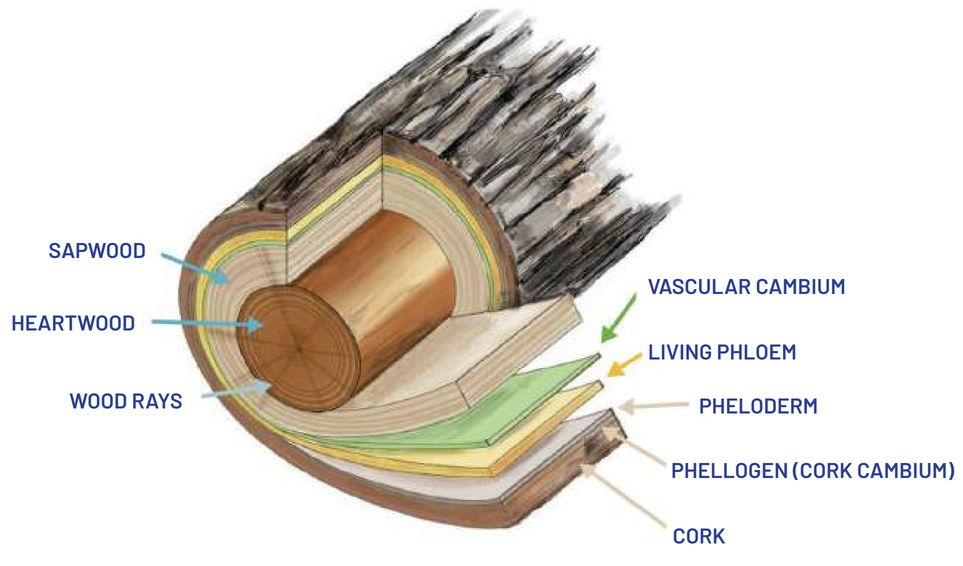


Figure 5 (J. Józefczuk). Functional tissues of a tree.

It is by far the most important chemical reaction on the planet and is shown below. When looking at the formula on the next page, the process seems utterly simple but when diving deeper, it's extremely complex. Maybe so complex that it only happened once in the history of the planet.

The substances needed for photosynthesis are water and carbon dioxide. Water comes from the soil but can be taken also from the air or fog, via the leaves. This is quite common in regions with high air humidity, such as mountain forests. Carbon dioxide is taken from the air, which enters the leaves through the stomata. Stomata are very small openings that are mainly located on the lower surface of the leaf. They regulate gas and moisture exchange in the plant. The plants also need mineral nutrients such as magnesium, nitrogen, potassium, iron, and manganese to synthesize chlorophyll. In the soil solution, these nutrients must be available for the tree. The final product of photosynthesis is glucose, which is a kind of carbohydrate, and the by-product is oxygen, which also is released into the atmosphere through stomata. Glucose is a universal source of energy for living beings, including trees. Starch, cellulose, and other organic compounds are synthesized from the glucose, which the tree needs for all its life processes, including building up its tissues. In addition to growth and development, the tree also uses some assimilates to fight against diseases and pests. Lots of photosynthates are also leaked into the soil where they are used by different soil organisms, mycorrhizal fungi included.

The intensity of photosynthesis depends on several factors. The most important are light intensity, temperature and the availability of water. The most suitable temperature for photosynthesis is 20-35°C. If the temperature is below 0°C, photosynthesis is inhibited or stopped. Differences may occur according to tree species. For example, evergreen trees (conifers) can also photosynthesize in winter, although at very low intensities. Different plant species and varieties have different requirements for light conditions. This is why light-loving plants grow poorly in conditions where there is not enough direct sunlight.

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

CARBON DIOXIDE WATER LIGHT SUGAR OXYGEN

C.2. Respiration

Trees need energy to grow. This energy is gained through the process of photosynthesis and made available for the tree through respiration. Respiration is the process by which glucose produced by photosynthesis is broken down by oxygen into water and carbon dioxide. The energy, which is released during respiration, is used for two main purposes – to ensure the growth processes and to maintain the functions of the tree as a living organism. For example, the formation of wood is driven by respiration is very intense in sites where the most active processes are situated like meristem tissues at the apex of shoots and active roots. Respiration as a gas exchange can take place both inside the cells (internal or cellular respiration) and between the tree as an organism and the external environment (external respiration). In cellular respiration, the energy released is used for biochemical processes. External respiration happens above and below ground. In root systems, oxygen in soil pores diffuses into the root hairs and gets transported to all parts of the roots. The carbon dioxide formed is then released into the soil, diffusing through the pores into the atmosphere. When the soil is too compacted and has a poor gas exchange, the respiration of the roots is severely inhibited, and thus functioning and growth are slowed or ceased. Above ground, the movement of both oxygen and carbon dioxide between the leaves and the environment takes place through stomata.

From the above, it is clear that respiration and photosynthesis are very closely related - one relies on the other. Compared to photosynthesis, respiration takes place over a much wider temperature range. Respiration is maximal at temperatures of 35-40°C. When the temperature rises further, the intensity of respiration decreases sharply. Another thing which affects respiration is air humidity. When the air is drier, stomata will close earlier, so the gas exchange will be stopped earlier, too. Respiration also takes place at sub-zero temperatures. As photosynthesis does not take place at sub-zero temperatures, the plant respires during this period at the expense of reserves. Therefore, the energy reserves of trees are low in the spring.

C.3. Transpiration

Water needs to be transported to all living cells in the tree to support their functions and turgor pressure. Looking at the formula of photosynthesis, water is also needed to produce carbohydrates. Water transport is thus crucial to the survival of the tree. Water transporting starts in the soil where water is absorbed by the root hairs, from where it is directed to the leaf cells via the vascular system like the tracheids or vessels. This vascular system, physically seen as water columns are delicate and may not be broken. The main force behind this system is transpiration, which is the evaporation of water taken from the soil into the atmosphere through the above-ground parts of the plant, mainly through the leaves. This process is described as the cohesion-tension theory that is based on negative pressure (tension). More physically, transpiration at the leaves creates a negative pressure that puts tension on the water column while the roots have a positive pressure. This water potential gradient is the *engine* behind the water transport that literally sucks the water upwards.

More than 95% of the extracted water escapes into the atmosphere through stomata and is not used inside the tree. It is just to keep the engine running. The conclusion is that a tree is basically a solar-driven water pump.

The process of transpiration also enables the uptake of dissolved nutrients from the soil solution into the roots. So, transpiration serves as a vehicle to carry nutrients through the tree. Transpiration also lowers the temperature of the leaves and thus prevents them from overheating. The intensity of transpiration is affected by the amount of water in the soil, humidity, temperature and wind. The lower the air humidity and the higher the temperature and wind speed, the more intense the transpiration. The intensity of transpiration in trees is regulated by the opening and closing of stomata. The stomata will close when the cells' turgor decreases due to external conditions, such as wind, heat or drought, and they will open when the turgor recovers due to the normalization of external conditions.

C.4. Phytohormones

Several important physiological processes in the tree are controlled by hormones. Plant hormones are chemical substances that plants produce in very small quantities, mainly in the primary meristems of young shoots or roots and in young leaves. From there, they are transported along the xylem or phloem to locations where they regulate cell activity and thereby plant growth and development. In essence, Hormones are signal transducers, converting an environmental stimulus into a physiological or anatomical response. Growth regulators can be divided into growth stimulators and growth inhibitors according to their effects.

Auxins are the most important of the growth-stimulating hormones. They are produced in the primary meristems of the shoots and roots, where they promote cell division and elongation (growth). When entering the lateral buds, the auxin induces the production of the inhibitor ethylene, which inhibits the growth of lateral shoots. When the terminal bud is removed, the flow of auxin to the lateral buds stops and they start to grow intensively. This means that the auxins control and direct the apical dominance. This can be easily observed and understood in the trimming of hedges, whereby the removal of terminal buds stimulates the active growth of lateral shoots.

Auxin preparates are commonly used by tree nurseries when propagating trees from cuttings. Treating the cuttings with auxin powders helps to raise the rooting efficiency. The other growth-stimulating hormones are gibberellins and cytokinins.

There are two groups of growth-inhibiting hormones. Abscisic acid is a plant hormone that inhibits cell division and elongation. It helps seeds and buds to remain dormant and inhibits the growth of shoots. Abscisic acid also causes abscission in woody plants (the natural fall of leaves and fruits). Abscisic acid is synthesized in adult leaves and transported within the tree mainly via the phloem. Ethylene is the only gaseous plant hormone. It plays an important role in ripening the fruit. The effects of ethylene and auxin are opposite; their interaction drives apical dominance (see above, auxins).

C.5. Defence System: CODIT

Trees become trees in order to grow above other plants and thus capture more light. This growth is a process that requires a lot of energy. It is therefore very important for a tree that the structure that is formed is not lost in the early stages of growth. A few things are very important in this respect: the stability of the tree, the transport of water from the roots to the leaves and the resistance to wood decay. The latter two go hand in hand: wood whose vascular tissues are destroyed by decay wouldn´t be able to transport water. On the other hand, for as long as trees have grown on Earth, they have experienced diverse types of damage but have still managed to survive and thrive.

To preserve itself, the tree has a number of strategies that work together. It is logical that the best protection for a tree is its bark. Also, the moisture contained in the sapwood prevents the spread of decay. Very few wood-decomposing fungi are able to infect the living sapwood, and those that can, usually do so only to a limited extent.

In addition, the tree can compartmentalise some damaged parts and form new wood around the critical or affected part. This is fundamentally different from humans, to whom healing is a normal process. Trees cannot be healed, only damage or dysfunctions can be compartmentalised. This mechanism was described in the 1970s by A.L. Shigo as the CODIT model. CODIT is an acronym that stands for the initials of the model's name. Originally CODIT stood for Compartmentalisation of Decay in Trees, but since there is also compartmentalization when there is no decay, today the D stands also for Damage. And if we take into account that the tree not only needs to prevent decay from spreading through the damage but also needs to protect its transport system (vascular tissues), then the D stands for Dysfunction. In other words, the tree tries to prevent the loss of its parts, for whatever reason.

The CODIT model shows there are two types of zones in the tree that can isolate the infected wood from the healthy wood: the reaction zones (walls 1-3) and the barrier zone (wall 4). These zones and their working principles are shown in Figure 6. The reaction zones form in the wood that normally has a different function, but which, due to circumstances, reacts by sealing off the dysfunction. The barrier zone, on the other hand, is the strongest one and it is built specifically for that purpose. It is produced by the cambium and forms a boundary between the affected wood and the new wood that forms after the damage. It is 3 to 5 cell layers thick and forms a kind of thin bark layer in the wood that strongly seals it off.

It should be considered that the CODIT model is not 100% effective. The most common misunderstanding is that instead of seeing CODIT as only a self-defence model, the zones have been taken as absolute anatomical borders that can stop everything. In real life, however, the self-defence mechanism supports the trees' own ability to cope with damage and dysfunction and slow down the spread of decay.

CODIT - REACTION ZONES

Wall 1 is formed by plugging up normally conductive vascular tissue above and below the wound; it slows down the spreading of harmful organisms in vertical direction.
Wall 2 is formed by lignin-rich cells of the annual rings and slows down the radial spread of decay/dysfunction.

Wall 3 is formed by medullary ray cells, dividing the stem into segments.
Barrier zone (**wall 4**), will be created by the cambium, usually after damage. It is the specialised cork-like tissue on the exterior of the tree that isolates the tissue present at the time of infection or wounding from subsequent growth.

Figure 6 (W. Peeters). CODIT-model based on A. Shigo.

SELF-CHECK QUESTIONS

1. Explain the difference between heartwood and sapwood. What is the importance of sapwood?
2. What are the pathways for the movement of water within the tissues of trees?
3. What factors influence the intensity of photosynthesis?
4. Explain the importance of transpiration. What does the intensity of transpiration depend on?
5. Which factors affect the crown structure of trees?
6. Describe different bifurcation types. Which factors influence the patterns of bifurcation?
7. What techniques can be used to influence the branch aspect ratio?
8. What do you understand by wind-sail factor and crown balance? How do they affect the stability of the tree?
9. What are the functions of the root system? How far does the root system extend?
10. Explain the root system.
11. What is the effect of pruning on hedges? How can this be explained?
12. Explain the essence of CODIT.

PRACTICAL EXERCISES

1. Remove from a tree a living branch (3-4 cm in diameter) which has plenty of smaller lateral branches attached to it. Attempt to separate a lateral branch of about 1 cm in diameter by pulling it apart from its parent branch. Now take bifurcated branches with approximately the same diameter and try to pull them apart (essentially pulling codominant stems apart). Can you feel the difference in the strength of the unions? How is this connected with favourable tree architecture?
2. Find a woodpile with clean end cuts or make some clean cuts with a saw. Locate samples illustrating the operation of the three reaction zones (walls 1-3) and barrier zone (wall 4) of a tree.

TERMINOLOGY

adventitious bud – bud arising peripherally from a place other than a leaf axil or shoot tip
adventitious root – root-like growth arising from roots or stems and having no connection to apical meristems
adventitious shoot – shoot that develops from an adventitious bud
apical or terminal bud – bud at the tip of a twig or shoot
apical dominance – condition in which the terminal bud inhibits the growth and development of the lateral buds on the same stem; the process is triggered by phytohormones
apical meristems – growing point in buds at the tips of shoots and roots
axillary (lateral) bud - bud in the axil of a leaf
axillary shoot – shoot rising at the axil of a leaf
bifurcation – branch junction in the crown of a tree in which there are two arising branches
barrier zone – a chemical and anatomical barrier formed by the cambium present at the time of wounding in response to wounding; inhibits the spread of decay into xylem tissue formed after the time of wounding; wall 4 in the CODIT model
branch arrangement – orientation and distribution of branches along a larger stem or main trunk
branch aspect ratio – the diameter of the branch relative to the diameter of the trunk, both measured immediately above the union; the branch union with smaller aspect ratio is stronger than those with a large aspect ratio
branch bark ridge – raised strip of bark at the top of a branch union, where the growth and expansion of the trunk or parent stem and adjoining branch push the bark into a ridge
branch collar – area where a subdominant branch joins another branch or trunk that is created by the overlapping vascular tissues from both the branch and the trunk (typically enlarged at the base of the branch)
branch protection zone – chemically and physically modified tissue within the trunk or parent branch at the base of a smaller one; slows down the spread of discolouration and decay from the subordinate stem into the trunk or parent branch
callus – the undifferentiated tissue in trees, formed by cambium in response to a wound; the cambium is from which the wound wood develops
cambium – thin layer of meristematic cells that give rise (outward) to the phloem and (inward) to the xylem, increasing stem and root diameter
cellular turgor; cell turgor – the pressure that water in a cell exerts on cell walls; loss of turgor, resulting from the loss of water from plant cells, causes the plant to wilt
central leader – main stem of a tree
CODIT – the model created by A. Shigo that explains the self-defence mechanisms of trees
codominant branches/codominant stems – forked branches nearly the same size in diameter, arising from a common junction and lacking a normal branch union; may have included bark
cork cambium – lateral meristem from which the corky, protective outer layer of bark is formed (also known as phellogen)
crown plasticity – the ability of trees to adjust the shape and size of their crowns in response to changes in their local competitive environment
dormancy – period of naturally reduced physiological activity in the organs of a plant with the potential for reactivation of growth
dormant or latent bud – bud originally developed in a leaf axil and connected to the pith by a bud trace that has not been stimulated to mature and grow; some buds remain dormant throughout the life of a woody plant
epicormic shoot – shoot arising from a dormant bud or from newly formed adventitious tissue
included bark – bark that becomes embedded in a crotch (union) between branch and trunk or between codominant stems; lacks axillary wood and causes a weak structure
lateral bud – vegetative bud on the side of a stem (contrast with terminal bud).
meristem – undifferentiated tissue in which active cell division takes place; found in the root tips, buds, cambium, cork cambium, and latent buds
parent branch – larger branch or stem from which a smaller, lateral branch arises

reaction zone – natural boundary formed chemically within a tree to separate damaged wood from existing healthy wood; important in the process of compartmentalization (contrast with barrier zone)
reiteration – the process whereby architectural units are replicated within a tree
root collar – flared area at the tree trunk base where the roots and trunk come together
root plate – the combination of large structural and smaller roots and soil near the base tree's trunk largely responsible for holding the tree erect
root plasticity – the ability of the root system to promote plant growth and development under changing soil conditions
shoots (long/short) – long shoot: a vegetative shoot, usually with many internodes and bearing apical bud; short shoot: arises on the long shoot in the axil of leaves, does not contain any apical buds
vascular system – a network of conducting tissues (xylem and phloem) that interconnects all tree organs and transports water, minerals, nutrients, photosynthates and various signalling molecules throughout the tree body
wound wood – lignified, differentiated tissues produced in woody plants as a response to wounding

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ESSENTIAL READING

UK Applied Tree Biology by Andrew D. Hirons and Peter A. Thomas. Retrieved from: https://vdoc.pub/documents/applied-tree-biology-35aneks5li50
Reference work on tree biology, provides essential and background information on tree biology without being hard to read. Must read.
USA The CODIT Principle. Implications for Best Practices (ISA) by Dirk Dujesiefken and Walter Liese.
Helps to understand thoroughly how CODIT works with the focus on tree physiology.
POL Elementary tree biology, ecology and biomechanics. A manual for Tree Assessors and Arborists by Piotr Tyszko-Chmielowiec. Retrieved from:
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All the information needed for understanding the root system and root architecture.
FRA La Taille des arbres d'ornement : du pourquoi au comment by Christophe Drénou
Book about pruning based on the concept of crown architecture.
FRA Le développement de l'arbre by Jeanne Millet
Books that explain in plain French how trees develop.
ITA Crown & Canopy Management Working with nature 8-11 September 2019 Exeter, UK by Stefania Gasperini and Giovianni Morelli. Retrieved from: https://www.trees.org.uk/Trees.org.uk/media/Trees-org.uk/Documents/Conference19/TueAM-2-Stefania-Gasperini-Giovanni-Morelli.pdf
Very interesting and clear about tree crown development and design. Must read!

ADDITIONAL READING

FRA La taille des arbres et des arbustes by Claude Le Maut
Book on pruning trees based on architectural models; special focus on the so-called "taille jardinée," continuous pruning and reduction to keep trees small in gardens.
FRA L'arbre, au-delà de idées reçues by Christophe Drénou
Debunking a hundred or so "ingrained" ideas about trees. Not specifically about crown architecture but contains many references to the topic. Also includes a card game on the development of trees.
FRA L'architecture des arbres des régions tempérées: son histoire, des concepts, ses usages by Jeanne Millet
Basic scientific work on the history, concepts and applications of crown architecture, incl. architecture of specific tree species.
FRA Face aux arbres. Apprendre à les observer pour les comprendre, by Christophe Drénou
Approachable basic work on the concepts of crown architecture, richly illustrated with examples.
ENG Demystifying Tree Forks: Vices and Virtues of Forks in Arboriculture by Drénou, C., Restrepo, D., & Slater, D. Journal of Botany Research, 3(1), 100-113.
Overview of the work of Duncan Slater on tree forks in the light of tree architecture.
FRA Racine et système racinaire des arbres: structure et developpement. Plante & Cité by Claire Atger. Retrieved from: https://drive.google.com/file/d/0B8owlcm9abDGVFJ6TjFJdkp3MWs/view
Structure and development of the root system.
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Influence of the environment and cutting on the development of the root system.
UK Fungi and trees: their complex relations by Lynne Boddy
A book that depicts the full story of trees and fungi.

1.1.2. Tree Development and Growth Stages

Aino Mölder & Robert Oetjen

GENERAL OBJECTIVE

To gain an understanding of the basics of tree growth and development taking place above and below ground. As each tree 'requires' specific management during the different stages of its life cycle, the knowledge gained helps to substantiate that specific management.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- point out the principal areas of growth and development in a tree;
- identify the different development stages of a tree;
- understand the architecture of trees and see the potential future development;
- explain the differences in development and growth stages; and
- establish evaluation criteria based on these stages to describe maintenance and remedial measures.

SEE TOGETHER WITH:

Tree Function and Structure, The Social Value of Trees

ESSENCE OF THE TOPIC

To secure healthy, stable and well-functioning trees for as long as possible, it is essential to understand the tree's development within the life stages. This is the basis for sustainable tree management.

During the life of a tree, it passes through inevitable growth and development stages, both from the perspective of a single year as well as through its whole life cycle and is subject to physical, biological and mechanical laws and the laws of thermodynamics. From its beginning as a seedling forming its first leaves, buds, shoots and branches, it continuously repeats that growth sequence year after year. This makes it a modular organism with functional units. The branching pattern of trees can be referred to as its architecture. According to the extent that the branching patterns have formed, it is possible to identify the tree's stage of development. This sequence of stages may also be called the ageing process. In contrast to the general understanding of ageing, the life stages of a tree do not necessarily follow a linear progression. For example, for tree species with good regeneration capacity and sufficient vitality, an old tree under favourable conditions may form a new crown. The water shoots (reiterations) that develop from the dormant or adventitious buds improve the capacity for photosynthesis. This, in a way, gives the tree a new life. Thus, the ontogenetic age is not strictly linked to its chronological age. This chapter introduces the concepts of tree growth and development. Tree development at different life stages will also be described.

KEY TERMS

Growth: apical growth, cambium, crown architecture, cumulative growth curve, gigantism, lateral growth, modular structure, reiteration

Development : ageing process, ARCHI method, carbohydrate balance, death, differentiation, functional units, growth rates, linear progression, life cycle, life expectancy, life stages, morpho-physiological model, Raimbault, regeneration

A. Growth Explained

In Chapter 1.1.1. we explained that trees, due to their wooden structure, can grow in height, making it possible to capture more sunlight. In a forest, this is a race towards sunlight in order to survive. Solitary trees, being more exposed, are not forced into growing in height. Striving to attain maximum sunlight absorption, they tend to grow a lower and wider crown with spreading branches. This chapter explains how growth happens both at the cellular and whole-tree levels. The growth curve allows us to understand the specifics of tree growth throughout the lifespan of a tree.

A.1. Physiological Growth

By tree growth, we mean an increase in the dimensions of both the above-ground parts of the tree as well as the root system. Growth represents quantitative changes in the life of a tree. At the cellular level, growth is understood as the irreversible increase in the dimensions (and hence the mass) of plant cells and organs, based on the multiplication of cells in the primary tissues (meristems). Depending on the location of the meristematic tissue, growth can be either primary (also called apical growth) or secondary (also called lateral growth). Primary growth is controlled by root apical meristems or shoot apical meristems, while secondary growth is controlled by the two lateral meristems, called the vascular cambium and the cork cambium. At the level of the tree as a whole organism, apical growth is the increase in length of the shoots and roots; and lateral growth is the increase in stem and branch diameter.

A.2. Modularity as Growth Pattern

In Chapter 1.1.1., the root and crown architecture were described theoretically based on meristems and axes and their hierarchical relationship. It was concluded that trees have a modular structure using specific strategies like gigantism or reiteration. In the latter, the same growth pattern is repeated over decades or centuries. The same phenomenon occurs in the growth and development of roots, which are also modular. This modularity, which in mathematics is called fractality, can be seen widely in nature. It is a mathematical code which helps describe complexity in nature. When this principle is applied to root or crown architecture, the modules are called architectural units. Modularity is not only expressed in the fractal structure of the tree's crown and roots but also in the growth of annual rings. Each year, the tree grows a new 'wooden cylinder' on the outside of its trunk, branches and roots. The annual rings may be absent in some tropical species that grow year-round.

Unlike animals and humans, for whom the loss of an organ or a body part is usually fatal or disabling, trees, thanks to their modular structure, can withstand a moderate loss of structural units (such as branches, twigs or roots): growth and development continue through cell division, elongation and differentiation in the remaining apical and lateral meristematic tissues. This characteristic makes it possible to carry out tree maintenance operations such as, if necessary, the raising, reduction, or thinning of the crown, or to be shaped in a desired way. So, modularity is an essential principle when speaking about the growth and development of trees.

A.3. Growth Curve

Tree growth is not a linear, upward process of uniform intensity. When plotting the cumulative increment in the function of the tree age, a non-linear relationship is seen. Increment is the quantitative increase in size (crown, growth ring, etc.) in a specified time interval (e.g., one year) due to growth. Cumulative means increasing by successive additions. This results in the cumulative growth curve (CGC), which for trees is sigmoidal (similar to many other biological organisms). The curve rises intensively in the early years and culminates in the middle of the tree's life. The culmination is inevitably followed by a decrease in the tree's vitality and its decline. This is shown in Figure 1, where in the young phase (1) the CGC shows an accelerating rate of growth, the mature phase (2) is characterised by a constant rate of growth and full vigour, and the ancient phase (in other words 'senescent') (3) is characterised by decelerating rate of growth.

When considering the current annual increment (CAI) for different life-cycle stages, leaf mass is a key factor, as this is where all carbon is captured. When the mass of leaves in young and middle-aged trees increases, the structure also continues to develop, and the annual growth rings will be more or less the same throughout this phase. When the tree has passed its full vigour phase, the leaf area no longer increases. Secondary growth continues, but the annual growth rings will become smaller and smaller, year by year. At some point, when the tree is no longer able to provide sufficient growth for all its parts (especially on ring porous trees), growth will be concentrated on those parts of the trunk which have the best connection between leaves and roots. The tree will become an ancient tree.

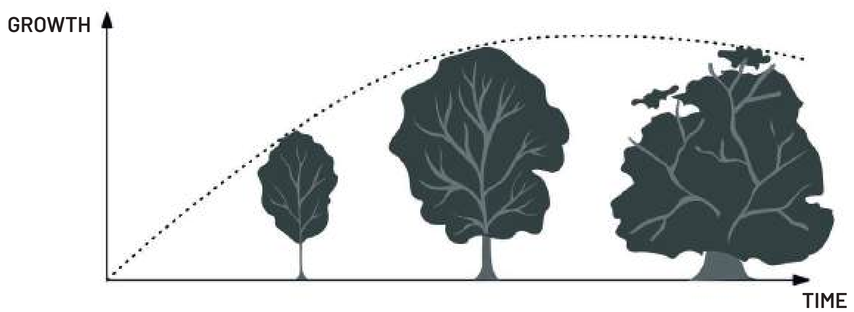


Figure 1. Cumulative growth curve during the life cycle of trees. (Adapted from Brack & Wood 1997)

B. Development Explained

Understanding the life stages of a tree is important in evaluating its overall health and the measures to be taken regarding its management.

B.1. Physiological Development

Development is defined as a sequence of qualitative morphological and physiological changes, i.e., changes in the shape and function of the plant´s parts. Development is initiated by the differentiation of cells that have undergone the cell division and elongation phase. During differentiation, they form tissues with a specific function, such as new wood, bark, roots, etc. Hence, tree growth and development are closely linked.

B.2. Ageing Process

The ageing process can be understood as morpho-physiological changes during the various life stages of a tree. This life cycle is much more complex than a linear progression from seed to death. In the context of forestry, understanding the growth stages is important for economic reasons, where decisions are mostly made based on the incrementality of wood formation. In an arboricultural context, however, understanding the morpho-physiological changes within the life-cycle stages has a different importance, related to appropriate tree management.

A tree's development and growth are linked to its genetic potential on the one hand and its growing environment on the other. For example, the length of the life cycle stages and the biological life expectancy depend on the tree species. Features of the growing site environment, such as urban conditions, may shorten the life of the tree. Hence, it is important not only to look at the age of a tree but also at the life stages.

B.3. Tree Development at Different Life Stages

Depending on the approach and the purpose of the work, many authors identify more stages in the life cycle of a tree, however, the 10-stage model of Pierre Raimbault is currently the best one for arborists. Although the transitions between the different stages are smooth and not defined by a specific age, it is useful, from a tree-care perspective, to consider these stages separately. Although the duration of these life stages depends on the genetic potential of the tree, its functional lifespan can be prolonged by applying the right tree management practices, including improving its growing conditions. In this chapter, we cluster the development stages into three broad categories or phases (Figure 2), namely young (by Raimbault stages 1 to 4), mature (stages 5 to 7) and ancient (early-, mid- and late; stages 8 to 10). In particular, a large number of subdivisions can be identified within the last stage, which is often the longest, featuring the gradual decline and eventual death of the tree. It is mostly in this stage where the non-linear progression occurs due to regeneration. Thus, in ancient trees, an important survival strategy is the presence of semi-autonomous functional units, whereby parts of the trunk may differentiate into autonomous parts. Each part has its own crown, stem and roots. In essence, one tree may functionally become two or more.

Non-linear progression can also occur earlier in the development of the tree and happens anytime when water sprouts are formed. Water sprouts are triggered by stress, over-pruning (or damage) and exposure to light (e.g. when other trees fall).

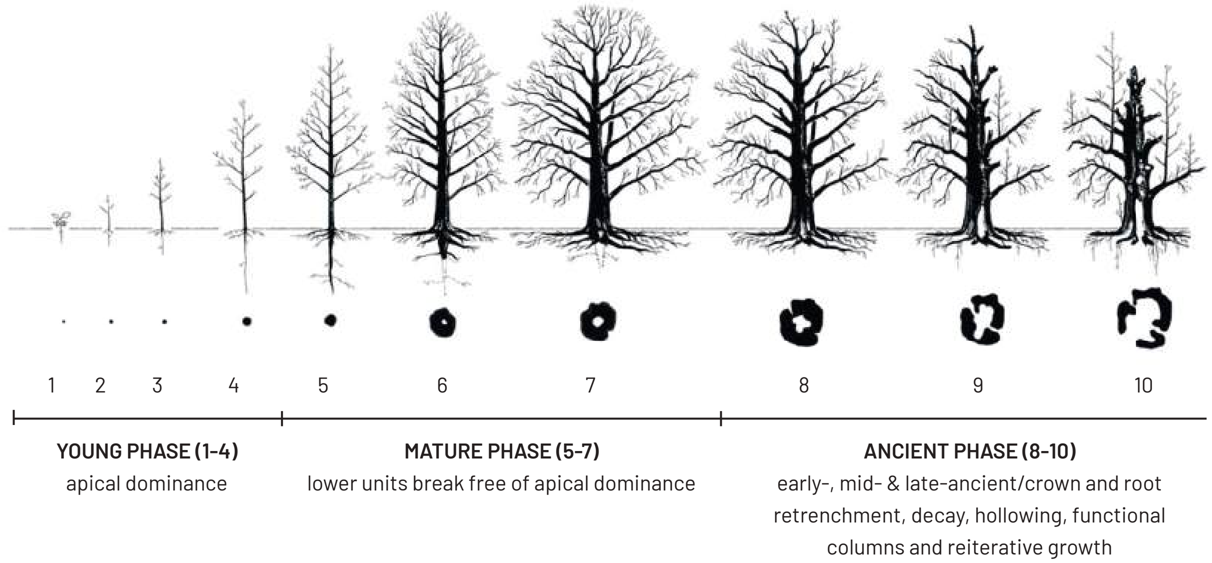


Figure 2 (J. Józefczuk). Morpho-physiological stages of tree development. Development of crown and root systems and corresponding trunk decay. (Adapted from Raimbault 1995; Lonsdale 1999; Fay 2002)

B.3.1 Young Trees: Accelerated Growth Rate

The life cycle of a tree usually starts from a seed. Stages 1 to 3 prepare the young tree to form its genetically inherent architecture by fierce hierarchy due to apical dominancy. The canopy structure of a young tree is simple and functional, deriving from the basic biological structure of the tree (Figure 3).

Thus, a young tree is like an independent and unique structural unit or module, which evolves according to a species-specific pattern. It should be noted, however, that there are some species for which apical dominance is absent - their terminal buds will form a flower or dry out (for example *Paulownia tomentosa*). In stage 4, apical dominancy is reduced causing lower branches to escape this hierarchy and start with the reiteration process. Growth is favoured by the lack of heartwood in the first decades, which means that all the xylem is used to channel water from the roots to the leaves. The tree also intensively expands its root system by exploiting the assimilates produced. The young tree is able to control its own physiological processes and successfully repel pathogens. Since flowering and fruiting consume a large proportion of the assimilates produced by photosynthesis, trees do not start fruiting until they have passed through the vegetative development stage and reached a certain age and energy level. The age at which flowering and fruiting begin is largely species-specific.

The first phase in the life cycle of an urban tree is of crucial importance, as this is when formational or structural pruning is done to lay the foundation for a sustainable canopy with a good structure. Functionality is also one of the quality parameters of the urban tree. For example, there are different requirements for trees in urban forests, parks and for street trees. These requirements are the basis for setting the pruning objectives for the tree.

Figure 3 (W. Peeters). Young beech trees.

You can see that the young tree is growing rapidly due to its simple crown structure and apical dominance. As young trees are well tolerant to pruning, it is important to develop a strong canopy structure and to ensure functionality, such as a clear traffic corridor, during this period.

B.3.2 Mature Trees: Constant Growth Rate

Over time, the intensity of incremental tree height growth decreases. However, when the tree reaches the beginning of the mature phase (stage 5), it initially retains all the functions necessary for growth and development, including apical dominance. There is an equilibrium between the growth of the crown and the root system. This means that at this time the tree is performing to the best of its ability the functions intended for it when it was planted. By late mature phase (stage 7), the canopy is established, apical dominance ceases, and the canopy becomes denser at the outside, letting less light enter the inner canopy. Branches and roots branch off into ever-new, relatively autonomous units. It is the stage of maximal expansion. At the same time, the lower branches of the tree also start to gradually die back and are shed from the trunk (Figure 4). The point at which a tree sheds a branch or limb is when it starts to consume more energy to maintain itself than it can produce. In the late mature phase, the tree's resistance to pathogens also begins to decline as more carbohydrates are needed to maintain growth on the ever-increasing structure. As a characteristic feature, a large proportion of tree species in this stage appear to have a flattening crown, as they have achieved maximum height.

Assuming that structural pruning has created a durable, balanced and functional crown, a mature tree will require relatively little maintenance. The intervals between prunings are longer, and pruning is mainly aimed at improving the light conditions within the canopy and mitigating risks from dead or damaged branches. When talking about sustainable arboriculture or urban forestry, it is in this stage where trees should be held for as long as possible as maintenance requirements and costs are relatively low.

Figures 4 & 5 (W. Peeters). The rounded crown of trees in their mature phase. The foliage is on the outside of the crown, making the water transport path to the leaves long and difficult.

B.3.3 Ancient Trees: Decelerating Growth Rate

This phase of a tree (stages 8 to 10) can be defined as the time between the beginning of the decline in vitality and the death of the tree. The leaves are mainly located on the outer edge of the crown. As the ancient phase progresses, the growth of the tree's crown diminishes. At the same time, the secondary growth of the stem and branches will continue because sapwood is necessary for conducting water from the roots to the leaves, however, the annual growth rings will gradually become thinner.

The anatomy and the spatial structure of the root system of an ancient tree also change. In response to the increase in mass of the trunk and crown, anchor roots become stronger, and the root system penetrates deeper into the soil. At the same time, the superficial lateral roots continue to grow and branch.

So, in summary, in the later stages of maturity, the canopy begins to recede, and dieback of branches in the top parts of the crown may occur, as less and less water reaches the higher parts of the canopy. One of the reasons for this is the change in the proportion of live, water-conducting sapwood compared with heartwood in the cross-section of the trunk, and the decreasing width of the annual growth ring. Also, the water distribution system within the canopy has become increasingly complex. While in a young tree, the simple structure allows water to rise from the roots to the top of the canopy in an almost vertical flow A mature tree will form functional units to optimise the transport from roots to shoots. These functional units will be more and more independent from each other, which will in the end cause the fragmentation of the tree. Water supply is also impaired by reduced root system capacity, which is often caused by root system damage (Figure 6). Both canopy and root system decline are mutually reinforcing processes. The decline in tree vigour is also accompanied by an increased susceptibility to fungal and insect damage. Cavities and knotholes often occur in older trees, which increase their value for biodiversity.

For tree species with good regeneration capacity, an old tree under favourable conditions may form a new crown, but at a significantly lower level than its original crown. This is made possible by a shortened water transport path due to the retreat of the top of the crown and the tips of the lateral branches. The water shoots (reiterations) that develop from the dormant and axillary buds also improve the capacity for photosynthesis. This, in a way, gives the tree a new life.

Figure 6 (W. Peeters). Crown retrenchment on an ancient beech-tree. In the present case, the cause of the crown reduction is root damage.

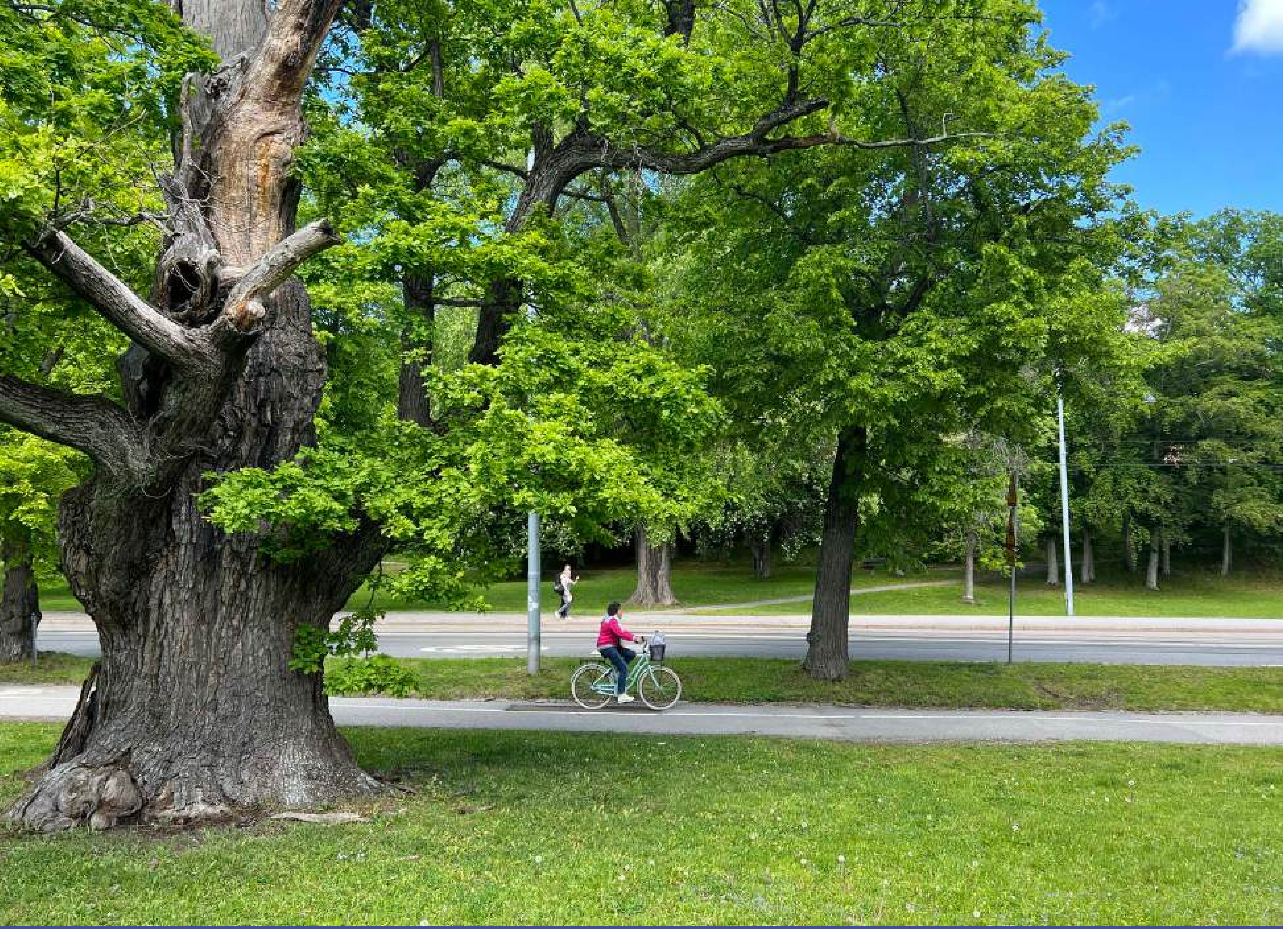
The maintenance needs of mature trees depend primarily on the location of the tree, with safety for people and property being a priority. Care for their growing conditions is essential. The installation of support cables (bracing) may also be an option. However, if the tree has had sufficient space to "age", pruning should be used where possible to encourage regeneration of the canopy. The management of an old and valuable tree usually requires a long-term maintenance plan to be drawn up and implemented.

B.4. Regeneration in the Later Life Stages of Trees

Regeneration is the natural process of replacing or restoring damaged or missing cells, tissues and even entire parts to full function in plants. Here, we focus on the regeneration of the tree itself, as it applies, for example, to an older tree producing a second crown. Regeneration capacity depends on the tree species and its vitality. Only a tree with sufficient vitality, or in other words its ability to deal with stress, can regenerate. If vitality is assessed adequately, the appropriate measures of tree care can be made and an assessment of life expectancy given. The characteristics of water sprouts on trees can give valuable information about its vitality and thus possible management measures. Three main types of epicormic shoots - orthotropic, plagiotropic and ageotropic have been distinguished based on growth direction and stress response. The types and characteristics of water sprouts are described in more detail by Tom Joye and Christophe Drénou in the context of tree architecture (ARCHI model).

IT'S ALL ABOUT
ENERGY
THE CARBOHYDRATE BALANCE

When does a tree die? Despite what we may think, tree mortality has only two principal mechanisms: **carbon starvation** and **hydraulic failure**, and both are linked. Hydraulic failure happen when embolism occurs at a massive scale in the xylem, destroying the water columns, which cuts off the water supply to the leaves, halting photosynthesis. Carbon starvation is simply an energy problem. It occurs when the available carbon resources (stored in the roots, leaves and wood) become depleted to the extent that they can no longer support basic metabolism (e.g. respiration, transpiration) and defence against external influence. In human terms, the tree has burnout. A depleted pool can recover if conditions for carbon assimilation (photosynthesis) improve. If not, a treshold will be crossed with no point of return, leading to the physiological deterioration of the tree. As we have seen, the tree's **energy balance** is a trade-off between its energy production and consumption. Since a tree can only spend the created sugars once, an investment in one aspect will come at the expense of another.



SELF-CHECK QUESTIONS

1. What is the difference between tree growth and development?
2. Explain modularity as a growth pattern.
3. Draw a growth curve of a tree in the function of its lifetime.
4. How do you visually differentiate between young and mature tree? How are the physiological processes different in them?
5. How do you visually differentiate between mature and ancient tree?
6. During which growth stage does apical dominance subside?
7. Can the length of development stages of a tree differ from species to species? Explain.
8. Compare the crown architecture of young, mature and ancient tree.
9. Compare two trees of the same species and age in two different growing sites: in a forest and on a street side in a city. Explain the differences.
10. May the root system of a tree of the same species differ when growing in different growing sites? Explain.
11. What is the difference between the movement of water and assimilates in the vascular tissues of a young and an old tree?
12. What is carbon starvation?

PRACTICAL EXERCISES

Observe trees of different ages and species. The best is to find an older tree with lots of water sprouts. Try to determine their life cycle phase. Relate your observations to the potential biological lifespan of the tree. You can do this by asking these questions (adapted after Tom Joye):

1. What is the (presumable) architectural model of the tree?
2. What are the observable reiterations?
3. What are the stress factors and reaction of the tree on those stressors?
4. Can you identify different functional units in the crown?
5. What type (position) of water sprouts do you find in the tree and what does it mean?
6. Make a conclusion of the observed tree's life stage based on the previous questions.

TERMINOLOGY

apical meristem – a group of cells found at the tips of shoots and roots that retain the ability to continue dividing, constantly forming new cells as the plant grow; responsible for the growth in length/height
dieback – a common symptom or name of a disease, especially of woody plants, characterized by progressive death of twigs, branches, shoots, or roots, starting at the tips
dormancy – period of naturally reduced physiological activity in the organs of a plant with the potential for reactivation of growth
lateral meristem – a tissue that consists of undifferentiated cells and is present on the lateral side of the stem and root of a tree; it is responsible in increasing the thickness of the plants
primary growth – root and stem growth in length; occurs at the apical meristems of trees
reiteration – the development of new shoots or branching systems; a process by which a tree duplicates its architecture, giving birth to new copies of its architectural unit
retrenchment – natural reduction of the crown of an old tree due to changes in its hormonal system and deterioration of water supply in the peripheral parts of the crown
secondary growth – increase in root and stem girth or diameter; occurs at lateral or secondary meristems of trees
translocation – movement of sugars in the phloem

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Good explanation of the cumulation growth curve

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1.2. ENVIRONMENTAL FACTORS – THE EFFECTS OF SOIL, SITE LOCATION, ECOLOGY AND BIODIVERSTY ON THE GROWTH AND DEVELOPMENT OF TREES

1.2.1. Soil Science

Aino Mölder, Robert Oetjen & Dieter Anseeuw

GENERAL OBJECTIVE

To acquire knowledge about the properties of soils and the natural processes taking place in soils. The knowledge gained supports the activities related to tree management and allows us to understand the value of soil as part of the ecosystem. This knowledge also serves as a basis for tree revitalisation.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- understand and explain the process of data collection on a tree site concerning soil;
- explain the effects of compaction in soils;
- understand and explain the water balance of the soil;
- understand and explain the required volume of soil suitable for the spreading of roots (rootable soil volume);
- understand and explain the organic matter content and soil life;
- describe the role and importance of mycorrhizae for the tree;
- explain the different aspects of soil sampling for an analysis of the mineral balance, organic matter content and/or soil texture;
- identify soil texture, structure and profile by tactile and mechanical means; and
- assess the physical, chemical, and biological characteristics of soils.

SEE TOGETHER WITH:

Ecology and Biodiversity, Site Selection, Social Value of Trees, Visual Tree Assessment and Hazard Analysis, Tree Care and Remedial Operations, Tree Site Improvement and Remedial Measures

KEY TERMS

Soil formation: soil, soil horizons, layers, topsoil, subsoil, parent material, weatherin

Physical characteristics: soil texture, structure, porosity, density

Chemical characteristics: nutrients, pH, pollutants

Biological characteristics: soil biota, organic matter, humus, mycorrhiza

Soil health: physical, chemical and biological processes; nutrient and water cycle; organic carbon, humus and humification, soil food web, gas exchange, clay-humus complexes, cation exchange capacity, compaction

Assessment of soil characteristics: data collection, site observation, soil sampling, laboratory tests

ESSENCE OF THE TOPIC

Soil is the essential growing environment for all plants, including trees. To be healthy, trees need healthy soil. To achieve good soil health, it is necessary to first understand what soil health means and what the natural processes are since the latter determines health. The natural processes include soil layering, water transport, food soil web, humification, gas exchange, etc., all of which need to be in balance to maximize ecosystem services like water buffering and retention, soil health or carbon storage. Every soil has three main groups of characteristics: physical, chemical and biological, which are all interconnected and affect the natural processes of soil and consequently soil health. Thus, a set of parameters from each of the three groups needs to be observed in order to adequately assess the soil.

A. The Concept of Soil Health

Soil health is the continued capacity of soil to function as a vital living system, sustain biological productivity and promote plant, animal, and human health. Soil health is determined by several physical, chemical, and biological properties, which are interrelated and affect the natural processes in soils. The most important of these are the water and nutrient cycle, the gas exchange regime and humus formation, as well as the soil formation process itself. A balance between these properties and processes ensures good soil health (Figure 1).

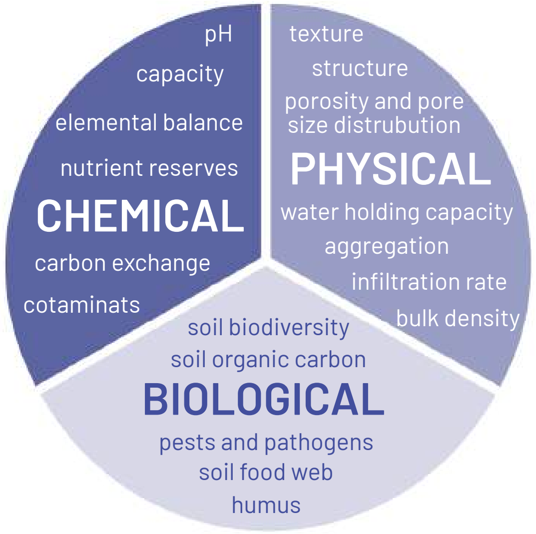

Figure 1. In a healthy soil, the physical, chemical and biological characteristics and processes are in balance. (Adapted from Soil Science Department North Dakota State University 2023)

A healthy soil suitable for most trees is loose, friable, and well-drained. It consists of approximately 45% minerals, 25% water, 25% air and 5% organic matter. It has good structure and texture, plenty of nutrients and a pH between 5.5 and 7.5. In healthy soil, the humus and clay minerals are bound together through adsorption processes. These associations are usually called the clay-humus complexes which, mainly due to their electronegative properties, are able to take up and hold the ions with positive charges. So, the clay-humus complexes work as a store of nutrients in the soil. These complexes may be bound together in larger clumps with different sizes and shapes, called soil aggregates. These aggregates create well-structured soil that has the optimal volume of pores which contain the air and water needed for soil biota and plant growth.

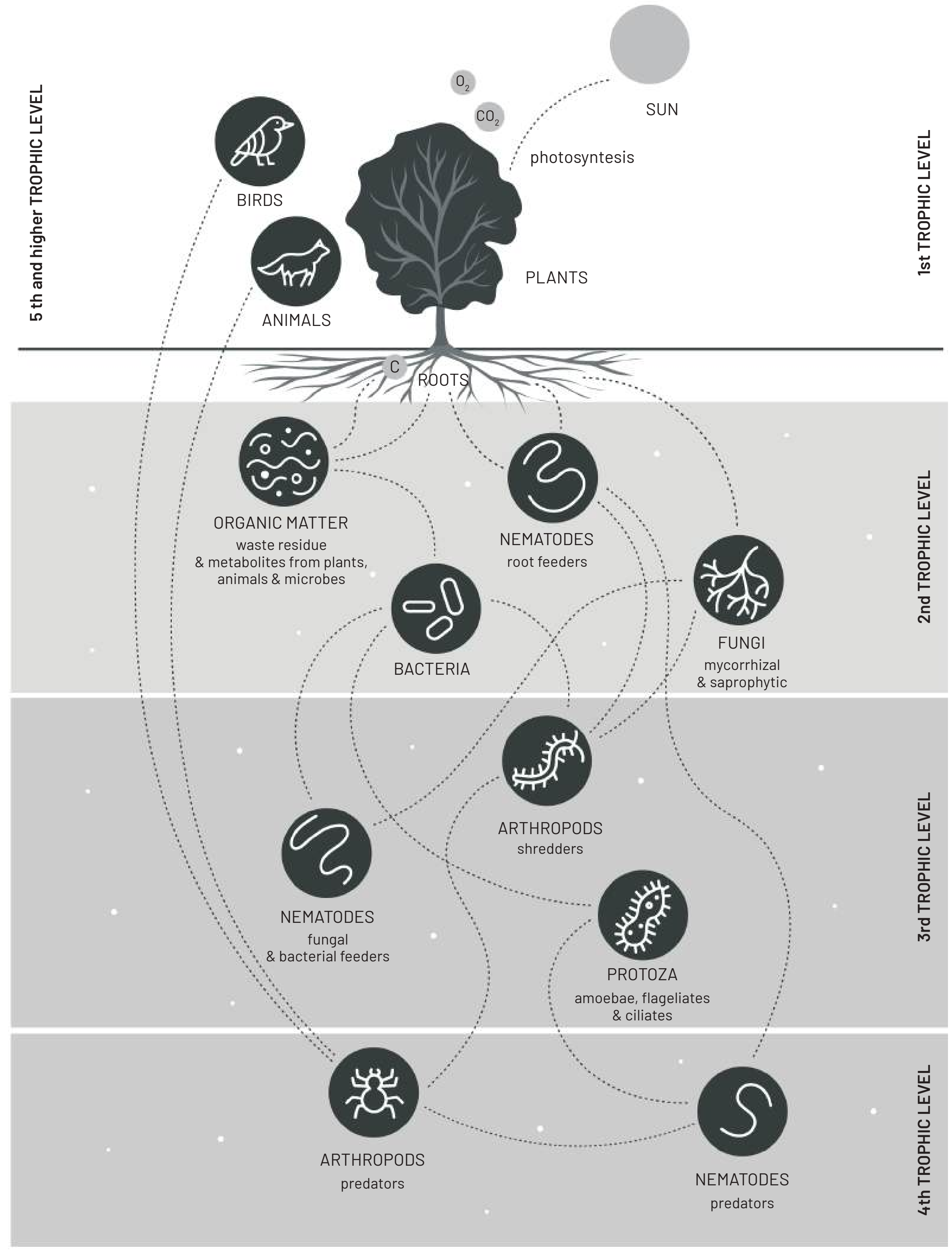

Figure 2. Soil food web. Healthy soil is a dynamic living system that is rich in life. The collective term for all these organisms is 'soil food web'. (Adapted from Soil FoodWeb Institute 2023)

Soil is the primary provider of nutrients and water for all the plants on Earth. It is a host for small, medium, and large organisms that are connected through the soil food web (Figure 2). This soil food web promotes many biological soil processes that help keep the soil and the plants that grow in it healthy.

B. Soil Formation as an Endless Process

Soil is a material composed of five main components – minerals, soil organic matter, living organisms, gas, and water. Soil is formed over a very long time by the interaction of many different natural processes. The essence of soil formation is the gradual weathering of parent material (rocks). Weathering can occur via physical, chemical, or biological processes. Physical weathering is the breakdown of rocks as the result of mechanical actions such as temperature changes, abrasion, or frost. Chemical weathering is the breakdown of rocks through a change in their chemical makeup. This can happen when the minerals within rocks react with water, air, or other chemicals. Biological weathering is the breakdown of rocks by living organisms of both animal and plant origin. The accumulation of material through the action of water, wind, and gravity also contributes to soil formation.

Usually, it is possible to distinguish different layers within soils. These are named soil horizons (Figure 3). The absence of this layering is classified as dirt. There are four main processes that influence the formation of soil horizons: additions, transformations, translocations, and removals. Although the appearance and composition of horizons can vary greatly, they are nonetheless connected with each other and with the atmosphere. In general, the surface horizons are dynamic and rich in life and organic matter. Below the surface horizons more stable, and often lower-fertility horizons can be found. Below them are the horizons that are only partially affected by soil formation. All the mentioned horizons lie on a layer of parent material with unaltered properties. Soil horizons usually are marked with the letters A, B, C and R. The two topmost horizons are commonly referred to as topsoil and the layers under them are subsoil. Topsoil is where most tree roots are located.

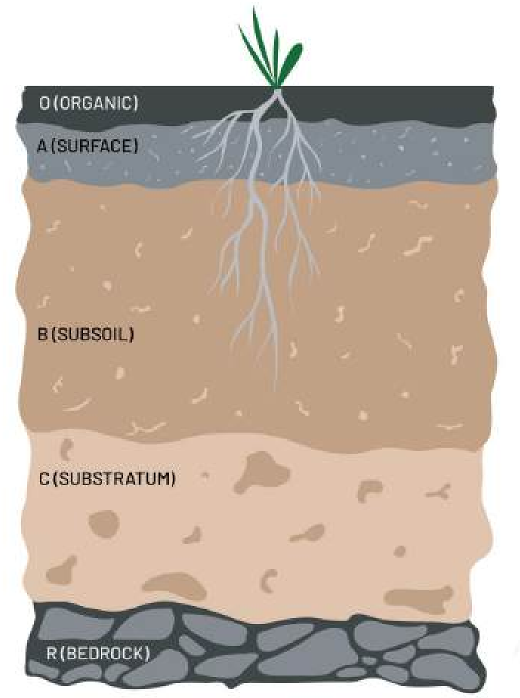

Figure 3. Soil horizons.

Soil qualities are also influenced by man through their various activities such as agriculture, construction, traffic, etc. In urban areas where excavation works, soil filling, etc. take place, the genetic horizons tend to be mixed with each other or the soil particles may be stratified in a different way than those in natural areas. Very often the urban soils are mixed up or replaced with various fillers, such as construction debris, demolition residues, etc.

Soil genesis is never ending – it goes on and on and will never stop as long as there is life on Earth. As it takes thousands of years for soil horizons to form, care should be taken to disturb them as little as possible.

C. Fundamental Soil Characteristics

Soil characteristics can be divided into three groups: physical, chemical, and biological. Together, they affect the properties of the soil, such as movement of water, nutrient cycling, gas exchange regime, and sustainability of soil organisms. These are called edaphic factors when assessing the health of the soil and the suitability of it for growing plants.

C.1. Physical Characteristics of Soil

The main physical characteristics of soil described below are texture, structure, porosity, and density.

Soil texture refers to the relative proportions of sand, silt, and clay particles irrespective of chemical or mineralogical composition. If the percentage of these fractions is known, the soil composition class can be determined by using the well-known triangle diagram, which can be found in the databases of FAO (Figure 4). Table 1 shows how to estimate the soil texture by a simple tactile method – trying to shape a ball or a ring from a moist soil sample. Soil structure refers to the way soil particles group together to form aggregates.

Soil porosity describes the amount of open space (pores) found between solid particles of soil. All pores found within the soil are microscopic and can´t be seen by the naked eye. The pores are filled with either air or water. Thus, the soil permeability, water holding capacity, air regime, etc. are all related to porosity. Based on the size of the pores, they are divided into 3 categories: macropores, mesopores and micropores. The large pores are called macropores (>75 µm). Most of the time, these pores are filled with air and in case of precipitation or flooding, etc. they allow water to quickly infiltrate and drain, similar to a sponge. Mesopores are mid-sized (30-75 µm); they have a capillary capacity for water adhesion, and this is the main reservoir of water available to plants.

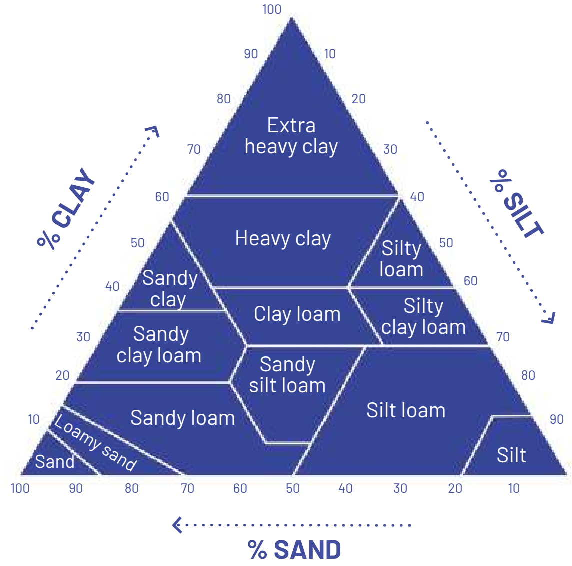

Figure 4. Textural triangle. Soil texture as a function of the proportion of sand, silt, and clay particle sizes (by the classification of FAO). The three sides of the triangle represent the percentages of sand, silt, or clay. The intersection points of three lines from each side of the triangle determine how the soil texture will be classified. For example, if a soil has 20 percent clay, 40 percent sand, and 40 percent silt, it is considered loam (see the triangle in the area labelled loam). (Adapted from Tree Assessor "Soil assessment", 2021)

Water found in micropores (5-35 µm) is firmly fixed by physical forces and is thus unavailable for plants to use. Soil bulk density is the relation between the mass and the volume of a sample of soil. As the soil always contains some air in addition to the solid particles, its density is always lower than the total density of only solid particles found in the same volume unit. When soil is compacted, for example by traffic, the dimensions and total volume of pores are reduced. As a result, the air and water-holding capacity of the soil decreases, and the plant-growing properties deteriorate.

LIGHT SOILS		MID-WEIGHT SOILS		HEAVY SOILS	
Coarse texture (sand)	Moderately coarse texture (sandy loam)	Medium texture (loam)		Moderately fine texture (silty clay loam to clay loam)	Fine texture (clay)
Not possible to shape a ball from the soil.					
Air regime: rich in air.		With optimal structure and porosity. Optimal water, air, and temperature regime. Good conditions for soil biota. Forms enough clay-humus complexes to ensure optimal levels of cation exchange.		Gas exchange capacity: due to high density tends to be poor in air. Poor gas exchange capacity.	
Temperature regime: warm.				Temperature regime: cold.	
Water regime: dry, poor in water.				Water regime: may be excessively moist.	
Nutrient regime: Poor in nutrients. Because of the lack of humus, it is not able to form the required amount of clay-humus complexes.				Nutrient regime: rich in nutrients, but poor ventilation may prevent the development of soil biota and the formation of humus.	

Table 1. Identification of soil texture by a simple field method. (Adapted from Bodemkundige Dienst van België, 2000)

C.2. Chemical Characteristics of Soil

The main chemical properties of soil are the content of plant nutrients and the pH level. Sometimes the soil can also contain substances harmful to plants.

Plant nutrients are chemical elements that are necessary for the growth and development of plants and, because of their inherent functions, cannot be replaced by another element. Nutrients are divided into macronutrients, of which N, P and K are primary and Ca, Mg and S are secondary. Examples of micronutrients are Fe, Mn, B, Cu, Mo, Zn, Co, and others. The nutrients must be in the right proportions in the soil, as a lack of one nutrient can prevent plants from absorbing another.

Soil reaction (pH) is the negative logarithm of the hydrogen ion concentration in the soil which can affect the uptake of some nutrients by plants. For example, in highly acidic soils with a pH of 5,5 or below, phosphorus may be deficient while other elements may become toxic. In alkaline soils, the availability of calcium, magnesium and potassium may increase with higher pH. Iron and manganese, however, undertake a physical transformation to solid particles and become unavailable because of a change in their chemical form. Most woody plants prefer to grow on near-neutral (pH ~ 7) or weakly acidic soils (pH ~ 6–6,5) (Figure 5). The soil reaction can be determined outdoors, for example, with special pH testers. However, it is difficult to alter the soil pH, particularly if there is a need to lower it. Rather, tree species should be selected according to the pH of the growing area.

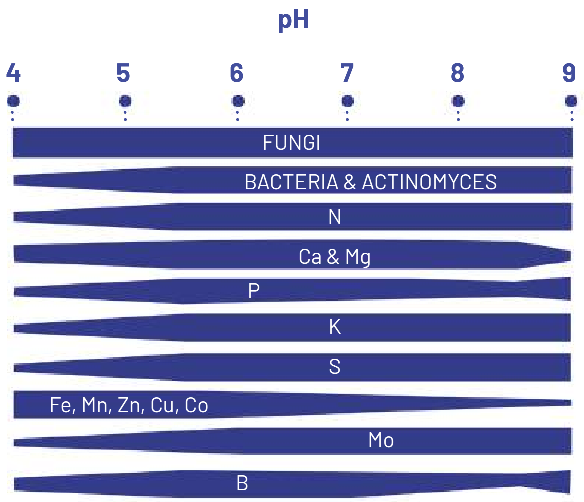

Figure 5. Impact of pH on accessibility of nutrients. The "sweet spot" for most trees is between pH 6 and 7. (Adapted from Tree Assessor "Soil assessment", 2021)

The most common soil pollutants are herbicides and pesticides, de-icing salt, and some heavy metals. The list of pollutants and the accepted concentrations of them are usually specified by national regulations and EU regulations. Pollutants may have an adverse effect on soil organisms and thereby affect soil health. Determining the content of pollutants is possible in the laboratory. Collecting information about previous land use can provide hints about the possible content of harmful substances.

C.3. Biological Characteristics of Soil

Soil is home to billions of organisms, ranging from one-celled bacteria, algae, fungi, protozoans, nematodes, arthropods, to the more visible invertebrates, insects, earthworms, small vertebrates, and plants. Together, they form the soil food web that can be seen as the 'biological engine' of functioning soils, – driving and transforming their physical, chemical, biological, and ecological processes. Soil organisms have a crucial influence on soil processes, soil health, water and air flows, and energy fluxes. Moreover, soil organisms fulfil key processes including biological processes such as respiration, nutrient cycling, mineralisation, and organic matter cycling. To promote tree growth, it is imperative to establish a stable and functioning soil ecosystem. The stability of an ecosystem is primarily dependent on the level of biodiversity, which is influenced by several factors, including abiotic conditions. Therefore, soil organisms must be well cared for. This means that the soil is disturbed as little as possible and it contains sufficient organic matter which provides food for the soil organisms.

The most important biological characteristics of soil are the abundant soil biota, the content of organic matter in various stages of decomposition, including humus, and the presence of symbionts such as bacteria and mycorrhizae. Soil biota consists of decomposers of different trophic levels, such as bacteria, fungi, worms, insects, and small mammals. Together, they form the soil food web (Figure 2).

Mycorrhizae are symbiotic relationships that form between fungi and plants roots. The fungi colonize the root system of a host plant, providing increased water and nutrient absorption capabilities while the plant provides the fungus with carbohydrates formed from photosynthesis. These processes would not be possible to the same extent without mycorrhizae. Fungi need a suitable temperature, airy environment, and suitable moisture for their development. Such conditions exist in forests but may be absent in urban areas. Some pollutants can also prevent the development of mycorrhizae.

One of the soil quality indicators is the presence of humus, which is the final product of decomposing organic matter. This process is called humification. The nutrients released from humus are available to plants (unlike undegraded organic matter). Soil containing an optimal amount of organic matter, including humus, is light and creates good

conditions for both soil organisms and plants. If the soil is compacted, the living conditions of the soil organisms and thus the growing conditions of the plants will deteriorate. On the other hand, if there is too much poorly decomposed or undecomposed organic matter in the deeper layers of the soil, its gas exchange regime deteriorates, and the denitrification process intensifies.

In summary, soil biodiversity, including its biological activity, is closely related to the physical and chemical properties of the soil, as it is the texture, density, porosity, pH, and other properties that determine whether the soil contains the optimal amount of water and air for soil life. Caring for the living conditions of soil organisms helps make the soil more resilient, thereby ensuring good tree growth.

KEEP IN MIND THAT SOIL ORGANISM NEED TWO ESSENTIAL THINGS:

HOUSE&FOOD

Thus, organic material (food) together with a good soil structure (house) is the key essence of the biological component. If one of these 2 conditions is not fulfilled, a sustainable system cannot exist. It will only last for a short time and break down if the measure is not repeated. For example, that is why adding mycorrhiza to unhealthy soils (where other conditions are not suitable) is not effective in the long term.

D. Natural Processes of Soil

Soil is not a static material with unchanging properties. It is a dynamic living environment for both plant roots and soil organisms. On the one hand, the parent material has a strong influence on the properties of the soil. On the other hand, several natural processes influence its development. The natural processes of the soil can be divided into abiotic and biotic. Abiotic processes are caused by physical and/or chemical forces such as wind, temperature, gravity, abrasion, chemical reactions, etc. Under the influence of these forces, minerals are leached and relocated in both horizontal and vertical directions. Chemical reactions also contribute to leaching. Together with biological processes, physical and chemical processes promote soil genesis, including the formation of horizons that was described in more detail above (Soil Formation). Biotic processes are caused by the organisms that are living in the soil, such as small animals, fungi, bacteria, etc. The biotic and abiotic processes are interconnected and together affect the plant-growing properties of the soil, such as humification, water regime, air regime, nutrient cycles, etc. Some of the most important natural soil processes that influence several soil capabilities, soil health included, are described below.

D.1. Cycle of Essential Nutrients and Water

Since the soil is one part of the Earth's ecosystem, it means that several chemical elements participate in the continuous cycle of matter between the soil and the atmosphere, where plants and animals are the connecting links.

Nutrient cycling occurs through both decomposition and synthesis processes. The most important are described below. In different phases of these processes, the same element can move from the composition of organic compounds to the composition of inorganic compounds and back. Gas exchange between the soil and the atmosphere is one of the links in the matter cycle. The nitrogen and carbon cycles are described in more detail below (D.1.2 and D.1.3).

The greatest of all the ecosystem services provided by soil is the retention of fresh water. The small particles of clay and silt slow its drainage. Like a sponge, they physically hold water through capillary forces. Understanding the movement of soil water is essential when working with the growing environments of trees.

D.1.1. Movement of Soil Water

Soil water is the water contained in the soil profile or flowing through it. Soil water is the medium from which plants take up the nutrients needed for their growth and development. Hence it is sometimes referred to as the soil solution. Water also ensures the performance of the physiological processes of plants. The most important characteristics of soil connected to the water regime are the infiltration and drainage rates, retention capacity and the water balance. It is logical that all those characteristics depend on the soil structure, porosity and density, all of which in turn are affected by the soil texture. The content of organic matter, including humus, also helps to stabilize the water regime.

Infiltration is the ability of the soil to allow water to soak into the soil. Infiltration allows the soil to temporarily store water, making it available for use by plants and soil organisms. The infiltration rate is the speed at which water enters the soil. It is usually measured by the depth (in mm) of the water layer on the soil surface that can enter the soil in one hour. The infiltration rate depends on soil texture and structure. The presence of organic matter promotes soil aggregation so that larger soil pores develop, allowing water to infiltrate more readily. Low infiltration rates lead to ponding on nearly level ground and runoff on sloping ground.

Soil drainage is a natural process by which water moves across, through and out of the soil as a result of gravitational force. The ease with which water drains from the soil is equally as important as its storage. For example, plants need some oxygen for the functioning of roots, but oxygen is scarce in soils saturated with water. Moreover, microbial decomposition of organic matter is more active under aerobic conditions. Poorly drained soils have limitations for a variety of land use practices, including growing trees.

Soil water retention can be understood as the total amount of water the soil can hold in. The soil's ability to retain water is strongly related to particle size: water molecules hold more tightly to the fine particles of clayey soil than to coarser particles of sandy soil. In addition, organic matter optimizes the water retention capacity of the soil. The field capacity of soil is the amount of moisture or water retained in pores after excess water has drained away by gravity. At field capacity, the water and air contents of the soil are considered to be ideal for most plants to grow. The content of available water in the soil which is not enough for the plant to survive is called the permanent wilting point (PWP). Thus, plants can utilise water within the range between the field capacity and the permanent wilting point. The water content of the particular soil depends on precipitation and evaporation on the one hand and on the texture of the soil on the other hand. It is a nonlinear, experimentally determined relationship between the suction (or tension) exerted by soil on the surrounding moisture and the soil's relative water content or wetness. This is illustrated in Figure 6.

The water content of the soil at any point in time is characterised by its water balance. The "deposits" for a particular site are influenced by precipitation or irrigation, the capillary upward movement of water from groundwater, and the horizontal movement of water in the soil, either due to differences in water potential or pressure from soil layers. The "withdrawals" are runoff, infiltration into groundwater and evapotranspiration. Thus, water balance is a variable over time influenced by weather, different water uses by plants in their different phenophases, soil texture and relief.

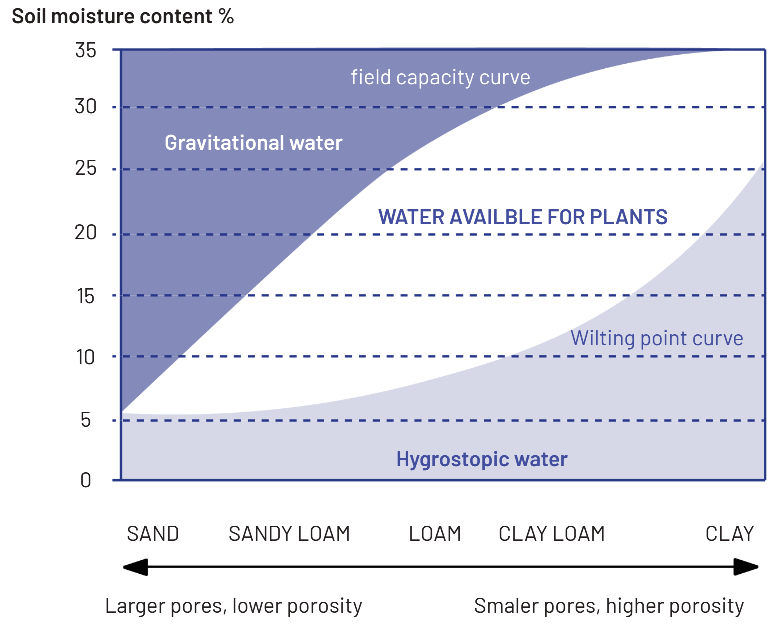

Figure 6. Availability of water depending on soil texture. (Adapted from The COMET Program, 2010)

D.1.2. Nitrogen Cycle

Nitrogen, highly relevant for trees, is necessary for their growth and development. However, nitrogen is often a limiting nutrient in many forest ecosystems because atmospheric nitrogen gas cannot be used directly by plants.

The nitrogen cycle is a multi-stage process during which nitrogen moves between the atmosphere and the soil, where plants work as the connecting link. To move through the different parts of the cycle, nitrogen must change its form. In the atmosphere, nitrogen exists as a gas (N_2), but in the soils it exists as nitrogen oxide (NO), nitrogen dioxide (NO_2), ammonia (NH_3), and ammonium (NH_4). The cycle ends with the release of nitrogen from the soil and its return to the atmosphere.

Thus, the nitrogen cycle plays a crucial role in maintaining healthy soils and promoting the growth of trees. Nitrogen-fixing bacteria that live in symbiosis with certain tree species, such as alder and black locust, can fix atmospheric nitrogen gas into a usable form. Nitrifying bacteria then convert this nitrogen into nitrate, which trees can take up and use.

Excess nitrogen in the soil, however, can also have negative impacts on tree growth and ecosystems. Nitrogen pollution from agricultural and industrial sources can lead to eutrophication, acidification, and other harmful effects. Therefore, understanding and managing the nitrogen cycle is essential for maintaining the health and productivity of ecosystems. The nitrogen conversion cycle is shown in Figure 7.

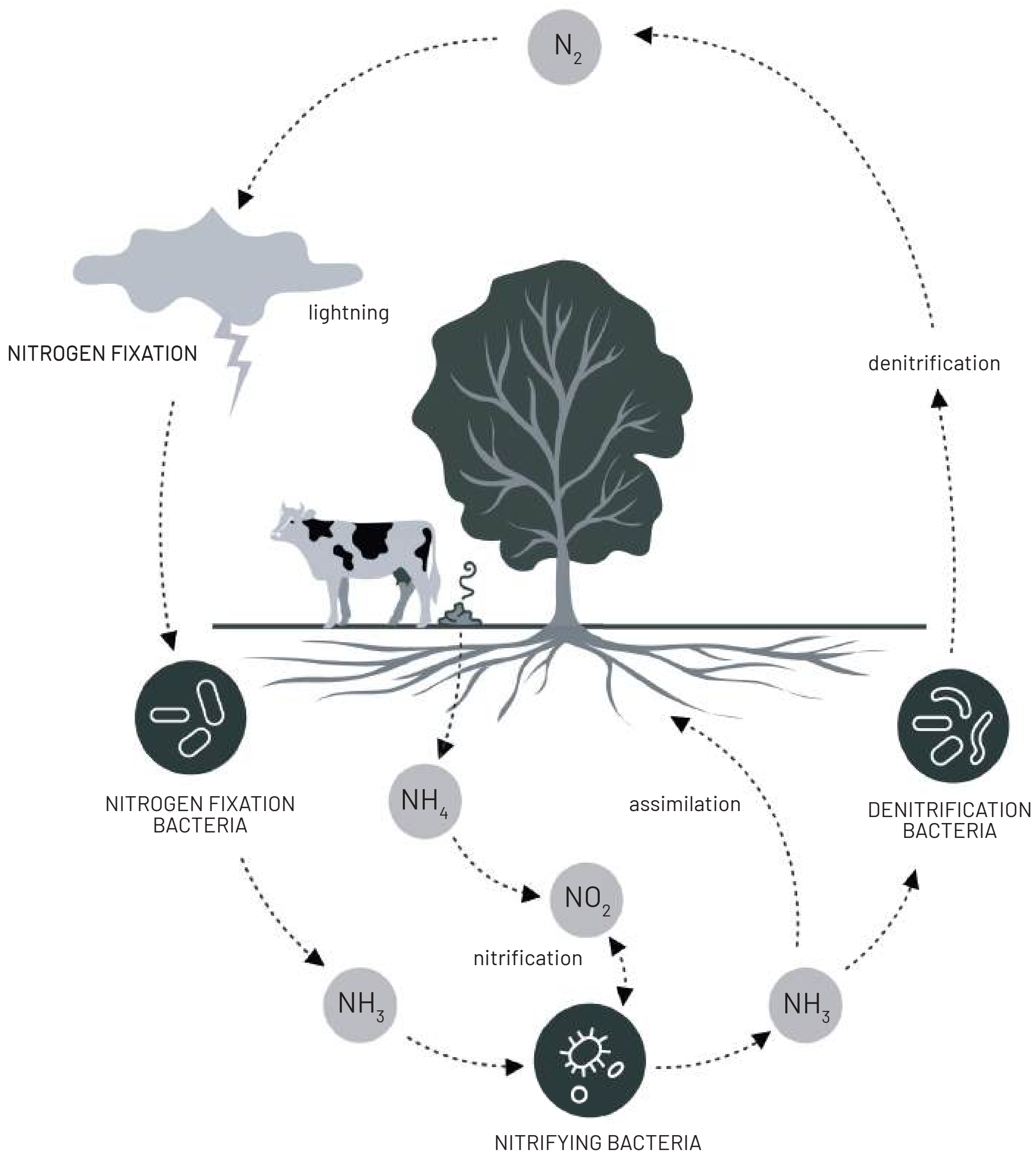

Figure 7. Stages of the nitrogen cycle. (Adapted from Soloneski & Larramendy 2018)

D.1.3. Carbon Cycle and Formation of Humus

The carbon cycle is the movement of carbon in the ecosystem between different components such as producers, consumers, decomposers, etc. The key processes in the carbon cycle are photosynthesis and soil respiration. During photosynthesis, gaseous carbon becomes a component of organic compounds. During respiration, organic carbon is released into the atmosphere as carbon dioxide. Both plant roots and soil organisms that break down plant and animal residues take part in soil respiration. The principles of the carbon cycle are shown in Figure 8. Due to its volume and composition, soil respiration affects the carbon dioxide content of the atmosphere much more than the other components of the carbon cycle.

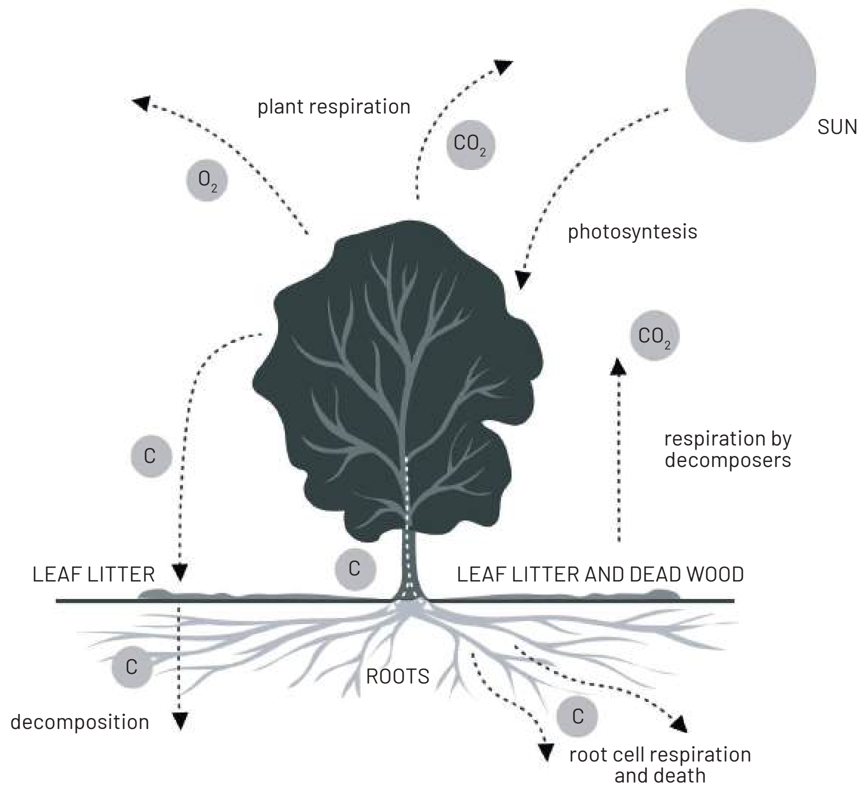

Figure 8. Stages and components of the carbon cycle. (Adapted from Acharya 2023)

One part of the carbon cycle is the formation of humus. Humus is the generic name for the organic material in different phases of decomposition and transformation in the soil. Within the humus, we distinguish stable (humic acids) and non-stable (fulvic acids) compounds. During the formation of the humus, two complementary processes take place simultaneously – humification and mineralization. Humification is the process during which plant and animal metabolic products and residue are broken down biochemically. Mineralisation is the process by which organic substances are converted into inorganic or mineral substances. These substances are mostly water, carbon dioxide, nitrogen, ammonia, and other compounds. The process of mineralisation is of great importance because complex organic compounds are transformed into simpler ones that are soluble in water and thus become available to plants.

The process of humus formation takes place over a long period of time. The speed and ratio of decomposition and humification depend on the composition of debris, soil properties, climate and soil biota. On average soils, the mineralisation of humus takes place at about 2% per year. The process of humus formation is shown in Figure 9.

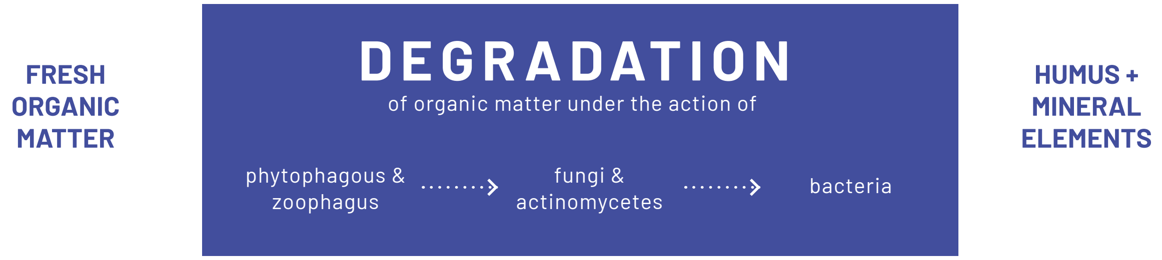

Figure 9. Stages of humification process; the formation of humus is one part of the carbon cycle.

D.2. Gas Exchange in Soil and Atmosphere

Soil is a breathing body. Pores which are not filled with water are filled with air – the main components of which are nitrogen, oxygen, and carbon dioxide. Air in the soil is in constant exchange with the atmosphere. The speed of this process depends on several factors including soil texture, structure, porosity, moisture, density, the content of organic matter, variations in atmospheric pressure, temperature, etc. In addition to the air exchange between the soil and the atmosphere, the composition of soil air is also influenced by microbiological activity in the soil. The most important gases in soil air are oxygen (O_2) and carbon dioxide (CO_2), which together make up an average of 21% of the air in well-ventilated soil, just as in atmospheric air. In the following, we will focus on the importance of oxygen and carbon dioxide in soil air.

Oxygen is the most significant for the metabolic activity of trees and other organisms. Roots need oxygen for respiration, which is the process by which they convert stored energy into usable energy. Without enough oxygen, roots can become stressed or even die, which can affect the entire tree. In addition, oxygen in the soil can be used by microorganisms that play important roles in the decomposition of organic matter and nutrient cycling.

Carbon dioxide is the main product of the respiration of roots, microorganisms and soil fauna. CO_2 in the soil air can increase the activity of microbes, which in turn has a beneficial effect on the mineralization of organic matter, the breaking up of mineral particles, etc., thereby making nutrients more available to plants. When CO_2 reacts with water, it can form carbonic acid, which lowers soil pH.

The ratio between oxygen and carbon dioxide is not constant, it changes in relation to the biological activity of soil organisms. They need oxygen to break down organic matter and release carbon dioxide. If the exchange of air with the atmosphere is limited, the oxygen content can drop very low and at the same time the CO_2 content increases. As noted above, several factors affect air exchange and thus soil air composition. In addition to the aforementioned, one of the root causes of poor air exchange may also be the specifics of the urban environment: widely used hard surfaces, low porosity resulting from soil compaction and the accompanying anaerobic environment. In addition, the organic matter content of urban soils may be too low.

D.3. Cation Exchange Capacity

A healthy soil is able to hold on to sufficient positively charged nutrient ions, critical to soil fertility. This ability is called cation exchange capacity (CEC). The microscopic soil particles called the clay-humic complexes possess a number of negatively charged sites, which can attract and hold oppositely charged ions such as H^+, Ca^{2+}, Mg^{2+}, Na^+, NH^{4+}, etc. CEC is an important index of nutrient status because exchangeable cations are the most important source of immediately available plant nutrients. The more clay-humus complexes there are in the soil, the more fertile it is. The CEC is related to the soil texture. The finer the texture, the more clay-humic complexes the soil contains. For example, loamy soils in general have more clay-humic complexes than sandy soils and are therefore higher in fertility.

E. Rootable Soil Volume

In order to ensure the health and longevity of trees, there must be a sufficient rootable soil volume for the development and spreading of roots. The volume is dependent on several factors, including the size of the tree (crown projection), climatic conditions, water availability, and infiltration percentage of the surface. Guidelines for required or suggested soil volume numbers may differ from country to country. Indicative minimum tree rootable volumes for normal soil are provided in the European Tree Planting Standard. However, based on the specifics of growing sites and conditions, a more detailed calculation may be needed. This is especially important when working in urban conditions where structural soils are often necessary. In this case, the ETT will inevitably be working together with a civil engineer.

WHEN CALCULATING THE ROOTABLE SOIL VOLUME, IT IS USEFUL TO ASK THE FOLLOWING

QUESTIONS

1. What is the desired image of the tree: how large will the crown grow and what will its life expectancy be? How to do this is explained in Chapter 1.1.2.
2. Will the root system be able to reach the groundwater level, or will it remain in the unsaturated zone? Less rootable soil volume is needed if water availability is unlimited.

F. Soil Assessment

The quality of soil needs to be assessed in two cases: if negative changes in tree vitality are noticed and before the planting of new trees. The suitability of the soil can be assessed either by carrying out a visual on-site assessment (Visual Soil Assessment, VSA) and/or by taking soil samples for analysis in a laboratory. Chemical analysis is always best to order from a lab. Regardless of the methodology, it must be ensured that the sample is representative of the entire growing site throughout the radius and depth of the root system. When assessing soil, it is critical to observe each of the three components of soil – the physical, chemical, and biological by a set of different parameters. Relying on only one of several parameters is not representative and can result in an erroneous conclusion. Regrettably, the focus is often placed on chemical characteristics, but this is misleading. Even though they are all interrelated, the physical and biological components are far more important than the chemical.

When starting the analysis of soil suitability for trees, the first step is to collect as much data as possible. It is useful to know the history of the site, which will help to determine if the soil is fertile, what the water regime is, if there may be pollutants present, etc.

Remember that soil assessments are for the evaluation of soil health, which is driven by natural processes. Soil health is what soil assessment is all about.

F.1. Visual On-site Soil Assessment

Visual soil assessment (VSA) is a method to assess soil quality in the field by, amongst others, assessing a profile pit and evaluating several soil quality indicators. When making the VSA, we usually try to assess the physical and biological parameters indirectly, based on literature and practical guides. This, however, can be subjective, similar to a visual tree assessment (VTA). So, the VSA is a part of a larger assessment process.

The set of parameters to be assessed can vary depending on the assignment and customized VSA workflow, but the VSA for trees should address at least the following questions:

QUESTION	WHY	HOW
What is the soil profile?	Soil profile provides a thorough understanding of the soil make-up and root environment. This description helps to interpret other questions.	Make a profile hole at least as deep as the roots, go through the layers until reaching groundwater level (if possible).
What is the soil texture?	By knowing the soil texture, it is better to put the water and nutrient cycles into context.	Fairly useful information.
Is the soil compacted?	Compaction negatively affects the water regime and gas exchange which in turn influence the biological component and leads to soil health deterioration.	Use an analogue penetrologger or -meter and try to go as deep as possible.
Where is the water level situated?	"Stains" from oxidation/reduction of soil form in anaerobic conditions, which results from prolonged water saturation, meaning lack of oxygen for soil life.	The presence of rust (orange) stains throughout the profile all the way down until the blue-coloured soil indicates permanent anaerobic conditions.
What is the soil structure?	Soil structure provides information about air and water management, pore volume and rootability of the soil. The size of the soil aggregates and especially the shape of the fracture surfaces give information about the airiness of the soil.	Dig a small hole. Focus on the soil aggregates and determine their size and distribution. Check the sharpness of the edges of the clods.
How stable is the soil?	Aggregate stability is a measure of the binding between soil particles. Soils with higher aggregate stability are less prone to smearing and erosion.	Shake soil aggregates in water and check the size before and after. The dissolving rate is a measurement of soil stability.
Where are the roots and what is the structure of the roots?	Roots are perfect bioindicators where conditions are suitable for growth.	Together with the soil profile, analyse the root depth and condition.
Is soil biota present, and where is it?	Earthworms are also perfect bioindicators for soil biota (activity). Finding an abundance of different functional groups of earthworms helps to interpret living soil activity.	Check for earthworms, especially the functional groups which can be determined very quickly on the field. Remember, earthworm activity varies during the year.
What is the rootable soil volume?	In the extent of rootable soil volume, roots are able to spread. The amount of soil needed is related to the tree size.	Estimate based on the depth of the roots and size of the tree.

Table 1. Visual on Site Soil Assessment questions. (Adapted from Anseeuw 2022)

F.2. Soil Sampling for Laboratory Analysis

The most common reason for ordering a laboratory analysis is to find out the nutrient content of the soil. But, if needed, labs can also provide data about soil texture, density, soil organic carbon, humus content, field capacity, etc. If it is decided to order laboratory analysis of the soil, it is important to submit a mixed representative sample taken from several sample points radially around the tree, as soil conditions may vary significantly over a small site area, especially in urban areas. It is important to note that different laboratories may use different analytical methods and units, thus giving somewhat different results. An accredited laboratory following the EU guidelines for soil sampling and soil analysis is the best choice. Laboratories usually provide services for interpreting the tests. It should be noted that laboratories usually provide soil assessments in the context of agriculture with their own benchmarks. For trees, quantitative benchmarks have not been developed up till now. A good knowledge of tree species and their habitat requirements is helpful here.

SELF-CHECK QUESTIONS

1. How are soil texture, structure and porosity interrelated?
2. How does the soil pH affect plant nutrient uptake?
3. What is soil compaction and how does it affect gas exchange and the water regime of soil?
4. Describe the movement of water within soil.
5. What are mycorrhiza and what are their importance?
6. How does soil compaction affect soil biology (organisms)?
7. What is the importance of soil organic carbon?
8. What is the soil food web?
9. What is the soil health?
10. What is humus and what is its importance?
11. How to understand the expression "soil biota is the engine that sustains the health of soil"?

PRACTICAL EXERCISES

1. Make a correct drilling core profile.
2. Assess the soil horizons and texture.
3. Observe and assess the soil biota and its activity.
4. Assess the water regime within the soil profile.
5. Observe the positioning of the roots.
6. Read and learn about earthworms and their functional groups.

TERMINOLOGY

bulk density – the mass (in kg) of 1 m^3 of unaltered soil; it is most often determined by field capacity; soil with a density of 900-1200 kg/m^3 is suitable for most woody plants
cation exchange capacity (CEC) – a measure of how many cations can be retained on soil particle surfaces
clay-humus complexes – complex compounds of soil humus and clay particles that, due to their negative surface charge, can attract and hold positively charged ions of plant nutrients
denitrification – a form of anaerobic respiration that results in the conversion of NO_3^- to primarily N_2O and elemental N (N_2)
detritus – plant- or animal originated dead and decaying organic material in soil
evapotranspiration – a term used to refer to the combined processes by which water moves from the earth's surface into the atmosphere; it covers both water evaporation and transpiration
field capacity – the amount of water remaining in the soil's micropores following the drainage of water due to the force of gravity
ground water level – groundwater is water that exists underground in saturated zones beneath the land surface; the upper surface of the saturated zone is called the water table
humification – the process by which dead and decaying organic matter are converted to humus by decomposing bacteria, fungi and other microorganisms
humus – the dark, almost completely decomposed plant- and animal-originated soil component that is rich in nutrients; its qualities are stable, and it improves the soil
leaching – the removal of dissolved ions from soil
mycorrhiza – a symbiotic association between a fungus and a plant consisting of plant root and fungal cells
porosity – the total volume of space between soil particles, expressed as a percentage of the total volume of the soil
soil aggregates – groups of soil particles that bind to each other more strongly than to adjacent particles; the space between the aggregates provide pore space for retention and exchange of air and water
soil health – a concept that describes the capacity of soil to sustain biological productivity, maintain environmental quality, and promote plant and animal health
soil horizon – layer present within soil bodies that is distinguishable from other layers; often generated through soil formation processes
soil respiration – an integral part of the carbon cycle that occurs between the atmosphere and the soil; in the respiration process carbon dioxide is produced when soil organisms and plant roots respire
soil structure – the indicator of the spatial structure of the soil; the structure is expressed in the ability of the soil to form clumps or aggregates of finer particles
soil texture – the indicator that shows the proportion of small (clays), medium (silts), and large (sands) soil particles
permanent wilting point – the moisture content of a soil at which plants wilt and fail to recover when supplied with sufficient moisture
weathering – physical, chemical, and biological processes that breakdown and transform rocks and minerals

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USA Comprehensive Assessment of Soil Health. Retrieved from: https://www.css.cornell.edu/extension/soil-health/manual.pdf

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1.2.2. Growing Site Selection

Aino Mölder & Robert Oetjen

GENERAL OBJECTIVE

To gain an understanding of the basics of tree selection based on the complexities of growing site conditions.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- compare different site conditions for urban and countryside trees;
- choose a tree according to prevalent edaphic factors on site;
- implement soil composition improvement methods where necessary;
- select trees for specific site conditions;
- identify aesthetic, biological, and arboricultural features of trees and assess their suitability for specific sites and positions based on these criteria; and
- understand the influence of the site conditions on the life expectancy of trees.

SEE TOGETHER WITH:

Tree Development and Growth Stages, Soil Science, Ecology and Biodiversity, Social Value of Trees, Tree and Shrub Planting and Aftercare, Tree Revitalisation, Structural Tree Management

ESSENCE OF THE TOPIC

The impact of the growing site and the function of the tree has a profound impact on its longevity. As tree selection is part of the (re)design process, a thorough strategy that combines the aspects of growing site constraints, ecophysiology, function, and aesthetics is needed for establishing trees sustainably. The essence of this strategy should guide the tree during its lifetime by facilitating the tree's natural processes above and below ground based on four aspects. Today, this integrated strategy can be referred to as the right tree in the right place for the right reason, which actually is a thinking methodology to approach trees in the (re)designing process. This strategy uses a three-step process which helps an ETT to translate the strategy into the designers' and architects' world. First, the site must be carefully assessed (diagnosed). Second, identifying and understanding the function of the tree leads to the determination of its final image. The third step follows by choosing the tree based on the criteria deducted from the previous steps.

Background for 3-step Site Selection Process

Urban and rural trees are similar as both provide important ecological, aesthetical, environmental and other values for people. However, the growing conditions in rural and urban environments differ widely and therefore affect the trees' longevity.

KEY TERMS

Growing site analysis: concept of three-step planning, above-ground analysis, under-ground analysis, edaphic factors, overhead infrastructure, underground infrastructure, environmental factors, urban sites, rural sites, life expectancy of trees

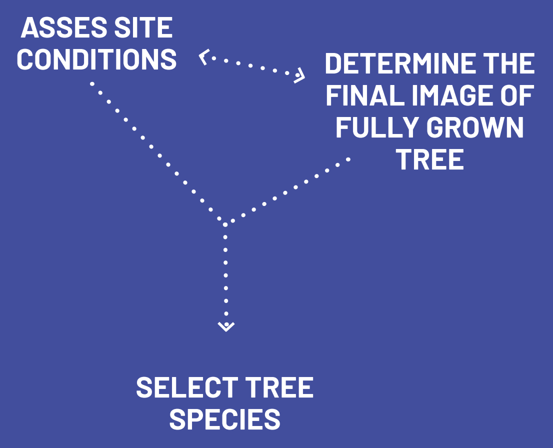
Principles of tree species selection: vision of fully grown trees, aesthetic qualities, ecosystem services, biodiversity, hardiness, hardiness zones, shade tolerance, climate changes, native species, alien species, invasive species, gardens, parks, paved areas, coastal areas

As we can see in Chapters Tree Development and Growth Stages and Soil Science, in the case of urban trees, it is important to provide conditions to support the natural processes of the trees and soil, so that they are able to achieve similar life expectancies to their counterparts in rural areas. Furthermore, trees can create a habitat suitable both for themselves and for other organisms living together with them, thus building an ecosystem. This means that there is no fundamental difference between rural and urban areas regarding the way trees work. The major difference is that in urban areas restrictive conditions like limited root space, unsuitable and compacted soil, conflicts with both above- and below-ground infrastructure, damage to roots by digging, drought caused by impermeable surfaces, pollution, etc. are far more numerous than in a country site. When working in urban areas, the most important question to be asked is: *What is the desired result and how much are you willing to invest in the tree?*

Considering the above question and the strategy *the right tree in the right place for the right reason is paramount*. In order to make an optimal decision to enhance life expectancy, it is useful to apply the three-step planning process. This methodology addresses the aspects of growing site constraints (step one), ecophysiology (steps one and three) function (step two) and aesthetics (step two). This three-step process is an easy-to-follow chronological method.

3 STEP PLANNING

is a model of thinking that leads to a compromise between the possibilities offered by the growing site and the selection of tree species suitable for that site.



A. Step 1 – Evaluation and assessment of the Site Conditions

Site evaluation is the first step in selecting proper trees for a planting site. It is important to consider both the above-ground and below-ground site attributes during the assessment and come to a conclusion. The site evaluation process has often been underrated, resulting in poor tree performance. This explains why trees planted in urban areas are so often unhealthy and short-lived.

A.1. Above-ground Site Analysis

In the above-ground evaluation, a thorough inventory of all existing infrastructural and environmental factors has to be made. Infrastructural facilities include buildings, hardscaping (i.e. walls, paved areas, steps, etc.), roads and pathways, overhead wires, street lights, signs, neighbouring properties, etc. These factors determine how much above-ground space is available. Environmental factors include climate features such as temperature, humidity, light and wind conditions. It is important to note that within the same climate zone, even within the boundaries of one city, there may be significant variations in the micro-climate. For example, high-rise buildings may cause notable shading or, on the other hand, intense light reflection. Closely spaced buildings may create wind corridors, increasing the effect of negative temperatures and even causing frostbite in cases of colder climates. Intense traffic in urban areas is usually a source of environmental pollutants, such as exhaust gases, chemical spills, de-icing salts, etc., which all affect the health of urban trees. In rural areas, for example, neighbouring land use practices (intensive agriculture, etc.) may have an important influence on the growing conditions of a particular site and should be assessed.

A.2. Under-ground Site Analysis

While the identification of the above-ground factors of growth sites is possible via observations, the underground part of the site is not visible.

The soil health, and especially the soil natural processes as described in the Chapter Soil Science, including such factors as hydrology, etc., need to be evaluated. Furthermore, infrastructural facilities such as pipelines, cables, foundations, curbs, etc., need to be identified and localised to answer the soil assessment questions. It is often necessary to consult with local cable companies, water/sewer departments, electric utilities, telephone and gas companies before selecting and preparing a growing site. Underground infrastructure location plans are also particularly important sources of information, and the skill of interpreting these is a useful tool.

A.3. Conclusion

When assessing the above- and underground growing sites, it is necessary to make an adequate conclusion to determine whether above-ground natural processes like full crown development of a tree and below-ground natural processes of soil can be secured. This determination, together with practical aspects like regulations, plant availability, species and arboricultural features of the trees, etc., allows one to decide what resources are necessary to achieve the desired result. In addition to the limitations arising from the growing site, as well as the opportunities it offers, it is also necessary to consider social, cultural, and economic factors when choosing the tree species to be planted.

B. Step 2 – Vision of Fully Grown Tree

When the assessment of the above- and below-ground features of a potential growing site has been completed, it is then necessary to establish a vision of the site when the trees have reached their full size. This can be called the desired or final image. This means adequately considering the growth potential for the particular species in ideal conditions, but also being realistic in terms of the existing limitations on the site. This is a mental exercise that provides guidelines for the selection of a suitable species. This is only possible if the main functions of the tree are thoroughly defined. In the past, when planning and designing with trees, the main considerations were aesthetics and traffic-related factors. Today, as the awareness of ecosystem services of trees is rising, it is necessary to consider additional functions. More information on the functions of trees is provided in the Chapter Social Value of Trees.

In reality, the final selection of the tree is a compromise between the ideal vision and the restrictions existing on the growing site. Because of this, some municipalities may use a classification of trees according to their life expectancy and other parameters like volume, height, etc.

In a specific municipality, for example, according to growing site characteristics, trees could be classified as:

- short-lived trees: the tree crown is not able to reach its full potential size; may be allowed to grow only a limited number of years (i.e., 25) or to a permissible height (i.e., 12m);
- future trees: tree crown reaches full potential size, and can grow until veteran stage; and
- elite trees: the tree can reach its full crown potential (width and height) and grow to the full extent of its biological age.

Specification about the final or desired image should be communicated and discussed very early in the design process as this affects construction and management decisions and should be fixed in a structural tree management plan.

C. Step 3 – Tree Species Selection

Tree species selection criteria can be classified as primary and secondary. In general, primary criteria are filters, and secondary criteria arise from human needs, such as ecosystem services and aesthetic factors (Figure 2). Based on this, a shortlist of suitable species can be made. When producing this, a professional arborist or ETT should always have an objective approach and not be dependent on what others (tree nurseries, municipalities, etc.) suggest. The arborist must go beyond the descriptions found in catalogues. The main fundamental principles for sustainable species selection are given below. Sustainable in this context means a methodology of selection where the chosen tree will thrive for generations.

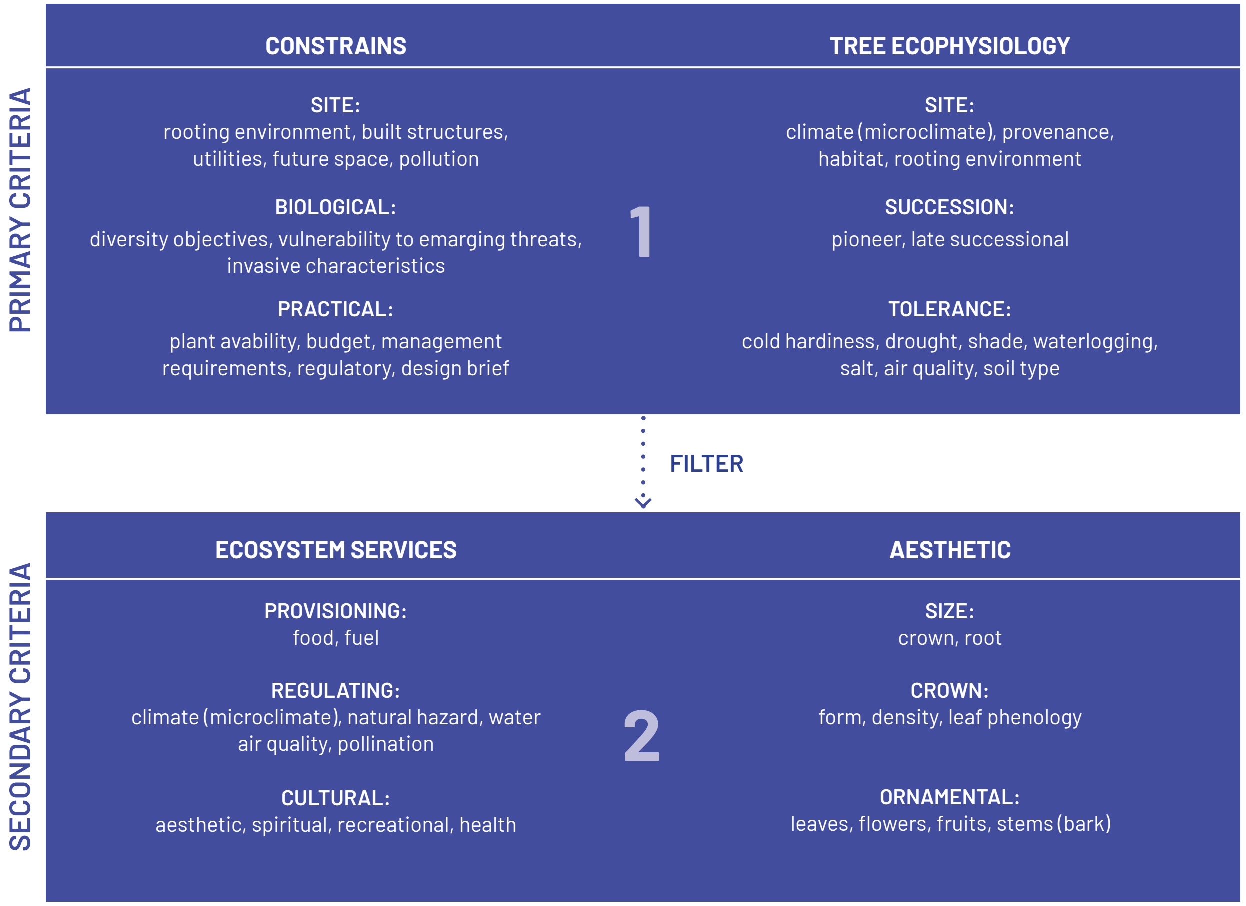


Figure 1. The species selection model. (Adapted from Hirons, A., Sjöman, H.)

C.1. Primary Principles for Sustainable Species Selection

The first principle, habitat and ecology, suggests looking at the natural habitat and ecology of the particular species, or, in other words, its ecophysiology. A habitat includes all possible places where a particular organism occurs (e.g., in southern Spain or in mountainous areas). Ecology studies the interaction of the species with its environment (e.g., shade tolerance, waterlogging). Across Europe, trees are found in a range of habitat types, including forests, shrubland and grasslands. Both habitat and ecology need to be assessed to screen suitability.

Ecosystem services and disease resiliency are best provided by areas rich in biodiversity, as this is done in nature. Biodiversity is simply the variety of life and has three main dimensions:

- genetic: the biological variation that occurs between species;
- species: the number of species in an area;
- ecosystem: the variety of ecosystems in an area.

Hence, when selecting a tree, it is necessary to think about the genetic variety, the diversity of species, and the habitat that the trees may create. More information is found in the Chapter Biodiversity and Ecology.

The question of whether to use non-native species is much debated. The following rules of thumb are relevant and should be considered:

- The more rural the site, the more native species should be selected to keep the features of a more natural landscape. As urban areas are fully man-made, species selection may be wider and is only restricted by their invasive character.
- Establish a "native backbone structure" in urban areas for resilience (see Chapter Ecology and Biodiversity for more info).
- Use the *proven urban* species for the less sustainable growing sites.

EUROPAN ATLAS OF FOREST TREE SPECIES

A useful tool for gathering information is the European Atlas of Forest Tree Species: (https://forest.jrc.ec.europa.eu/en/european-atlas/atlas-download-page/). Here you can identify the natural habitats for tree species using the tree species matrix, and get thorough descriptions of all European tree species.
For example, the description of *Fagus sylvatica*, useful for ETT, includes the following:

"European beech tolerates very shady situations and does not thrive on sites that are regularly flooded or which have stagnant water, since it needs good drainage and will not tolerate waterlogged or compacted soils. Beech furthers soil conservation due to its production of a large quantity of litter (around 900g/m² per year). The root system tends to be shallow, making it susceptible to drought when compared to coniferous stands. However, there appears to be some genetic variability across different climatic zones, since trees in southern Europe are able to cope better with drought than those in the north."

Another source for thorough ecological information is the EC Habitats Directive Interpretation Manual (https://www.natura2000.nl/sites/default/files/Bibliotheek/Europa/EC%202013_Interpretation%20Manual_EUR28.pdf). Here, for example, the habitat of the Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers includes the following description:

Forests of hardwood trees of the major part of the river bed, liable to flooding during regular rising of water level or, of low areas liable to flooding following the raising of the water table. These forests develop on recent alluvial deposits. The soil may be well drained between rising or remain wet. Following the hydric regime, the dominant woody species belong to Fraxinus, Ulmus or Quercus genus. The undergrowth is well developed.

NO INVASIVE EXOTIC SPECIES!

Invasive alien tree species (IAS) are trees and shrubs that are introduced accidentally or deliberately into a natural environment where they are not normally found. This has serious negative consequences for their new environment because they have invasive characteristics and threaten biodiversity. In order to combat this problem, the European Commission enforced a law The Invasive Alien Species Regulation (Regulation (EU) 1143/2014) which includes a set of measures to be taken across the EU in relation to invasive alien species. The core of the Regulation is the list of Invasive Alien Species of Union concern (Union List). This list, consisting of 41 plants and 47 animals, includes six trees (*Acacia saligna, Ailanthus altissima, Baccharis halimifolia, Hakea sericea, Prosopis juliflora* and *Triadica sebifera*) which are subject to restrictions on their keeping, importation, exchange, sale, use, breeding, cultivation, growing and release, in addition to measures for their early detection, eradication or management. For more information on policy and management, check the national authorities on biodiversity or forestry. Note that countries can apply more regulations than the EU Union list, based on the potentially invasive character. For example, in Belgium, next to the Union list, the Harmonia list makes a distinction between a black, watch and alarm list and is far more elaborated than the EU's list.

Tree survival and adaptation to different regions of the world are determined by hardiness zones. The European hardiness zone map divides Europe into 11 zones, ranging from -51°C to 10°C. The map is available in many public databases. If planning to plant a tree, it must be ensured that it will tolerate the year-round conditions of the particular area. However, the recommendations found there must be viewed critically, as they generally do not show the specifics of the micro-site.

More and more, climate change is affecting our environment. As the impact of global warming is increasing, it changes the regional or local climate. Scientists can use models to accurately predict the new regional or local climate for the near future, but the effects become uncertain the further into the future we look. Especially problematic is foreseeing what the situation will be like in large urban areas. Talking about sustainable tree selection implies thinking about the climate in 2050 or 2100. The best strategy is to take the models on climate change of the national weather agencies and think about what consequences this will have on the habitat and ecology of the desired species. For example, the climate in Flanders (Belgium) will shift towards more extremes regarding rainfall and temperature: more severe and more frequent summer droughts, more wet winters and more severe floodings. These phenomena are more extreme in urban areas. Combining this information with the example of the riparian forests depicted above, we can substantiate why *Fraxinus, Ulmus* or *Quercus genera* are valuable options to use. On the other hand, in the more northern regions of Europe, these climatic changes allow for the more extensive spread of diseases and pests. For example, *Ophiostoma ulmi* and *Ophiostoma novo-ulmi* lead to the death of *Ulmus glabra* and *Ulmus laevis*. *Hymenoscyphus fraxineus* leads to the massive death of *Fraxinus excelsior*. Additionally, the prevalence of ever-warmer winters allows the overwintering of *Ips typographus* causing the extensive death of *Picea abies*. Thus, the selection of species depends greatly upon the climatic characteristics of certain regions.

C.2. Secondary Principles for Sustainable Species Selection

The aesthetic qualities of trees are usually considered to include abundant and long-lasting flowering, unusual foliage, which may be coloured or variegated, and a growth habit that may be pyramidal, pendulous, spherical or even creeping. Trees add variety to the landscape, shield views of technical installations and highlight views that are to be exhibited. Individual trees or groups of trees can act as accent trees in the landscape. The ornamental qualities of different tree species should be explored in a dendrology course.

During the tree selection process, it is also important to consider the various arboricultural features of the desired species. This means having a thorough knowledge of a species' biology, which determines, for example, the tree's response to pruning. The arboricultural features also affect establishment and maintenance costs for selected species. Just as a reminder – a big tree has a big root system! If there is not enough space for the roots, choose a smaller tree. When choosing a tree, the location of the growing site in relation to sunlight also should be considered. Trees suited for partial sun/partial shade will adapt to a site receiving three to six hours of direct sun. Trees that require some shade are adapted to sites receiving less than three hours of direct sunlight. Most large trees grow best in full sun. Sunlight reflected from glass or walls on buildings can increase the heat load on a tree planted near a building.

C.3. Selection of Tree Species for the Most Common Growing Sites

Besides the fact that the growing site specifics vary widely between the rural and urban environments, they also may vary greatly within the same city limits. For example, within a town, there may be areas of urban forests, gardens, public spaces, buildings, etc. Here are some guidelines for selecting tree species according to the site specifics.

Parks and urban forests have very few restrictions on crown and root development imposed by built infrastructure. Thus, forests and parks belong to the growing sites of the highest quality. The choice of tree species in parks derives primarily from the principles of landscape architecture. However, in forest parks and urban forests, other factors, such as recreation and ecosystem services, are also important. In these environments, it is important to consider the values of biodiversity, species, and age variation. Inclusion of non-native species can be considered. Regardless of whether it is a park as an architectural landscape form or an urban forest fulfilling an ecological and recreational function, the selection of species must consider their suitability for the specific region. Geographical latitude, maritime or continental climate, altitude, year-round distribution of precipitation and extreme temperatures are important parameters.

In contrast to parks and forests, the choice of tree species for paved areas such as city streets, squares, pedestrian areas, etc., often presents serious constraints to designers. These limitations can originate from air- and water-impermeable surfaces. The soil under the pavement is typically compacted and poor in soil biota, including mycorrhizal fungi. It also tends to be dry because rainwater runs off rather than being absorbed by plants. Depending on the technology used for making the pavement, it also may be poorly aerated and overheated by the sun. Soil like this is considered inhospitable for roots. Consequently, trees suitable for paved environments must tolerate at least moderate drought and their tolerance to temperature fluctuations must be higher than average. In addition, their fruits must not cause conflicts with users of streets, parking lots, yards, and squares. As there are no size limits for this category, it is possible to use a wider range of species. One of the most important criteria is the decorativeness and variability of different tree species.

There are gardens of different sizes in cities and rural settlements. Depending on the size of the plot, gardens in urban areas are often divided into a smaller front garden and a larger back garden. The selection of tree species for the front garden generally has the same restrictions as elsewhere in densely populated urban areas. When choosing the size of the tree, it must be considered that its crown does not extend over the fence to endanger people walking on the sidewalk or come into conflict with overhead lines, streetlights, or signs. Therefore, small or medium-sized species are suitable for small gardens. Decorativeness is another important criterion, for example, not only blooming but also foliage with different colours and different fractures add beauty. A desired plant group for small gardens are pyramidal, columnar and spherical forms of deciduous trees and conifers, as well trees with a two-dimensional (flat) crown that have been designed by special pruning methods in nurseries. Compared to front gardens, back gardens typically offer more options for tree selection because there is more space. When choosing a place to plant a tree, it is good to remember that even when the tree is fully grown, it should be possible to maintain it from its own plot. Sufficient space around the trees allows them to form a species-specific crown.

Trees recommended for coastal sites have no restrictions for size. The only criterion is that the trees that will be growing in coastal areas have to be tolerant to saline conditions and wind exposure. There may, however, be some other restrictions caused, for example, by infrastructure and hardscaping. Therefore, it is important to evaluate species' tolerance to other relevant conditions, such as soil, shade, drought, or waterlogging, before making a final decision.

SELF-CHECK QUESTIONS

1. What does the above-ground growing site analysis involve?
2. What does the under-ground growing site analysis involve?
3. What restrictions need to be considered when choosing urban trees?
4. How do the growing conditions of urban trees affect their life expectancy?
5. What is a micro-climate and how should it be considered when choosing a tree?
6. What are the advantages and disadvantages of non-native tree species?
7. What is the European Union List?
8. Explain the concept of invasive species and the risks involved.
9. How might climate change affect the choice of tree species?
10. Which arboricultural features affect the choice of tree species?
11. How are the risks of using alien tree species managed in your country?

PRACTICAL EXERCISES

1. Select a suitable tree, based on the under-ground site analysis, for the street where you live or work.
2. Assess the above-ground site for a tree to be planted on the street where you live or work.
3. Assess the final image of a tree to be planted on the street where you live or work.
4. Search the literature for what the urban climate will be in the nearest city in the year 2100.
5. Choose a tree growing nearby and research its native habitat and ecology. Analyse and compare that with its present growing conditions.

TERMINOLOGY

biodiversity – the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems
ecosystem services – many and varied benefits to humans provided by the natural environment; often divided into four categories: supporting, provisioning, regulating, and cultural services, e.g. refers to natural pollination of corps, clean air, extreme weather mitigation, human mental health and physical well-being
edaphic factor – the physical, chemical, and biological properties of soil that result from biologic and geologic phenomena
hardiness – a term that describes the ability of plants to survive adverse growing conditions (e.g., at low temperatures)
microclimate – a local set of atmospheric conditions that differ from those in the surrounding areas; the term may refer to areas as small as a few square metres or as large as many square kilometres
shade tolerance – a term used to describe a tree species' ability to become established, grow and persist under shade or low light intensity and duration
structural soil – a medium that can be compacted to pavement design and installation requirements while still allowing root growth; it is a mixture of crushed stone and soil containing mineral and organic parts

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Comprehensive guide for selecting the right tree. Chapter 2 'The principles of tree selection for green infrastructure' is enlightening.
UK Trees in Hard Landscapes A Guide for Delivery by Trees and Design Action Group. Retrieved from: https://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_tihl.pdf
Comprehensive guide for selecting the right tree but more technical. Chapter 2 'Species Selection Criteria' is very relevant and specific.
UK Trees in the Townscape. A guide for Decision Makers. Retrieved from: https://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_trees-in-the-townscape_november2012.pdf
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USA Choosing Suitable Trees for Urban and Suburban Sites: Site Evaluation and Species Selection by Edward F. Gilman, Laura Sadowski. Retrieved from: https://hort.ifas.ufl.edu/woody/documents/EP310.pdf
Good overview on site evaluation and species selection.
EU List of Invasive Alien Species of Union Concern by the European Commission. Retrieved from: https://era.org.mt/topic/list-of-invasive-alien-species-of-union-concern/
As the title says.
EU The European Forest Atlas. Retrieved from: https://forest.jrc.ec.europa.eu/en/european-atlas/atlas-download-page/
Very detailed explanation of the most native tree species in Europe. A must download!
EU European Tree Planting Standard (2022). Retrieved from: https://www.eac-arboriculture.com/eac-guides-and-european-arboricultural-standards.aspx
Shortly provides the main principles of site selection, the rootable soil volume calculating methodology included.

ADDITIONAL READING

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1.2.3. Ecology and Biodiversity (Nature Conservation and Environmentally Friendly Procedures)

Peter Hjelmqvist & Daniel Daggfeldt

GENERAL OBJECTIVE

To acquire knowledge about ecology in order to understand how the tree ecosystem functions, including the role of biodiversity in this system. This knowledge serves as the basis for tree management from an ecosystem management perspective, which is a more holistic approach to tree management.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- understand the ecological importance of trees;
- understand the impact of tree work and remedial measures on conservation and wildlife habitats;
- recognise the need to maintain trees in their natural state with respect to all forms of biodiversity;
- use environmentally friendly tools and machinery for tree work;
- take the protection of wildlife and biodiversity as an important starting point in tree management;
- be aware of the negative impact of invasive species; and
- understand the ecological impact of tree decay.

SEE TOGETHER WITH:

Tree Function and Structure, Tree Development and Growth Stages, Soil Science, Site Selection, Social Value of Trees, Diagnostic Features, Visual Tree Assessment, and Hazard Analysis.

ESSENCE OF THE TOPIC

Trees do not stand in isolation but are, instead, part of a wider ecosystem. This system is driven by biotic and abiotic natural processes, and sustainable arboriculture involves guiding the tree within these processes. It is, therefore, essential for a professional arborist to understand the structure and flows of the ecosystem in which the tree is situated. The very essence of an ecosystem is that minerals and energy flow through it based on a complex structure, which is more commonly known as the food web. This web is driven by abiotic and biotic factors, the latter determined by species living in populations. Hence, understanding population dynamics is also crucial to understanding the functioning ecosystem and biodiversity.

Biodiversity refers to the variety of life and has a genetic, species, and ecosystem dimension. Biodiversity helps to keep ecosystems healthy and vital by creating a stable food web. This stability is called functional biodiversity and is driven by the same natural processes that drive the ecosystem. Stability means resilience to external factors that affect the environment, such as climate change or pathogens. Basically, it means that the tree is part of a complex ecosystem and sustainable management involves focusing on enhancing the ecological processes in a holistic manner with respect to population dynamics. To put it in other words: tree management is not just about the tree but also about the ecosystem surrounding the tree. This core idea is essential to understanding the concept of biodiversity. Indeed, adopting an ecosystem approach that includes biodiversity should be the standard mindset in modern tree management.

KEY TERMS

Ecology and biodiversity biosecurity, ecosystem, ecosystem services, endophytes, epiphyte, functional biodiversity, fungi, habitat, invasive species, mycorrhiza, saproxylic

Management: environmental impact, nature conservation, re-wilding, veteranisation

Tree: ancient tree, dysfunctional wood, die back, epicormic, reiterative growth, retrenchment, stem rot, veteran tree

A. Ecology

A.1. Ecosystem

An ecosystem is an ecological system consisting of all the species in the system and the physical environment with which they interact. Both components are linked together through nutrient cycles and energy flows. The first component, called the biotic component, is the living part and is mainly driven by population dynamics. The latter component, called the abiotic component, is the non-living part and is driven by natural abiotic processes. The biotic and abiotic processes that take place in the soil are described in Chapter 1.2.1. Soil Science. Do not confuse the ecosystem with a habitat or biotope. A habitat is a place where an organism makes its home. A biotope is, spatially, a more or less homogeneous area. This area is characterised by features that differ from those areas that surround it and is therefore inhabited by a typical community of organisms. Examples include ponds, forests, and grasslands.

An ecosystem is an ecological system consisting of all the species in the system.
To summarise, an ecosystem is made up of the following components, all of which interact with each other:
- Abiotic components
- Biotic components
- Energy flow
- Nutrient cycles

Abiotic Component
An abiotic factor is a non-living part of an ecosystem that shapes its environment. In a terrestrial ecosystem, these factors are climate, water, light, soil, air, and minerals. Each of these factors is driven by abiotic processes. To understand an ecosystem, one has to understand these abiotic processes. In a tree-rich ecosystem, two abiotic factors are crucial to tree survival. Water is essential for the functioning of cellular processes, and all life on Earth requires water to exist and survive. Sunlight is the primary source of energy for all ecosystems. Air is a global constant factor, but the climate, soil, and mineral supply account for the wide variety of life.

Biotic Component
Biotic factors include interactions between organisms, such as disease, predation, parasitism, and competition among species or within a single species. In addition, living organisms themselves are biotic factors.They fall into three main categories: producers, consumers, and decomposers. This concept is called the energy pyramid of trophic levels. All three categories are necessary for nutrient and energy cycling.

- **Producers:** These organisms, which include plants and algae, convert abiotic factors into food. A tree is a producer because it converts sunlight into carbohydrates.
- **Consumers:** These organisms consume producers or other consumers to obtain food energy.
- **Decomposers:** These organisms break down organic matter from dead plants and animals into inorganic components, like carbon and nitrogen.

Energy Flow
All ecosystems involve the transfer of energy, as energy itself cannot be destroyed. Energy flows into terrestrial ecosystems as light energy from the sun. Trees catch this light energy and convert it into chemical energy (carbohydrates) through photosynthesis. Remember that the strategy of the tree is to capture as much light as possible using as little energy as possible. This energy transfer continues in the form of food webs. Many animals, such as birds and invertebrates, depend on trees for their food.

Nutrient Cycles
In an ecosystem, almost no minerals and energy are wasted. They are, instead, conserved by a complex food web. As a consequence, we get highly efficient, perpetual cycles, such as the nitrogen, phosphorous, carbon, oxygen, and water cycles. To understand an ecosystem, one has to understand these cycles. In simple terms, there are 3 different types of processes that take place within a typical terrestrial nutrient cycle: litter, biomass, and soil.

Energy flow and nutrient cycles are exquisitely shown in the mycorrhiza, which is a symbiosis of fungi and trees. The process goes as follows: carbohydrates produced from photosynthesis are transferred from the tree to the mycorrhizae. In return, the mycorrhizae increase the tree's ability to absorb water and nutrients.

A functioning ecosystem produces meaningful outputs like oxygen production, water buffering, food, etc. When those outputs are beneficial for mankind, we call them ecosystem services. The opposite term is ecosystem disservices. For more about this, see The Social Value of Trees.

A.2. Population Dynamics

Ecology and biodiversity are very closely linked by organisms. Organisms are organised in populations, and population dynamics is the bridge to understanding the link between ecology and biodiversity. Ecologists use biotic and abiotic factors to predict population changes and ecological events. By investigating how these factors interact, ecologists can gauge what is happening in an ecosystem over time. They may also be able to predict ecological events like species die-offs, overpopulation, changes in growth rates, and disease outbreaks. Population dynamics refers to the changes in populations over time and what causes these changes. A population depends on four parameters (natality, mortality, emigration, and immigration), which describe the size, structure, and composition of population change over time. This knowledge is crucial for us to apply biodiversity in practice. Sustainable populations in dynamic equilibrium are the main goal of population management. The maximum population size is limited by an ecosystem's abiotic and biotic factors, called the carrying capacity. Sustainable populations – read: stable populations – do not exceed the carrying capacity of the ecosystem.

THE FUZZY LINE
OF BIODIVERSITY IN ARBORICULTURE AND (URBAN) FORESTRY

When talking about the biodiversity of a single tree or a group of trees, it is impossible not to include population dynamics for two main reasons. Firstly, a tree is part of an ecosystem in which numerous species interact with each other. Secondly, the concept of biodiversity at its core refers to multiple organisms, which means that a tree, being part of a population, is a component of an important building block of diversity. They represent the diversity of life at the level of individual species. Moreover, we need to look at the ecosystems at different levels (micro = single tree, meso = group of trees, and macro = (urban) forests) because at each level the same concept of functional biodiversity applies. Reading between the lines, biodiversity is not fixed to a single tree. This implies that the line between arboriculture, which is more about a single tree (or small group of trees), and a large group of trees like (urban) forests fades. This is, for example, seen in an age distribution curve of urban forests.

B. Biodiversity

B.1. Definitions

Biodiversity refers to the variety of life on Earth within a specific environment and on a defined scale. It could be about the number of species present in a defined area or how far apart on the tree of life the individuals of a population are, i.e., the genetic difference between them. It all depends on the context.

We define three types of biodiversity dimensions:

- **Genetic:** the biological variation that occurs between species;
- **Species:** the number of species in an area;
- **Ecosystem**: the variety of ecosystems in an area.

This means that biodiversity is more than just about species; it also encompasses the types of habitats in the area (e.g., a single tree habitat or a group of trees with no vegetation beneath, etc.). The genetic dimension focuses on genetic variability (e.g., clones or not). All three types also include 'functional diversity', which refers to functionally disparate species or groups of species within a population, such as different feeding mechanisms, different motility, or whether the species are predator or prey. As the current diversity is a record of how species and their interactions have evolved to survive various conditions over millions of years, biodiversity is also the recipe for resilience to future changes in the conditions on earth. Ensuring biodiversity and maintaining ecosystems protects all lifeforms against diseases, climatic or hydrological changes, and other known or unknown threats. An apt analogy would be to see biodiversity as a plane. When a few components break down, the plane will not crash. But when one too many critical components fail, the plane crashes.

B.2. Why does it Matter?

Life on earth is currently going through the sixth mass extinction, and most scientists argue that this is mainly due to human activities, with changes in land use being the most prominent cause of biodiversity loss. Some of the loss is easy to measure, for example, the decline or extinction of large mammals. On the other hand, it is estimated that there are approximately 8 million species of which only 1.7 million have been described so far. This means that many species will be lost without us knowing they ever existed or understanding what role they had in the food web. Biodiversity matters for two main reasons:

- We are intertwined with the ecosystems in which we live. More than 75% of global food production relies on animal pollination, stable ecosystems minimise damage from floods and droughts, and a green urban environment lowers the heat island effect in our cities. The European Commission has estimated in its *Business Case for Biodiversity* that more than half of global GDP depends on nature and that the world lost 3.5-18.5 trillion euro per year in ecosystem services from 1997 to 2011. Hence, we cannot live without biodiversity.
- Biodiversity is the key indicator of the health of an ecosystem and is often referred to as resilience. This resiliency ensures a stable environment in multiple ways. Without it, civilizations cannot thrive, as history has shown us dozens of times. A wide variety of species cope better with threats than a limited number of them in large populations. Even if certain species are affected by pollution, climate change, or human activities, the ecosystem as a whole may adapt and survive.

B.3. What are the Threats to Biodiversity?

There are numerous threats to biodiversity, many of them are interlinked. Studies have concluded that the single most important threat to biodiversity is change in land use. Another important threat to the loss of functioning ecosystems and species is fragmentation. This occurs when human activities and infrastructure block movement within and between locations. Climate change is affecting tree populations in multiple ways, as the natural distribution and habitat conditions of species change. One of Europe's most important forest species, the beech (*Fagus sylvatica*), has experienced a declining growth rate in most of its current natural distribution, both in ecological and socio-economic terms. As new species are introduced to cope with the new climatic conditions, we also increase the risk of invasive species competing with existing natural ecosystems. The increasing frequency of severe weather events such as storms, droughts, and longer summers is also beneficial to many pathogens on trees. The spruce bark beetle (*Ips typograhus*), for example, can sustain two generations in a growing season. Furthermore, the impact of fungal pathogens may increase as trees are subjected to more abiotic stress, which lowers their defence systems. Changes in temperature and humidity may also be beneficial to pathogen species.

B.4. Policy for Reversing Biodiversity Loss Strategy

Biodiversity loss is a symptom of many things and, hence, cannot be addressed directly. There are short-term solutions to maintain our most threatened (nearly extinct) species and habitats, such as breeding and re-introducing species or protecting a nature reserve. But, to reverse biodiversity loss radically, a strategy is needed. This strategy is known globally as the Convention on Biological Diversity (CBD), established in 1993. It forms the basis for the world's biodiversity plan, especially in the European Union. The EU's biodiversity strategy for 2030 is a comprehensive, ambitious, and long-term plan to protect nature and reverse the degradation of ecosystems, with the Natura 2000 project as the main tool. The core idea of these strategies is to establish a network of well-functioning ecosystems that enable biodiversity to thrive at all levels (genetic, species, and ecosystem) over the long term.

In the urban context, too, it is essential to have diverse and functioning ecosystems to maximise the services they provide. Remember that a city is an ecosystem in which the same components of ecosystems and population dynamics apply. Fragmentation and rapid change pose major threats to biodiversity, and hence the strategy required is a connected green infrastructure with a diverse age and species structure. This will sustain a

resilient and sustainable urban forest. In the same way, lost ecosystems constitute a cascade effect of climate change. By slowing down and reversing biodiversity loss, we also cause positive feedback in the same system.

Legislation

Management of veteran, heritage, and other trees that provide valuable habitat is also affected by legislation around conservation, biodiversity, and other forms of protection. In nature conservation, tree managers and arborists are obliged to know European, national, regional, local, and site-specific regulations regarding this.
The foundation of EU conservation is based on both the biodiversity strategy (updated every 10 years) and the Natura 2000 network. Together with the European Habitats Directive and the Birds Directive, the network forms the cornerstone of Europe's nature conservation policy. There are today more than 1,000 animal and plant species and 200 habitat types protected at various levels by EU law, and *the European Red Lists of Species and Habitats*. This list of protected species can vary depending on the level and the local extent of the threat they face.

Even in urban environments, species and habitats are protected. For example, the biggest European beetles, *Lucanus cervus* or *Cerambyx cerdo*, which are mostly found on century-old oaks, are safeguarded by both the European Habitats Directive and the Convention of Bern, which was adopted in 1979.

Further guidance on species and habitat protection, including updated interpretation manuals and Red Lists of Threatened Species, can be found on the *European Commission web portal for Nature and Biodiversity*.

C. Assessing Biodiversity

We have described why we need biodiversity and the strategies that exist to maintain it. Biodiversity is a widely used tool for estimating the complexity, stability, and thus the general health of an ecosystem. But as any good strategy needs evaluation tools, so we need tools for assessing biodiversity. There are several ways to assess the biodiversity of trees. Some of the most used biodiversity indices include:

- **The 10-20-30 % rule:** This rule states that no more than 10% of the total population of street trees should belong to the same species, 20% to the same genus, 30% to the same family, and 5% to the same variety. Using this rule is good in theory but requires some caution when applied in practical situations. Not all tree species are equally well adapted to the wide range of sites and conditions found in cities.
- **The Shannon diversity index:** This considers both the number of species and their relative abundance. It measures the uncertainty in predicting the identity of a randomly chosen individual in the community based on the frequency of the occurrence of different species.
- **The Simpson diversity index:** This also considers the number of species and their relative abundance, but it is weighted more heavily towards the most abundant species. It measures the probability that two individuals randomly selected from the community will belong to the same species.

There are many other biodiversity indices, like the Species Richness, Evenness Index, or Beta Diversity index, which have been developed for specific purposes or to address particular aspects of biodiversity, such as functional diversity or genetic diversity. The choice of the index will depend on the particular questions being addressed and the available data.

D. Applied Biodiversity on Trees

As explained above, there are different types of biodiversity; genetic, species, and ecosystem. This implies different levels of ecology (organism, population, community, ecosystem, and biosphere) at which a strategy for preserving biodiversity can be implemented. For example, managing trees with a focus on conservation involves managing the ecosystem, the tree, and its surroundings. In contrast to conventional arboriculture, decay, dysfunctional wood, and storm damage may be an asset rather than a problem needing remedy. In practice, though, the ecosystem approach often conflicts with the needs and conditions of the urban environment, such as safety, small planting pits, shared space with infrastructure, etc. A tree specialist should make thorough decisions regarding both aspects. In what follows, we describe this strategy at the micro, meso, and macro level.

D.1. Micro Level (Individual Tree Habitat)

Trees have evolved over at least 50 million years and have developed intimate relationships with many organisms from micro to macro levels. Examples include mycorrhizal and nutrient cycling together with fungi; the provision of habitat for lichens, mosses, and animals; and the production of pollen and nectar as a food source for invertebrates – all these organisms being interlocked with one another in an intricate eco-web.

A single tree houses a wealth of biodiversity both below and above ground. These associations are often highly correlated with tree species, and most increase in number as the tree gets older. When it comes to habitat value, native trees are usually considered of higher importance and have less risk of interfering with other parts of the local ecosystems. Habitat trees are defined as standing live or dead trees that provide ecological niches such as cavities, bark pockets, dead branches, cracks, sap runs, epiphytes, or trunk rot. They are the culmination of processes that provide a rich habitat for species below and above ground. Naturally occurring habitat trees are often veteran or ancient trees; however, in a managed context, they can also be younger. Trees that have been pollarded or heavily pruned tend to develop habitat features at a lower chronological age.

Trees do not stand alone: they are part of an ecosystem, and they coexist with hundreds or even thousands of soil fauna and flora, including mycorrhizal symbionts. Some species in an ecosystem have an exclusive relationship with each other, others are less specific. These associations can be used to assess the state of a tree or a stand of trees. As an example, the Mycological Tree Assessment methodology, developed by the mycologist Gerrit Jan Keizer, uses the presence or absence of certain fungi to determine the condition, life stage, and life expectancy of the tree.

THE
HIDDEN TREE

The tree species-specific ecosystem, developed by mycologist Gerrit Jan Keizer, clearly and comprehensively explains the link between the tree and the various tree-associated fungi. It is increasingly being used amongst arborists to assess tree stand and condition through a mycological tree assessment. By the tree species-specific ecosystem, also called the hidden tree, the mycologist actually means the complex soil food web of soil flora and fauna around the tree. The web protects the fine root parasites and intersively exchanges nutrients and carbohydrates between mycorrhizal symbions and fine roots. The core idea is that the tree is at the centre of its own species-specific ecosystem, which it itself influences. Each tree species possesses, roughly, its own typical soil food web, which is dynamic throughout its successive life stages.

D.2. Meso and Macro Levels (Population Tree Habitat)

As we scale up from the singular tree to a group/population of trees, we need population dynamics to apply the biodiversity concept. We saw that population dynamics describe the size, structure, and composition of population changes over time. Hence, it is important to look at the different aspects and factors that influence these changes. Regarding population dynamics, the main goal for professional arborists and urban foresters should be to strive towards stable populations and keep them stable. To achieve this, it is necessary to examine the following practical aspects that contribute to population stability:

- Physiological age distribution
- Size structure distribution
- Species distribution

To ensure sustainability, it is important to maintain a balanced distribution of the tree population based on the physiological stage, size, and distribution of the trees. Keep in mind that this is a dynamic balance as trees and their associated species create habitats for each other. The habitats are not static; they develop and change with time and finally disappear as trees collapse and decay. Organisms that live in these microhabitats have to find new ones when the old one disappears. A sustainable tree population, and its associated species, contain trees of all age groups (as well as a wide range of species) in different physiological life stages. The principal idea for stability is continuity. Basically, this means replicating and diversifying the micro level (individual tree habitat) in the biotope. There should, therefore, be a continuous succession of habitat trees to provide for all organisms in the biotope. E.g., the lack of veteran tree succession is one of the major problems facing Europe's tree populations. One of our main challenges is to bridge that gap.

E. Biosecurity

E.1. Native or Introduced?

Trees have evolved alongside pests and pathogens, with many of these organisms being important in nutrient recycling and the ageing process. Some are potentially more harmful than others. The increasing international plant trade, both to and within Europe, provides opportunities for damaging pests and pathogens. Stress factors, such as a changing climate with drought and flooding, also make trees more susceptible to pests and pathogens. People working in the arboricultural industry can also act as vectors for pathogens as they access and move across different sites. The transport of soil, cuttings, and machinery is also a route by which pests and pathogens can be carried between sites.

Biodiversity plays a major role in building resilience against pests and pathogens. Risk spreading, for example, by avoiding monocultures, ensures that a population becomes less sensitive to a disease associated with a specific species of tree. Functional biodiversity is another example of how biodiversity provides biosecurity. In a functioning ecosystem, the natural enemy of a pathogen is present and will control or regulate its spread. An ETT should be aware of the risks that pathogens and pests can bring to a tree population, be able to enact preventive methods, and know how to carry out a biosecurity risk assessment. When performing such an assessment, both the potential impact and the likelihood of the risk occurring should be analysed. This methodology can be similar to a risk matrix used during a tree risk assessment.

Ultimately, the discussion concerning native and introduced tree species highlights the importance of balancing human needs and desires with the health and well-being of the natural world. By working to protect and restore native ecosystems while also carefully considering the potential impacts of introducing new species, we can strive to create a more sustainable and resilient future for both people and the planet. More information is to be found in the Chapter Site Selection.

E.2. Hygiene Factors

Hygiene factors are important considerations when it comes to the biosecurity of trees. Here are some examples of hygiene factors that are important for maintaining the biosecurity of trees:

1. **Cleaning tools and equipment:** Tools and equipment used in tree maintenance, such as saws and pruning shears, can spread diseases if they are not properly cleaned and disinfected between uses. Regular cleaning and disinfection can help prevent the spread of harmful pathogens
2. **Disposing of plant debris:** Plant debris, such as fallen leaves, can harbour pests and diseases that can spread to other trees. Proper disposal of plant debris can help prevent the spread of these harmful agents.
3. **Quarantining new plants:** When introducing new trees to a site, it is important to quarantine them for a period of time to monitor for any signs of pests or diseases. This can help prevent the introduction and spread of harmful agents.
4. **Monitoring for signs of pests and diseases:** Regular monitoring for signs of pests and diseases can help catch and contain outbreaks before they spread to other trees.

By paying attention to these and other hygiene factors, it is possible to maintain the biosecurity of trees and protect them against the spread of harmful pests and diseases.

Figure 1 (B. Roobroeck). This veteran plane tree in Wroclaw (Poland) has a huge core of dysfunctional wood, which, although not needed for the tree itself, forms a habitat for numerous insects (micro-scale). When zooming out to the macro-scale, it is necessary to have a population of trees with this dysfunctional wood in order to create a sustainable insect population. This can imply that it is better to severely prune or top a tree instead of removing it. When deciding on which course of action to take, it is also crucial to communicate to the stakeholders the context in which the measures are to be taken. Such trees can, moreover, help to communicate the concept of biodiversity to the general public as they pass by.

MANAGEMENT OF DYSFUNCTIONAL WOOD (ON VETERAN TREES)

Conservation of ecological value can conflict with the conventional approach to risk management around (urban) trees. Hence, a balance between safety and biodiversity (conservation of the tree as a habitat) is needed. This is especially the case for veteran trees. Different groups of species are associated with different levels of dysfunctional wood, from dead, partly decomposed wood to wood that is damaged or weakened, but semi-functional. A lot of these species only use a specific type of dysfunctional wood or certain tree species as a habitat. Some species of animals, fungi, or lichens depend on the presence of wood in a highly decayed state, or on a particular type of decayed wood. Of the long list of species closely associated with dead wood, many can also be found in cities. For example, the relict and charismatic beetle species, protected at the European level, *Osmoderma eremita/barnabita*, requires brown wood decay and specific habitat conditions - large decayed deciduous tree trunks - although it is not picky about their species and inhabits lindens, oaks and *Robinia*.

Dysfunctional wood is particularly valuable when it is left to decompose at its place of origin, where it promotes natural habitat creation. Creating microhabitats is an option where a lack of suitable habitats has been identified or where it is not feasible to leave unstable dysfunctional wood in place. This can be done on dead trees or dead parts of trees. Alternatively, it can be carried out on living trees that would otherwise be felled, a method known as veteranisation, which involves creating features normally only found on damaged or veteran trees. Techniques that increase biocenotic value include cuts that create artificial cavities and bores that create openings and breakouts. They are intended to accelerate decomposition processes (colonisation by fungi) and/or create refuge or breeding sites for various organisms.

According to European Tree Pruning Standard EAS 01:2021, the management of dysfunctional wood includes leaving dead branches on trees for biodiversity purposes. Deadwood should only be removed completely during formative pruning. In crown maintenance practices, dead and dying branches in the permanent crown should be retained (completely or reduced) for biodiversity reasons, as long as it does not compromise safety. Dead branches can also be reduced to stubs or broken off. Stable dead stubs can be left. On veteran or ancient trees, deadwood should be preserved as much as possible in order to protect the associated habitat and the decay processes under natural conditions (in the crown and on the ground), while keeping risk at an acceptable level. Dysfunctional wood that must be removed can be left in habitat piles, re-erected, or tied to another tree where it does not compromise safety or infrastructure.

Veteran trees should never be managed in isolation but rather as an integral part of an ecological and historical landscape, as well as members of broader tree populations. Since veteran trees by definition are only replaceable over a long period of time, it is crucial to properly manage and maintain existing veteran trees. Their lives need to be prolonged until a new generation of trees can replace them. A European Tree Technician should be aware of best practices and promote better veteran tree management.

The conclusion we would like to show is that dysfunctional wood in veteran trees – here used as a metaphor for biodiversity – is a highly valuable habitat that needs to be left to ensure sustainable populations. Inherent in preserving these habitats, however, is a conflict between safety and biodiversity, which should be resolved by using specific approaches as the desired function of dysfunctional wood varies according to context and different life stages of the tree.

SELF-CHECK QUESTIONS

1. What are the two main reasons we need biodiversity?
2. What are two threats to biodiversity in general? Why?
3. Which four factors determine population dynamics?
4. What is an ecosystem, and what are its main components?
5. Explain the European Union strategy for the conservation of biodiversity.
6. How do you assess biodiversity?
7. Explain the macro-level biodiversity of trees.
8. What is a habitat tree?

PRACTICAL EXERCISES

1. Find a mature or veteran tree and try to identify a large portion of dysfunctional wood (large branch, xylem core, etc.). Look closely at the wood and try to find evidence of habitat for one or more species. Think of what the species could be and if it causes a problem for the environment.
2. Calculate a diversity index like the Simpson index from a dataset (municipality).

TERMINOLOGY

ecosystem – complex of living organisms, their physical environment, and all their interrelationships in an area

ecosystem services – many and varied benefits to humans provided by the natural environment; often divided into four categories: supporting, provisioning, regulating, and cultural services, e.g. refers to natural pollination of corps, clean air, extreme weather mitigation, human mental health and physical well-being

biocenotic – when a diverse community inhabits a single biotope

biodiversity – (from "biological diversity") refers to the variety of life on Earth at all its levels, from genes to ecosystems, and can encompass the evolutionary, ecological, and cultural processes that sustain life

biosecurity – measures aimed at preventing the introduction and/or spread of harmful organisms (e.g., viruses, bacteria, etc.) to animals and plants to minimize the risk of transmission of infectious disease

dysfunctional wood – the loss of physiological function in woody tissues, especially water conduction in sapwood; dysfunctional wood plays a vital role in habitat and biodiversity

functional diversity – components of biodiversity that influence how an ecosystem operates or functions

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ESSENTIAL READING

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Comprehensive and must-read guide about the efforts aimed at preventing a pest or pathogen outbreak.

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Contains a very impressive table about the ecological importance of tree species

1.3. THE AMENITY AND SOCIAL VALUE OF TREES

1.3.1. The Amenity and Monetary Value of Trees

Bregt Roobroeck & Oliver Bühler

GENERAL OBJECTIVE

To have an understanding of how the value of trees and tree management interact and affect ecosystems and the surrounding environment. This knowledge will form a solid basis for communicating with other stakeholders about the value of trees.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- know the relevant methods of calculating the monetary value of amenity trees;
- understand the principles of amenity valuation and establish an amenity valuation form;
- perform a value assessment of a tree according to the amenity valuation method; and
- understand and explain the relevant methods for the calculation of ecosystem values.

SEE TOGETHER WITH:

Ecology and Biodiversity, Social Value of Trees, Protection of Trees on Construction Sites

ESSENCE OF THE TOPIC

Seen from an anthropocentric perspective, trees deliver numerous ecosystem services, which strengthen their position as a multifunctional asset in space and time. Urban trees, especially, are confronted with a lot of stakeholders, such as house owners, building constructors, and municipality organisations, all of whom put pressure on the trees. Not all stakeholders understand the value of trees; therefore, translating the value of trees into a universal monetary value is a helpful communication tool. By translating, for example, the ecosystem services of trees to a sum of money, an ETT can easily communicate this value to the stakeholders.

Tree valuation is important in two principally very different situations:
- When a tree is damaged or destroyed by a third party, the tree owner will often claim compensation. It is therefore necessary to apply a monetary value to the damage or the whole tree. In cases like this, often so-called formula methods are used to calculate the compensation.
- Ample and increasing evidence documents the benefits of trees for humans. It is very useful to monetarise these ecosystem services for a variety of purposes, such as city planning and communication with the public or decision-makers. This requires implementing and combining scientific model calculations, such as those attempted by the software package i-Tree. Currently, not all ecosystem services have been translated to a monetary value.

The monetisation of trees moves tree management beyond a mere management perspective and towards decision-making based on value by focusing on the functions that trees serve.

KEY TERMS

Basic economics: benefit-cost ratio, capital, effectiveness, efficiency, rate of return, return on investment (ROI), yield

Valuation: Ecosystem services, pyramid of valuation, monetise

Methods of valuation: CAVAT, contingency pricing, i-tree, hedonistic pricing, tree appraisal, tree quantification

Introduction

Amenity trees are any trees that are not grown or managed for their value as timber or another crop but instead provide other benefits or values (Doick, et.al, 2018). Examples include trees found in parks and other open spaces, those lining the sides of streets, railways, rivers and canals, and those in gardens.

It is, at best, difficult to quantify the monetary value of trees that are planted with other functions than the production of wood in mind. Nevertheless, many situations call for such quantifications: private or public tree owners might want to claim compensation for damaged or destroyed trees and legitimate their claims before insurance companies or courts. Moreover, being able to estimate the value of the numerous ecosystem services provided by urban trees facilitates planning and management and enables more precise communication with other professional groups, politicians, and the general public. It is never easy to quantify the monetary and non-monetary values of urban trees, but it is an important step towards more informed decisions and the subsequent improvement in environmentally and economically sustainable management of the urban tree resource.

Urban trees are known to contribute to numerous ecosystem services and need to be quantified for the reasons given above. Diving deeper, we see the following applications of monetising:
- justification of compensation claims, out of court or in court;
- protection of trees during construction work;
- communication of the value of ecosystem services;
- facilitation of planning, management, and maintenance of the urban tree resource;
- procurement of funding for planting or managing urban trees.

The economic valuation of trees has a long tradition, originating in forestry. However, traditional methods for valuing market-priced goods are only of limited use when trying to quantify the amenity value of urban forests and trees, as the main values of most urban forests and trees simply have no market price. To value, for example, the aesthetic value, architectural contributions, or public health effects of urban trees is and will always be difficult. However, over time, different approaches to addressing the challenge of determining the monetary value of urban trees have been proposed.

A. Basic Economic Language

Learning to speak the economic language of policymakers and managers can be difficult; however, with the following concepts, an ETT will have the essentials needed to communicate effectively in the field of tree management.

Note that this is about the function of the tree as a product, with the stem and crown volume as the most important output. It is not about how to organise a company.

A.1. Efficiency and Effectiveness

In tree management, it is important to strive for both effectiveness and efficiency. Effectiveness is the capability of producing the desired result or the ability to produce the desired output. This can be a large tree situated in a square that provides shade during hot summers. Effectiveness answers the question of whether the product does what it is supposed to do. So, for example, if that same tree in the square is a very small tree like a *Robinia pseudoacacia* 'Umbraculifera', the crown volume will be too small to cast a meaningful shadow. Hence, the *Robinia pseudoacacia* 'Umbraculifera' is not effective because it does not achieve the desired output, namely cooling. Effectiveness is thus defined as the degree to which something is successful in producing the desired result.

Efficiency is defined as the ability to accomplish something with the least amount of wasted time, money, effort, or competency. If the large tree on the square does not have the required space to fully develop its natural crown, then it is not efficient. The same can be said about topping, which is usually an expensive pruning technique carried out to reduce the crown. Wouldn't it be better to use a smaller tree with just formative pruning to get the same final image (output)? The latter is more efficient because there is less effort (time) or fewer resources (money) needed than there would be for the larger tree.

By focusing on both effectiveness and efficiency, tree management can ensure that trees are not only achieving their full potential but also doing so in a way that is sustainable and cost-effective.

A.2. Maximising Tree Function

To maximise or optimise the effectiveness and efficiency of a tree's function, tree management should regularly evaluate performance metrics, identify areas for improvement, and implement strategies to streamline processes and optimise resource allocation. This means that a strategy with a vision, goals, key performance indices (KPIs), and benchmarks is needed. In other words, we need a plan for optimising based on regularly evaluated data. But what exactly do we mean by maximising the function of a tree or urban forest?

In the chapter Tree Development and Growth Stages, we saw that the tree's cumulative growth curve consists of 3 stages based on its rate of growth. This is represented in the sigmoid curve on the next page. These rates can be considered to be the yield or the rate of return (RoR). The RoR is the net gain or loss of an investment over a specified time period, expressed as a percentage of the initial cost of the investment. So, for example, in Phase 1 of the growth rate, the crown volume of a large tree on the square grows each year by 10%, meaning the RoR is 10%.

Maximising tree function, and thus ecosystem services, is all about getting the volume as high as possible and stretching it as long as possible in time. The effectiveness of a tree's functions implies a space and time dimension. Maximising efficiency can be seen as reaching the full potential of the tree's function with the least amount of wasted time and money.

Considering we see such trees as environmental engineers and thus strive for efficiency, it is crucial to maximise the value of these trees. It is our job, therefore, to maximise the function of trees.

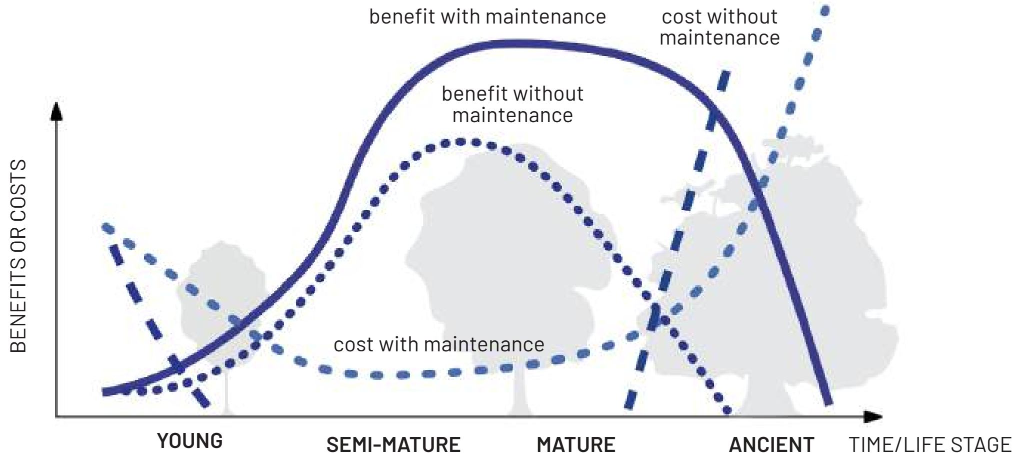

Figure 1. Theoretical impact of maintenance on the benefits and costs of trees throughout their life cycle, with and without maintenance. Cost and benefits show an inverse pattern, and benefits associated with maintenance reach a higher level. (Adapted from Vogt, Hauer and Fischer, 2015)

A.3. Return on Investment

Return on investment (ROI) is a financial metric used to evaluate the profitability of an investment relative to its cost. It measures the amount of return on an investment in relation to the investment's cost and is also known as the benefit-cost ratio. The ROI formula is:

ROI = (Gain from Investment – Cost of Investment) / Cost of Investment

Do not confuse ROI with RoR; the RoR is the percentage of the investment's gain or loss over its initial cost, whereas ROI is the ratio of the investment's gain or loss to its initial cost. The higher the ROI, the more profitable the investment is considered to be. ROI is a great tool to make decisions about investments, such as a tree bunker system. It is also used to compare the profitability of different investments or investment strategies. For example, is it better to focus on large trees with high construction costs for cooling, or should the focus be on a lot of small trees with low construction costs?
It is important to determine the break-even point. This is the point when revenues equal losses (costs) and is shown in the graph. Determining it depends on several factors, but the RoR is crucial in this story. Hence, if trees grow faster, the RoR increases, and the break-even point will be achieved faster. However, quantifying the monetary value of trees is a rather difficult concept, and many approaches are available, like replacement cost methods, preventative expenditure, and estimation of the extent of an ecosystem service in relation to its construction and management costs.

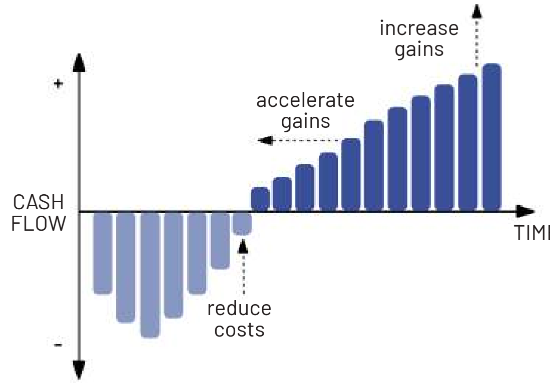

Figure 2. This figure visualises the ROI over time, depicted when the cash flow is 0. The cash flow can be seen as the sum of the costs of planting and maintaining the trees, whereas the gains are represented as ecosystem services. (Adapted from Business Encyclopedia 2023)

Let us examine three methods of achieving a higher benefit-cost ratio. Firstly, maintenance costs can be reduced during the planting phase. Selecting a tree that is compatible with the site will help avoid future difficulties, leading to less need for maintenance. Secondly, proactive and preventative measures cost less than ad hoc, reactive maintenance, as they significantly reduce the disservices and indirect costs caused by tree failure, pests, and other issues. Lastly, an optimal allocation of maintenance resources (e.g., labour, money, and time) is important to maximise the number of trees requiring management.

To fulfil the second and third optimisation approaches to achieve the best possible benefit-cost ratio, we need to ensure that the assessment of the health of the tree(s) is carried out efficiently. A quantitative approach to appraising the condition of the tree(s) allows for better decision-making, helping us to optimally allocate resources. Furthermore, the ability to detect early stress would increase the efficiency of proactive and preventative maintenance.

Several studies have shown that the order of magnitude of the benefit-cost of a single tree is around 5, or an RoR of 5% per year. So, for every euro spent on the tree, five euros are gained. These ratios, however, were neither calculated on optimally managed trees nor were all ecosystem services calculated. Therefore, this ratio can be increased even further by, firstly, minimising management costs and, secondly, using better models to compute all the ecosystem services that the tree provides.

A.4. Capital

Capital in a tree context refers to the resources that are available for investment or other purposes, such as tree amenities. It includes all forms of assets, including, for example, crown volumes of various trees that can be used to generate yield in the form of ecosystem services. A good illustration of this concept is the carbon stock in trees, which can be considered a valuable form of carbon storage. Capital is an essential factor in creating value for trees, as it provides the resources necessary to invest in opportunities that can generate income and profits, such as ecosystem services over time. In this sense, capital is an input that can increase the value of a business. To better understand this concept, we first need to look at how valuation works.

B. Pyramid of Valuation

Valuing amenity trees presents a challenge due to the fact that the benefits and services they provide are intangible and not traded in markets, which precludes the use of income or sales-based approaches for valuation. Their value can be considered as the present worth of future ecosystem services. As a result, amenity trees can still be assigned value if someone anticipates or expects them to provide current and future benefits and satisfy needs and desires.

In search of value, the pyramid of valuation was introduced (see Figure 3). The pyramid works as follows: First, all ecosystem services are scored according to their importance and how their importance is affected by specific interventions (qualitative valuation). Second, we establish functions for a smaller selection of ecosystem services to quantify the biophysical impact of a scenario (quantitative valuation). This selection is done based on the availability of data and the scientific credibility of quantification functions. Ecosystem services for which there is too little scientific information or consensus remain in the first group. Finally, starting from the second group, we will also develop functions or key figures for an even smaller group of ecosystem services to determine their monetary value. The advantage of this approach is that we value as complete a bundle of ecosystems as possible.

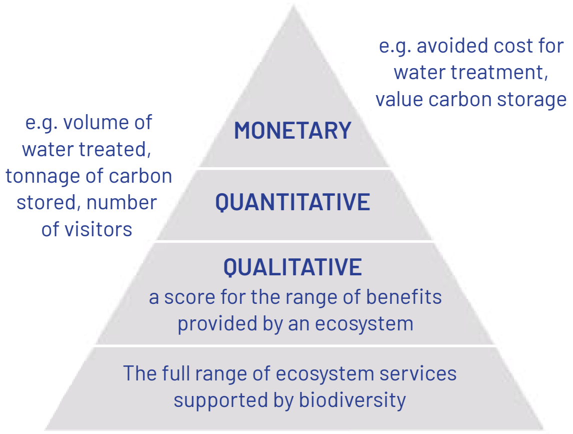

Figure 3. The pyramid of monetising ecosystem services. The more these services are expressed in monetary value, the clearer it is for all stakeholders to understand what the value is. The problem is that it is extremely difficult to monetise all tree ecosystem services. (Adapted from TEEB 2009)

Be aware that valuation exercises that examine only one ecosystem service are misleading. Focusing only on one ecosystem service, such as air quality or stormwater management, can lead to unsustainable use and disastrous effects on other ecosystem services. Valuing a bundle of ecosystem services does not mean valuing everything. Monetising the current value of all ecosystems is in itself of little policy significance because without biodiversity our life on earth is also impossible. So, the more ecosystem services can be quantified in a monetary way, the more citizens will value greenery. The top of the pyramid should therefore be made as broad as possible.

Monetary value is a pragmatic way of reasoning in a capitalist model. By pragmatic, we mean that 'putting a price tag on nature' does not really feel right, yet we need this for negotiation with other stakeholders. In essence, the act of valuing serves as a communication tool.

Notice that there is a difference between the inherent value of a tree and the value of ecosystem services. The latter can be seen as the RoR, while the first is the capital.

C. Methods of Valuation

As already mentioned, quantifying the monetary value of trees is complex as not all ecosystems are monetised today, and there are a wide variety of approaches already in use. Below, we describe the most important methods with examples.

C.1. Contingency and Hedonistic Pricing

Some of these approaches originate from what could be described as a more economic rather than arboricultural starting point. This is, for example, the case for so-called contingency valuation methods, also referred to as 'willingness to pay' estimates. This is the maximum price that a customer is willing to pay for a product or service. In the context of trees, willingness to pay reflects the perceived value that individuals place on trees and the benefits they provide, such as clean air, shade, and aesthetics.

For example, if a city government proposed to cut down a row of mature trees to widen a road, a group of concerned citizens might express their willingness to pay to prevent the trees from being cut down. Their willingness to pay might be based on their appreciation for the beauty of the trees, the shade they provide on hot days, and their ability to improve air quality in the area.

Willingness to pay can also be used as a tool for valuing trees and their benefits, such as carbon sequestration, reduction of stormwater runoff, and increased property values. By conducting surveys or experiments to determine how much individuals are willing to pay for these benefits, policymakers and city planners can gain a better understanding of the economic value of trees and make informed decisions about tree management and conservation.

Another approach is referred to as hedonistic pricing, where the valuation of trees is based on housing market transactions and differences in house prices according to their proximity to forests, parks, or water. In the case of trees, hedonic pricing is used to estimate the value of trees based on their location and the surrounding environment. For example, a tree located in a park or on a street with well-maintained sidewalks and attractive landscaping may be more valuable than a tree located on a street with poor lighting or heavy traffic.

C.2. Tree Pricing with Formula Methods

However helpful knowledge about economic approaches and methods might be for arboricultural professionals, it is plausible to suppose that the main focus for most ETTs will be on methods for individual tree pricing or on quantifications such as tree appraisal and subsequent valuation of ecosystem services. These two forms of appraisal are described below.

Tree Appraisal

Determining prices for single trees or tree groups is necessary, for example, to determine the amount of compensation for damaged or destroyed trees. The methods are considered 'easy to use' for professionals but often rely on difficult assessments of such factors as the current and expected tree age, tree vitality, tree health, and damage, as well as an assessment of location, architecture, and aesthetics. The most common methods of establishing the value of individual trees are based on the cost of replacing a damaged or vandalised tree (i.e., replacement cost) and are adjusted according to commonly used factors, such as tree vitality, damage type, location, aesthetics, overall amenities, age, and even the provision of environmental services, all of which in the end deliver a comparable monetary value. Several (national) models and formulas have been developed in recent decades, with slight but significant differences. Some formulas only allow a reduction of the intrinsic value, whereas others also allow the value to increase under certain circumstances. Some models work with age-related depreciation in value, as implemented by insurance companies when it comes to the insurance of cars or household effects. Whereas other methods claim that age and tree value are not related.

Tree appraisal with formulas integrating structural tree data with amenity values is, to some extent, based on subjective judgement, and it is advisable to train and discuss tree appraisal with colleagues and experts in order to maximise the comparability and consistency of the valuation results.

Below are some of the common formula methods for individual tree appraisal:

- Belgium: *Uniforme methode voor waardebepaling van bomen*
- Denmark: *VAT19, Værdisætning af Træer*
- Germany: *Methode Koch*
- Sweden: *LITA, The Linear Index of Tree Appraisal*
- UK: *Capital Asset Valuation of Amenity Trees (CAVAT) & The Helliwell System*
- USA: *Guide for Plant Appraisal*
- Netherlands: *Nederlandse Vereniging van Taxateurs van Bomen (NVTB)*

Quantification of Ecosystem Services

The ecosystem services of urban trees become increasingly weighty arguments when it comes to planning new city trees and/or preserving existing ones because tree management is not only about maintaining trees. It is also about managing their function in the field. Although there are numerous toolkits for calculating ecosystem services available for green infrastructure, like GI-Val or VITO Natuurwaardeverkenner, and ECOPLAN, only one specialises in urban trees, namely i-Tree.

i-Tree is a state-of-the-art, peer-reviewed software programme from the United States Department of Agriculture (USDA) that analyses urban forest structure and associated impacts.
It consists of several free tools, the most important being i-Tree Eco. This tool - and the other i-Tree tools - can help strengthen (urban) forest management and associated ecosystem services by quantifying forest structure and the environmental benefits of trees. Under the motto 'Trees pay us back', trees become ATMs, because trees with the highest possible yield give us all kinds of benefits, especially environmental ones. These include air purification, carbon reduction, and water infiltration.

Currently, it is the best tool as it is:

- an already established, effective, and proven tool in the United States;
- the best (scientific, comprehensive) platform to calculate the ecosystem services of trees; and
- experiencing a strong advance in Europe, making it the reference in the near future.

The models used in the different tools are based on peer-reviewed scientific studies. Of course, many ecosystem services are not easily quantifiable (think of recreation, aesthetics, or social benefits). The architecture of the programme i-tree Eco is designed in such a way that it does three things:

1. It measures the structure of the urban forest: the number of trees, species diversity, size (diameter class), height, and so forth.
2. It quantifies functions: each tree has one or more functions: fine dust capture, cooling, and so on. Among other things, i-Tree has formulas that calculate how much particulate matter is captured per canopy volume.
3. It validates; that is, it converts the quantified functions into money.

To obtain reliable estimates of the magnitude of ecosystem services, it is necessary to provide reliable data about the urban forest structure. The most important input variables for the model calculations are tree species, diameter, crown dimensions, and tree condition. Cities already using tree inventories for other purposes will often be able to provide the necessary data, at least partially. Indeed, it is also possible to use i-Tree just based on a sample inventory of a delimited area. However, whereas the formula methods for tree pricing specifically target individual trees, i-Tree shows its true worth when working on a larger scale, e.g., the tree population of a city district or even an entire city. Although developed in the USA, large parts of i-Tree have, in recent years, been adapted for use in Europe as well. The number of studies using i-Tree to analyse urban tree populations, including their ecosystem services, is ever-increasing, with highly interesting examples from countries such as the UK and Sweden.

Several studies have shown i-Tree's potential for quantification, valuation, and documentation of the ecosystem services of urban tree resources. For example, the New York City Tree Map is an interactive portal open to everyone and relies on various kinds of information about individual trees, including the ecosystem services provided (scanbelow a QR code). A prominent European example is the London I-Tree project, opening the eyes of I-Tree's potential for many other European countries (find more information on the project website by scanning QR code below). Keep in mind that i-Tree is not management software (asset management) and will not become so in the coming years.

New York City Tree Map

London iTree project

SELF-CHECK QUESTIONS

1. Explain the pyramid of valuation.
2. What is the difference between return on investment and rate of return?
3. Explain the concept of maximising the tree's function and support your story with a graph.
4. How does i-tree work, meaning what is the architecture of the programme?
5. What is hedonistic pricing?
6. What is the difference between efficiency and effectiveness?
7. Explain how the monetisation of trees moves tree management beyond a mere management perspective and towards decision-making based on value.

PRACTICAL EXERCISES

1. Calculate the ecosystem services with i-tree Eco on 30 trees.
2. Explain to a non-tree-minded person why trees are an investment.
3. Do a tree appraisal for a tree that has been damaged on a construction site.

TERMINOLOGY

ecosystem services – many and varied benefits to humans provided by the natural environment; often divided into four categories: supporting, provisioning, regulating, and cultural services, e.g. refers to natural pollination of corps, clean air, extreme weather mitigation, human mental health and physical well-being

formula methods – appraisal methods often used for compensation claims; the monetary value is calculated based on a variety of inputs

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1.3.2. The Social Value of Trees

Bregt Roobroeck

GENERAL OBJECTIVE

To have a general knowledge of the function and impact of trees on their surrounding environment. This forms a solid basis for unlocking the true value of these ecosystem engineers.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- review the historical and cultural heritage of trees; and
- describe the various social and psychological effects of trees in an urban environment.

SEE TOGETHER WITH:

Ecology and Biodiversity, Social Value of Trees, Protection of Trees on Construction Sites

ESSENCE OF THE TOPIC

People cope well with greenery because it creates an environment that keeps humans physically healthy, mentally healthy, and safe. These three human values are provided to us through the functioning of trees, namely their provision of ecosystem services that can alter the physical environment. Hence, trees can be seen as ecosystem engineers, as they engineer the ecosystem. That ecosystem, no matter how urban it might be, consists of an aerial, soil, and water component, which is to be kept as healthy and resilient as possible. Consequently, a physically healthy environment often results in a mentally healthy and safer environment, augmenting the three human values. As trees produce the most ecosystem services, they are the most important elements of the urban green infrastructure. Combined with the fact that they are the most multifunctional assets of the urban environment, it is strategic to maximise this potential function of trees, as we see in the chapter Amenity and Monetary Value of Trees. This is done by sustainable tree management.

A. Trees in the Bigger Picture

Why do we, as humans, find trees important? During the lockdowns of the COVID pandemic in 2020 it was clear why we needed urban greenery. The social aspect that urban green infrastructure like parks provide is indispensable. Humans cannot cope very well without greenery. If we look at what humans as a species value the most, we can divide them into human, social, cultural, and economic values (Figure 1). Focusing on human values, we mainly come up with physical and mental health and safety. Physical health can be defined as the condition of your body, whereas mental health refers to the state of your psychological and emotional well-being. Safety is not only limited to ensuring a non-dangerous environment but is also related to a healthy environment in its aerial, soil, and water components. Hence, trees should be able to contribute to a healthy environment (Figure 1). Our health is largely influenced by our lifestyles, followed by our genetics, environment, and medical care.

KEY TERMS

Trees in the bigger picture: ecosystem, ecosystem engineers, environment, human health, maximise

Ecosystem services: cultural services, disservices, Millennium Ecosystem Assessment (MEA), (non-)anthropocentric value, psychological well-being and stress reduction, provisioning services, regulating services, supporting services, TEEB, urban heat island, valuation, water buffering, willingness to pay

B. Trees as Environmental Engineers

Trees can be described as environmental engineers because of the many ways in which they can modify and improve the physical and biological characteristics of the environment in which they grow. One of the primary ways in which trees function as environmental engineers is through their ability to absorb and store carbon dioxide through photosynthesis. This helps to mitigate the impacts of climate change by reducing greenhouse gas concentrations in the atmosphere. Another example is that trees play a critical role in managing water resources by intercepting and filtering rainfall, reducing runoff and soil erosion, and regulating water flows in rivers and streams. They also help to improve water quality by absorbing and filtering pollutants from the soil.

So, trees can change their environment in the interest of societies, and they do it in a pretty cheap and multifunctional way. Hence, the idea of maximising their environmental engineering role is functional and effective management. This is explained in the chapter Amenity and Monetary Value of Trees.

C. The City as an Ecosystem

A city is like an ecosystem in several ways. Just as an ecosystem is made up of various living and non-living components that interact with one another, so a city, too, is made up of various components such as people, buildings, (green) infrastructure, and natural resources that interact to create a functioning system. Like an ecosystem, a city also has energy flows and nutrient cycles that sustain life and growth. Additionally, cities have complex webs of relationships between various components, just like ecosystems have complex food webs and symbiotic relationships between species. The city is an ecosystem with three components: air, water, and soil. In a liveable, healthy city, we use an urban green structure to keep those three components healthy. The most significant components of this green structure are urban trees. Given that we see such trees as environmental engineers and we strive for efficiency, it is crucial to maximise the value of trees. It is the ETT's job to maximise the function of urban trees (Figure 3).

D. Ecosystem Services (ES)

As trees are the most significant assets of urban green infrastructure, urban trees can produce both ecosystem services and disservices. We explain below what ecosystem services and disservices are and how to classify them.

D.1. Valuation of Ecosystem Services

As we saw in the chapter Amenity and Monetary Value of Trees, we need to monetise ecosystem services to communicate with a broad spectrum of stakeholders. In order to monetise, valuation is needed; however, value is more than the utility or importance that something has for us. In other words, the value indicates how much

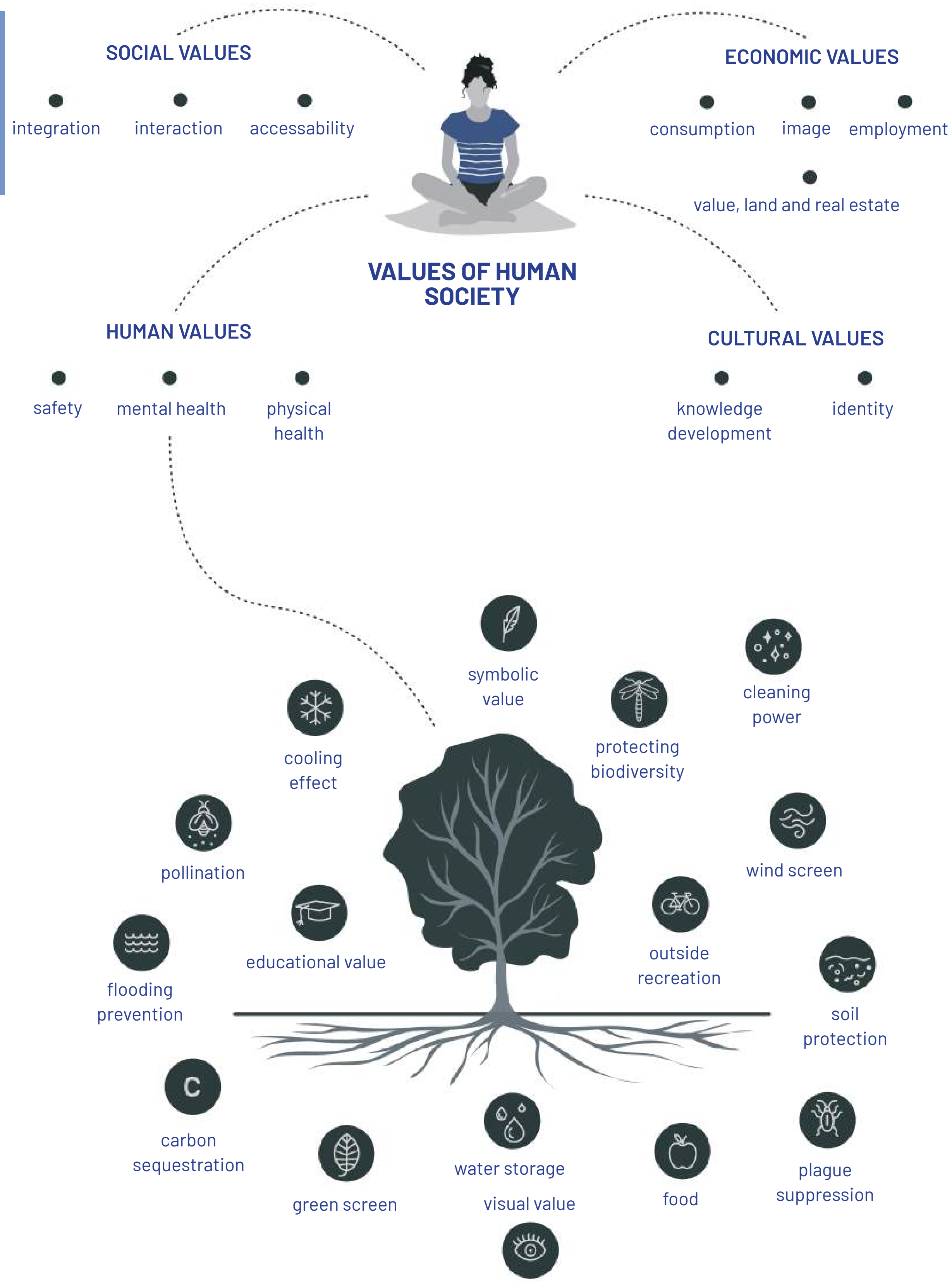

Figure 1. When looking at these human values, we see that safety, together with physical and mental health, are the key elements. These three elements represent what we, as individuals, value the most. So, trees that have a positive effect on these values are highly desired by us. Below, the corresponding tree-related ecosystem services of these values are depicted. (Adapted from Cobra-Groeninzicht)

someone wants something. In economic terms, value means "how much of something else we are willing to pay for it" (willingness to pay). For ecosystem services, the value rarely equals the price we pay because most ecosystem services cannot be found in a market and are, therefore, *free*. Although they cost nothing to the end-user, it does not mean that they have no value: a concept often referred to as "the tragedy of the commons". It is important to mention that willingness to pay does not fully represent the true value of the ecosystem. The intrinsic value is the non-anthropocentric value and can be defined as the value something has, independent of its context, its environment, or its position in a larger whole. Nature has an inherent value, independent of any value it has for humans. This is often forgotten (Figure 1).

TOTAL VALUE OF ECOSYSTEMS

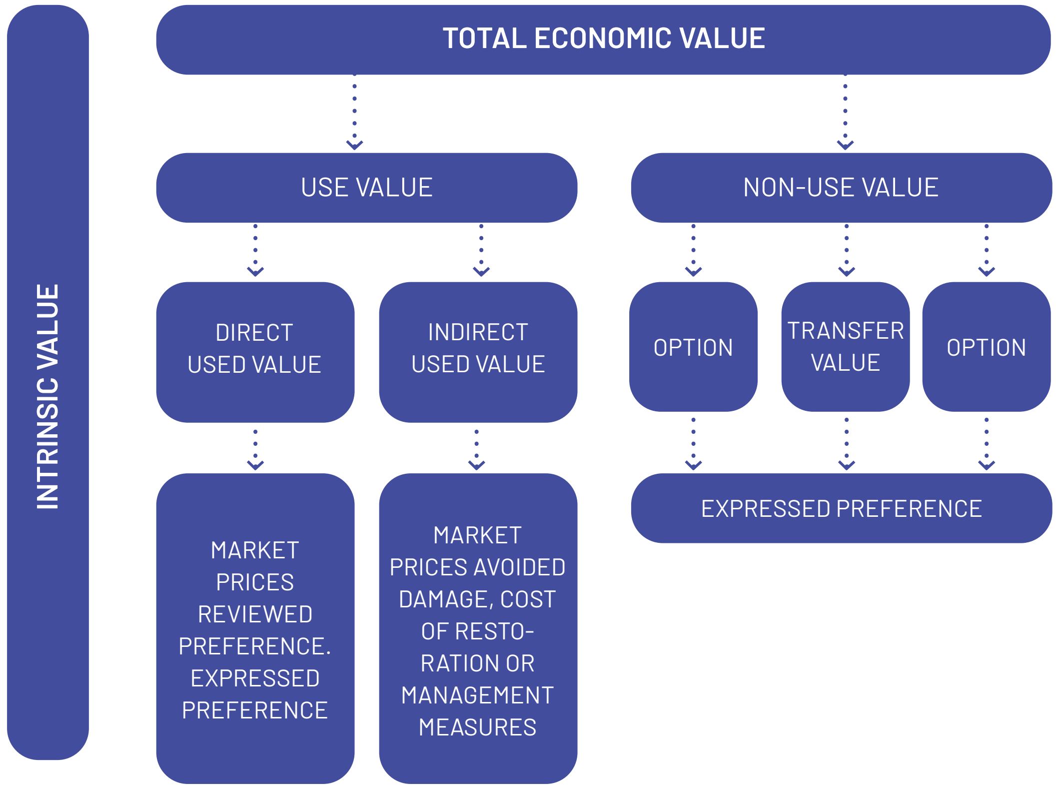

Figure 2. The total value of ecosystems is the sum of the intrinsic and economic value. As we can see, the value of ecosystems is complex, and the valuation of ecosystem services is difficult because not all value can be monetised. (Adapted from Hanley et al, 1997)

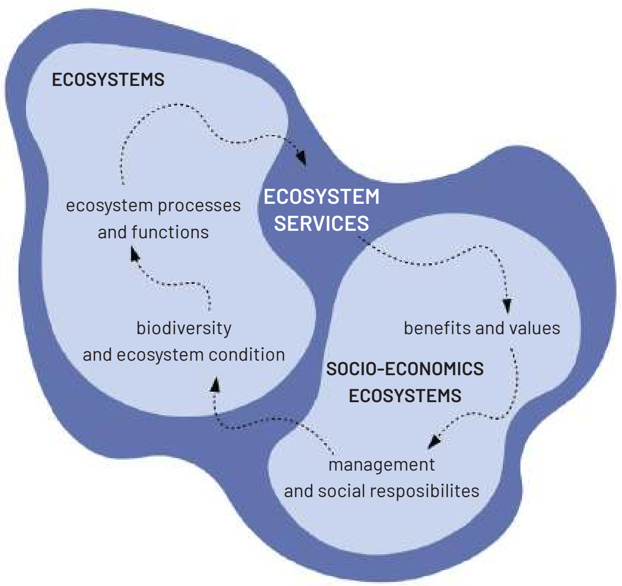

Figure 3. The four parts of an ecosystem service are connected in a positive feedback loop. First, benefits and values are determined. Second, these ecosystem services need to be integrated into management and social responses, which improve the condition of the ecosystem (third step), resulting in better ecosystem processes and functions (fourth step). Better functioning enhances the benefits and values. (Adapted from Liquette et al., 2016).

D.2. History of Ecosystem Services

The basis of ecosystem services (in an international context) goes back to 2005. At that time, the United Nations released the Millennium Ecosystem Assessment (MEA), i.e., the state of biodiversity and natural resources available to humans. It concluded that worldwide, 15 of the 24 ecosystem services studied were in decline because they were not being used sustainably. This conclusion resulted in politicians and policymakers recognising the importance of the concept of ecosystem services.

At the European level, the TEEB (The Economics of Ecosystems and Biodiversity) initiative in 2007 provided the framework for identifying the economic benefits of biodiversity and the incremental costs of biodiversity loss. For more on TEEB scan QR code.

TEEB webiste

D.3. Grouping of Ecosystem Services

Ecosystem services are commonly grouped into 4 major groups:

1. Provisioning (production services): the products obtained from ecosystems. Trees provide a variety of products that are used by people, such as timber, fruits, nuts, and other forest produce. Trees also provide fuelwood, which is a primary source of energy for many people in rural areas.
2. Regulating services: services that regulate the ecological balance. Trees play a vital role in regulating various ecosystem processes, such as air and water quality regulation, climate regulation, and soil erosion control. Trees absorb carbon dioxide and release oxygen, which helps mitigate the impacts of climate change. They also help to regulate water cycles, prevent soil erosion, and protect against natural disasters like floods and landslides.
3. Cultural services: non-material benefits. They can provide recreational opportunities, inspire and further spiritual and religious beliefs and practices, and maintain traditional knowledge. Trees and forests are also important for cultural practices and traditional uses of natural resources.
4. Supporting services: services that are necessary for the production of all other ecosystem services. Trees provide a range of supporting services that are essential for the functioning of ecosystems, such as nutrient cycling, soil formation, and habitat for biodiversity. Trees play an important role in maintaining the health and resilience of ecosystems by supporting the growth and survival of other species.

E. Ecosystem Services of Trees

Trees are the most multifunctional assets of urban infrastructure. There are 18 ecosystem services related to urban trees, as shown in the Figure 4. Here, we only discuss the most common ones. In light of the human values already discussed (physical and mental health and a safe environment), cooling, water buffering, psychological well-being, and reducing stress are the most relevant. The first two are extremely relevant for urban climates, as climate changes make weather phenomena more extreme, especially in highly urbanised areas. Note again that the physical environment has an air, soil, and water component. The ecosystem services that trees provide include the smart ability to alter these components simultaneously, making them efficient (and thus cheap) service providers.

E.1. Cooling the Urban Heat Island Effect

The urban heat island (UHI) effect is the phenomenon of urban areas being several degrees warmer

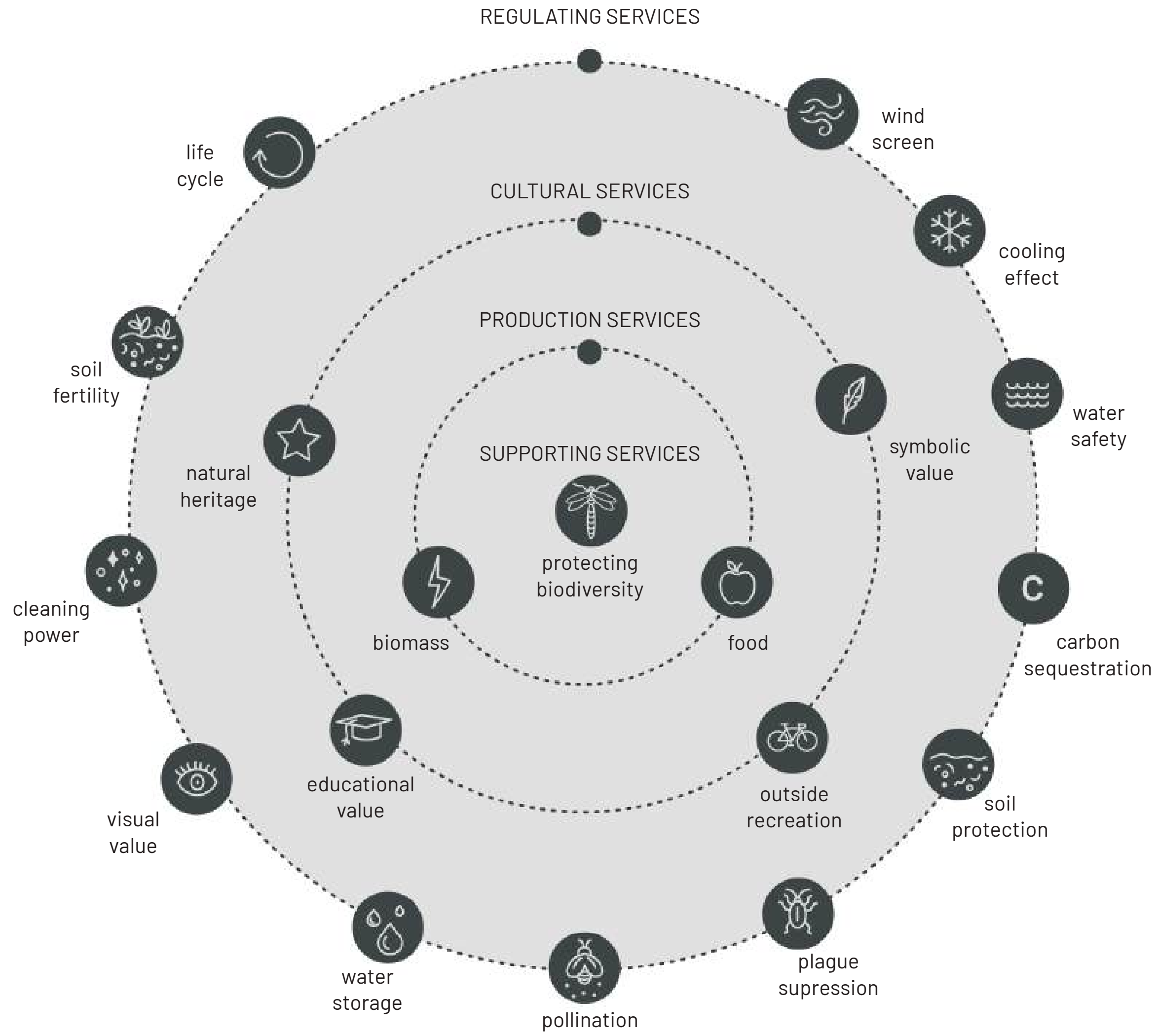

Figure 4. The 18 ecosystem services of a tree, divided into four service categories. Note that trees are among the most multifunctional assets of the cityscape. (Adapted from Cobra-Groeninzicht)

than the surrounding rural areas. This is primarily caused by the high concentration of buildings, pavements, and other heat-absorbing materials in urban areas, which can absorb and re-emit heat.

The UHI is particularly noticeable at night and under calm weather conditions. The difference in temperature is on average 5 to 10°C higher than the surrounding countryside. This is because cities, built of concrete, brick, and other materials that absorb heat easily, heat up faster and release heat slower than rural areas. Consider, also, the street canyons that can store a lot of heat.

Trees can help mitigate the urban heat island effect by providing a cooling effect through several mechanisms. Firstly, trees provide shade, which reduces the amount of direct sunlight and heat that reaches the ground. This can help reduce surface temperatures and provide a cooler microclimate for people to enjoy.

Secondly, trees release moisture through a process called transpiration, which cools the air around them. This can help lower air temperatures and reduce the heat island effect. In addition, trees can also help reduce the amount of energy needed for air conditioning by providing shade and reducing the amount of heat that enters buildings.

E.2. Water Buffering

When discussing water buffering and/or stormwater management by trees, the distinction between the natural and urban water cycles is essential (Figure 5).
To concretise the ecosystem service of urban trees, focus on the disruption of the existing (urban) hydrological cycle. The continuous growth of land take in our cities puts pressure on the natural hydrological cycle. By 'land take', we mean the space in which we travel, live, work, and relax such as public squares, roads, car parks, and so on

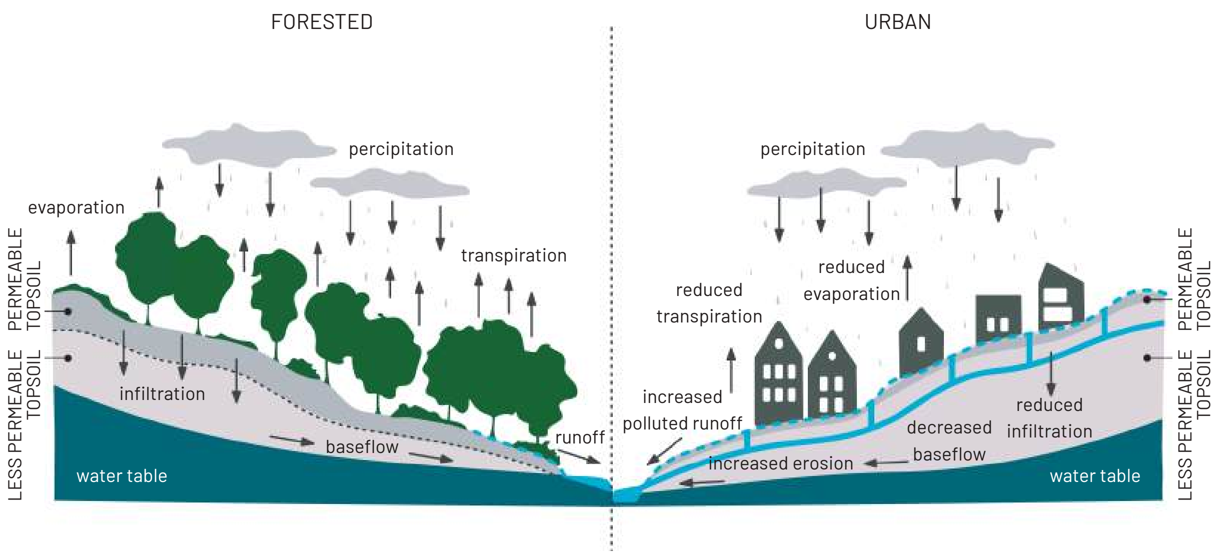

Figure 5 shows the major differences between the natural and urban water cycles (Boulomytis, Zuffo, Imteaz, 2017). Due to the high degree of paving in cities, there are lower amounts of precipitation that evaporate back. Transpiration represents the escape of water (water vapour) from plants along the stomata in the leaves. Fewer trees and less transpiration result in more water on the earth's surface, which then cannot, or to a much lesser extent, infiltrate due to the small infiltrating surfaces. This leads to a higher percentage of (polluted) runoff, which can increase erosion as well as reduce underground water flow. (Adapted from Walsch et al, 2004, and Boulomytis, Zuffo, Imteaz, 2017)

(Department of the Environment, 2017). Add to this climate change, which means we have to cope with more extreme precipitation, and we can see that the hydrological cycle will change in the future.

Trees can play an important role in mitigating these issues by providing a stormwater buffering effect. Trees can intercept rainwater, which can reduce the amount of runoff that enters stormwater systems. In addition, trees absorb water through their roots and release it back into the atmosphere through transpiration, which can help reduce the amount of stormwater runoff that is generated.

Furthermore, the canopy of trees can intercept rainwater and reduce the amount of rainfall that reaches the ground. This can help reduce the velocity and volume of stormwater runoff, which can help prevent flooding and erosion.

E.3. Psychological Well-Being and Stress Reduction

More than 100 studies have shown that exposure to natural environments, including trees and forests, can have a positive impact on mental health and well-being. Humans are instinctively drawn to nature and other living things, so the connection with nature is in our DNA and is referred to as the biophilia hypothesis. Spending time in nature has been linked to reduced stress levels, improved mood, increased feelings of vitality, a stronger connection to the natural world, and improved social cohesion.

Trees in particular are thought to be especially beneficial for psychological well-being. One reason for this is that trees produce phytoncides, natural compounds that have been shown to have a calming effect on the human nervous system. Phytoncides, which are released by trees and other plants, have been found to reduce levels of the stress hormone cortisol and increase feelings of relaxation. A more common term is forest bathing, which refers to the reduction in stress, aggression, fatigue, and feelings of depression we feel when we are in a wooded area.

In addition, trees provide a sense of connection to the natural world and can foster feelings of awe and wonder. This can be especially important for those living in urban environments, where access to nature may be limited. Studies have found that exposure to natural environments, including trees and green spaces, can improve mood and reduce symptoms of anxiety and depression.

Finally, trees provide a sense of beauty and aesthetic value that can have a positive impact on mental health. Studies have found that exposure to natural beauty, such as trees and other plants, can enhance feelings of well-being and reduce symptoms of depression.

In conclusion, trees play an important role in promoting psychological well-being. From producing calming compounds to providing a sense of connection to the natural world, trees offer a wide range of benefits that can help improve mental health and the overall quality of life. As such, it is essential that we work to protect and preserve our tree populations, both for their ecological and psychological benefits

F. Disservices

Urban trees can also bring about various forms of harm, nuisance, and expense, which are referred to as ecosystem disservices. While there is no widely agreed definition for this concept, ecosystem disservices can generally be described as functions, processes, and characteristics of the ecosystem that result in negative impacts on human well-being. These concepts, including ecosystem services and disservices, are anthropogenic and emphasise the human assessment of ecosystem properties and functions.

People have different ideas of what is beautiful and useful, so what one person may find beneficial, another may find unattractive, pointless, unpleasant, or hazardous. Common examples are:

- Leaf litter and debris: Trees shed leaves, twigs, and branches that can accumulate on the ground, leading to reduced access to sunlight, tripping hazards, and an increased risk of wildfire.
- Allergens: Trees can produce pollen and other allergens that can cause respiratory problems in people with allergies. More information about allergy and pollen news for Europe can be found on website (to see scan QR code).
- Resources: Conflicts between trees and solar panels or farming land are mostly related to reduced yield due to tree shade and/or water.

Conclusion

It's important to note that the benefits of urban trees outweigh the disservices, and many of the negative impacts can be mitigated through proper management and planning. Therefore, efforts should be made to preserve and increase the urban tree population to enhance the benefits of ecosystem services while minimising disservices. This is where an ETT can make the difference.

Pollen news for Europe

SELF-CHECK QUESTIONS

1. Explain the city as an ecosystem.
2. What is an ecosystem service?
3. Name five ecosystem services of trees and explain their relevancy in an urban area.
4. What do we mean by "trees as environmental engineers"?
5. Explain the urban heat island effect and the role of trees in mitigating it.
6. What is the difference between the natural and urban water cycles?
7. Give two examples of tree disservices.
8. Explain how trees lower stress.

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ESSENTIAL READING

World Routledge Handbook of Urban Forestry Edited by Francesco Ferrini, Cecil C. Konijnendijk van den Bosch, Alession Fini
Reference work on urban forestry

EU The Urban Forest: Cultivating Green Infrastructure for People and the Environment by David Pearlmutter, Carlo Calfapietra, Roeland Samson, Liz O'Brien, Silvija Krajter Ostoić, Giovanni Sanesi, Rocío Alonso del Amo
Provides the first comprehensive catalogue of tree species that is cross-correlated with the ecosystem services they provide in different regions of Europe. It also provides a useful classification of the socio-cultural benefits of urban green space, the barriers to their equitable access, and solutions for overcoming them.

POL Small movie of the city as a forest by Bomenstichting. Retrieved from: https://www.bomenstichting.nl/nieuws/film-de-stad-als-bos.html
Very good introduction video of some ecosystem services of urban trees.

ADDITIONAL READING

UK London iTree report by Treeconomics. Retrieved from: https://www.treeconomics.co.uk/wp-content/uploads/2018/08/London-i-Tree-Report.pdf
Comprehensive quantification of the urban forest of London with i-Tree.

1.4. TREE QUALITY ASSESSMENT, PLANTING AND AFTERCARE

1.4.1. Plant Quality Assessment – Species and Nursery Stock Selection

Wim Peeters

GENERAL OBJECTIVE

To facilitate the selection of species and cultivars according to relevant parameters. To ensure that nursery stock material complies with national quality standards to guarantee establishment success and reduce management problems.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- specify the right plant (in terms of species, cultivar, quality, and size) for the right place;
- conduct and/or supervise the quality control of nursery plants while taking into account the relevant specifications and nursery standards; and
- have a basic understanding of underlying nursery production principles.

SEE TOGETHER WITH:

Function and Structure of Trees, Soil Science, Site Selection, Ecology and Biodiversity, Amenity and Monetary Value of Trees, Tree and Shrub Planting and Aftercare

ESSENCE OF THE TOPIC

Plant quality in terms of product quality is a prerequisite to achieving healthy, safe, and long-living trees, and thus a prerequisite to ensuring that the investment in tree planting is returned fully in terms of ecosystem services. Plant quality encompasses measurable parameters that can be easily assessed during quality control. However, the selection of species and cultivars suited for the specific local conditions at the planting site is also of crucial importance. More on that in Chapter 1.2.1 Soil Science and 1.2.2 Site Selection. For a healthy urban forest, everything starts with healthy, good-quality trees. Trees are usually raised in nurseries.

KEY TERMS

Plant Quality: breakpoints, containerised tree, delayed incompatibility, cultivar, European Tree Planting Standard (ETPLS) genus, inspection, multi-stemmed tree nursery, root-balled tree, species, stock standard

Regulation: biosecurity, imported trees, ISO code, phytosanitary export certificate, plant passport, quarantine organisms, traceability code

Nurseries are commercial companies that aim to grow trees in a cost-efficient manner so that the trees can be sold for a good price and the nursery makes profit. The trees they deliver are their end product. When the trees are planted, however, these same trees are not an end product but a resource that we start utilising. Remember that we want trees to get old, as described in Chapter 1.3.1. The Amenity and Monetary Value of Trees.

The nursery and the tree planter may have divergent interests. Therefore, it is essential that there is clear communication with the nursery, which should have a very good description of the client's requirements. This starts with the plant passport. To ensure the best quality trees for a specific project, it is important to translate the given requirements (desired image) into a quality specification for the tree nursery. If, for example, the crowns have to be lifted to a height that exceeds the total tree height at planting time, it is not so important for all the branches to be spread equally as they will all have to be removed in the process of formative pruning. It is, instead, far more important to have smaller branches that can be easily removed.

A. What is Plant Quality?

A.1. Does it Matter?

It is very important to properly describe the requirements for the tree so that the trees that are delivered best meet these requirements and are optimally suited to grow into the desired final image. It is important for all parties to have a clear description of the trees to be delivered. For the nurseryman who has to deliver the trees, it is also very important that this description be delivered on time so that he has the necessary time to collect or ensure the right quality. When assisting a client as a tree consultant, try to involve yourself in this process as well.

When trees are inspected upon delivery, it is crucial to keep in mind that they can only be rejected based on the provisions described in the specifications, which, for public projects, are usually laid out in the tender. What is not described has, therefore, not been requested, which means no trees can be rejected based on this argument. The specifications should also describe the key variables that determine whether or not the ordered trees are accepted. Once again, good communication between the two parties on the desired product is key.

The inspection of the trees upon delivery is important and not to be overlooked. The client – or the ETT on behalf of the client - wants a guarantee that the trees of the requested quality will actually be delivered. It is also vital for the contractors who are carrying out the work because they are the ones who have to give a regrowth guarantee and provide the necessary aftercare. In practice, contractors are sometimes reluctant to reject bad-quality trees because of short deadlines, the extra effort, and the delay involved. An ETT, however, should not compromise on lower-quality trees, as we want trees to get old, and the best way to do this is by starting with good-quality plant material.

A.2. Inspection of Delivered Trees

Before the inspection of the delivered trees can start, the plant passport has to be checked. See Section B.2 Plant Passport for more information.

When drawing up the specifications for delivery, it is advisable to use the national rules usually used. If not, the European Tree Planting Standard (ETPLS) can be used. Anything deviating from the standard descriptions must be clearly described in the "special specifications". Contractors must submit a written request for inspection in which the following items are included:

- Proposed inspection date
- Location of storage (on or near the site)
- Detail of trees with measurements

If the trees are inspected on delivery, it can be very useful if an inspection form is drawn up in advance. Good preparation ensures that the same characteristics are consistently checked from the first tree. Make sure that the breakpoints, i.e., any aspect of the tree that fails to meet the set requirements, are clearly marked in the form. When trees are selected for delivery in the field, inspection upon delivery is still necessary. In principle, each tree is inspected individually, but for large numbers, it may be permissible to do a random check and inspect only a limited number of trees. If the sample is negative, more trees can be inspected. For root-balled or containerised trees, it might even be a good idea to buy a few extra trees and open the root ball or the container to make a thorough check. This can save a lot of money, which makes the extra cost a reasonable expense.

When trees are rejected, they must be returned within 24 hours. If the trees are replaced, a new inspection must be carried out.

The following are examples of issues that are wrongly used for rejection:

- The pruning wounds are too close together;
- The end buds are not big enough;
- The tree has grown too fast;
- There are lichens on the trunk;
- The branches are too thick/thin.

Also, keep in mind that trees are living products. So be tolerant of small, easily resolved defects that have no impact on the quality of the mature tree, such as a small double top, a broken branch(es), or a small irregularity/ kink in the trunk. Think well about the desired image. After inspection, an inspection report must be delivered in which the results of the inspection are communicated. Inspection does not relieve the contractor of responsibility for regrowth and internal quality.

A.3. Criteria

We can divide the requirements we place on trees into three categories:

1. Physiological requirements concern the physiological qualities of the tree, such as the size of the root ball, the size and number of pruning wounds, and the dominance of the terminal bud.
2. Aesthetic requirements concern external characteristics such as a straight leader, a balanced distribution of branches in the crown, and so on.
3. The final appearance may differ depending on what is demanded within the framework of a specific project. For this, it is important to differentiate according to how a tree should grow.

As you can deduce, this means having sufficient insight into the architecture of the tree crown and root system (for more information, see Chapter 1.1.1 Function and Structure of Trees).

The European Tree Planting Standard (ETPLS) deals with all issues concerning plant quality. The most important issues are repeated here. For full details, see the ETPLS. There may be national variations described in national standards for government specifications. Please consult these national standards, as they are outside the scope of this study guide.

CHECKING PLANT QUALITY

- Trees should show no characteristics of diseases, pests, injuries, or weeds either above or below ground. Annual twigs must be fully hardened off. The trunk should have a normal course (thicker at the bottom than at the top) without damage or stem wounds or bruises. Pruning wounds should be no bigger than 2 to 3 cm and surrounded by callus formation. Fresh pruning wounds are out of the question. The crown should be balanced according to the habit of the species.

- In species susceptible to sunscald, such as beech, there should be a mantle of small wedges that are regularly distributed, rather stocky, and up to 2 years old.

- Multi-stemmed trees should have a single root system. Multiple trees planted together should not be accepted. All trunks should be equivalent in length and thickness growth, and the trunks should be well fused, without branch inclusions or other problems.

- The root system should be proportional to the above-ground area and be regularly covered with hair roots. The root system should also be sufficiently branched and healthy and should certainly not be dried out. The main roots should not show any twisting or tuberous growth, kinks, or bends sharper than 90°.

- Root-balled trees should have a root ball that is cohesive and packed with digestible material. Check the root ball by putting your foot on it and gently pulling the stem. When the tree moves in the root ball, it is not cohesive and should be rejected.

- Container trees should be containerised for at least one growing season, but not more than two years in the same container so that the container is fully rooted, with no girdling roots, and no crimp edges. The container must have the following minimum volume for the tree-size class:

Size class	Min. container volume [litres]
10/12	25
12/14	50
14/16	50
16/18	65
18/20	65
20/25	100

Source: ETPLS

- The trees should be delivered unpruned.

- The trunk circumference is measured 1 m above the root collar. Trees of size 20/22 have a girth of at least 20 cm and a maximum of 22 cm.

- The trees should have been replanted regularly, with the last replanting occurring at least two years prior to delivery. The root collar should be straight, undamaged, and visibly located at the top of the root ball or container.

- The root ball must be of a minimum size, and there must be a minimum number of times that the tree has been transplanted (see below).

CHECKING PLANT QUALITY

- The root ball must be of a minimum size, and there must be a minimum number of times that the tree has been transplanted (see below).

Size class	Min. root ball diameter [cm]	Number of times tree has been transplanted
10/12	30	2
12/14	40	3
14/16	45	3
16/18	50	3
18/20	55	3
20/25	60	4

Source: ETPLS

- In grafted trees, there should be no thickening or buckling at the graft. The graft and the roots should be well fused, and the tree should not have been grafted on roots known to have problems that can result in delayed incompatibility.

- For bare-root trees, roots up to size 12/14 should be at least 25 cm long. From size 14/16 on, the roots should be at least twice as long as the smaller size number. So, for a size 16/18 tree, the roots should be at least 32 cm long.

B. Regulation of Plant Quality

B.1. Biosecurity of Imported Trees

When ordering trees from a nursery, it is not unusual for the nursery to have imported the desired trees from other associated nurseries across Europe. This means an augmented biodiversity risk. A list with 300 names of quarantine organisms within the EU has been compiled. These organisms are subject to zero legal tolerance and must, therefore, not appear on imported goods. They are checked by the institution responsible in each EU member state (e.g., The Federal Agency for the Safety of the Food Chain (FASFC) in Belgium) in cooperation with customs. Some examples of quarantine organisms relevant to ornamentals are fire blight (*Erwinia amylovora*), leaf spot disease on *Prunus* (*Xanthomonas campestris* pv. *pruni*), sudden oak dieback (*Phytophtora ramorum*), *Xylella fastidiosa*, East Asian longhorn beetle (*Anolophora chinensis*), oak processionary caterpillar (*Thaumetopoea processionea*), and the larger eight-toothed European spruce bark beetle (*Ips typographicus*). For more on this, see Chapter 1.2.3. Ecology and Biodiversity.

B.2. Plant Passport

A plant passport contains essential information for trading seeds, cuttings, plants, and trees within the EU. The passport states the identity and origin of the product and the details of the producer. This information is obligatory. When selling or buying plants (and thus trees), you need a plant passport for any plant intended for planting, such as:

- propagating materials;
- potted plants, bedding plants, or tub plants intended for consumption;
- boxwood, conifers, and roses (companies that grow and trade these plants need to register with an inspection service).

A plant passport always contains the following elements:

- botanical name;
- ISO code of the grower's country of residence, followed by the phytosanitary registration number;
- traceability code (not necessary for materials that are ready for sale to an end user);
- ISO code of the plant's or plant material's country of origin or production;
- an image of the EU flag;
- the words 'Plant passport'.

A passport can only be issued for plants that do not contain harmful organisms, as the plant passport is meant to prevent the further spread of such organisms.

For certain plants, you need a phytosanitary export certificate when you export them to or import them from non-EU countries.

If in doubt, check the website of your national institute responsible for the implementation of the plant passport and/or the European website.

SELF-CHECK QUESTIONS

1. Can you provide an extended overview of tree species/cultivars produced for arboricultural use?
2. Are you able to identify and name tree species/cultivars that are commonly used in arboriculture?
3. Why is nursery stock quality important for the long-term performance of a recently planted tree?
4. What are the main parameters used for assessing the quality of the roots, stem, and crown of nursery-grown trees?
5. Can you name and explain the relevant national nursery standards for arboricultural products?
6. What are the most common flaws of nursery trees?
7. Suggest how to control root quality in balled and burlapped/container trees?
8. Propose a checklist for quality control at delivery.

PRACTICAL EXERCISES

1. Find a nursery where you can walk freely and check the quality of their trees with either the ETPLS or your own checklist.
2. Set up a tender where you describe the required plant quality for a replacement of street trees in your neighbourhood.

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EU European Tree Planting Standard by European Arboriculture Standards. Retrieved from: http://www.europeanarboriculturalstandards.eu/

The standard of planting in the European Union. A must read.

EU National nursery stock standard

Check the national standards for plant quality. This is slightly different in every country.

EU Plant passport https://food.ec.europa.eu/plants/plant-health-and-biosecurity/trade-plants-and-plant-products-within-eu_en

Web site with information on plant passports.

EU National organisation responsible for the implementation of the plant passports

Check the national organisation for information in their own languages to get help with plant passports whenever this might be necessary.

ADDITIONAL READING

USA Routledge Handbook of Urban Forestry by Francesco Ferrini, Cecil C. Konijnendijk van den Bosch, Alessio Fini

The chapters by Sjöman et al. present a condensed and applicable description of the plant selection process (see references for details).

1.4.2. Tree and Shrub Planting and Aftercare

Bregt Roobroeck, Wim Peeters & Ben Bergen

GENERAL OBJECTIVE

To prepare and organise tree and shrub planting, transplanting, and aftercare in relation to the environment and complex growing site conditions.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- take existing landscape elements into account when planting trees and shrubs;
- improve the soil to meet the plant's requirements and environmental protection guidelines;
- encourage mycorrhiza association by careful treatment of the site and the choice of tree and shrub species;
- carry out correct tree planting and aftercare relevant to the prevailing site and environmental conditions;
- explain the importance of weed control and mulching in the early stages of tree establishment;
- describe post-planting aftercare and formative pruning methods;
- describe and choose the procedures involved in lifting and transportation, from preparation through to execution and aftercare;
- take account of the latest version of national standard specifications and professional good practice when describing planting arrangements or planned deviations to these planting arrangements; and
- define and describe the quality requirements and delivery modalities of the planting material and trees to be delivered.

SEE TOGETHER WITH:

Soil Science, Site Selection, Plant Quality Assessment, Tree Revitalisation

KEY TERMS

Preparation: action plan, methodically, quality assessment, site selection

Planting: anchoring, European Tree Planting Standard (ETPLS), lifting, planting pit, rootability, rootball anchoring root management, root rot, smeared, transport, tree protection

(Big) tree transplanting: Plantability study, mulching, Newman frame, noose technique, scoop technique, pallet technique

Aftercare: crown development, oxygen balance, soil balance, and water balance

ESSENCE OF THE TOPIC

Transplanting trees is the most unnatural event a tree can face. Roots and the crown are pruned in preparation for transplanting, which implies disrupted natural growth. Moreover, the environment for the plant changes above and below ground. A good plan of action with appropriate equipment and techniques minimises plant shock and allows the plant to adapt and continue growing in this new environment. The bigger and/or older the tree, the more crucial it is to proceed methodically. This means creating and applying standards and protocols. It is here that the European Tree Technician should apply his or her knowledge and add value.

Introduction

This chapter describes the steps to be taken when planting and transplanting trees. It describes the important points that need to be considered when consulting on or supervising this kind of work. We do not go into depth into the practical and technical aspects of planting; for this, we refer to the European Tree Planting Standard (EAS 01:2021 (EN)). When planting trees, certain prerequisites must be met so that the tree can grow to its predetermined desired image, since in nature, the tree will grow according to the conditions it encounters above and below ground.

As discussed in Chapter 1.2.2 Site Selection, it is important to choose the right tree species for the right location. In our modern cities, with their complex urban environment, it is quite a challenge to provide sufficient high-quality underground space for trees. That is why preparation, planting, and aftercare are so essential. Complex or not, the following steps and parameters should always be taken into account when dealing with planting and aftercare.

European Tree Technicians are expected to take part in and supervise the transplanting process, from planning to execution, starting with the appraisal of the tree, planting site, and transport. Always carefully consider the condition of the tree before transplanting, as well as the benefits and disadvantages of transplanting. It might be better to replace it with a new, young tree.

In the exam and in practice, a step-by-step plan outlining the approach for planting trees may be requested. The plan should contain a correct overview of what needs to be done and all the requirements for how it should be done. The aim is to make the time between uprooting and planting as short as possible and to provide an optimal habitat. The plan always includes an evaluation at the end, or in the intermediate stages if needed. This plan of action goes beyond just the planting itself. In the preparation, you will have to check, for example, whether you need permission to dig in the vicinity of utility lines or take measurements for traffic problems, and so on. It usually consists of preparation, the work itself, the timing of evaluations, aftercare, planning, timing, and delivery, as explained below.

A. Planting

Planting a tree includes all the steps from quality control when purchasing at the nursery to aftercare, as stated in the European Tree Planting Standard (ETPLS). It generally consists of the following procedures:

1. Time of planting
2. Transport
3. Root management
4. Site and soil amendment
5. Planting pit adjustments
6. Tree placement/planting
7. Anchorage systems
8. Stem and crown protection
9. Mulching
10. Water supply systems
11. Tree pruning at planting

Prior to these steps, a suitable tree has been chosen, as described in Chapter 1.2.2 Site Selection. In this chapter, we do not focus on site selection or soil improvement. More information is found in Chapters 1.2.1 Soil Science and 1.6.2 Revitalisation of Trees. This chapter focuses on the most essential tips and tricks. More detailed information can be found in the European Tree Planting Standard (ETPLS).

A.1. Transport, Lifting, and Timing

Transportation should be carried out using equipment appropriate to the size of the tree and its weight, in accordance with ergonomic requirements and work safety regulations. Optimal fixing and support on the transport vehicle is important to prevent damage to the branches, trunk, and roots. Specific measures should be taken to prevent the roots from drying out during transport or storage. When lifting the tree, the root ball and the trunk should be supported so that the tree remains in a stable position. The tree should be lifted by the stem as little as possible. If the tree has to be lifted in this way, then it is crucial to spread the weight to ensure the stem or bark (sap flow) is not broken.

Normally, professional tree nurseries know how to transport and lift normal-sized trees. For big tree transplanting, refer to Part B. Bare-rooted trees and trees with a root ball should be planted when the tree is dormant, according to the timetable in the ETPS.

A.2. Planting Pit Preparation

Trees depend strongly on their growing environment. Planting the best species for the given location is very important to get the best results. More information on that subject can be found in Chapter 1.2.2 Site Selection. Information about the soil itself is discussed in Chapter 1.2.1 Soil Science.

In the urban environment, especially after construction work, poor soil quality and compaction are major problems. Preparation of the planting location should not be limited to the planting pit itself but should stretch as far as possible to prevent trees from growing in a so-called 'flowerpot'. Bad soil quality outside the planting pit can halt tree growth as soon as the complete pit is fully rooted. The tree should be encouraged to grow beyond it.

When improving the soil, it is important to locate and, if necessary, break compacted layers to increase the rootability and permeability of the soil so that the tree will have more root space, and the soil can retain more water. Clay soils, in particular, can cause specific problems as they do not easily drain water. Improving the soil in and around the planting pit can increase the permeability of the soil, which would cause water to collect in the pit during periods of rainfall. This will result in root rot in wet periods and drying trees in periods of drought.

When the planting pit is drilled in heavy soil, the walls of the pit can be smeared. This will prevent the roots from growing out of the pit, resulting in circling roots. Smearing can also have an impact on the drainage qualities of the soil, resulting in a bad tub effect similar to that which can happen in clay soil. For a better understanding of soil, refer to Chapters 1.2.1 Soil Science and 1.6.2 Tree Revitalisation.

A.3. Root Management and Mulching

When planting, it is essential to maintain as many roots as possible and ensure that the root system consists of both structural and small roots. For the root architecture and classification of roots, refer to Chapter 1.1.1 Tree Function and Structure. It is impossible to (trans)plant trees without cutting their roots. The tree will react to root cutting in the same manner as when its branches are cut: many small shoots that grow independently from each other will grow from the cut. Just as happens

when branches are cut, roots that have been cut will keep their branched feature and never return to the original hierarchy with a single leader. This will influence the stability of the tree.
For the same reason, the roots need to be spread as much as possible. This is especially important for container-grown trees, as circling roots can grow to become strangling roots, which can cause problems as the tree gets older. When the central root disappears, stability has to be provided by lateral roots. When these roots do not grow out of the stem in all directions, the tree might get uprooted. These kinds of problems can occur decades after the time of planting.

In the ETPLS, the following recommendation is given: "For bare-rooted trees up to a stem circumference of 14 cm, roots must be at least 25 cm long. For trees above a stem circumference of 14 cm, the minimum root length is double the circumference class's lower limit (e.g., 20/25 cm circumference: minimum root size 2 × 20 = 40 cm)."

The current trend in urban forestry is to plant increasingly large tree stock. However, it is recommended that smaller trees are planted in general (preferably between 12–16 cm stem circumference), as these will:

- suffer less from planting shock;
- require a less intensive and shorter aftercare period;
- demonstrate better hierarchy (forming one dominant leader);
- resume growth faster;
- exhibit less quality loss related to nursery practice (e.g., topping, fertilising); and
- adapt better to the local environmental conditions.

This does not mean that planting larger trees can never be justified, but it is not to be preferred. For more information, see the European Tree Planting Standard 4.1.5 to 4.1.7.
When planting, the lifting and planting depth of the tree are points of interest. It is important that the root collar is visible so that roots are not buried, and the tree is not planted too deep. To prevent root damage, tree fixatives are applied before filling the planting pit. When the planting pit is backfilled, an irrigation wall is applied just outside the outer border of the planting pit to prevent water loss and to force the water to moisturise both the existing and newly formed roots. Mulching needs to be applied in a layer that is not so thick that it prevents aeration of the soil. Never pile up any kind of mulch to the base of the tree. Absolutely prevent piling up the mulch on the stem base (volcano mulching).

A.4. Anchorage Systems and Protection

An essential part of tree planting is the positioning and support of the trees in a vertical position until their roots are established, thereby ensuring vertical stabilization. The following are commonly used methods:

- Rootball anchoring
- Staking;
- Low trunk fixation (allows more movement for the stem and promotes root growth)
- Guying

To prevent root damage, stakes must be placed before the tree is put in the planting pit. When applying anchoring, make sure underground utilities are not damaged during the installation. Any anchoring systems that need to be left in the ground while the structures are being staked should be removed after approximately 3 years. Guying is appropriate only when planting larger trees – fastened at an angle of 20-30 degrees to the trunk at a height of ½ to ¾ of the stem with the anchors fixed to the ground.
Stem protection from sun scorch and heat stress can be done by using paint, reeds, bamboo, wraps, and shading shields. Do not forget mechanical protection from gnawing, browsing, and antler damage, as well as protection from damage by mowers or grass trimmers.

A.5. Soil Improvement

Sometimes, the soil in and around the pit requires improvement as it doesn't meet the required standard. Our starting point should be to choose the most suitable species. Only when this is not possible, or is an insufficient solution, is soil improvement an option. When considering the best course of action, the following natural cycles should be kept in mind:
Trees in the forest shed their leaves annually, even evergreen trees. Autumn leaves will form a layer that will decay, feeding microflora, plants, fungi, and animals. Trees will also feed the microflora in the soil by leaking exudates into the soil. Fungi are most important as they can form mycorrhiza that provide the tree with essential minerals from the soil. Together with all other microflora, they also protect the tree against the parasites which are the clean-up crew in the ecosystem (soil food web). As we have already discussed in many topics, it is all about enhancing natural processes. When planting trees, it is important to take this cycle and the many interactions into account. That is truly what ecological design with trees is all about.

A.6. Pruning at Planting

It is usually advised to prune trees strongly at planting because they will have lost a lot of roots when transplanted, and pruning should restore the balance between the crown and the roots. Practical trials conducted to assess the effect of pruning always assume that a lot of roots are lost. Indeed, those field trials show that trees that are heavily pruned do indeed take root better. However, the question is whether, in this way, we are not solving problems by creating new ones. Indeed, the European Standard on Tree Planting states unequivocally that it is *'not advisable to compensate for poor-quality plant material by pruning'*. Moreover, trees must not have been recently pruned before delivery. The only thing that may be trimmed is minor damage to above- or below-ground parts. How should we prepare trees so that they experience as little stress as possible from planting? Pruning at planting may indeed help trees with poor root systems grow, but this masks poor quality in the first place. According to Claire Atger, who has specialised in root research for more than 25 years, pruning is only a temporary solution that pushes the problems forward. In other words, if it is really necessary to prune at the time of planting to restore the balance between the crown and the roots, then the tree should be rejected.

B. (Large) Tree Transplanting

B.1 Plantability Study

Proper preparation is the beginning of any transplantation, especially for large trees. So, a preliminary survey is crucial before transplanting and has two main purposes. The first is to answer the questions below, and the second is to produce unambiguous instructions.

QUESTIONS

1. Is it absolutely necessary to transplant the tree(s)?
2. Is the tree suitable (species and condition) for transplanting?
3. Is the new location suitable for the transplanted tree?
4. Which method will be used for transplanting?
5. What preparation work is necessary for transplanting?
6. What are the aftercare measurements?
7. What is the timeline of the transplanting process?
8. What are the estimated costs?

Never take for granted that transplanting will be successful, as it is delicate work. Dare to weigh up the pros and cons, and always assume that you are the professional who will describe and manage the entire process. Certainly, don't let yourself be hunted by the demands of the client. This attitude and criticism should test whether it is absolutely necessary to transplant the tree. Secondly, checking if the tree is suitable or not depends on numerous parameters and guidelines for making decisions. Each company, and ETT, has their own method, but the following parameters should be taken into account. Basically, there is a physiological and an engineering dimension to consider when assessing suitability.

Tree condition: There are many ways to assess tree condition, but the moral of the story is not to focus on one parameter. Assess should be based on a set of parameters, such as:
- Bud formation
- Crown discolouration
- Crown defoliation
- Water sprouts
- Diseases and pests

Tree vitality: The essence here is to figure out if it is physiologically worth the effort of transplantation. It could be that life expectancy is low, so transplantation is of no added value and a waste of resources because the tree is not able to survive in a sustainable way. It is, though, sometimes better to cut down a tree in poor condition and replace it with an equivalent high-quality tree from a nursery. Assess based on the following questions:
What is the resilience of the tree?
What is the life expectancy of the tree?
Is the tree in good enough condition to be transplanted?

Structure of the tree: The essence here is to check the mecanical properties of the tree, mainly to assess the method of transplantation. Answer the following questions carefully:

- Crown architecture:

Is pruning necessary for transplantation, and if yes, what pruning actions are needed?
Is anchoring of the tree possible (mechanical strength) for transplantation?
Does the crown system allow transplantation (size)?

- Root architecture:

What does the root system look like (superficial roots, form of the root ball, stability roots, etc.)?
Does the root system allow transplantation?

The next topic to be assessed are the **site conditions**. Many external, site-specific conditions influence the possible transplantation project. Therefore, assess the following questions on site conditions:
Is there enough space for the transplantation to be carried out?
Is the route for transplantation suitable (above and below cables, utility lines, etc.)?
Are the old edaphic factors compatible with the new ones (e.g., the water level of the new site can be significantly lower than the old one, which implies adaptation of the tree for water supply)?

It can be the job of an ETT, sometimes with specialist assistance, to customise the above assessment into a checklist, flowchart, procedure, and so on.

When the suitability of the tree and the new site have been evaluated, the right **transplantation technique** should be chosen. In practice, five types of techniques are usually used for transplantation. These techniques can vary and depend on the size of the tree, the volume of the root ball to be transplanted, the distance of the transplantation, and the environment. The choice of technique is tailored to the specific situation.

The best option is usually determined in consultation with specialists. This also includes transportation specialists, if needed.

- **Noose technique:** A common technique is to place a noose around the tree. In principle, this is possible for species with a trunk circumference of up to 1 m. If it is possible to support the root ball, the noose method can be used for heavier trees. Beware: Damage is more likely in the spring because growth is starting. This is especially applicable to species with thin and smooth bark (*Carpinus*, *Fagus*, *Tilia*…).
- **Scoop transplantation technique:** One of the easiest methods is the use of a giant machine that scoops out the tree with a sort of ice cream scoop. This method is very quick but has some limitations. The soil can get 'lubricated' and should be assessed immediately after planting. The root ball is limited to a diameter of 2.4 m. This makes this method more suitable for smaller trees. The method is nicely shown in the video below (scan QR code).
- **Tow transplantation technique:** This method is chosen if the tree is to be moved in a straight line over a short distance (a maximum of a few hundred metres). Slabs or metal plates are pressed under the root ball, which means extra workspace is needed. A solid anchor point must also be present to get the load (the tree) moving. Again, lubrication is a problem that is very difficult to observe. It is advisable to always go for a fixed anchor point driven into the ground. Moving with excavators seems spectacular but is rarely a success. In the video below (QR code), the method is nicely shown. Also, consider the use of a chain pulley for moving the tree.
- **Newman frame technique:** This is a fairly efficient way of transplanting a solid root ball but has the disadvantage of a pin having to be placed right through the trunk. This is a fairly large operation, and in some cases there will be so much pressure in the wood that the pin will not be removable. On the other hand do fungi need oxygen to decay wood; Closing the hole can thus slow or even stop decay.
- **Pallet technique:** This is one of the most efficient ways to transplant trees that need to be transported to another location. The tree has to be transported in an upright position, and a lot of space is required for pallet placement because the plates are slid under the root ball. Pipes are pressed under the root ball, and cross beams are placed under these pipes for hoisting.

When the technique has been chosen, preparations need to be made for the transplant. Depending on the technique (with the exception of the scoop technique), preparations start ideally two years in advance. This consists mainly of root preparation, preferably section by section (digging in phases), but in practice, trees are often transplanted without such preparation. On average, the ratio of the root ball diameter is 7-10 times the stem diameter. Digging should be as deep as groundwater or disrupting soil layers but is seldom more than one metre. The crown of the tree to be transplanted can undergo up to a 30% reduction – crown lifting, volume reduction, and codominant stem reduction; however, this is not always necessary. Stem bandaging and careful trimming of the roots should be applied. The roots and the crowns should also be protected from drying out. The weight of the tree and root ball must be determined as precisely as possible in order to select the correct equipment with the appropriate lifting capacity and deflection. There should be complete clarity prior to transplanting about the aftercare (mainly watering) for at least 3-5 years after transplanting. For aftercare procedures, refer to Part C below.

Scoop transplantation technique (please scan with your phone)

Tow transplantation technique (please scan with your phone)

Pallet transplantation technique (please scan with your phone)

B.2. Transplantation Report

The report gives answers to the questions stated in B.1. The report should cover, at a minimum, the following topics:

- Rooting pattern: This can be done by means of trial trenches, but the use of ground radar is also a possibility if available;
- Moisture management: Make sure you get a clear picture of how the tree gets the moisture in the old site (hanging water profile, groundwater profile, roots in sewers, or a combination of sources) and how this will happen on the new site;
- Route: If the tree needs to go to another site, map the possible routes. Be sure to map the necessary traffic measures;
- Permit: For some operations, such as transportation, permits may be required;
- Tree preparation: Find out what preparation will be necessary for the tree;
- Method of transplantation: Be sure to determine in your preliminary research how you will move the tree. Can you hoist at the trunk? Is a transplanting machine convenient? Should you use the pallet method? Can you drag the tree?
- Make arrangements around aftercare for the tree;
- Include a cost estimate.

Figure 4 (Jēkabs Ozols, "Labie koki" Ltd., Latvia 2020). Large-size tree transplanting with manual root ball preparation and using heavy machinery.

THE ETHICS OF TRANSPLANTING

Replacing old trees to create new landscape solutions raises important questions. Where is the ethical boundary here? Do we prefer to transplant instead of adapting the design to reality? In practice, it is technically possible for people to transplant any tree, but is this the way to treat nature and trees? Each transplantation has a major impact on the tree, the environment, and carbon emissions. The idea that any tree can be moved to accommodate any construction work is wrong. Such re-plantations should be kept to a minimum, and every effort should be made to maximise the inclusion of existing trees in projects. Actually, there is very rarely a good reason to transplant a tree. The task of an ETT should be to prevent transplanting. Good design aims to take into account the existing trees, as illustrated in the following case. An ETT should always consider transplanting big trees as the last option.

This mature horse chestnut (*Aesculus hippocastanum*) with a root plate of 8m by 12m and situated in the vicinity of Riga (Latvia) was transplanted in 2019. Although the tree was protected by national law, the project developer managed to get permission to move the horse chestnut by 200 metres. Luckily, this technical tour de force ended successfully and is a nice example of what is technically possible; however, it illustrates that a protected tree is in fact not completely protected. Unfortunately, this decision sends the wrong signal to society and lacks ethics. Only in very specific situations of a general common good, such as the expansion of a metro or harbour, would it possibly be justifiable. Here, this was not the case, as it was on private ground.

C. Aftercare

The last step – aftercare – in the (trans)planting process is, again, crucial for the survival and condition of the tree but is often overlooked. Aftercare is needed to support the tree through the 'plant shock'. Most of the trees that do not receive this care will die due to a lack of water or grow into trees that deviate from the predefined desired image. The following problems can occur during aftercare and should be prevented, monitored, and/or solved:

- Oxygen balance
- Water balance
- Soil balance (chemical, physical, and biological)
- Crown development

The oxygen balance in the soil is a very important factor for tree establishment. It is therefore very important to monitor the oxygen percentages. Notice that in the first year, the oxygen percentage will not be optimal and will change during the season. Too much organic material can act as a sponge and create a disruption layer. Insufficiently decomposed organic matter causes anaerobic conditions because of the oxygen demand of these composting processes. The water balance should be carefully monitored and controlled by a soil moisture sensor based on the water retention curve of the soil. It is better for the tree to be given small amounts of water regularly than to be given large amounts of water occasionally. Soil balance should be monitored with a visual soil assessment and lab analysis, as seen in Chapter 1.2.1 Soil Science. Regarding crown development, in the first year(s), the tree will invest in root development, which implies a more transparent crown due to lower shoot growth, smaller leaves, and a more yellowish leaf colour. Aftercare usually stops when root development is back to normal and results in normal shoot length. There are no known extensive shoot length numbers in the literature, which means that evaluating what constitutes normal shoot length will depend on the experience of the tree specialist. The tension of the anchoring system should be checked for at least 3 years on large trees. For smaller trees, the system should be removed after three years.

SELF-CHECK QUESTIONS

1. How wide should the planting pit be? (Minimum parameters depending on the plant size)
2. What should be done if tree saplings have to be stored on-site without planting for several days?
3. What is more dangerous - planting a tree too deep or too shallow? Why?
4. What is important when planting containerised plants?
5. How is a planting bed for a hedge prepared?
6. Is it always necessary to replace the existing soil with an improved substrate? Explain.
7. What other options to stabilise trees are there if wooden stakes cannot be used?
8. What is the lifespan of a tree stabilisation system? What should be done afterwards?
9. Should the crown be reduced before planting? In which cases should pruning be carried out? In which cases should pruning not be carried out?
10. When planting a large tree using a root bunker system, should the same soil be used as for the lawn?
11. How can damage to the adjacent hard surfaces be avoided in the future as the tree grows?
12. How can large trees be transplanted without prior preparation?
13. Is fertilisation the primary care measure during the first growing season? Explain.
14. Why are trees prepared before planting?
15. Draw up a logical and well-founded plan of action for a tree transplant.
16. Identify the points of attention and bottlenecks in a transplanting project.
17. Rule out the most common mistakes or problems when planting and transplanting trees.

PRACTICAL EXERCISES

1. Go to a young street tree and check if the tree is planted too deep or not.
2. Go to a big tree and try to make a scenario where you need to make a plantability study. Divide this task into multiple small problems like:
   a. Is it technically possible to transplant?
      What needs to be checked and how will you check this?
      What are the parameters?
   b. Based on the studies, what technique would you use?
      How should the tree be prepared?
      Transplanting method
   c. What would be the aftercare?

TERMINOLOGY

planting – refers to prepared plants from nurseries (bare root/with root ball/containerized)

transplanting – refers to uprooting a tree from a growing site, with or without prior preparation (ideally 2 years of manual preparation), transporting, and planting in a different location

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Comprehensive guidelines for tree transplanting

GER Urban Tree Management for the sustainable development of green cities by Andreas Roloff
Good overview of transplanting large trees in chapter 12.

1.5.
DIAGNOSIS AND EVALUATION OF TREE DAMAGE

1.5.1. Diagnostic Features

Kamil Witkoś-Gnach

GENERAL OBJECTIVE

To understand what diagnostic features are in relation to tree assessment and management. This includes assessing the importance of the diagnostic features, predicting their future development, and taking any necessary action.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- identify abiotic and climatic factors affecting trees in a given environment;
- recognise symptoms of climatic damage;
- recognise urban pollution symptoms;
- trace and identify root damage symptoms;
- identify the presence or absence of diseases, pests, and infestations and their influence on the tree and the tree's ecosystem;
- recognise factors that contribute to tree infections and infestations;
- identify the agents of wood decay, cankers of the bark and leaf diseases, as well as understand the link between them;
- identify mechanical defects (cracks, cavities...);
- be aware of the biological cycles of fungal and insect species;
- identify the main types of wood decay and wood-decaying fungi on living trees;
- assess the necessity for specialist research;
- take measures to support the defence mechanisms of the tree / be aware not to take any action that could harm the natural defence system of the tree; and
- propose suitable prevention and management measures in accordance with European, national, and regional regulations, as well as with legislation governing environmental and nature protection.

KEY TERMS

Diagnostic features: cankers, diagnostic features, dry branch, fungal fruiting bodies, frost cracks, hollows, ivy, lightning strips, necrosis, pruning wounds, reiterations, sunburn, surface injury, weak fork, wood decay, wound wood

Assessment of diagnostic features: biodiversity, cavities, CODIT, compensatory growth cracks, deadwood, growth stage, fungi, habitat, hollows, insects, microorganisms, nest, reaction wood, reiteration, root system, tree adaptation, tree biomechanics, tree ecosystem, tree microhabitats, wood decay, wound wood

SEE TOGETHER WITH

Function and Structure of Trees, Tree Assessment, Ecology and Biodiversity

ESSENCE OF THE TOPIC

The essence of this chapter is to highlight the significance of diagnostic features in tree assessment. Trees undergo structural changes throughout their growth, and these changes can impact the overall condition of the tree or specific parts of it. Human activities can also contribute to changes that affect the functioning of trees. Therefore, identifying and assessing these features allows us to select the appropriate tree management recommendations.

Diagnostic features are symptoms that can manifest in the tree itself, as well as in the tree's growing site. These features are identified, assessed, and evaluated during the tree assessment process because they provide essential information about the tree's physiological or mechanical condition and allow for future prognosis. While some features are easily recognisable and assessable, others are more complex in nature and require interpretation. It is important to note that the presence of a diagnostic feature does not automatically imply a specific action. Other factors, such as risk management strategies, tree benefits, and site specifics, should also be considered.

Diagnostic features can originate from biotic or abiotic factors. Since trees have the ability to adapt to changing conditions and damage, the assessment considers not only the diagnostic trait itself but also the tree's reaction to weakening and its capacity for compensatory growth. In essence, the key principle is to observe and interpret the diagnostic features that influence the functioning of a tree, which assists in assessing trees for different purposes. It's also helpful to use a set of diagnostic features to assess and not rely on one feature (see Chapter 1.2.1 Soil Science: Visual Soil Assessment). Note that although the purpose is primarily that of safety, ecosystem service issues such as cooling or biodiversity (dendro micro-habitats) may also be considered.

A. Diagnostic Features

A.1. Definition

The term "diagnostic feature" has emerged in the field of tree assessment to distinguish it from the concept of wood defects commonly used in forestry. This distinction is important because many wood defects are natural characteristics of trees that primarily affect the suitability of the wood for economic use but may not significantly impact the overall condition or stability of the tree or its parts. It is crucial to avoid attributing a negative connotation to these natural tree characteristics by labelling them as defects.

When assessing trees, it is essential to not only identify the diagnostic features present but also observe how the tree reacts to the symptom. Understanding these compensatory growth mechanisms and observing the reactions of trees to weaknesses provides valuable insights during tree assessment. It allows for a comprehensive evaluation of the tree's adaptive capacity and compensatory responses to maintain stability and overall health.

In the following sections of this chapter, we will explore different types of diagnostic features and their significance. A thorough understanding of these features will enhance the ability of tree assessors to accurately evaluate the habitat, condition, and stability of trees, thereby contributing to effective tree management practices.

A.2. Compensatory Growth

When assessing diagnostic features in trees, one important aspect to consider is compensatory growth. Compensatory growth refers to the tree's ability to respond and adapt to weakening or damage by initiating additional growth in specific areas. By observing and evaluating compensatory growth, tree assessors can gain valuable insights into the tree's adaptive capacity and its ability to recover from damage. Compensatory growth can manifest in various forms, depending on the type and severity of the diagnostic feature. Some common examples include the following:

- Branch thickening: When a branch becomes weakened or damaged, the tree may respond by thickening the tissues near the base of the branch. This extra growth provides additional strength and support to compensate for the compromised area.
- Reaction wood: In response to stress or leaning caused by factors such as wind or slope, trees can produce reaction wood.
- Adventitious Roots: When the primary root system is damaged or compromised, trees may develop adventitious roots. These roots emerge from locations such as the trunk or major branches and serve to supplement the function of the damaged roots.
- Compensatory crown growth: In cases where the crown of a tree has been partially or significantly removed, the tree may respond by producing new growth from the remaining branches or dormant buds. This compensatory crown growth helps to restore the tree's photosynthetic capacity and overall vitality.
- Bark and cambial layer regeneration: Following damage or wounds, trees can initiate the growth of new tissues and layers to cover and protect the affected areas. This regenerative process aids in maintaining physiological processes, such as conducting water.

During tree inspections, assessors should carefully evaluate the extent and effectiveness of compensatory growth in response to diagnostic features. This assessment involves examining the location, size, and vigour of the compensatory growth and comparing it to the importance of the feature. Additionally, the assessor should consider whether the compensatory growth is sustainable in the long term.

In cases where compensatory growth is observed, appropriate measures can be taken to further enhance the tree's recovery and mitigate the impact of the diagnostic feature. These measures may include pruning techniques to promote optimal branch distribution, tree support systems to alleviate stress on weakened areas, or soil management practices to improve root health and vigour.

By understanding and considering compensatory growth in the assessment of diagnostic features, tree assessors can make more informed decisions regarding tree management strategies and prioritise interventions that support the long-term health, stability, and vitality of trees.

A.3. Diagnostic Features and Dendro Micro-Habitats

Diagnostic features in trees serve multiple purposes, not only providing information about the condition and stability of the tree but also providing ecosystem services that include dendro microhabitats. These microhabitats play a vital role in supporting biodiversity within the tree ecosystem. Various features, such as cavities, hollows, cracks, and decayed wood provide unique habitats for a wide range of organisms, including insects, birds fungi, and microorganisms. These microhabitats offer shelter, nesting sites, foraging opportunities, and breeding grounds, all of which contribute to the overall biodiversity of the tree and its surrounding environment. Being able to understand and assess these diagnostic features is essential for effective tree management, as they help identify the ecological value of the tree and determine appropriate conservation measures. This concept of dendro micro-habitats is especially relevant for veteran trees, as shown in Figure 1.

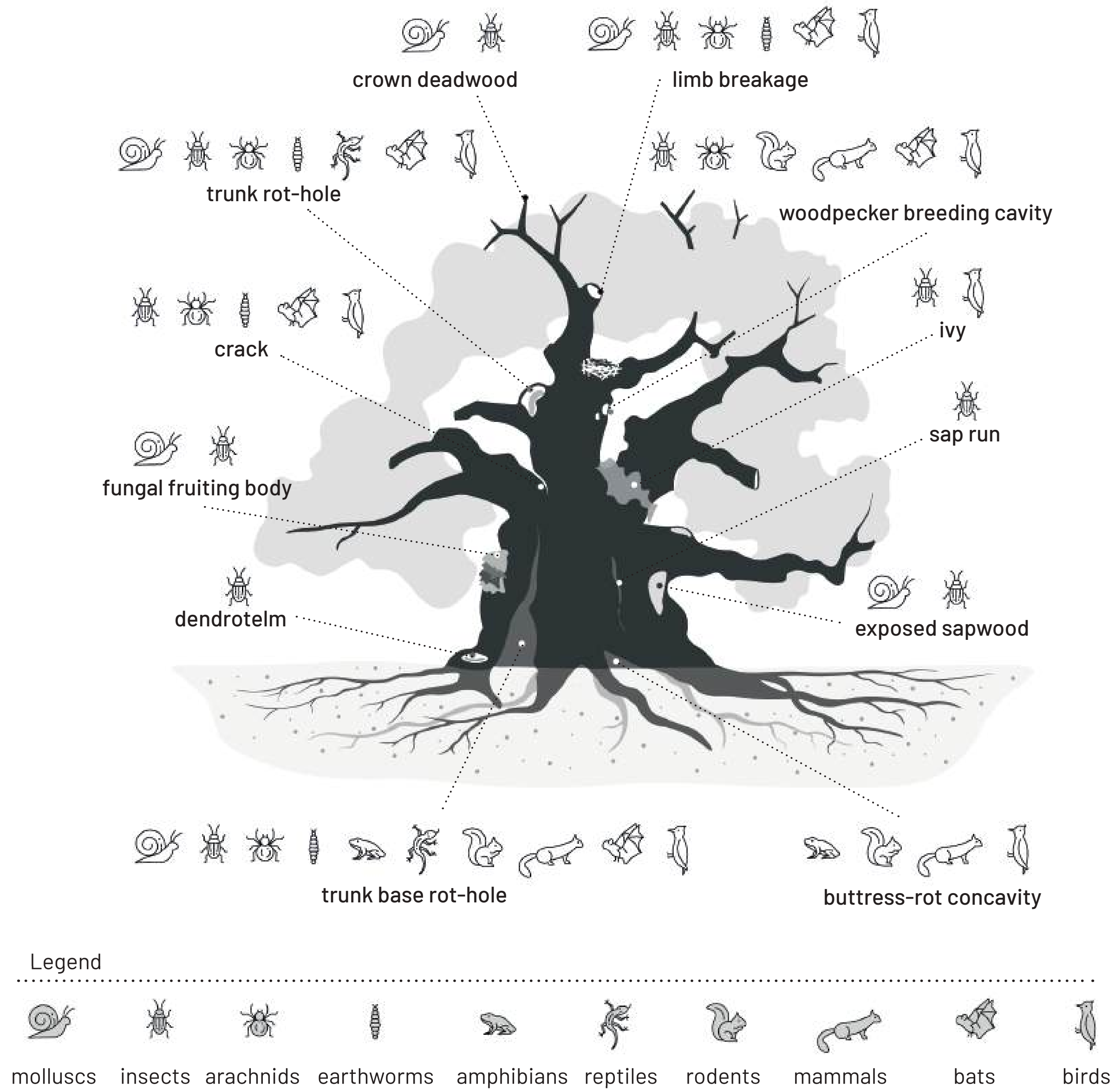


Figure 1(K. Witkoś-Gnach, 2022). A range of microhabitats typically associated with veteran trees. These include hollows, rot, cracks, sap runs, fungal fruiting bodies, exposed wood, and many others. These microhabitats are used by a range of species from bats and birds to insects and other invertebrates, mammals, fungi and many other plants and animals.

B. Assessment of Diagnostic Features

Diagnostic features found on trees vary widely, and the following list provides some common examples. It should be noted that this catalogue is not exhaustive, and many other characteristics and combinations may be observed on trees. However, the principles of assessment remain consistent across all features. When assessing diagnostic features, the key considerations include the following:

1. Influence on the tree: Determine whether a particular feature has an impact on the overall condition of the tree.
2. Importance of the feature: Assess the significance of the impact of the feature on the whole tree or its specific parts (for example, assessing if a feature affecting the crown surface reduces the cooling benefit it provides).
3. Tree reaction and compensatory growth: Evaluate how the tree reacts to the feature.
4. Need for specialised analysis: Determine if further specialised analysis is necessary to fully understand the importance of the feature.
5. Methods to reduce influence: Identify methods to mitigate the influence of the feature and recommend appropriate treatments. Always consider the importance of dendro microhabitats and adapt management recommendations to avoid losing them.

Depending on the level and type of assessment, it may be advisable to document all significant characteristics found on the tree along with a detailed description. Identifying and recording all significant diagnostic characteristics, however, can be time-consuming and inefficient. Additionally, the sheer number of parameters to be entered may make it impractical to effectively manage a large number of trees. To overcome this challenge, the use of parameter categories is highly recommended. Categorising parameters helps to group trees effectively, facilitates the selection of appropriate treatments, and helps to determine the urgency of action. This allows for better organisation and analysis of the collected data. To assess diagnostic features, the following scale can be used as a reference:

Scale for assessment of the importance of diagnostic features:

- 0 – None: The tree has resolved the issue, and there is no significant influence on the tree.
- 1 – Minor: The feature has no significant impact on stability, either in normal weather or extreme conditions. It does not significantly affect tree health.
- 2 – Moderate: The feature increases the likelihood of a tree or part of it falling during extreme weather conditions, but it is not expected to fall in normal weather. The feature weakens the physical condition of the tree, but its significance is limited to a small part, and the tree shows good compensatory growth and resilience.
- 3 – Serious: The characteristics pose an increased likelihood of a tree, or parts of it, falling even in normal weather conditions. The feature significantly weakens the overall condition of the tree or its significant parts. The tree's response to the weakening is weak to moderate.
- 4 – Critical: The process leading to the fall of a tree, or part of it, is initiated or expected to occur in the near future, even in windless weather conditions. The feature will cause the tree to die in the short term, and it is combined with the tree's failure to respond to weakening.

EXAMPLE OF ASSESSING THE IMPORTANCE OF A DIAGNOSTIC FEATURE

Assessing the significance of wood decay in the root system, like other diagnostic features, relies on various factors, including tree growth stage, vitality, habitat, location, surrounding conditions, and the presence of other diagnostic features. There is no one-size-fits-all rule for determining when action should be taken, so general guidelines are provided below.

For young or semi-mature trees, significant decay in the root system is uncommon, just as substantial dead branches in the crown are not expected. If any decay is present, young and vigorous trees often compensate for it efficiently.

In mature trees, minor decay in localised areas at the base of the trunk and between the root flares is typically expected at this growth stage. If wood decay affects a substantial portion of the tree's circumference, further specialist assessment is necessary to evaluate its significance. Advanced decay is characterised by highly decomposed wood along the entire or majority of the trunk base that offers little resistance when being probed. Other diagnostic features that indicate weakened tree stability and an increased risk of falling include the presence of perennial fruiting bodies of wood-decaying fungi.

When assessing veteran or ancient trees, decay in the root system should be anticipated. It's important to note that decayed or decomposed wood forms valuable habitat, which adds to the overall value of such trees.

C. Examples of Diagnostic Features

Examples of diagnostic features in different parts of the tree are as follows:

Tree Surroundings:

- Changes in ground level: Alterations in the elevation of the ground around the tree, which may affect its stability and root health. Ditches and groundworks: Disturbances to the soil caused by construction or excavation activities, potentially impacting root systems.
- Soil cracks: Visible cracks in the soil around the tree, indicating soil compaction or drying conditions, sometimes indicating excessive movement of the root system.
- Soil compaction: Compression of the soil, impairing its characteristics.
- Fungal fruiting bodies: Fungi present on or around the tree, indicating decay or potential health issues.
- Soil sealing: The covering or compaction of the soil surface, hindering water infiltration and root respiration.
- Changes in groundwater level: Fluctuations in the water table, affecting root health and soil moisture.
- Soil erosion: Loss of topsoil due to water or wind, potentially exposing tree roots.

Root System:

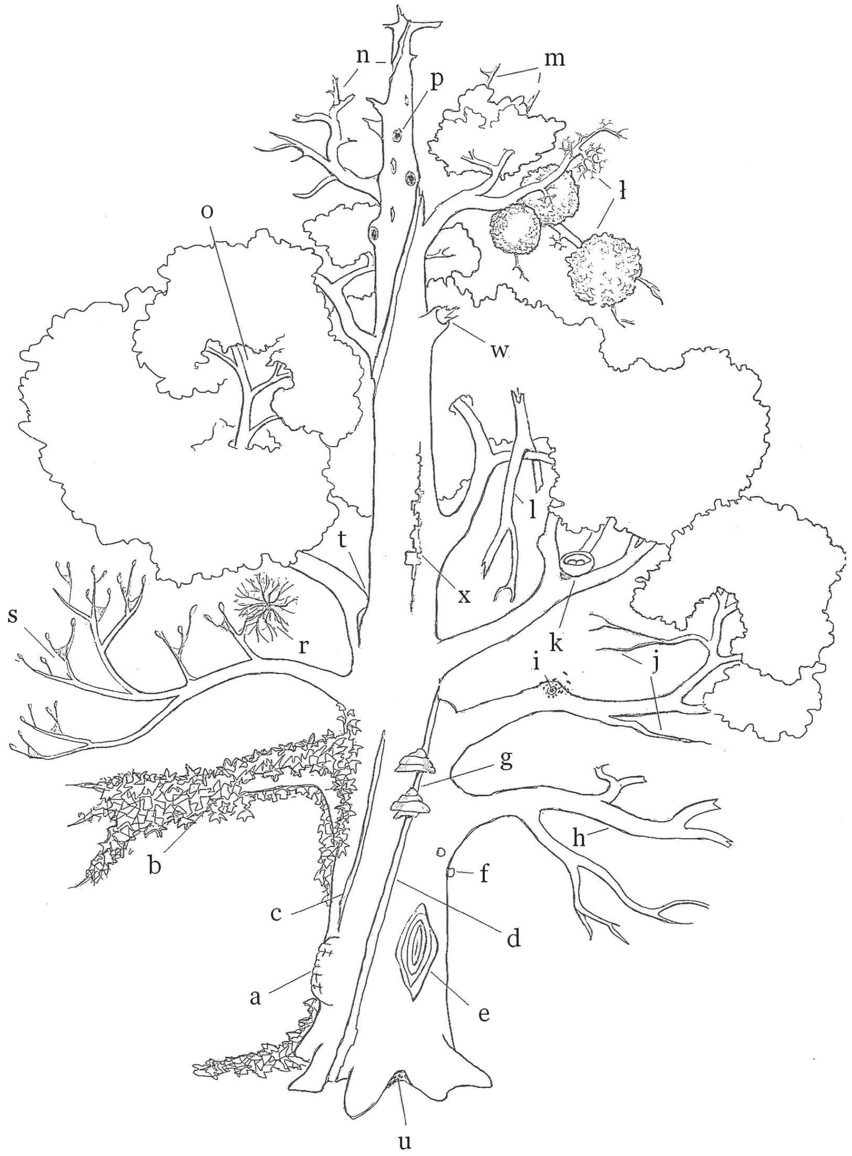
- Broken roots: Roots that have been damaged or severed, affecting stability and nutrient uptake.
- Fungal fruiting bodies: Visible fungi on roots, indicating wood decay.
- Wood decay: Internal decay of root wood, compromising structural stability.
- Adventitious roots: Additional roots growing from non-traditional locations, potentially compensating for damaged roots.
- Girdling roots: Roots that encircle the trunk or major roots.
- Compensation growth: New root growth or thickening in response to damage or stress.

Trunk:

- Bark damage: Injuries or wounds to the trunk's outer layer, potentially exposing underlying tissues.
- Cracks: Visible splits or fissures in the trunk, indicating structural weaknesses.
- Injuries: Physical damage to the trunk, such as cuts or wounds, affecting the tree's health and stability.
- Growth abnormalities: Irregular growth patterns, including excessive or stunted growth, indicating potential issues.
- Wounds: Open injuries or wounds on the trunk, increasing areas of dysfunction.
- Non-tree vegetation: Presence of plants or vines growing on the trunk.
- Decay: Internal decomposition of wood tissues.
- Cavities: Hollowed areas within the trunk, often caused by decay or previous damage.
- Compensatory growth: Increased growth or thickening of the trunk in response to stress or damage.
- Fungal fruiting bodies: Fungi present on the trunk, indicating internal decay.

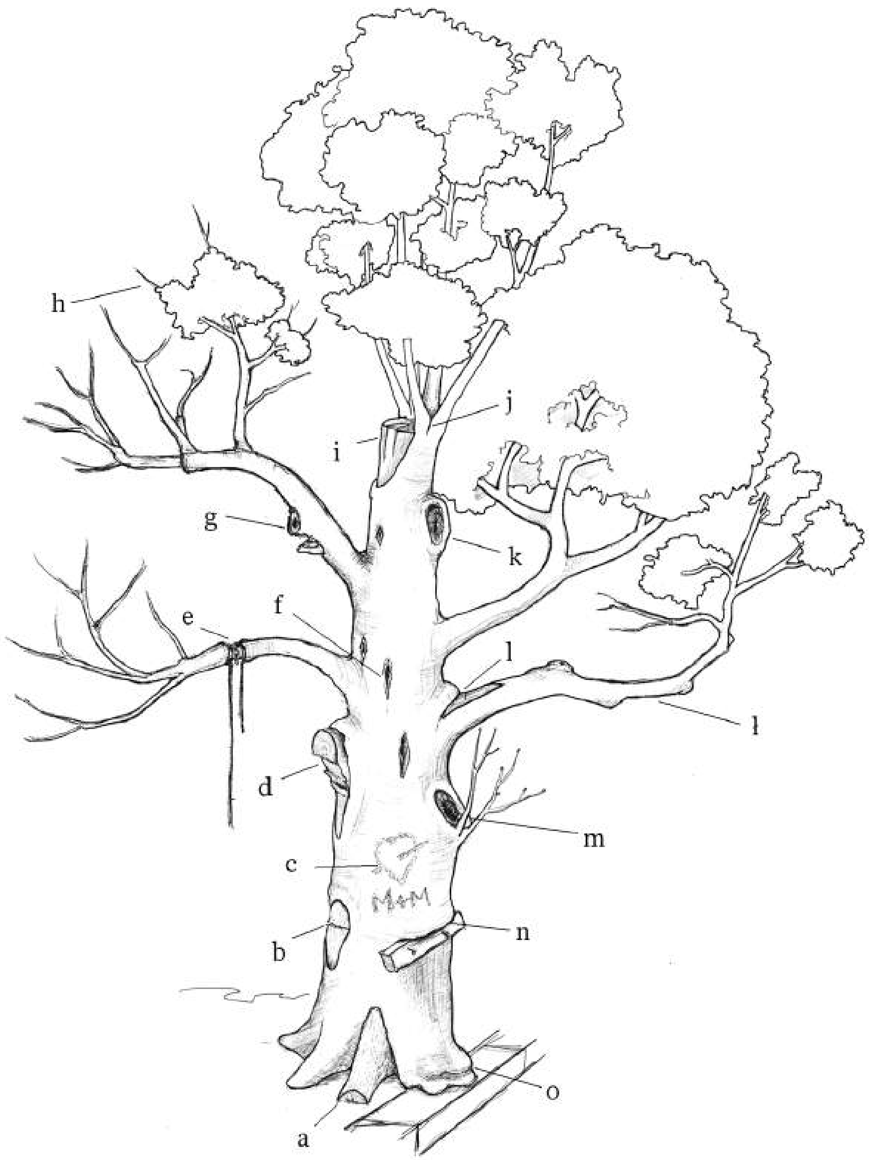
Crown:

- Cracks: Visible splits or fissures in the branches or main stem, indicating potential structural weaknesses.
- Lean: The degree of inclination or tilting of the crown, suggesting potential imbalances or wind load stress.
- Stem shoots: Abnormal growth of shoots directly from the main stem.
- Injuries: Physical damage or wounds on the branches or main stem, increasing areas of dysfunction.
- Growth abnormalities: Irregular patterns of growth within the crown, such as excessive or stunted growth.
- Weak forks: Poorly attached or weak branch unions, prone to splitting or failure.
- Non-tree vegetation: Growth of other plants or vines within the crown.
- Foliar disease: Diseases affecting the leaves, such as discolouration, spots, or abnormal defoliation.
- Cavities: Hollowed areas within branches, often caused by decay or previous damage.
- Reiterations: Secondary growth or branches, indicating changes in crown structure.
- Crown asymmetry: Imbalance or uneven distribution of foliage within the crown.
- Mechanical support systems: Installation of artificial supports or braces.



a – cankers and swellings
b – ivy
c – frost cracks
d – lightning strips (spiral shape)
e – bacterial canker
f – bacterial canker
g – fungal fruiting bodies; effect on stability depending on fungus species
h – dry branch
i – beehive; branches with habitat hollows should not be removed
k – bird nests; do not remove
l – hanging broken-off branch
ł – mistletoe
m – deadwood indicating problems with water transport or root damage
n – deadwood at the end of the branch indicating water transport problems
o – reiteration
p – hollows in dead wood
r – "black broom"
s – insects that feed on leaves
t – bifurcation crack
u – cavity at the base of trunk; important for saproxylic organisms
w – places where branches have broken off
x – sunburn

Figure 2 (J. Stolarczyk). Examples of diagnostic features of natural origin.



a – cut root and necrosis
b – necrosis at transverse cut causing impaired conduction
c – surface injury
d – damage from incorrect pruning
e – branch strangulation
f – damage from climbing spikes
g – incorrect pruning
h – deadwood indicating water conducting problems
i – stub from a cut limb
j – shoots from dormant buds grow on the stub
k – wound from the removal of a branch that is too thick; wood decomposition
l – crack as a result of branch weight
ł – excessive reduction of the branch "lion-tailing"; many pruning wounds and bad load distribution
m – decomposition after limb removal with regenerative shoots
n – reaction of the trunk to a damage
o – restricted development of the stem base; here in the form of a kerb

Figure 3 (J.Stolarczyk). Examples of diagnostic features of anthropogenic origin.

SELF-CHECK QUESTIONS

1. Explain what diagnostic features are. Give examples of three features that can be found on each of the following parts of a tree: the root system, trunk, and crown.
2. Explain the difference between wood defects and diagnostic features.
3. Name a fungi species causing brown rot.
4. Describe a weak fork.
5. What is the role of reaction wood in trees, and where can it be found?
6. Describe what might cause regenerative shoot growth in the tree crown.
7. What are reiterations?

TERMINOLOGY

axillary wood – a kind of reaction wood that forms in tree forks
adaptive growth – in tree biomechanics, it is the process whereby the rate of wood formation in the cambial zone, as well as wood quality, responds to gravity and other forces acting on the cambium
CODIT – the confinement of dysfunction within an anatomically discrete region of plant tissue, due to passive and/or active defences operating at the boundaries of the affected region
dieback – the death of part of a plant, usually starting from a distal point and often progressing proximally in stages
deadwood – dead, non-living branches and limbs in a tree crown
decay – process of wood degradation by fungi
included bark – bark embedded in a tree fork
pathogen – causal agent of disease; usually refers to microorganisms
weak fork – tree fork that has a degree of deteriorated stability
wound wood – differentiated tissues produced on woody plants as a response to wounding

For the Reference list, essential and additional readining please check 1.5.2.

1.5.2. Tree Assessment

Kamil Witkoś-Gnach

GENERAL OBJECTIVE

To perform tree assessments according to current industry standards. To also understand the relationship between tree assessment and risk management, recognise the role of assessment in identifying and mitigating potential risks associated with trees, and take into account the distinction between basic and advanced tree assessment.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- take existing landscape elements into assess tree stability and mechanical resistance to bending, fracture, and uprooting;
- assess crown wind-sail factors and their effect on tree stability;
- understand the difference between danger and risk in tree-related situations;
- identify mechanical and biological defects that indicate the likelihood of failure or instability of the tree (or parts of the tree) and classify the tree in a risk class;
- assess the stability and likelihood of failure of trees and classify the tree in a risk class;
- appraise the merits of hand, electronic, sonic, and mechanical decay detection devices;
- assess the biological health and structural strength of trees by visual control or the use of simple tools;
- assess the condition of trees and detect external signs of reduced condition;
- list the advanced diagnostic methods available to arborists;
- describe the visual tree assessment to be carried out (parameters, method, etc.); and
- indicate the life expectancy of the tree based on the current situation.

SEE TOGETHER WITH:

Function and Structure of Trees, Soil Science, Ecology and Biodiversity, Social Value of Trees, Diagnostic Features, Pruning, Tree Care and Remedial Measures

ESSENCE OF THE TOPIC

The essence of tree assessment lies in its fundamental role within the fields of arboriculture and urban forestry. It encompasses various approaches and scales, focusing primarily on evaluating the condition of individual trees.

KEY TERMS

Tree assessment principles: branch or tree failure, leaf colour, mechanical integrity, pests and diseases, physiological condition, shoot growth, structural stability, tree architecture, tree biology, tree development stage, tree life expectancy, tree stability, vitality

Tree assessment risk: advanced tree assessment, basic tree assessment, diagnostic features, diagnostic tools, tree assessment process, tree work recommendations

Risk management: acceptability of risk, benefit-risk analysis, likelihood of tree decline, risk analysis, risk of benefit loss, risk of harm

The objectives of tree assessment are twofold: ensuring public safety and maintaining trees. By assessing both the mechanical integrity and physiological condition of trees, potential conflicts can be identified, allowing for appropriate management strategies to be implemented. In other words, all tree work follows from a tree assessment. Note that it is crucial to use the data from the assessment to underpin an evidence-based decision. A tree assessment evaluates the results of previous maintenance, the current state of maintenance, and any necessary future maintenance to be performed. The evaluation of future maintenance plays a crucial role in urban planning, biodiversity conservation, and the provision of ecosystem services. It involves the systematic gathering of data through various tools and methods, enabling informed decision-making and promoting the well-being and resilience of trees. Overall, tree assessment is an essential practice that combines science, expertise, and practical application to maintain the health, safety, and sustainable structural management of trees and is essential in data-driven arboriculture and urban forestry.

A. Tree Assessment Principles

Tree assessment serves multiple purposes beyond the monitoring of safety and health. It plays a crucial role in urban planning, informing decisions regarding tree preservation, removal, or replacement. It also aids in the management of tree populations, allowing for strategic planning of maintenance activities. Before any tree work is conducted, it is crucial to assess the tree using appropriate tree assessment methods. Therefore, tree assessment should always be prioritised to ensure proper planning of tree work procedures. Although tree assessment mainly provides valuable data for the asset management of trees, it is also used for research and analysis. By systematically collecting information on tree condition and performance, researchers can study aspects of tree biology, ecology, and urban forestry. This data-driven approach enables evidence-based decision-making in tree management and contributes to the development of best practices in arboriculture.

When planning any tree assessment, several general factors need to be considered, such as when the assessment should best be carried out, the legal status of the tree, its growing conditions, site usage, etc. In tree assessment, two main factors are typically considered: mechanical integrity and physiological condition. Mechanical integrity refers to the structural stability of a tree, assessing its ability to withstand external forces such as wind, storms, or the weight of its own branches. This evaluation involves inspecting for signs and diagnostic features that could lead to branch or tree failure. The assessment of the tree's physiological condition focuses on its overall health and vitality. It involves observing factors such as leaf colour and density, shoot growth, the presence of pests or diseases, and signs of stress or decline. By assessing the tree's physiological condition, tree assessors can identify potential issues early on and implement appropriate management strategies to maintain or improve tree health.

B. Tree Assessment in the Context of Risk Management

B.1. General Considerations

It is important to note that tree risk assessment is a distinct systematic process used to identify, analyse, and evaluate tree-related risks. Although it can be part of a tree assessment, it is not synonymous with it. It can be understood by drawing parallels with traffic safety management systems. Just as traffic safety involves various policies, institutions, and stakeholders, tree risk management also requires the involvement of multiple parties, such as tree officers, arborists, tree assessors, and tree owners, all of whom will be subject to certain legal requirements that must be taken into account. Together, they form an integral part of tree risk management, with tree assessment being a significant component. Tree assessment is one part of risk management. We go deeper into the topic of risk management in Chapter 2.1 Work Site Safety and Risk Assessment When Carrying Out Tree Work.

In some countries, the terms 'tree assessment', 'tree risk assessment', or 'management' are used interchangeably, despite the use of the terms having specific legal implications. Therefore, it is crucial to recognise and differentiate between them because these terms are distinct processes, each with its own roles and stakeholders. Tree specialists primarily focus on evaluating the condition and integrity of trees, while risk management involves a broader effort that necessitates collaboration among stakeholders and compliance with relevant legislation. It is important to avoid conflating these domains, as tree specialists might lack expertise in risk management. Tree assessors, particularly when acting as contractors, may not have the full capabilities or authority to implement comprehensive tree risk management procedures. Nevertheless, they can offer expertise in tree assessment to guide tree owners in managing tree-related risks.

It is important to refrain from constantly linking trees with risks. It is also essential to acknowledge that the loss of a tree carries its own risks, as it entails forfeiting the benefits it provides. It is crucial to communicate this subject in a balanced manner, avoiding unnecessary terms such as "hazard" that may overly emphasise risks.

B.2. Risk Management Principles

In the context of risk analysis, tree assessment plays a vital role. It involves assessing the likelihood of tree decline, collapse, risk of harm, and risk of benefit loss. Various tools and approaches can be employed for risk management procedures, such as ISO 31000. The acceptability of risk is determined through a benefit-risk analysis, which evaluates the need for risk reduction.

The evaluation of the risk of benefit loss involves assessing the value of trees in terms of their role in providing ecosystem services, functioning as green infrastructure, and supporting microhabitats and associated organisms. The vulnerability of these benefits and the risk of tree loss are considered. It is important to account for both current values and potential future benefits that trees may provide.

The benefit-risk balance serves as a tool for tree management and decision-making. It combines environmental and conservation considerations with the need to manage public safety requirements. Striking a balance between tree benefits and risks to public safety is essential. It is important to justify interventions by demonstrating clear positive outcomes, as reducing risks may have negative effects on benefits. Non-intervention is also a valid management option, depending on the circumstances.

In summary, while tree assessment and tree risk management are distinct processes, they are interconnected in ensuring the safety and well-being of both trees and the public. By understanding their separate roles and involving relevant stakeholders, effective risk management strategies can be developed which consider the balance between tree benefits and risks to find a balance between the benefits the tree provides and the risks it poses in order to achieve sustainable management of the tree.

C. Context and Scope of Tree Assessment

C. 1. Scope

Tree assessment should be tailored to the specific management objectives and characteristics of the trees being assessed. In both rural and public urban areas, standard basic tree assessments can be carried out on most trees. Certain trees may require further investigation and advanced assessment methods. For example, ancient and veteran trees, and trees designated as nature monuments possess unique ecological and historical values that necessitate specialised considerations. Assessing these trees goes beyond typical tree inspection practices and requires a deeper understanding of their biodiversity, dendro-microhabitats, historical significance, or landscape history. These assessments should be conducted by experts who possess the knowledge and specific expertise required. However, it is important to clarify that an arborist's worksite inspection, drive-by survey, or tree inventory are not considered to be within the scope of tree assessment.

It is crucial to recognise the diverse objectives and characteristics of trees when conducting assessments. The management goals may range from ensuring public safety to monitoring tree health, preserving biodiversity, or preserving historical and cultural heritage. Each objective may require a different approach and assessment framework.

The ultimate outcome of the tree assessment is a report that guides tree care or management decisions. As a result of the tree assessment, for those trees that require attention either for public safety or for other treatments related to their current maintenance (tree care measures, advanced assessment, pruning, etc.), it is recommended to indicate the technology, the urgency of the recommendation, and the periodicity (in case the treatment should be performed periodically).

C.2. Types and Levels of Tree Assessments

By following the defined steps and approaches outlined, for example, in the European Tree Assessment Standard (ETAS), tree assessors can conduct thorough and standardised assessments to ensure they follow an established approach. The process is influenced by the input of the tree owner/manager and the complexity of the assessment subject. The following tree assessment levels are presented according to the ETAS:

- **Basic Tree Assessment** involves evaluating the physiological or mechanical condition of individual trees to identify diagnostic features, their value, and other issues requiring attention. This assessment is conducted from ground level and at various angles, utilising visual and sensory methods along with simple tools. The main objective is to determine the current state of the tree and identify factors that could impact its value, health, or safety.
- **Advanced Tree Assessment** serves as a follow-up stage to the initial assessment and employs more detailed and complex methods. This may include in-depth visual assessments, modelling, calculation methods, the use of devices, or specialist deployment.

Note the importance of an ETT in determining the need for further investigation, selecting suitable methods and equipment, and coordinating or conducting the necessary investigations. This means that an ETT should know when basic and/or advanced tree assessment is necessary. In Chapter 2.3 Tree Care and Remedial Measures we go deeper into this role of an ETT.

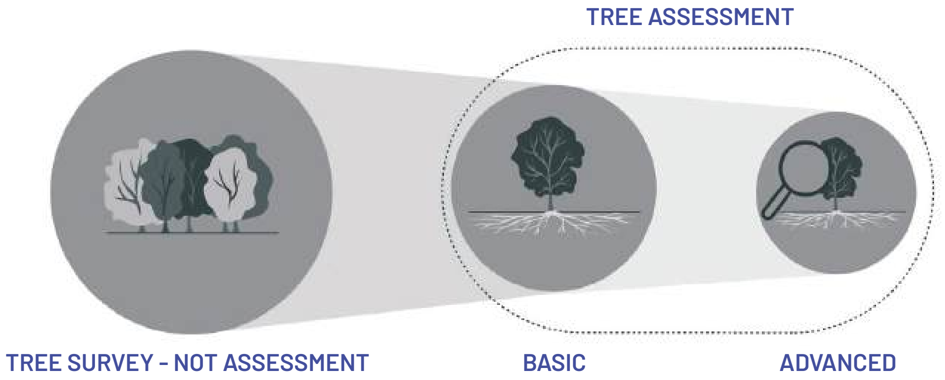


Figure 1 (K. Witkoś-Gnach, 2021). Different levels of tree assessment.

C.2.1. Basic Tree Assessment

The basic assessment involves conducting a comprehensive visual examination of the entire tree from ground level. The assessor walks around the tree, carefully observing and evaluating the surroundings, trunk base, trunk, limbs, branches, shoots, and leaves. Simple tools such as binoculars, probes, or mallets may be utilised to aid in the assessment process. However, it is important to note that the basic assessment has limitations in assessing internal tree parts, root systems, and upper crown regions.

Tree inspection should adhere to fundamental principles, considering factors such as the tree's development stage, life expectancy, physiological condition, and mechanical condition, as well as its benefits and value. It should also extend beyond the tree itself to include an evaluation of the site where the tree is located.

Based on the findings of the basic assessment, appropriate management methods can be selected and designed to ensure the ongoing health and safety of the tree and its surroundings. If the basic assessment does not provide sufficient information to evaluate identified features, a specialist assessment should be recommended. Simple tools can be used as part of the tree inspection process to acquire additional knowledge about the tree and its potential diagnostic features. The use of additional devices is not mandatory unless specified in the task requirements.

When assessing the intensity of use, it is essential to identify the objects within the tree's crown projection and the use zone, typically with a radius of 1.5 times the tree's height. However, it is important to consider that different countries may employ different zoning practices. The presence of people in the vicinity of the tree is of utmost importance, and identifying the types of objects surrounding the tree aids in resource planning, determining the intensity of tree care, and deciding on potential changes in land use.

C.2.2. Advanced Tree Assessment

A specialist tree assessment is an expert assessment that aims to perform a detailed analysis of the condition of the whole tree or its individual parts and their significance for the tree's surroundings and the tree itself. It is often implemented as a recommendation from the basic tree assessment. The choice of assessment method and diagnostic tools should be adapted to the scope of the assessment. On the basis of the expert assessment, it is possible to select and design appropriate procedures connected with tree maintenance while minimising the risk to the tree's surroundings.

TREE INSPECTION PROCESS

The tree inspection process includes the following tasks, as depicted in the flowchart below. Note that this flowchart differs from the one developed by EAS standard which is described in Chapter 2.3. Tree Care and Remedial Measures. The flowchart of EAS is a presentation of the whole tree assessment process, including risk analysis and assessment – so this one presents a much broader context. However, the flowchart shown below is just for the basic tree assessment. The two flowcharts don't contradict each other.

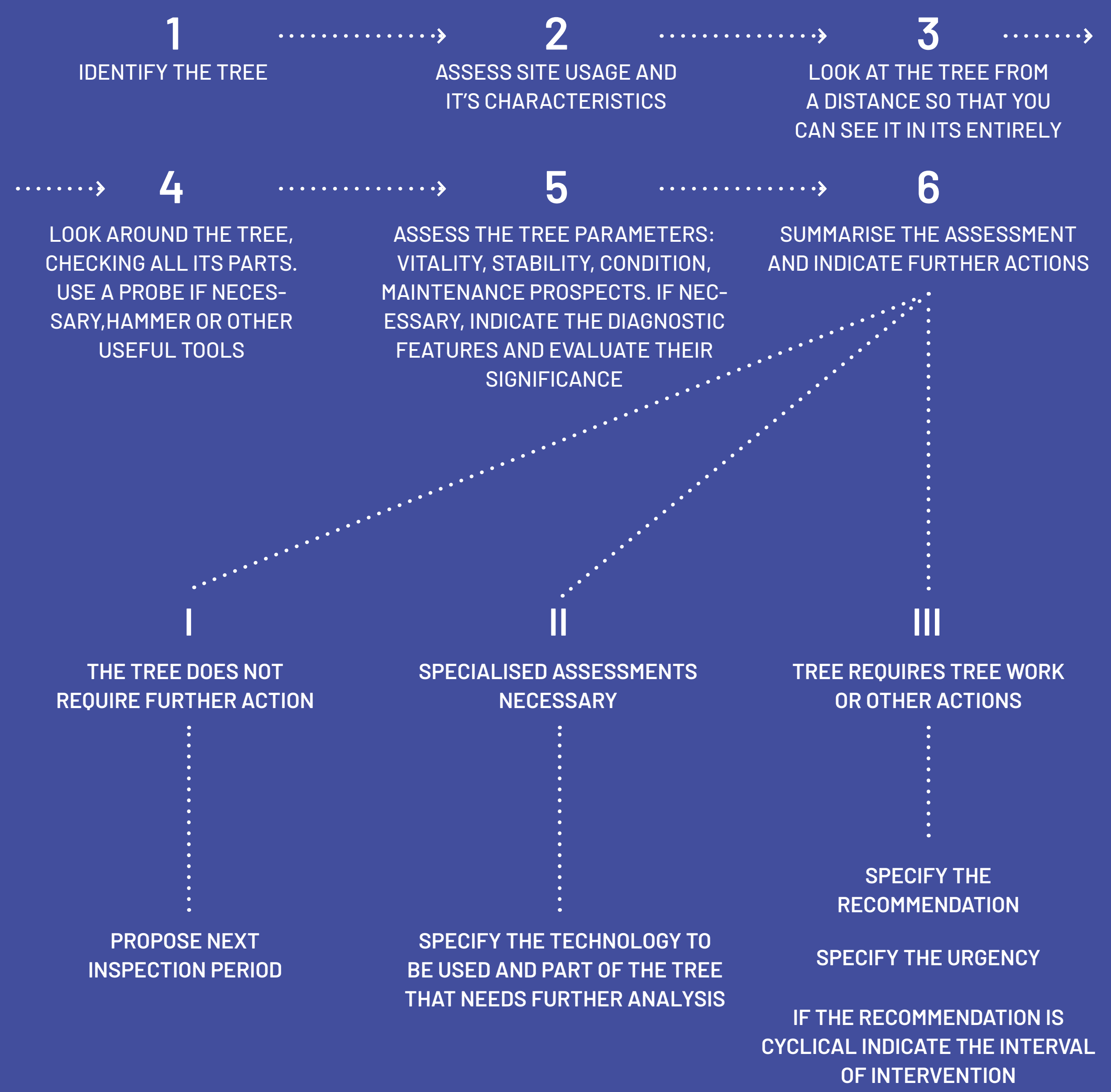


Figure 2 (K. Witkoś-Gnach). Assessing trees also includes evaluation of dendro micro-habitats.

It is worth pointing out that the specialist assessment can give more precise recommendations for tree work compared to the basic assessment. Based on the study, other recommendations to either improve the stability of the tree and its parts or to maintain the tree can be modified or adapted accordingly. Some cases may require the use of several methods and tools in order to obtain a comprehensive assessment. However, it is important to remember that specific diagnostic tools have their limitations and serve different assessment purposes. Therefore, the user needs to have a high level of knowledge and experience when using them and interpreting their results.

An advanced assessment will often use a variety of techniques to gather specific information on some or all of the following areas:

- aerial tree inspection that requires technical access equipment and appropriate tools;
- evaluation of mechanical protection systems (e.g., steel cables);
- detection of wood decay in the trunk or branches, examination of tree stability in the soil, and susceptibility of the trunk to fracture;
- the use of calculators to assess tree safety factors;
- evaluation of ancient and veteran trees;
- detailed analysis of habitat conditions;
- detailed assessment of soil conditions;
- specialist examination of associated organisms (including protected species);
- examination of the structure and development of the tree root system;
- biomechanical analysis and stability/safety assessment of the tree;
- evaluation of physiological parameters such as gas exchange and water potential;
- valuation of the tree; and
- analysis of the presence and importance of pests and diseases.

D. Tools for Tree Assessment

Simple tools can be very helpful in basic tree assessment, enabling tree assessors to gather accurate and detailed information about the condition and health of trees. The use of specific tools enhances the effectiveness and efficiency of the assessment process. Tree assessment involves the use of other equipment such as measuring tapes, callipers, cameras, or even aerial technologies like drones or aerial lifts. These tools provide additional capabilities for gathering accurate measurements, capturing visual documentation, and accessing difficult-to-reach areas of trees.

Here are some tools that are commonly used when carrying out a basic tree assessment:

Mallet: A mallet is a tool used to tap the trunk of a tree to assess its internal condition. By tapping different areas of the trunk, a trained assessor can listen for variations in sound and tone. These variations can indicate areas of decay or hollowing within the tree. The mallet test helps identify potential features that may compromise the structural integrity of the tree.

Metal Probe: A metal probe is a rigid rod with a handle that is used to examine the condition of the root base and major roots of a tree. The probe can be inserted into the soil around the root base to assess root health and detect any signs of decay or damage. By carefully probing the root zone, tree assessors can gather valuable information about the tree's root system.

Binoculars: Binoculars are essential for inspecting the upper portion of the tree crown, especially for tall or inaccessible trees. With binoculars, tree assessors can closely examine the branches, leaves, and overall canopy structure. This allows them to identify hollows, cavities, bird nests, cracks, weak bifurcations, and other factors that may indicate potential risks or structural issues.

Other technologies can be used in the scope of advanced tree assessment. Further descriptions and details of tools for advanced tree assessment are included in the European Tree Assessment Standard. Advanced tree assessment methods utilise advanced technology to gain more detailed insights. The following description includes the most commonly used methods.

Sonic Tomography: This method examines the wood structure of a trunk by comparing the flow time of a shock wave between sensors mounted on the trunk. It detects wood decay or the presence of cavities by analysing variations in wave flow time. In cases where results are uncertain, a resistance drill may be used to directly examine the wood structure and cross-check the tomography results.

Resistance Drills: Resistance drills assess wood density by slowly screwing a thin drill bit into the wood of a trunk or branch. The results are analysed to evaluate the real wall thickness and can be compared with tomograms for additional insights.

Static Pulling Test: This test evaluates both the resistance of the trunk to breaking and its stability in the soil. By applying a point load and measuring the response of the root ball and trunk, the test simulates the tree's behaviour under high wind loads. Calculations based on tree statics models help assess the safety factor and fracture strength of the trunk.

Dynamic Load Test: This test measures the reaction of the tree (root ball and/or trunk) under actual wind load. Using an anemometer placed near the tree, the force exerted by the wind is measured. The result is an assessment of the tree's strength and safety factor, which indicates its ability to withstand wind loads.

There are numerous manuals and guidelines for tree assessment that have been produced worldwide. These manuals, guidelines, and industry standards provide valuable resources for tree assessment, encompassing various approaches, levels of assessment, and risk management considerations.

Figure 3. Basic tree assessment tools.

E. Overview of Tree Assessment Approaches and Methods

One of the most recognisable is the series of publications by Claus Mattheck, who is the creator of the Visual Tree Assessment (VTA) method and author of the striking term "The Body Language of Trees" ("The Body Language of Trees" 2015). Another method for tree evaluation is the Statics Integrating Assessment (SIA) by Lothar Wessoly ("Manual of Tree Statics and Tree Inspection" 2016). The SIA method takes the height of the tree, the tree species, and the form of the tree into account. The Integrierte Baumkontrolle (IBA) method by Reinartz & Schlag is based on the assessment of the reaction of the tree to wood decay. The ARCHI method, which was developed by Drénou, is a French method that is based on tree architecture. It looks at the development of new growth in the tree to assess mainly the condition and vitality of the tree. Additionally, the International Society of Arboriculture (ISA) has published "Tree Risk Assessment," which presents a methodology with indicators to assess risk levels. Many countries have developed simplified versions of risk assessment based on the ISA methodology. ISA offers the Tree Risk Assessment Qualification (ISA TRAQ), obtained through a course and exam. The VALID Tree Risk Assessment, or Quantified Tree Risk Assessment (QTRA) by Ellison (2005) takes a slightly different approach. It estimates the statistical risk of accidents by considering the potential value of the damage caused. Comparing these values with the costs of preventive treatments helps in making rational intervention decisions.

In addition to these specific methods, there are industry standards to consider. In Germany, the widely recognised Baumkontrollrichtlinie (FLL 2020) is a tree inspection guideline developed by the Committee and the Working Group on "Tree Care/Control" of Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL), an association of green maintenance professions dedicated to creating and disseminating industry standards. Tree assessment standards have also been established in other countries, such as Poland, the Czech Republic, Slovakia, Australia, and many more.

SELF-CHECK QUESTIONS

1. What is the scope of a basic tree assessment?
2. What are the basic tools used for tree inspection?
3. What are diagnostic features, and why are they important in tree inspection?
4. What are the common methods used for specialised tree assessment?
5. List and describe the advanced diagnostic methods available to arborists.

TERMINOLOGY

basic tree assessment – an initial evaluation of the physiological or mechanical condition of individual trees, conducted from ground level using visual and sensory methods, simple tools, and basic data collection techniques
diagnostic features – injury, decay, damage, or other condition that influences the functioning of a tree in the context of its stability or health
mallet – a tool often made of rubber or sometimes wood used for sounding a tree
probe – a thin steel rod that is used for the inspection of cavities and roots below ground
physiological condition – a measure of the ability of a tree to carry out all life processes properly, including compensating for tree damage and other negative influences from the living and non-living environment
structural integrity – refers to the probability that a tree or part of it will fall; when assessing stability, factors such as diagnostic characteristics, the habitat, and environment of the tree, as well as defensive and compensatory reactions are considered
tree risk management – application of policies, procedures, and practices used to identify, evaluate, mitigate, monitor, and communicate tree risk
tree work recommendations – one or many alternatives that are promoted to achieve a desired outcome, based on professional judgement

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Book on typical damage symptoms and conspicuous features for common tree species
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UK Principles of Trees Hazard Assessment and Management by Lonsdale, D.
As the name says, the principles of tree hazard assessment
EN Tree inspection manual by Witkoś-Gnach, K. Retrieved from: http://tree-assessor.dobrekadry.pl/wp-content/uploads/2022/07/inspekcja_drzew_final_EN_lekki.pdf
Very good overview and detail for basic tree assessment.

ADDITIONAL READING

UK Applied Tree Biology by Hirons A., Thomas P.
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UK Common sense risk management of trees: Guidance on trees and public safety in the UK for owners, managers, and advisers, by National Tree Safety Group NTSG. (2011). Retrieved from: https://ntsgroup.org.uk/wp-content/uploads/2016/06/FCMS024.pdf
Risk assessment applied in the UK landscape but still relevant for other countries
DE Manual of Trees Statics and Tree Inspection by Wessolly, L., Erb, M.
Advanced information on tree statics and advanced inspections.

1.6.
TREE CARE AND REMEDIAL OPERATIONS

1.6.1. Pruning

Christian Nielsen & Wim Peeters

GENERAL OBJECTIVE

To have a general knowledge of pruning techniques and their impact on the tree. It is about understanding why and how to (or not to) prune a tree, as well as ensuring that pruning work corresponds to accepted standards.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- describe the pruning procedures according to the current National Standard Specifications and professional best practices, as well as describe the anticipated derogations;
- describe the appropriate pruning method to achieve the specific desired result, the best period for pruning for the chosen species, and the life stage of the tree.

SEE TOGETHER WITH

Function and Structure of Trees, Tree Development and Growth Stages, Site Selection, Amenity and Monetary Value of Trees, Tree Care and Remedial Measures

Note: This chapter covers neither the shaping of trees (e.g., topiary) nor pruning for fruit or flower production.

ESSENCE OF THE TOPIC

When we prune a tree, we always disturb its natural development and habitus. This means that the tree will react to pruning by developing a different crown with a different architecture from the original habitus.

KEY TERMS

Pruning objectives: habitus, desired image, life expectancy, natural image, safety, vision

Pruning strategy: dendro micro-habitats, limb attachments, risk

Pruning and development: chronological age, developing stages, final image, lifespan pruning objective, veteranisation

Impact of pruning: bifurcation, compartmentalisation, callus formation, European pruning standards, epicormic, photosynthesis, redirect crown increment, reiteration, stem forks, sleeping bud wound response, wound wood

Other techniques: coronet cut, fracture pruning, pollarding

Pruning group of trees: mono-species, thinning

This disturbance of the tree's habitus is, in most cases, permanent, and we can no longer talk about a natural tree. Furthermore, pruning has both a biomechanical and a physiological component. For these reasons, it is essential that pruning serves a specific purpose, which is why we should always ask two questions:
- Why do we need to prune the tree?
- What happens if we don't prune the tree?

There are reasons to prune trees. Trees that develop naturally can cause a conflict of interest with our environment, mostly for safety or aesthetic reasons. By pruning trees in urban areas, we can prevent them from being lost due to failure or damage. Furthermore, it is also easier to correct structural problems when the tree is still young. By eliminating structural problems in the young tree, we prevent future problems and minimise risks to their well-being. So, it is very often necessary to 'correct' the form of the tree whenever that is in our interest. We never prune trees for the tree itself. This applies to shaped trees, too, since creating an artificial form is a goal in itself. Conclusion: by pruning, we intervene in the natural process of the tree shaping its habitus. Moreover, the more our desired "final image" differs from the natural image, the more work and resources tend to become necessary to achieve the desired image. It follows that we have to deal with these consequences as the tree's development is changed permanently as a result. Before we start pruning, we must have a clear idea of any future or current problem and a clear idea about the tree's "final image" (final image = what the tree is going to look like when it reaches maturity).

A. Why Prune Trees?

Chapter 1.1.1 revealed that all trees have their own species-specific habitus, determined by genetics and the local environment. The ability of a tree's crown and roots to adjust their shape and size in response to their environment is called plasticity. We also saw that the crown structure is a medium or strategy to get as much light as possible to outcompete the neighbouring trees. Through evolution, surviving tree species were rewarded for highly competitive strength and efficient reproduction. Forest trees have to struggle for light and grow fast and straight. If, however, a tree of the same species is standing alone and has to withstand storms without being sheltered by neighbouring trees, it might form a low, broad-spreading crown that captures lots of light. Thus, many of our deciduous species have various natural tendencies towards making forks and multi-stemmed trees, steep branch angles, and branch junctions with included bark when growing in the open (Figure 1). These traits may have improved competition and horizontal crown spread during evolution and can be part of a tree's "natural image" when growing in the open, whereas trees that have to compete for light in a forest grow straighter upright. When we grow trees in the open but want to shape them like upright-growing forest trees, we interfere with their natural development. So, knowing the natural habitus of a tree and how it forms its structure helps to answer the question of what happens if we don't do anything.

As we saw in Chapter 1.2.2 Site Selection, it is necessary to establish a vision of the site when the trees have reached full maturity. This desired "final image" is the size and structure we want from the tree when fully developed. So, choosing the desired or final image in modern arboriculture is about guiding the tree during its lifetime by facilitating the tree's development. This means pruning as little as possible, or, to express it more clearly, the final image of the mature tree should be as close to the natural habitus as possible. On the other hand, unpruned trees more often experience breaks and partial destruction.

Furthermore, unpruned trees tend to develop more conflicts with human interests and infrastructure, which leads to later severe damage due to the pruning of very thick branches (Figure 2). This is where an ETT has great added value. It takes a lot of knowledge and experience to know the habitus, to assess the natural development at the specific site, to identify future problems, to figure out the final image of a tree, and to know what pruning action (or not) to apply.

B. Pruning Objectives

Pruning of trees may serve many different goals, which are typically reflected in the following commonly known terms (see Chapter 2.3 Tree Care and Remedial Measures and the European Tree Pruning Standard):

- Nursery pruning
- Establishment pruning
- Formative (or structural) pruning
- Ground clearing / crown lifting
- Crown reduction
- Crown thinning
- Utility thinning (reducing the crown to avoid airborne cables etc.)
- Sanitary pruning/cleaning (removal of dead and weak branches)
- Restoration pruning (after damage)
- Fraction pruning (creating semi-natural breaks of the branch for habitat development)
- Retrenchment pruning
- Veteran tree pruning
- Shaping/Pollarding pruning

These terms clearly indicate that many different goals and techniques may be involved in pruning trees.

Figure 1 (C.C.N. Nielsen). Evolution has taught trees to compete for space and adapt their form to the environment: a broad crown in the open, an upright stem in the woods.

Figure 2 (C.C.N. Nielsen). Pruning of a branch that exceeded the maximum acceptable branch diameter. This leads to stem rot and faster tree degeneration.

C. Impact of Pruning

C.1. Physiological Impact

C.1.1. At the Cut

The physiological process at the cut involves several stages:

1. The entrance of air into the system. When tissue is damaged, air will enter the system, bringing with it spores of fungi and bacteria. Air will have an influence on the cell wall, which will be oxidated, causing some resistance against the development of the spores or bacteria that enter. The endophytic fungi inside the tree will also react against the development of wood-decaying fungi.
2. Wound Response: The tree responds to wounding by initiating a series of physiological processes to protect itself and its transport system and close the wound.
3. Callus Formation: The tree will form callus or wound tissue around the wound to protect the surrounding tissue from further damage and initiate an occlusion of the wound. The callus tissue is made up of undifferentiated cells that can develop into various types of cells depending on the tree species and the type of pruning performed.
4. Compartmentalisation: The tree also begins to compartmentalise the wound by creating chemical/physical barriers/zones inside the wood to restrict pathogens from spreading in the tree's woody tissue. This process encapsulates the damaged tissue and prevents the spread of decay and disease, thus protecting the transport system. This process is energy consuming, which means that compartmentalisation depends on tree vitality and the time of pruning.
5. Wound wood: The wound is closed by wound wood (phase 4 according to the CODIT-principle). The undifferentiated callus cells differentiate into various tissues like cork cambium, bark cells, cambium, and xylem, all of which go to form the well-known wound wood we see emerge around the site of the wound. In addition, other living tissues from bark and wood may also contribute to callus development. The resulting wound wood is notably distinct from the tree's normal wood (e.g., having a higher resistance to decay).

Successful pruning results in effective closure of wounds ("occlusion"), which is wanted as fast as possible. See Chapter 1.1.1. Function and Structure of Trees to see how this physically works.

C.1.2. On Tree Development

Pruning changes the shape of the crown in different ways:

- **Tree shape:** The removed branch material leaves behind a crown with a different shape, which may be intended (e.g., by shaping trees) or not wanted (e.g., by late structural pruning).
- **Reiteration:** Trees commonly react with reiterative growth responses, through which new shoots are created. These new shoots may be of adventitious (from totipotent tissue) or epicormic origin (from sleeping buds). Vigorous trees may create 0.5-2-metre-long new shoots during the first growing season after pruning, and this also has a marked impact on crown shape. Thus, the extent of reiteration depends on the vigour of the tree. The pruning dose must, therefore, be adjusted to the expected reiteration, which will vary with the site, species, variety, age, and vigour of the tree.
- **Redirect crown increment:** Whenever an unwanted limb has too dominant a growth (e.g., in a stem bifurcation, the emergence of a very thick branch within a cluster of branches, or a steep upward growing lateral branch), the growth of such a limb can be almost eliminated by heavy reduction (or removal). In this way, the crown increment is redirected towards the desired structure of the crown. Figure 3 shows a young oak (*Quercus robur*), and how repeated reductions within a poorly structured crown move it in the direction of one single vertical shoot, which develops to form the future crown.
- **Production of epicormic shoots:** Particularly when target pruning large, vigorous branches, epicormic shoots must be expected on the stem below the pruning wound. Some species are particularly prone to developing epicormic shoots on the stem and sometimes even generate sprouts around the stem base if the pruning dose is too high. This is commonly seen with *Tilia* species. Thus, the pruning dose and pruning frequency must be adjusted to the expected growth response of the tree.
- **Photosynthesis:** A permanent reduction in the amount of foliage may reduce carbohydrate production and thus weaken the carbohydrate balance and vitality of the tree. However, where revitalisation of a tree's rhizosphere (root zone) is not possible, trees with a permanently poor water supply may benefit from having a reduced crown volume, as reduced foliage may enable longer periods with open stomata in the remaining foliage. All in all, such trees may benefit from having a smaller woody body to maintain.

C.2. Biomechanical Impact

The tree crown is always subjected to mechanical loads from wind and gravity. Rain and snow may increase both of these sources of load severely – snow in particular because it blocks the aerodynamic adaptability of the crown (Nielsen 1990). In areas with an excess probability of storms or heavy snow cover, the liability to rupture within the crown can be reduced by proactive reductions of the lever arm and the size of protruding branches and limbs with weak attachment. Similarly, trees with limited root spread or suspected poor anchorage are liable to being uprooted. In these cases, too, it may be beneficial to reduce the crown size and the storm lever arm to reduce the risk of storm damage (refer to Figure 4).

Figure 4 clearly shows that *any* reduction of crown size, either from the top or from the bottom, will reduce the integral of the wind load on the tree, which means that pruning reduces the loads exerted by wind and gravity on the crown and root system. This subject is widely misunderstood in arboricultural literature.

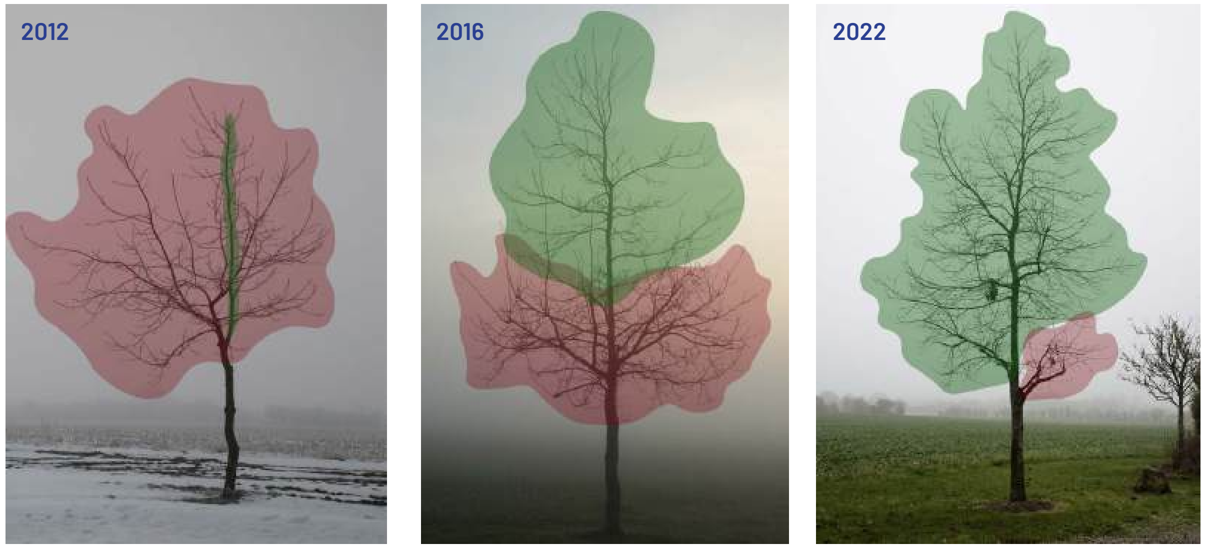

Figure 3 (C.C.N. Nielsen). Redirect crown increment through pruning: Through repeated pruning, the increment within this Quercus robur crown was redirected from the dominant, poorly structured crown in 2012 (red marking) towards a single vertical shoot (green marking) that came to develop into the shown crown in 2022. Please notice the reiteration (regrowth) after pruning within the broad spreading crown (red circle) in 2016 and 2022. Reductions of the "red crown" were carried out once a year during the 10 growing seasons. All photos were taken in late winter in the shown year.

Many trees also have structural weaknesses, like narrow stem bifurcations (forks) or ingrown bark at branch attachments. Breaks and the creation of large, unrepairable wounds may be prevented if the load on such weak attachments is reduced by pruning. With stem forks, this is commonly done by reducing the stem and crown size of one of the two bifurcations. The earlier, the better, as shown in Figure 3, where the crown structure can be changed by intensive pruning. An early neutralisation of fork problems eliminates the need for later stabilisation with braces or cables.

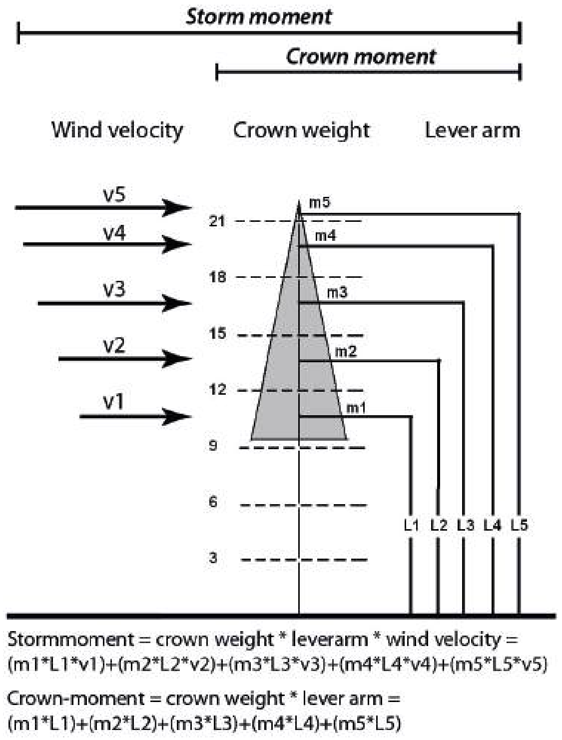

Figure 4. The storm load on a tree's anchorage system may be expressed by the "storm moment", which is the integral of wind speed by crown weight over tree height. As the wind profile is commonly not easy to predict, the crown moment can be used as a more applicable indicator of storm load on a tree. Adapted from Nielsen (1990).

D. Good Pruning Strategy Enhances Cost-efficiency in the Long Term

Strategically well-planned pruning is dedicated to reducing risks: The risk of premature removal of an otherwise valuable tree and the risk of man and material being damaged by falling limbs from unstable unions on the stem or crown. Thus, pruning should assist in ensuring a high socio-economic and environmental yield from investment in urban trees. Besides developing a formal urban tree strategy, the planning and implementation of a formative pruning programme is among the most important tasks of urban tree management, as it reduces later problems and expensive risk management. Trees with neglected formative pruning commonly develop three defects, although these defects vary in frequency among species and varieties:

- stem bifurcations (Slater 2015);
- week limb attachments due to ingrown bark or poor structure;
- branches with steep angles.

Formative pruning aims at reducing all three problems in due time; see also section C.1.2 above. Unfortunately, older urban trees in most European cities have been left to grow without proper early formative/structural pruning, which leaves us facing an elderly and very valuable urban tree population with many defects. In such cases, pruning should be devoted to solving structural problems with minimum impairment and loss of tree stability and safety. Trees not previously managed with professional formative pruning very often have very thick branches later removed with target pruning (i.e., at the stem), which exceed the maximum advisable branch diameter (see EAC 2021). This leads to a lack of wound closure by wound wood, permanently open pruning wounds, the spread of decay through these wounds into the trunk, and, finally, to the premature felling of trees (Figure 2). Quite a lot of trees in parks, church yards, and gardens are lost due to prior unprofessional pruning, which gives us a poor economic and environmental return on our tree investment. Of course, this is not the case with those trees grown or designated for creating dendro micro-habitats for nature protection purposes.

Pruning should seek to reduce management costs, not increase costs and the need for later treatment. Example 1: Proper formative pruning when trees are young pays us back many times over by prolonging the tree's life span and by reducing difficult pruning and interventions at a later stage of development. Example 2: Giving trees a heading cut of the stem not only introduces rot and decay to the stem, but it also enhances the costs of maintenance and pruning for the rest of the tree's life span. Pruning should contribute to an improved cost-benefit ratio, as also discussed in Chapter 1.3.1.

E. Pruning and Development Stages – The Pruning Matrix

A central and old discussion in arboriculture is the question, "How may thick branches be cut along the stem (e.g., removal cut)?" From a strictly biological point of view, the answer is fairly complicated. Arborists, however, need simple guidelines to work with. Such simple limits for "the critical upper branch diameter for a removal cut (target pruning)" are now given in the EAC pruning standard (TeST 2021). Branch diameter limits are 5 and 10 cm for poor and good compartmentalising tree species, respectively. Furthermore, for young trees, branches thicker than 1/3 of the stem diameter (just above the junction) should not be pruned. It is anticipated that pruning of branches thicker than these limits may result in permanently open wounds (Figure 2) and that pruning of branches below these limits should enable the tree to close the wounds and prevent decay from spreading (see Section B.1. in this chapter). Thus, these limits are set to maintain healthy trees without decay and hollow cavities. If the goal is different – like, for example, carrying out active veteranisation of trees for the accelerated production of habitats – then these limits may not be applicable.

However, these branch diameter limits should ideally be adjusted according to the tree's ability to compartmentalise and close the wound, and this ability is, above all, dependent on the vitality and increment of the tree. For this purpose, the EAC standard introduces a pruning matrix, where different guidelines are provided for different combinations of pruning objectives and developmental stages (Table 1). The essence of the matrix is that the pruning techniques are determined by the final image, the pruning objective, and the stage of development of the tree. So, once again, understanding the developing stages is crucial for sustainable arboriculture.

An ETT should consider this (slightly complicated) differentiated pruning matrix as a guideline and not as a mandatory rule. The point is that tree vitality is definitely not closely coupled with the age or maturation of trees; therefore, before pruning, the ETT should carefully consider scaling the critical pruning limits down (or up) depending on the actual vitality of trees.

Many street trees, young or old, have poor vitality due to poor rooting conditions. Whenever the stem increment is low (e.g., with average stem growth rings below 3 mm), there will be a deficit in carbohydrates for compartmentalisation and growth of wound wood around the pruning wound. Thus, the risk of a permanent open wound with progressing decay is enhanced when trees have poor vitality. In such cases, the critical branch diameter should be scaled down from the limits in the standard. Although there surely is no linear relationship between chronologic age and vitality, trees' vitality also tends to decrease when they move into maturity, or at the latest, when they enter the transition to the degradation phase. Thus, when dealing with elderly trees, particular focus should be put on the lifespan concept of trees (Dujesiefken et al 2016). Except for relatively small branches, removal cut/target pruning should ideally not be carried out on elder trees with poor increment. If a branch constitutes a problem in old trees with poor increment, only shorten or reduce the branch.

FINAL IMAGE	PRUNING OBJECTIVE	Young/ semi-mature tree with temporary crown	Young/ semi-mature tree with only permanent crown	Mature tree (only permanent crown)	Veteran tree	Neglected/ mismanaged/ mutilated tree
Semi-natural tree	A: Structural pruning	1/A	2/A	3/A	4	5
	B: Conflict resolution	-	2/B	3/B		
	C: Bio-mechanical stabilisation	-	-	3/B or 3/C		
Shaped tree	D: Shaping	1/D	2/D			6

Table 1. The tree pruning matrix from the European Tree Pruning Standard aims at suggesting different pruning regimes for different combinations of objectives and tree developmental stages. (From TeST, 2021)

F. Other Pruning Techniques

All the common and specialised pruning techniques are well described in the European Pruning Standard. For the pruning of ancient/veteran trees, specialised skills, extra safety measures, and a thorough understanding of ancient tree biology are required. It should not be carried out without certification or qualified supervision. For example, fracture pruning or coronet cutting involves more risky operations with the chainsaw, which makes it more difficult for the operator to have full control over the work he/she is carrying out. Other techniques, like retrenchment pruning, aim at lowering the crown and thus reducing the physical forces needed to pull up water to the photosynthesis apparatus.

Further, ETTs are expected to have some knowledge regarding the pollarding of trees. The critical branch diameter for pollarding is much smaller than for fully crowned trees, as stem and wound wood increment tend to be strongly reduced. Whereas in healthy trees, around 40% of the tree's sugar balance is used for branch, stem, and coarse root growth, resources for these tasks are probably less than 10% in pollarded trees. Never remove several branches in a bunch with one cut (Figure 5). Wounds caused by pollarding should be small enough to allow occlusion to take place before the next pollarding operation.

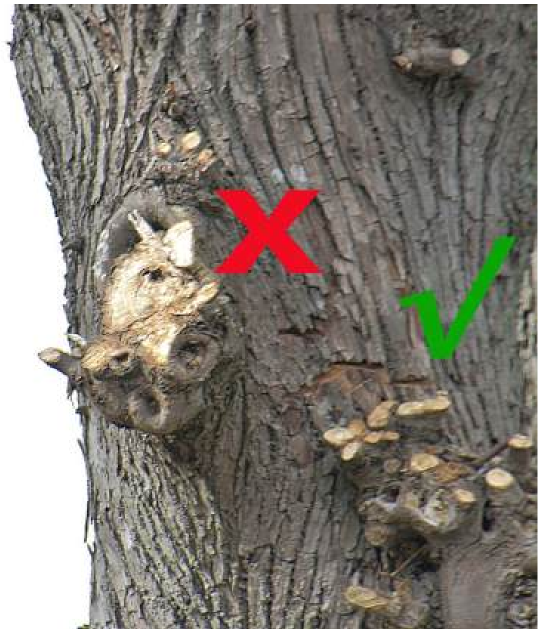

Figure 5 (C.C.N. Nielsen). Wounds after pollarding. Never remove many branches with one deep cut. Wounds must close/compartmentalise before the next pruning.

G. Pruning Group/Rows of Trees

Competition within closed groups of trees may be altered by thinning or pruning. In even-aged groups, competition may be reduced by crown reductions; whereas in uneven-aged groups, strong ground clearing (crown raising) may enhance light access and space for the younger generation in the understory. This kind of competition regulation commonly demands very frequent interventions and is, therefore, a much more expensive approach than thinning, although it is commonly coupled with selective thinning. The heterogeneous look of such uneven-aged structures may, however, be highly interesting.

When managing mono-species tree lines along avenues and roads, a harmonisation of the appearance is commonly desired. Thus, before pruning, a prior inspection and assessment must be carried out to define the desired tree height, crown width, and crown lifting (clearance) to aim for along the entire tree line.

It has, though, become more and more popular to preserve and prolong the life span of tree lines by replacing dead trees with individuals of other species that might be better adapted to the site. Mixtures of species can also be used to enhance habitat diversity and resilience to climatic extremes. Homogeneity of appearance may not be a goal in such cases, and pruning tactics must be defined individually for every tree row of this kind.

SELF-CHECK QUESTIONS

1. Explain why a reduction cut should take place close to branch ramification.
2. Explain why the topping of trees should be avoided (from an arboricultural point of view).
3. Can you give examples of three types of branches which constitute problems, and which should be addressed in formative pruning work?
4. Discuss the pros and cons of pruning before planting.
5. Explain the major considerations of formative pruning. Also, discuss the concepts of temporary and permanent crowns.
6. Discuss ground clearance and formative pruning on street trees versus trees on other sites.
7. Describe the consequences of a heading cut of the stem where the stem is thicker than 15 cm.
8. Give exact limits for upper branch diameter when pruning thick branches. How does this limit change when trees grow old? Should this limit be adapted to the vitality of trees?
9. Present some central factors and mechanisms that change radically when trees undergo the transition from the mature to the degradation phase.

PRACTICAL EXERCISES

1. Consider the young *Tilia cordata* tree (Figure 6). The tree is one of many similar trees surrounding a churchyard. The photo is typical for trees 12 years after establishment.

1. Describe the problems of the tree.
2. Describe the causes of the problems.
3. How could this situation have been prevented?
4. Discuss possible solutions for future management.

Figure 6 (C.C.N.Nielsen). The young Tilia cordata tree.

TERMINOLOGY

The European Tree Pruning Guide serves as the primary source of proper terminology. Further definitions are given below.

branch bark ridge – elevation of bark texture where stem and branch bark are pressing against each other during secondary growth
branch collar – thickening around the branch base (one should always prune outside the branch collar)
cleaning or sanitation pruning – removal of dead, broken, or weak branches in the crown
crown raising – removal of lower branches in the crown (commonly, to enable traffic below the crown); an issue resolved by formative pruning
crown reduction – reduction of the extent of the crown (e.g., for reduction of wind load)
crown thinning – removal of individual branches to reduce crown density without (primarily) reducing its extent
establishment- or transplantation-pruning – reducing/removing twigs and outer branches to balance the water balance of the transplanted tree (this task is still debated among professionals)
formative pruning – structural pruning to establish the desired stable crown architecture
flush cut – pruning a branch inside the branch collar (must be avoided)
ground clearance/clearance/crown raising – a branch-free height below the crown to be kept free for traffic
heading cut – removal of a tree limb on the middle of a stem or branch node (normally not recommended)

included bark – a branch junction to the stem by which no branch bark ridge is created in the crotch; instead, the bark of the stem and branch squeeze against each other, creating an unstable branch junction
maximum branch diameter to prune – the critical branch diameter above which spread of decay and lack of wound occlusion may be expected
natural bracing – when branches touch, intercling, or grow together within the crown (or with infrastructure)– may induce included bark
permanent crown – crown to stay on tree throughout the entire life of the tree
reduction cut – shortening of a branch close to a ramification
removal cut – removal of branch along the stem (= target cut)
temporary crown – the lower part of the crown to be removed during crown lifting and formative pruning
topping of trees – removing large parts of the crown from the top, cutting thick stem parts (normally not recommended)

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ESSENTIAL READING

EU European Tree Pruning Standard by TeST.
The reference work on pruning trees as it explains the pruning matrix.

USA An illustrated Guide to Pruning by Gilman
A good comprehensive book on pruning.

EU Trees – a Lifespan Approach by Dujesiefken D., Fay N., de Groot J.W., de Berker N.
Must read on how pruning is influenced by the developing stages.

EU European Tree Worker Handbook, EAC
Basic understanding of the tree morphology and anatomy.

USA A New Tree Biology by Shigo
The fundamentals of CODIT.

ADDITIONAL READING LIST

UK The Anatomy and Biomechanical Properties of Bifurcations in Hazel (*Corylus avellana L.*) by Slater
A PhD concerning the evaluation of forks.

1.6.2. Tree Revitalisation

Christian Nielsen

GENERAL OBJECTIVE

To have a general knowledge of how to improve the health, growth, and life expectancy of urban trees by reducing problems with soil and poor root vitality.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- be able to identify and describe normal growth and architecture, as well as diagnostic features indicating poor vitality;
- be able to identify the horizontal and vertical extensions of the root zone;
- be able to analyse the soil condition and the vertical distribution of roots across the soil profile;
- have knowledge about the requirements for good root growth;
- have knowledge about techniques to improve the growth media for trees;
- improve tree sites in accordance with technical regulations; and
- carry out operations such as soil decompaction, soil aeration, and soil replacement.

SEE TOGETHER WITH:

Tree Development and Growth Stages, Soil Science, Site Selection, Diagnostic Features (abiotic agents & biotic agents), Tree Assessment, Trees on Construction Sites, Tree Site Improvement and Remedial Measures

ESSENCE OF THE TOPIC

Tree revitalisation is the process of restoring the health and vitality of trees that have been damaged or weakened due to various factors, such as disease, pests, environmental stress, or improper care. One of the main causes of urban tree deterioration, however, is related to the soil, often the compression of the soil. Basically, tree revitalisation aims at improving the tree's water and carbohydrate balance, which stimulates the tree's regenerative and protective processes, thereby stimulating the increment and defence mechanisms of the tree. This essentially comes down to the improvement of the growth media. Therefore, the ETT should be able to assess the possibilities and limitations for improvement of the tree's growth media. As most tree condition problems are soil-related, it's essential to improve the soil.

KEY TERMS

Carbohydrate-balance: carbohydrate -budget, fine root turnover, root decay, sugar

Diagnosing: diagnostic features, life expectancy, root friendly, soil compaction, soil horizon, soil vitality, symptom controlling

Solution: air pressure, chemical imbalance, loosening the soil, natural process, radial trenching, vertical mulching

Monitoring: baseline data, monitoring goals

By improving, we mean getting as many of the natural processes of the soil back up and running as possible. It is rarely possible to get all three components of soil health (chemical, physical, and biological) back to optimal levels, but the root environment will at least be improved by revitalisation work. So, our goals are to improve soil processes that improve soil health and encourage high longevity for roots, which will, in turn, sustain tree vitality.

It is essential to know that revitalisation is a process. In Chapter 2.4 Tree Site Improvement and Remedial Measures, we explain in more detail the process of tree revitalisation in practice with a detailed flow chart; however, for this chapter, the following steps are a good starting point:

- Diagnosing a tree's decline
- Choosing the right solution
- Monitoring

The Carbohydrate Balance

Revitalisation work basically aims at improving the carbohydrate balance and thus the increment and defence mechanisms of the tree. An improved carbohydrate balance will improve increment in general, enhance twig and leaf mass, improve leaf colour, enhance root regeneration, and, above all, improve the maintenance of barriers for decay within the living woody body. Ancient trees always have more-or-less hidden wounds in their roots, stem, and crown, where the woody body degenerates and dies back. But even without decay, ancient trees will have problems supplying the whole crown with enough water. As the stem becomes bigger, the tree is no longer able to provide sufficient growth for its complete structure. A central purpose of revitalisation work is to slow down the spread of decay and degeneration. Or, to put it in the terms of urban forest managers, to enhance the remaining life span of the tree by several decades. Alternatively, we can draw an analogy with human medicine: It is not about fixing a broken leg; it is about improving the patient's immune system and general fitness so that he or she will recover from the broken leg faster.

The carbohydrate balance is an accounting of the input and output of carbohydrates ("sugar"). The input of sugar from photosynthesis, and the output of sugar from growth and maintenance respiration. The balance is improved either by enhancing photosynthetic productivity or by reducing inefficient sugar consumption. The production (input) of sugar in elder or stressed trees is commonly limited by a poor water supply to the crown (causing prolonged closure of stomata), although the shaded leaves lower in the crown can continue to carry out photosynthesis. This, again, is most commonly caused by poor root conditions. Therefore, an improvement in the growth media is often very effective in enhancing root distribution, root longevity, photosynthesis, and sugar reserves.

Poor root conditions also tend to speed up the 'fine root turnover'. Fine roots have a life span of 6-12 months on average (some live many years, others live only a few weeks or days), meaning that the fine root population tends to be replaced at least once a year in a healthy tree with a good soil environment. It is anticipated that the turnover of fine roots is many times enhanced in urban trees with poor growth conditions.

In normal, healthy deciduous forest trees with a "normal" viable carbohydrate balance, the sugar produced is consumed by the following sinks (a sink is a carbohydrate-consumer within the tree):

- +/- 30% is used for the development of new leaves (in spring and summer)
- +/- 30% is used for the current renewal of fine roots (fine root turnover all year around)
- +/- 30% is used in branches, stem, and woody roots for increment, wound protection, and repair of rot barriers.
- +/- 10% is used for mycorrhizal fungi and other soil organisms.

This carbohydrate budget is a rough average covering one year – a dynamic equilibrium (with inputs and outputs) of carbohydrates stored and used in various places at various times of the year. In urban trees with poor growth media, fine root turnover is likely to consume more than 60% of the total carbohydrate budget, which reduces the resources for growth and maintenance.

B. Step 1 – Diagnosing a Tree's Decline

B.1. Finding the Cause(s)

Tree revitalisation specifically aims to improve the tree's fundamental life processes, with a focus on a longer-term increase in the remaining life expectancy of the tree. The focus lies in finding the cause or multiple causes of the tree's deteriorating health and not on controlling the symptom (diagnostic features). Of course, in practice, both are dealt with at the same time. The purpose of the investigation is to identify the most critical factors and mechanisms that limit the carbohydrate budget. These may either be flaws in carbohydrate production (photosynthesis) or mechanisms that heavily consume carbohydrates.

When searching for the cause(s) of deterioration (Chapters 1.5.1. Diagnostic Features and 1.5.2. Tree Assessment) we must carefully look at how the tree is reacting to the stress it is suffering from. By reading or assessing the state of the diagnostic features, an ETT is able to deduce the overall or partial condition of the tree. However, the diagnostic features, which are, in essence, symptoms of natural processes that occur above and below ground, are not the cause. An ETT should go deeper to find the source(s) of the problem, which mostly lie in these natural processes. As we saw in Chapters 1.2.1. Soil Science and 1.1.2. Tree Development and Growth Stages, it all comes down to being able to assess the natural processes of the tree (above and below the ground).

Tree revitalisation is a biologically complicated matter and may be at the edge of the competencies of many ETTs. A correct diagnosis is a particularly complex matter that demands extensive knowledge and experience. Some ETTs may develop specialised skills within the subject, but all ETTs should be aware of the possibilities this provides, as well as the techniques used within it. Support from specialists in urban soil management and tree biology will often be needed.

B.2. The Most Common Cause: Soil Problems

In essence, we want to make non-root-friendly soil into root-friendly soil. The diagnosis clarifies whether this is possible and how to achieve a root-friendly soil environment by assessing the different soil horizons. In urban soils, these horizons can be lacking or reduced to just one. Ideally, we want good conditions within all three components of soil vitality (physical, chemical, and biological) in the root-friendly horizons. In real life, however, we are often restricted by the site at hand. In particular, the biological component may be difficult to restore as the necessary ecosystem interactions (decomposition of leaves, interactions with low flora, migration of soil fauna, etc.) are absent. It is not always easy to introduce these interactions in a built-up environment. But wherever we can remove paved surfaces and restore a more natural system, we should. Success in the application of mycorrhiza inoculum varies a lot, partly because of the many unknown interactions of fungi with climate and soil components. Therefore, it is essential to add mycorrhizal fungi that are appropriate for the tree species and are of local origin. Commercially available inocula might not contain the right fungi, and their origin may be unknown. So, the fungal species in the inoculum may not be appropriate for the tree species or environment.

URBAN SOIL

Very many urban trees do not grow; they seem to remain static in size and shape and then gradually degenerate. The reasons very often relate to problems below ground. Although it is often due to limited root space (Urban 2008), it is very often a consequence of poor soil conditions and poor root health as well. Although suburban areas might still have some authentic, natural, and undisturbed soils, most soil in European cities is not natural but instead consists mainly of fill materials. Old historic cities may have several metres of old building materials, debris, waste, and random soil materials placed above the original historical soil surface. Quite often, various qualities of "mull" soils (topsoil from forests or agricultural land with organic material) have been used as fill material with the intention of improving growth conditions, often with poor results due to poor layering or compaction. Organic material needs a good gas exchange in the soil to have a positive effect on growth conditions. Urban soils are very often compressed with poor gas exchange (oxygen down, carbon dioxide up). Thus, 'good mull' in deep horizons often does not do any good; in fact, quite often the opposite is the case. A high content of organic matter below 30 cm often induces fermentation or anaerobic respiration, through which phytotoxic substances are produced. Many urban soils contain old building materials like iron, broken glass, brick, concrete, and mortar. Although brick material and coarse sand might be beneficial in improving stable structures, aeration, and drainage, bricks are commonly associated with mortar and cement, which provide the soil with an unfavourably high pH value ($pH > 8$), which induces a deficiency of manganese, iron, and phosphorous. Urban soils commonly lack or have poor biological activity in the form of natural soil flora and fauna. Thus, normal soil food webs and carbon cycling should not be expected in urban soils (though they might be stimulated). Relevant mycorrhizal fungi are not to be expected either. However, in our experience, the most frequent problem in urban soils is the compression of the soil, leading to poor gas exchange and waterlogging. Other problems related to water include a lack of available water and inadequate natural drainage, which can cause anoxia (an anaerobic condition). Compression often induces secondary problems with water, such as surface runoff and poor drainage).

Often, we must be satisfied with an improvement in the physical components of soil ecology (porosity, drainage, gas exchange), as improvements in the chemical components of soils are often somewhat more complicated. A very low pH is the easiest chemical problem to deal with. Laboratory analysis may reveal nutrient imbalances, which may also be counteracted by targeted fertilisation. However, as soil compaction and poor gas exchange in deeper soil layers are the most common problems in urban soils, large improvements will often only be possible by improving gas exchange in these deep soil layers (O_2 down, CO_2, and poisonous gases up). Furthermore, a high availability of oxygen is also likely to have a beneficial spinoff on the chemical and biological components of soils.

The main task of soil diagnosis is to clarify whether a soil horizon is "root friendly" or "root hostile" by using soil profile assessments. It should also reveal the reasons for the condition of the soil as well as analyse the effectiveness of any measures taken. To do this, it is important to carry out the soil profile analysis at a proper distance from a larger tree on the site (3-8 metres from the trunk), so that the vertical distribution of roots can guide you in the interpretation of the "root friendliness" of the different horizons.

Step 2 - Choosing the Right Solution

Once the cause of the tree's decline has been identified, steps can be taken to provide the tree with the proper care it needs to recover. As already stated, this is mostly a soil problem, and in Chapter 1.2.1. Soil Science, we explain the natural soil processes that are the foundations of soil health. As previously discussed, a system consisting of physical, chemical, and biological components is required to maintain soil health for trees. Below, we describe what happens if these natural processes fail by showing the common problems in urban soil. The focus here is to recognise these problems and know what type of natural process(es) they influence. Practical technical solutions are explained in Chapter 2.4.

- The anthropogenic influence on urban soils: Very often, the soil is made up of artificial "fill materials" of a more-or-less beneficial kind. However, the layering of the fill materials is often not suitable.
- Poor gas exchange in the soil: low or abundant levels of O_2 and accumulation of CO_2 in the subsoil. Gas exchange and drainage can be evaluated by several parameters: A) odour/smell; B) colour (a blue-grey colour is a sign of reduced iron, whereas a red or yellow colour is a sign of oxidised iron); C) the condition of roots (absence of roots where roots should otherwise be present); D) the state of compression or cementation of the soil; and E) the presence of earthworms (their number should be evaluated conservatively as they may eat their way through compressed soil, but they create good macropores). If poor gas exchange is the only problem in the soil, then it is commonly easy to solve.
- Compression of the soil (commonly leading to poor gas exchange, anoxia, poor natural drainage, and a lack of deep roots or roots characterised by a clustered presence of finer roots): Soil compaction can be measured in several ways, as discussed in Chapter 1.2.1. "Loosening" the soil with air pressure has become increasingly popular, although, despite frequent positive effects in the short term, we do not really know very much about the intensity and vertical distribution of new macropores after the loosening. Certainly, the soil is not loosened bulk-wise; only scattered macropores and/or cracks are created. Moreover, in soils with a high clay content, simultaneous injection of a stable substrate into the macropores is crucial, as, otherwise, the pores risk being clogged by mud after rainfall. Alternatives for loosening soils are radial trenching, vertical mulching, and soil replacement.

- Lack or excess of humus: Soil fill often consists of pure mineral materials without organic material. This can be remedied by adding compost or sphagnum IF (AND ONLY IF) the enriched soil layer has access to oxygen. Excess humus in soil fill is a common problem in deeper soil layers because gas exchange is limited. This issue of excess humus may, therefore, be lessened by improving the gas exchange in the soil.
- The removal of organic matter over many years: Very often, this is solved by adding a mulch layer under the trees; however, adding mulch after years of having removed all the leaves can seriously disturb the fungal ecosystem, such as mycorrhiza. The point is that mycorrhizal fungi protect tree roots against parasitic fungi. Mycorrhizal fungi can benefit from nitrogen-poor circumstances, but not from a thick layer of mulch.
- Unfortunate layering: If humus-rich layers are buried under layers of gravel or sand, these layers may be remixed with the use of a digger. Compression may also be reduced efficiently through "soil profile rebuilding".
- Lack or excess of water: The soil column may be completely dry due to a slope in the terrain and/or compressed topsoil. Alternatively, the soil might be waterlogged due to poor drainage in the subsoil. Both problems may be solved by proper remedial action.
- Chemical imbalances or pollution: It is common to have a pH above 8 in urban soils. Lowering the pH with sulphur is possible, but it demands a thorough analysis in the soil lab to determine the amount of sulphur needed. Reducing the pH too fast can alter or destroy the soil food web. Also, it may take time for the soil to reach a new balance in the acid/Ca balance. For safety reasons, amendment with sulphur should only be carried out spot- or trench-wise so that roots can find soil spaces with different pH values. Adding organic material (sphagnum) to the topsoil will also mitigate a high pH.

An example is shown in Figure 1.

Figure 1 (C.C.N. Nielsen). Soil analysis: As a minimum, a soil profile must be analysed before initiating any soil improvements. This profile shows three layers of soil fill. Large roots are only present in the upper 15 cm layer. Horizons 2 and 3 are lightly compressed. Spread clusters of fine roots are found in all three horizons. The deepest and 3rd horizon has a high content of organic matter but also has a blue-grey colour. This colour indicates Fe+2 – the reduced (and phytotoxic) form of iron. This indicates a lack of oxygen. Initiatives to improve the gas exchange in deep layers might improve the "root friendliness" of this layer.

SCREWDRIVER TEST

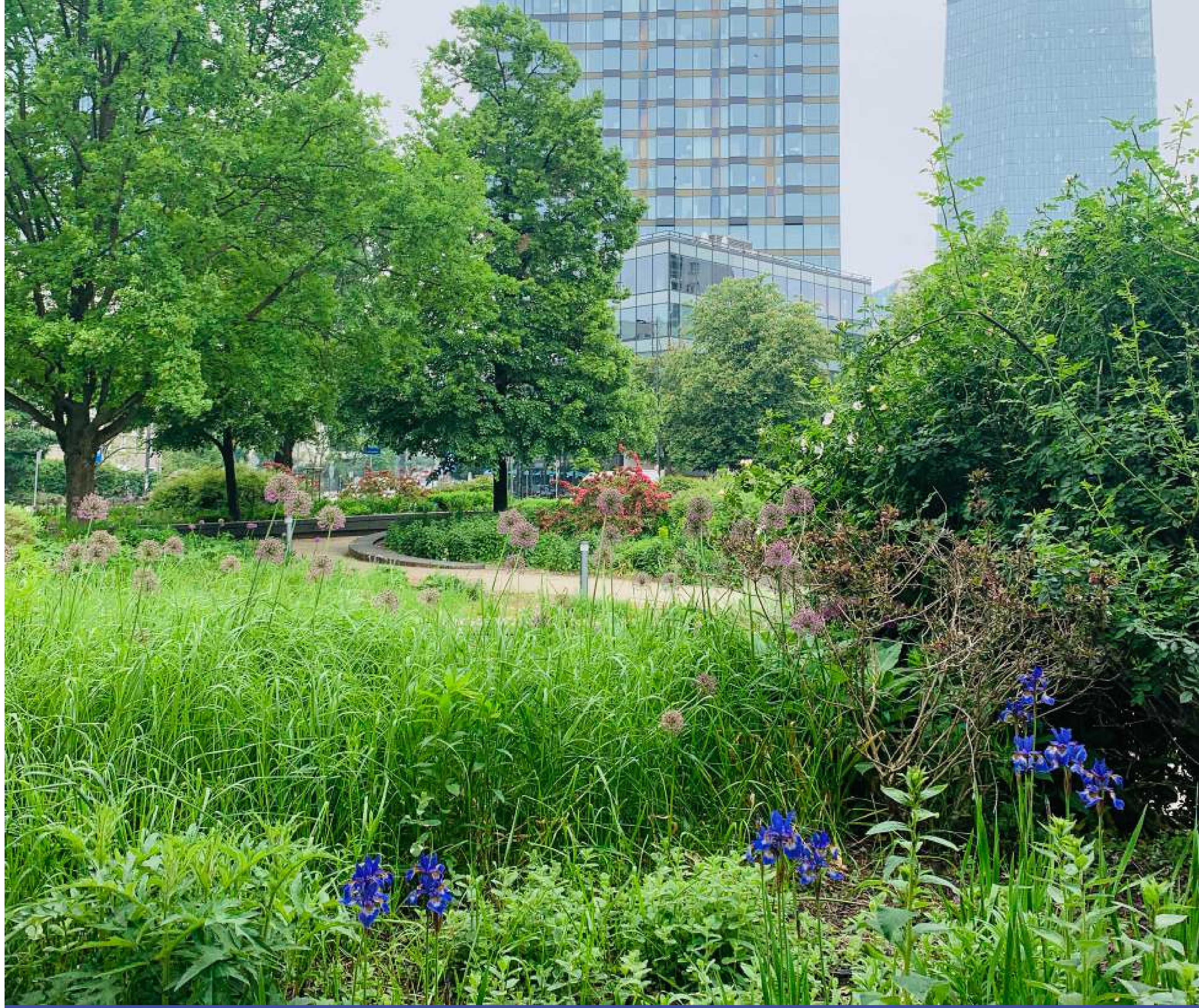
The "screwdriver test" is the simplest and quickest method for assessing soil compaction. Test the soil by inserting a screwdriver into the soil (this works best if done 2 days after rainfall during the growing season). If the screwdriver goes into the soil easily, the soil has minimal or no compaction. If the screwdriver can be pushed into the soil but requires some pressure, the soil is moderately compacted. If the screwdriver cannot be driven into the soil by hand, the soil is severely compacted (Cappiella et al 2006). Please be aware of the strong bias inherent in this method if the soil is dry. When assessing the soil profile, it is recommended to use the "screwdriver test" horizontally in every important soil horizon in order to reveal barriers to gas exchange and drainage.

Step 3 - Monitoring

Tree revitalisation is an ongoing process, and it is important to monitor the tree's progress over time to ensure that it is responding to the care it is receiving. Monitoring involves regularly checking the progress of the tree's health and growth after implementing the revitalisation plan. Here are the steps involved in the monitoring process of tree revitalisation:

1. Establish baseline data: Before initiating any revitalisation work, it is important to establish baseline data on the tree's health and condition. This includes information such as tree species, size, age, location, and any existing issues with pests, diseases, or environmental stressors. This baseline data serves as a reference point for tracking progress during the monitoring process.
2. Set monitoring goals: The goals of the monitoring process should be clearly defined and specific to the tree's needs. These goals should be based on the tree's baseline data and should be measurable, achievable, and relevant to the revitalisation plan. Goals could include increased foliage density, improved root growth, or reduced pest infestation.
3. Regular inspections: Regular inspections are necessary to evaluate the tree's progress towards meeting the monitoring goals. These inspections should occur on a predetermined schedule and should involve a thorough examination of the tree's foliage, bark, roots, and soil.
4. Record-keeping: All monitoring data should be recorded and maintained in a database or other record-keeping system. This data should include the tree's baseline information, monitoring goals, inspection results, and any maintenance activities or treatments performed.
5. Adjustments to the revitalisation plan: Based on the results of the inspections and monitoring data, adjustments may need to be made to the revitalisation plan. For example, if the tree is not responding well to a particular treatment, alternative treatments may need to be considered. These adjustments should be made in consultation with a qualified tree care professional.
6. Continuous monitoring: Tree revitalisation is an ongoing process, and monitoring should continue for the life of the tree. Regular inspections and record-keeping should continue to ensure that the tree remains healthy and thriving.

Chapter 2.4 explains in more detail how this works in practice.



SELF-CHECK QUESTIONS

1. What is tree revitalisation?
2. What is the carbohydrate balance/budget?
3. How do urban soils differ from old-growth forest soils?
4. Describe common problems with urban soils.
5. Explain fine root turnover.
6. Which soil factors commonly limit root vitality in urban soils?
7. At what distance from a tree do you analyse the soil profile in order to gain an understanding of its vertical root distribution?
8. Beside soil compression, what other factors may cause tree roots to be absent in the upper 50 cm soil layer?

PRACTICAL EXERCISES

1. Go in the field to an urban tree, make a soil profile, and then assess the soil profile for root friendliness.

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ESSENTIAL READING

The text in this chapter summarises many years of scientific work and practical experience within different fields of science (whole tree physiology, biomass research, forest ecosystem research, root morphology and soil science). The present text is essentially new and similar is not found otherwise. We cannot recommend any additional reading list.

UK Up by Roots (International Society of Arboriculture) by James Urban.
Reference work on working in urban soils. Some chapters explain methods of remediation, and remodification of urban soils for trees.

1.6.3. Trees on Construction Sites

Christian Nielsen & Bregt Roobroeck

GENERAL OBJECTIVE

To know how to protect trees on construction sites before, during, and after construction; and to know how to implement these strategies in practice. This involves being able to plan, instruct, supervise, and control tree protection work on construction sites.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- describe methods used to prevent damage to trees on construction sites during remedial operations;
- make a site survey of the future building site or location of an event and give the preconditions for the preservation and/or protection of trees;
- make an arboricultural impact analysis based on the design of the future site or location for an event;
- describe the protection measures in the arboricultural impact analysis (erecting fences, trackways, root pruning, trunk protection, etc.);
- contribute to a roadmap for tree protection during events; and
- supervise the implementation of and compliance with the protective measures imposed in the tree impact analysis and/or roadmap.

SEE TOGETHER WITH:

Amenity and Monetary Value of Trees, Social Value of Trees, Soil Science, Diagnostic Features, Tree Assessment, Tree Revitalisation

ESSENCE OF THE TOPIC

As we saw in Chapter 1.3.1. Amenity and Monetary Value of Trees and 1.3.2. Social Value of Trees, ecosystem services increase with size. To maximise tree benefits, preserving trees should be the priority strategy on construction sites for an ETT. When dealing with trees at event sites and construction or demolition sites, it is vitally important to protect valuable trees.

KEY TERMS

Involvement and communication: site control, site meetings

Prior construction work: arboriculture impact analysis (AIA), compliance with regulations and policies, construction methods, tree protection plan (TPP), potential impacts, technical and management mitigation measures, site organisation

During construction work: clean cut of severed roots, control and violation of TPP

After construction work: monitoring

Concepts: crown protection, critical root zone (CRZ), tree protection zone (TPZ), stem projection

This process is divided into 3 phases:
- Phase 1: Prior to design and construction work
- Phase 2: During the construction work
- Phase 3: After the construction work

As part of the first phase, it is essential that an "Arboricultural Impact Assessment" (AIA) of the construction work be carried out. The AIA assesses the impact on the tree of the proposed works and forms the basis of communication with the stakeholders as it makes the proposed work and scenarios specific. The AIA will lead to a tree projection plan which tries to minimise the impact on the tree or trees in question. Therefore, when construction works impact trees, the AIA must be properly carried out. During the construction work, the essence is to supervise, inform, and/or guide critical actions. After the construction work, the trees need to be monitored for a sufficiently long period of time, as the impact of the construction work can stay hidden for several years.

Throughout the whole process, communication between the arboricultural specialist and the client is essential. Keep in mind that tree protection starts already in the (re)design process and should, ideally, be an integral part of the definition of the project.

A. ETT Involvement and Communication

A typical process for establishing or maintaining green infrastructure has a (re)design, construction, and management part. In an ideal world, an ETT can have a great impact on preserving trees during the (re)designing process. However, in reality, the ETT is not always consulted during the (re) design stage, but when construction has already started with all its consequences. Note that architects and planners commonly lack knowledge about soil, roots, and trees and, therefore, fail to respect the needs and demands of the trees. Hence, it is important that ETTs are involved in the design and planning process as early as possible by defining optimal growth conditions for trees, identifying valuable trees and their root zones on the site, analysing the impact of the (re)design on the trees, and defining any protective actions necessary to prevent or mitigate negative impacts.

However, tree specialists are very often consulted to deal with damages to trees and soil that have occurred during a construction or demolition process by entrepreneurs. Construction personnel have, in general, very little knowledge about tree and soil biology and, in particular, no understanding of the negative effects of root severance, soil compression, and other tree demands within the rooting zone.

In conclusion, an ETT is therefore needed to guide planners, architects, and entrepreneurs in their work around trees and is the first contact point for the tree stakeholders. Basically, an ETT coordinates actions around trees.

The following communication scenarios commonly involve ETTs on construction sites:

- Design process meetings
- Site control on the field: informing and monitoring the contractors in the field
- Site meetings: giving status updates and analysing problems
- Reporting to the client

When communicating, it's important to write it down in a report or email as legal documentation.

B. Prior to Construction Work

Throughout the entire design process, from the idea and concept to the final design, architects, designers, and planners must have an overview of the preservation status of standing trees and any potential impacts that the designs might have on the soil, the root environment, and the trees on the site.

B.1. Arboricultural Impact Assessment (AIA)

Whenever construction or demolition work is to be carried out in the vicinity of trees, a plan for tree protection as well as monitoring during the work process must be arranged before any work is initiated. The core idea of an AIA is to describe the expected effects of the activities on the trees. By activity, we mean the changes in use or design of the space below and above ground in the vicinity of the trees, either temporal or permanent. This is done by collecting data, making an objective analysis, and describing the impact to the stakeholders. In essence, the AIA answers the following questions:

1. Can the tree be sustainably preserved in its current location while maintaining at least the same technical quality (condition, vitality, residual lifespan, etc.) and amenity (value, function, etc.)?
2. If not, what are the mitigating actions needed to have a positive answer to Question 1.
3. In many cases, the trees' actual growth conditions are not optimal and, in such cases, options for revitalisation should be described.

To answer these questions, the AIA consists of the following steps:

- Desk research
- Field survey
- Analysis
- Advice and conclusion

B. 1.1. Desk Research

To start with, identifying the scope of the assignment is crucial and should be stated very clearly to the client. This can be done by postulating the above questions and defining what will be evaluated and what will not. To best understand the current situation, the ETT should then gather all the information on the plans, project specifications, relevant policies and regulations, past studies, as well as on how the work will be done practically (e.g., machines, storage location, etc.). Also list the bottlenecks, conflicts, and crucial activities with regard to the planned construction work.

B. 1.2. Field Survey

The next step is to conduct a site inspection by evaluating the existing trees and vegetation. Data such as the health, size, age, species, and condition of each tree is often absent from desk research and should be gathered by carrying out a tree inventory. Information on significant features such as root systems and wildlife habitat, as well as information on trees with cultural or historical significance, should also be collected when performing this task. In practice, a lot of time will be consumed by searching for roots on which an impact assessment can be carried out. This is done by mapping the root zones of the tree and performing a soil quality assessment, as seen in Chapter 1.1.3. Soil Science. For example, if the trees are affected by a temporary lowering of the groundwater table, the AIA must deal with the consequences for the trees and provide guidance on how to mitigate damage to the trees (such as irrigation in the event of a lowering of the groundwater level).

B. 1.3. Analysis

When the information from the desk research and the field data is gathered, the analysis can start. Based on the site plans and project specifications, the analysis should have an objective response to the postulated questions. The analysis should have more or less the following structure:

- **Evaluate potential impacts:** Use the combination of field observations, site plans, and modelling to assess the potential impacts of the proposed development on trees and vegetation, both above and below ground. This may include predicting tree mortality rates, changes in tree growth and health, as well as impacts on wildlife and other ecological processes. Think, also, about the option of moving the trees to a new location.
- **Identify technical mitigation measures:** Determine what measures can be taken to minimise impacts on trees and vegetation, such as pruning, root zone protection, and retaining or relocating trees. Consider the feasibility, effectiveness, and cost of each measure. This can also be included in the tender specifications.
- I**dentify management mitigation measures:** Determine what structural communication and monitoring are needed between all the stakeholders during the process. This can also include tender specifications.
- **Determine compliance with regulations and policies:** Evaluate the project's compliance with the relevant regulations and policies, such as local tree ordinances, environmental laws, and so on.

B. 1.4. Advice and Conclusion

The conclusion must clearly answer the questions postulated in the project definition of the AIA, and the advice should also be straightforward and easy to understand for non-tree specialists. This can be achieved, for example, by sketching the life span before and after the activities. This can be visualised by a colour code on a digital map. Further, list all the preconditions and requirements that the activities around the tree must meet as a minimum. The preconditions must be practically feasible. Last but not least, in order to preserve a tree that would otherwise be cut down during the planned construction work, alternatives must be explored. For this, the ETT will often have to look outside his/her own field. This requires consultation and coordination with experts in other fields. There may be technical, alternative proposals in which the implementation has no or less impact on the tree. Keeping the existing trees should be the first goal of an ETT.

B.2. Tree Protection Plan

The Tree Protection Plan (TPP) is a document that outlines measures to protect trees and other vegetation during construction or development activities. It specifies the actions needed to prevent the loss of the tree or mitigate the negative impact. It should be negotiated and finally accepted by all the other stakeholders. This process of coordination should, at a minimum, involve tree officers, engineering advisors, and the entrepreneurs. It is strongly advised that the head entrepreneur establish a construction site work plan that is coordinated with the tree protection plan. In some countries, it is part of the arboricultural impact analysis for trees on building sites (or the AIA is part of the TPP), although these documents might also be separate documents.

A TPP typically includes the following information (though not limited to it):

- **Tree protection zones (TPZ) and Critical root zones (CRZ):** The establishment of tree protection zones around each tree based on the field survey of the IAI, which delineate areas where construction activity is prohibited or restricted to prevent damage to roots, trunks, and branches. The TPP should also include the type of protection (fences, signalisation, etc). Ideally, the establishment of fences and protection measures are implemented by the owner, developer, or municipality before the constructor is allowed on the site so that the contractors do not own the fences. However, it is fairly common that the establishment of fences and protection is part of the construction tender. Further, where digging is necessary within a TPZ, the definition of the Critical Root Zone is necessary, and any activity within the TPZ should be supervised by an arboricultural officer.
- **Tree preservation measures:** Specific measures that will be taken to ensure the long-term health and viability of the trees, such as pruning, soil improvement, mulching, and watering.
- **Construction methods:** Details of construction methods that will minimise the impact on the trees, including the use of specialised equipment and techniques to protect the root systems and other sensitive areas around the trees. Techniques and costs for revitalising compressed soil should be presented and estimated; however, prevention should always be the first option.
- **Site organisation:** A plan with the location of the TPZ and where materials, machinery, etc. can be stocked, and where transportation is possible. Making a map helps the contractor organise the working sites within which restrictions need to be respected, such as the location of any temporary ground protection that needs to be installed.
- **Monitoring and maintenance:** Plans for regular monitoring of the trees during construction as well as ongoing maintenance to prevent any form of damage. This includes the frequency of the monitoring of the construction site.
- **Communication:** A procedure for reporting tree protection plan violations: a) type of report; b) responsible supervisor; and c) phone number/email addresses of entrepreneurs and supervisors. Explain the role of the ETT and what authority he/she has.
- **Contractor informing/training:** Requirements for contractors to be trained on the tree protection plan and to follow best practices for protecting trees during construction.
- **Permits and approvals:** Any necessary permits and approvals from local or state authorities to implement the tree protection plan. Also, suggest defining financial compensation and/or fines for violation of the tree protection plan and setting up large labels on fences that explain the fines that will be given if the tree is damaged. This is highly recommended. Use national rules for communicating tree value. Put the value of the tree on a large sign on the fence.

C. During Construction Work

During the construction, the process must be controlled, monitored, and reported on with photo documentation. Site visits can be carried out at random and/or when crucial activities around the trees occur. Violations of the tree protection plan must be communicated to stakeholders and the authorities. If damage to soil, roots, stem, or crown is noticed, remedial measures may be organised – at once when roots are severed or after project closure when soils are compressed. The tree protection plan may be continuously communicated to all constructors working on the site, particularly subcontractors, who may not be sufficiently informed about the tree protection plan. Explain the consequences of not following the TPP and what the role and authority of the ETT are in site inspection.

TREE PROTECTION PLAN (TPP) AS A LEGAL CONTRACT

The manager of the tree protection plan may be the owner, the builder, or the local authorities. No matter who manages the TPP, it should be part of the legal basis of any construction work. As mentioned previously, the TPP should also contain clear figures for fines or compensation in case of violation of this plan, implying that the TPP should be included in the tender as one of the criteria. This implies that tree protection plans are most commonly defined on construction sites. However, the concept of tree protection plans is not limited to construction but also stretches to demolition projects or events held in public parks.

Whenever damage to stems or roots is identified, the following actions should be taken:

1. Severed roots thicker than 30-50 mm must be treated with a clean cut and covered in order to avoid desiccation of the soil and root cambium. The soil volume around cut roots should be filled with a proper urban soil substrate, which allows good gas exchange and good water retention.
2. Stem bark wounds must be covered with black plastic within a few days (after 14 days the plastic cover will have no effect) in order to stimulate "surface callus" (woundwood on the exposed woody surface) – see references of Stobbe et al.

D. After Construction Work

When the construction/demolition work has ended, a follow-up meeting should be carried out in order to discuss any violations of the tree protection plan that have occurred. Final remedial measures must be taken, and the costs of these measures should, if legal, be covered by the stakeholder who violated the tree protection plan. During this meeting, where constructors are "handing back" areas and trees, it is important to emphasise that the actual symptoms of the tree are less relevant, as the consequences of severed roots or a destroyed root zone often do not show until years later (typically after drought events). It is therefore wise to monitor the trees for several years (approximately 5 years). Also, make sure that at the end of the construction work, a final report is made and the condition of the trees is documented.

E. Concepts of the Tree Protection Plan

As already mentioned, the protection of the tree root system is the No.1 priority when dealing with trees on a construction site. In order to communicate clearly with all stakeholders, it is necessary to clearly

E.1. Tree Protection Zone (TPZ)

Tree protection zone (TPZ in the US, reference Clark) = Root Protection Area (RPA used in the UK, reference BSI) = "Trädskyddområdet" (SE, reference Östberg). This is the area that is considered to be occupied by a significant number of tree roots responsible for tree health and stability. Please note that the TPZ also involves protection of the crown space – so TPZ ensures protection both above and below ground and reaches as high as the tree.

There are numerous standards for TPZ. BSI takes a radius around the tree equivalent to stem diameter * 12. The Polish standard has varying definitions (Dworniczak). Several other estimates are used in various literature, but it should be noted that root spread varies a lot between tree species and depends also on the ability of the soil to provide a deep-rootable rhizosphere. Trees compensate for shallow rooting by extending the horizontal

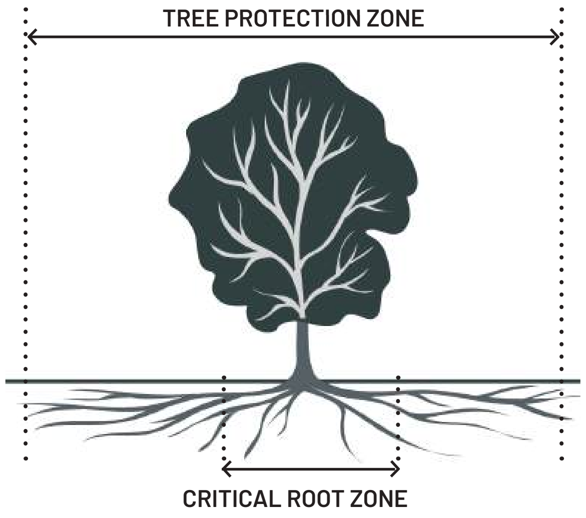

Figure 1. Definition of TPZ and CRZ. (Adapted from C.C.N.)

Figure 2 (C.C.N. Nielsen). Protection of the TPZ with a fence.

roots further. TPZ around ancient and veteran trees is 15 x stem diameter (measured at 1.50 m above ground level) or 5.0 m beyond the edge of the canopy, whichever is greater. However, it is strongly recommended that a root specialist carry out local mapping of root spread, especially with valuable trees. Östberg suggests investigating root spread through vacuum digging. See also Chapter 1.6.2 for more information on the methods used to carry out this task. Care should be taken to avoid soil compression and severed roots. TPZ should be protected by stable fences that are difficult to move. If traffic cannot be avoided inside the TPZ, the soil should be protected with temporary ground protection that both prevents soil compaction and provides oxygen and water for tree roots. It is suggested that a maximum of 20% of the TPZ should be covered with temporary ground protection.

E.2. Critical Root Zone (CRZ)

The Critical Root Zone (CRZ) is the portion of the TPZ that contains the absolute minimum of roots for tree survival. This concept is a fluid one. When the root system (or the soil) is damaged within the CRZ, it may be necessary to irrigate and/or artificially anchor/guy the tree for a number of years until the roots have regenerated. Root damage can be an entry point for decay, so an intensive follow-up might be necessary. Please note that the CRZ varies extremely in urban environments depending on the soil type and among species and clones. Thus, local investigations to assess the CRZ are necessary in urban soils, and this task should be carried out by a tree root specialist. None of the European guidelines provides clear definitions for the size of CRZ's, but they mention in various contexts critical root diameters that should not be exceeded when digging inside the TPZ: 25 mm (BSI), 30 mm (Dworniczak, SkovByKon) – 50 mm (Östberg). Ideally, the critical root diameter increases with tree size but decreases with vitality. Very often, the tree protection plan contains values for the TPZ and the CRZ The CRZ is commonly expected to be restricted to an area within the crown dripline, but this is not always true. Trees developing very shallow root systems due to soil conditions compensate by growing thick "cable roots" at large distances from the trunk. Root spread and root diameter also vary considerably between tree species and varieties. For example, *Populus trichocarpa* clones

only develop very few sinker roots but form very widespread, thick horizontal roots. In large poplar trees, such roots may still have diameters of more than 100 mm at distances far outside the crown dripline. Thus, local investigations to assess the relevant TPZs and CRZs are recommended.

E.3. Crown and Stem Protection

There is always a risk of branches being ripped or broken due to crane work. During the preliminary discussions with the entrepreneurs, the positioning of cranes and their work radii should be noted. Prevention of damage should be the starting point. As the Tree Protection Zone is three-dimensional and is as high as the tree, the ripping of branches should also be part of the penalty clause that is part of tree protection measures. It might be necessary to prune trees to reduce the risk of branch breakage and improve their stability. Prior crown reductions may be preferable to ripped crowns but are only acceptable when other measures are out of reach. And don't forget that removing and changing parts of the root system has consequences for the crown or might provide access for root decaying fungi.

In the proximity of street trees or other trees surrounded by a permanent hard surface, stem and buttress roots should be protected. The most efficient tool is a wooden box which is stabilised from the inside and strong enough to resist any contact from machinery used during the construction. Commonly, drain tubes are used to maintain a distance between the box and stem, but more firm anchorage (e.g., to the stem) may be necessary.

If soil, roots, stem, or crown have been damaged by the end of the construction project, remedial measures may be necessary – please refer to Chapter 1.6.2. Tree Revitalisation.

Figure 3 (C.C.N. Nielsen). Stem protection of trees surrounded by a permanent hard surface next to a construction site.

Figure 4 (C.C.N. Nielsen). The protection box has been pushed around and lifted in order to place remnant soil inside of it.

PROTECT TREES WITH LICHENS

These two large oaks (*Quercus robur*) in the vicinity of Riga in Latvia were threatened by a large urban development in 2015. Behind the oaks, a road needed to be enlarged, and the project developer wanted to cut them down. During the tree inventory, the lichen *Pleurosticta acetabulum* was discovered on the tree bark of one of the oaks. This epiphytic lichen growing on deciduous trees in parks and mixed forests is considered to be rare in Latvia, and, as a result, it was considered important to protect the oaks. This example illustrates beautifully how a very small species can protect a very large species.

SELF-CHECK QUESTIONS

1. What is an AIA and how is it structured?
2. How can you carry out an investigation of root spread prior to defining the tree protection plan?
3. Why is it important to include the 3 phases of tree protection in construction/demolition projects?
4. How far out from the stem will there be important roots?
5. What is the difference between TPZ and CRZ?
6. Present methods to detect/define the TPZ.

PRACTICAL EXERCISES

1. Find a case where you can create a small AIA and emphasise the analytical part of the analysis.
2. Find a site with trees where construction is or will be started and evaluate the TPP on site if possible or make a scenario where you need to perform a TPP.
3. Explain in simple terms what the need for a TPP is.

TERMINOLOGY

Critical Root Zone (CRZ) – The area around a tree containing roots essential for the health and stability of the tree / the minimum root growth for tree survival. The CRZ should be defined for every individual tree by a root specialist, but the following diameter limits for roots to be severed may provide some guidance: 25 mm in BSI, 30-50 mm in Östberg and 30 mm in Dworniczak and 30-40 in SkovByKon. This diameter limit should be set individually and much lower for veteran trees.

crown diameter – average distance between crown driplines on opposite positions of the tree

crown dripline – the vertical projection of the crown periphery on the soil

tree protection plan – a plan for greenery and tree protection written by an arborist after soil and tree investigation, also including instructions for continuous control during the work phase

Tree Protection Zone (TPZ) = Root Protection Area (RPA used in the UK) the area around the tree where the soil contains a significant amount of root material important for the maintenance of the current tree health status; TPZ is commonly beyond (outside) the crown dripline

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Stobbe, H., Schmitt, U., Eckstein, D., Dujesiefken, D. (2002). *Developmental stages and fine structure of surface kallus formed after debarking on living lime trees.* Ann. Bot. 89, p 773-782.

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Small reference book on Arboricultural Impact Analyse for Dutch speaking. Check the video to know what it is all about.

USA Tree Protection on Construction and Development Sites: A Best Management Practices Guidebook for the Pacific Northwest by Oregan State University. Retrieved from:
https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8994.pdf
Helps to understand the TPZ and CRZ.

CAN Compendium of Best Urban Forest Management Practices by Treecanada. Retrieved from:
https://treecanada.ca/resources/canadian-urban-forest-compendium/13-tree-protection-during-construction-trees-and-building-foundations/
Starting point to find examples of tree protection plans of Canadian cities.

ADDITIONAL READING

The text of this chapter provides the necessary knowledge for an ETT. Depending on your home country and language skills, some of the references may be relevant.

GER Baumschutz auf Baustellen – Grundlagen und praktische Umsetzung. Jahrbuch der Baumpflege.
Reference book on Arboricultural Impact Analyse.

USA Why Definitions Matter: The Tree Protection Zone and the Critical Root Zone by James Clark et al. Retrieved from:https://www.researchgate.net/publication/357128085_Why_Definitions_Matter_The_Tree_Protection_Zone_and_the_Critical_Root_Zone
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Practical and visual reference book, a basic checklist for tree related work on construction sites.

NL Handboek bomen norminstituut bomem 2022. Retrieved from: https://www.norminstituutbomen.nl/instrumenten/handboek-bomen/
The institute has made some very good graphical poster 'working with trees' to communicate with all stakeholders. Interesting for all countries.

SWE Skydda träden vid arbeten by Länsstyrelserna. Retrieved from: https://www.lansstyrelsen.se/download/18.26f506e0167c605d5693d6f6/1612448938162/Broschyr%20-%20Skydda%20tr%C3%A4den%20vid%20arbeten.pdf
4-page brochure on working with trees on constructions site.

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A Checklist for good management of trees

DK SkovByKon (2023): Koncept for beskyttelse af træer på byggepladser. Retrieved from: https://www.skovbykon.dk/byggeri-anlaeg
Explaining the Concept for the protection of trees on construction sites.

UK Tree roots in built envrionment by the Arboricultural Association. Retrieved from: https://www.trees.org.uk/Book-Shop/Products/Tree-Roots-in-Built-Environment-2
Sets out a comprehensive review of tree root biology and covers a broad range of practical issues that need to be considered to grow trees successfully in our towns and cities and to realise the significant benefits they provide in built environments.

NL Een boom hoeft geen obstakel zijn' by Van Iperen (CROW).
Slides about utility lines and trees. There is also a handbook about it: Combineren van onder- en bovengrondse infrastructuur met bomen.

1.7. CASE STUDIES

1.7.1. Case Study: A Veteran Tree

Peter Hjelmqvist & Daniel Daggfeldt

INTRODUCTION

This case study illustrates the development and life stages of trees that are not linear in their evolution. These veteran trees exhibit a rich biodiversity and historical value, which means that we may need to manage them using different points of focus to those normally employed when carrying out general tree management.

RELATED WITH

Tree Function and Structure, Tree Development and Growth Stages, Ecology and Biodiversity, Amenity and Monetary Value of Trees, Social Value of Trees

Note: This chapter covers neither the shaping of trees (e.g., topiary) nor pruning for fruit or flower production.

A. DESCRIPTION OF THE CASE

Site

A veteran ash (*Fraxinus excelsior*) grows in the courtyard of Ängsö Castle, situated on the island Ängsö in Lake Mälaren, about 80 km northwest of Stockholm, Sweden. The tree was planted around 1750, when the castle gained its current appearance. The estimated age of the ash is around 250 years, based on the archive material below.

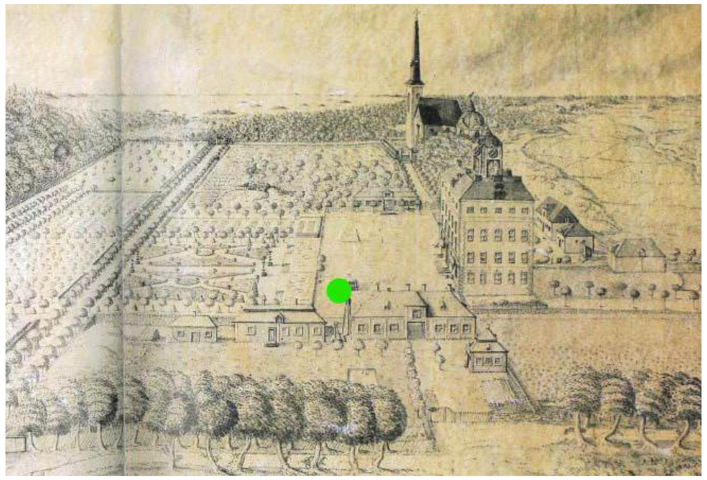


Figure 1 (Ulrika Rydh). Photograph of a wall painting of the castle and its surroundings from 1740 to 1750 with no trees in the castle courtyard. The green dot indicates the position of the ash.

Figure 2 (Ulrika Rydh, Photograph of a wall painting). Ängsö castle around 1790 on an ink washing by Isac Kjölström. A row of six young ash trees is visible in front of the castle. The one remaining is at the far end of the row.

The climate by Lake Mälaren is milder than it is inland, and the sheltered courtyard provides favourable microclimatic conditions for the tree and associated saproxylic species. This ash is known to be the northernmost place in Europe where the hermit beetle (*Osmoderma eremita*) has been found. This beetle is listed on the IUCN Red List (endangered) and has been granted the highest EU protection status through the habitat directive. The tree is protected by the following laws:

- The Swedish Environmental Code (12 kap. 6§ miljöbalken), based on its age, girth, and extensive hollowing.
- State Architectural Heritage (Statligt byggnadsminne), due to the ash standing within the border of the protected area.

Tree

The tree shows signs of heavy pruning and other forms of tree management traditional to Sweden, such as cavity filling with concrete. The recent heavy pruning has caused large open cross-section surfaces at the top of the stems and dysfunction in the sapwood in many places, leaving dead strips of bark along the trunk and decayed heartwood. The veteran ash consists of a central hollowed stem about 250 years old with an abundance of microhabitats, the most valuable being the wood mould in the central cavity.

The tree shows good vitality and resilience, as evidenced by its response of activating epicormic growth on the whole surface of the stem, not only by the heavy pruning cuts at the top of the crown but also at the base where orthotropic epicormic growth has developed into a colony. The age of the crown in 2019 was estimated to be approximately 15 years.

The main risk for the ash was recognised as:

- Ash dieback (*Hymenoscyphus fraxineus*);
- the high number of visitors to the site (compaction and safety demands);
- mismanagement (such as the recent heavy pruning); and
- the structural properties of the tree.

There were 3 management concerns from the administrating foundation:

- To retain the tree for as long as possible.
- To keep and improve the habitats, especially for *Osmoderma* (on the Swedish red list as near threatened).
- To make sure there is no elevated risk to visitors or surroundings.

To meet these objectives, the contractor assessed the tree visually and identified a potential weakness in the unions between epicormic shoots and trunk at the large pruning cuts at the top of the crown. Otherwise, despite the major hollowing, the main trunk was considered stable due to its large circumference at the base and its pyramidical, heavily tapered shape. The tree's vitality, prospects, and ability to react with epicormic growth after pruning were assessed as good. The pruning work that was carried out in April 2019 had two objectives. Firstly, to reduce the weight of the part of the crown originating from the weak point caused by the large pruning cuts in the upper stem to prevent failure. And, secondly, to allow more light to fall on the lower crown to build up and retain a lower secondary crown. To achieve these goals, the work was performed in the following way:

- The tree was worked on from a MEWP/articulated boom lift (25 m reach) to get access to the thin top of the crown and to avoid damaging the habitat on the main trunk. The long reach also meant that the MEWP could be parked outside the RPA (root protection area).
- Small-diameter branches were pruned with handsaws using the cut-and-hold technique.
- Target pruning and internodal and nodal cuts were used.

The suggestions for further management by the tree specialists (ETT and VETCert) were:

- extend the protection zone around the tree as much as possible;
- revitalise with mulch;
- stop the leakage of wood mould from the lower cavity with the use of a retaining construction;
- add wood mould to the hollow trunk; and
- prune the crown every 4th or 5th year to maintain a lower crown.

Figure 3 (D. Daggfeldt). The veteran ash in the castle courtyard with a large cavity in the main trunk and a young crown after previous heavy pruning.

Figure 4 (D. Daggfeldt). A handful of clones around the base of the ash create a colony. Note the low fence marking a protection zone around the base. This area could, of course, be larger and mulched for the benefit of the tree.

Figure 5 (D. Daggfeldt). An articulated boom lift with a 25-metre reach was used to access the top of the crown without unnecessarily compacting the ground within the root protection area. The pruning was carried out by handsaws using the "cut-and-hold" technique to prevent damage to the tree caused by falling branches.

Figure 6 (D. Daggfeldt). The heavy pruning has led to heartwood decay, dysfunctional sapwood, and vigorous epicormic growth, creating functional units.

Figure 7 (D. Daggfeldt). After pruning. Note the number of branches on the ground, the maintained symmetric young crown, and the retained epicormic growth.

B. Explanation of the Case

Tree Function and Structure

The architecture of the ash (*Fraxinus excelsior*): The architectural model is Rauh's. The veteran ash has transferred from a single stem with strong apical domains (see Figure 2) to old age polyarchy. This is deducted from answering the four questions below. Of course, be aware that this is an oversimplification due to the mixing of the models in reality.

1. Is branching present? Is it sympodial or monopodial? Ash builds stems in a monopodial manner, and the structure consists of 3 axis categories.
2. Is the growth of the stem and branches rhythmic or continuous? The growth of ash is rhythmic, like most trees in temperate regions, where a dormant period interrupts the primary growth.
3. Is the growth of the axis plagiotropic and/or orthotropic? The growth is orthotropic, with a strong apical dominance.
4. Is the position of the flowers lateral or terminal? The flowers are positioned laterally on all axes.

Functional tissues: The original 250-year-old stem consists of functional units of sound sapwood connecting the crown with the roots. Heavy pruning has caused dysfunction in the sapwood and dead strips of bark along the stems. Old cavities have also disrupted the once-complete cover of functional sapwood around the stem and divided the stem into functional units.

Photosynthesis: The veteran ash stands in an open and fully sun-exposed environment. An important site condition for an old ash with high light demand (Ellenberg 1992). The young, re-iterated crown provides the tree with a large leaf surface for effective photosynthesis. High photosynthesis is crucial for the tree to maintain functional units, distribute adaptive growth, and store energy. Ash has one of the shortest growth seasons of all trees in Scandinavia (June to October).

CODIT: Ash doesn't produce true heartwood; the core consists of less durable ripewood. This leads to moderate resistance to hollowing by heartwood decay fungus. But the species has resistant sapwood, which allows old ash to build durable sapwood walls around the decaying non-durable heartwood or ripewood.

Tree Development and Growth Stages

Many trees have the ability to renew themselves and go back into development stages, as well as establish ancient colonies, primarily by activating epicormic growth. This ability comes from the necessity to adapt to defoliation by browsing animals and storm damage. When assessing trees, especially chronologically old trees, it´s important to recognise this process and identify the different life stages that the various components of a single tree might exhibit. Just like the Ängsö ash, different parts of the same tree can demand different management approaches. Functional sapwood and functional units are other important features to look out for when assessing veteran trees. A general knowledge of tree architecture helps form substantiated recommendations for managing veteran trees. By examining the crown structure, ramification, and the presence of reiteration, we can judge what general development stage the different parts of the tree are in, and what effect management might have on the tree's growth. According to Pierre Raimbault, centennial trees undergo a series of phases or life stages, from germination to death by old age. The model consists of 10 stages, as we saw in the Chapter Tree development and Growth Stages.

Applying this model, the Ängsö ash is clearly in its final stage and fits well with the description of phase 10. A stage very few trees ever reach. The tree in this stage shows extensive hollowing and sinks into itself. The apical dominance from trees from 1790 above) is now gone, and the buds have become progressively more independent from the whole of the tree, forming columns (functional units) along the trunk and developing their own root systems. Note that each column has an apical dominance that only affects its own column.

When assessing the vitality and resilience of old trees, it is important to distinguish between *decline* and *senescence*. Decline is a regression before the tree has reached its maximal expansion and is independent of age. It can be caused by biotic and abiotic stress factors such as drought or fungal infection. Senescence, however, is the last phase in the tree's development, when it reaches its maximal expansion.

A natural ageing process in old trees is the reduction in the size of the crown needed to trigger epicormic growth in the lower crown and cause a reorganisation of growth in the tree. This process is called *retrenchment* and can be caused by various mechanisms, such as alterations in the hormone balance, hydraulic restrictions, changes in light intensity, and wounding. When managing veteran trees, indications of this process can be used when assessing the tree's resilience and can guide the arborist in undertaking retrenchment pruning.

Ecology and Biodiversity (Nature Conservation and Environmentally Friendly Practices)

Nature Conservation

Managing veteran trees should also be about managing tree populations and the ecosystem around those trees. This ecosystem also consists of very small features on the tree: the so-called dendro-microhabitats. The age structures in most European tree populations have seen a large reduction of old trees during the last 200 years due to human conflicts, exploitation, and unsustainable forest management. The remaining veteran trees need protection, and new tree generations must be given a chance to establish and thrive to ensure a sustainable age dynamic in the population. As we saw with *Osmoderma eremita*, this endangered species needs a very specific habitat type, namely old, hollow living trees with large cavities containing a lot of decayed wood, on which the larvae feed. In order to maintain the population, as we saw in Chapter 1.2.3. Ecology and Biodiversity, a population needs continuity. So, this beetle represents the reason why we need very old trees and a constant *flow* of new veteran trees to keep the species thriving.

Environmentally Friendly Practices

The foundation of the arboricultural industry is to care for trees, which should have an overall positive impact on the urban environment. However, arboricultural practices also have some negative impacts on the environment. Fossil-fuelled machinery and transportation of personnel and brushwood being some of them. Another major problem is unnecessary tree work, especially unnecessary tree removal. So, when managing veteran trees, the first question we should ask is what happens if we don't do anything to the tree? Maybe doing nothing – or just adding mulch – is the best solution.

Furthermore, the European Tree Technician should always employ the most environmentally friendly practices. For example, hand or battery tools should be used, if possible; veteranisation practices should be considered instead of removal; brushwood should be left on site to create habitat or removed to avoid habitat traps; habitat trees should not be felled; and habitats should not be destroyed during tree work. A common-sense risk management approach is paramount to avoid using up the tree budget on unnecessary interventions and the unnecessary removal of trees.

The Amenity and Monetary Value of Trees

As the tree already has a reduced crown and a decaying stem, the common ecosystem services associated with crown and stem volume, such as cooling, water buffering, etc., are lower than on mature trees. So, the tree is already past its point of maximised ecosystem services. However, the unique character of a veteran tree is that other ecosystem services like specific habitats, unique aesthetic image, history, and so on are still increasing. This means that the veteran tree still has high amenity value because of its unique features, albeit ones that have shifted from those that regulate by nature towards those that support, for example, habitats and cultural ecosystem services. Unfortunately, today it is still very difficult to truly monetize ecosystem services. For example, the calculation with the Belgian method (uniforme methode voor waardebepaling van bomen – uniform method for determining the value of trees) is only around 6,000 euro. Although the factor 'added value' was the highest, it is still not the real value.

The Social Value of Trees

The veteran tree, with its majestic presence and rich history, holds important social value. This ancient specimen serves as a living witness to the passage of time, offering a sense of connection to our natural heritage. This singular tree may have been planted to honour a specific event or a local celebrity. A hedge row or tree avenue may tell us about the historic use of a site. The social and heritage value of trees is often irreplaceable, and if we lose the tree, a part of our history is also lost. Sometimes, there is a communal value, but at other times, the tree may be very important to just a few people. Further, its imposing stature, gnarled bark, and expansive canopies create unique habitats, attracting a diverse range of flora and fauna. Veteran trees in general provide shelter, food, and nesting sites for numerous species, contributing to biodiversity conservation, as we saw above. Also, from an aesthetic standpoint, their beauty and grandeur enhance landscapes, parks, and gardens, providing a sense of tranquility and wonder.

1.7.2. Case Study: Tree Revitalisation

Christian Nielsen

INTRODUCTION

This case study examines the tree revitalisation of a deteriorating old beech. This case was chosen because the soil assessment plays a crucial role in the revitalisation process. Be aware that this case hits the limits of what an ETT can be expected to solve. To make sure that the diagnosis was right, a specialist in soil-root interactions was attached to the project. You need to be either a specialist in soil and root functions or bring in external specialists to accurately determine the problem. An ETT should, however, be able to oversee and manage the problem!

SEE TOGETHER WITH:

Tree Function and Structure, Soil Science, Site Selection, Tree Revitalisation, Tree Site Improvement and Remedial Measures

A. DESCRIPTION OF THE CASE

Site

A red beech (*Fagus sylvatica* 'Atropunicea') stands within the garden of the parsonage, next to the rural village church of Ejby by Lille Skensved in Eastern Zealand, Denmark. The location is well-suited for tree growth, with clayey soils and high nutrient content supporting high growth rates. The site is situated far away from wind-exposed coastlines. However, the meso-climate around this particular tree is slightly more exposed as it stands on a small hill, elevated 20 meters above the surrounding landscape. The red beech tree was planted at the end of World War One to commemorate the reunion of North Schleswig and Denmark. North Schleswig had been under German rule from 1864 to 1919. The tree exhibits strongly asymmetric crown development, and dead branches continue to fall. The parish council has sought assistance to improve the tree's health and prolong its remaining life expectancy. The case is described in a 2 min video below (please scan with your phone):

Description of the case

The Tree

The crown is extremely asymmetric, having many dead branches towards the prevailing wind direction (west) and a more normal and healthier crown towards the east. The tree looks as though it has been growing in a wind-exposed part of the west coast of Denmark; however, in reality, it stands many hundreds of kilometres inland. The tree was grafted 20 cm above the ground. There was no serious sign of genetic incompatibility that could explain the crown symptoms. Some spots on the

Figure 1 (C.C.N. Nielsen). Fagus sylvatica 'Atropunicea'

lower bark were dead, but there was no decay behind these spots, and they were not coupled with the asymmetry in the crown. Small outgrowing knots were found spread along the stem, but they cannot explain the crown symptoms. There were also no wounds or injuries, either on the stem or on the root buttress.

The soil was investigated in 35 cm diameter drilled holes, providing the following facts (Figures 3A, 3B and 3C):

- Clayey loam down to 82 cm
- Very humus rich soil down to 82 cm
- Vital roots down to 30 cm
- Few living roots between 30 and 82 cm
- A pH of 6 in all horizons down to 82 cm
- Many large stones were found at a depth of 50 cm

Figure 2 (C.C.N. Nielsen).

Figure 3A (C.C.N. Nielsen).

Figure 3B (C.C.N. Nielsen).

Figure 3C (C.C.N. Nielsen).

B. EXPLANATION OF THE CASE

Tree Function and Structure

The tree crown was earlier much larger in height and width, but the crown has been degrading at the top and towards the west for several decades. How did the tree originally have a larger crown? It is commonly known that roots spread vigorously during youth and early maturity in both horizontal and vertical directions, and that vertical roots commonly degenerate and die at older ages. It is interpreted that the original large crown was developed and sustained by deep vertical roots under and around the stump during the stages of the tree's life in which it was expanding in size. Later, these deep central roots degenerated, and the tree lost its supply of water from the deeper horizons during the summer dry periods. Since the degradation of the deep central roots, the tree has needed to grow deeper roots along the horizontal root system for water supply during the prolonged dry summer periods where water is depleted in the upper 30 cm.

Roots excavated from the soil horizon from 30-80 cm were commonly without or with very few "short roots" (diameter < 0,5 mm), which take up water and nutrients. Also, a study of the root surface revealed a rough, uneven, and scratched pattern. Laboratory microscope analysis supports the field observation, showing many deep holes in the root surface caused by dead side roots. It is concluded that the conditions for root growth are very poor in the soil space below 30 cm.

However, the tree is supposed to use enormous amounts of carbohydrates (sugar) to repair and maintain the roots in these deeper soil layers. Healthy trees in healthy soil consume roughly 30% of the total carbohydrate budget to maintain the fine root section alone. This tree probably allocates 2/3 of total sugar-production to the root system to sustain deep roots.

Figure 4A (C.C.N. Nielsen). Picture of the root surface at 20x magnification. Also visible in a simple field 10x botanic magnifying glass.

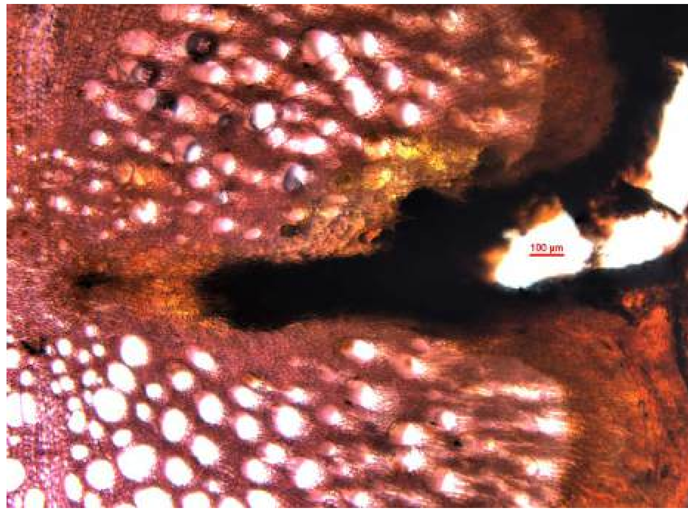


Figure 4B (C.C.N. Nielsen). Cross section of a root, where a hole in the bark was observed. It can be seen that the hole derives from a dead side root. The microscope picture is at 60x magnification. The object is stained with Safranine O.

Soil Science

There are at least two observations that lead us to conclude that the tree is growing on soil fill:

1. The homogenous high content of humus across the entire soil horizon down to 82 cm depth (infiltration or leakage of humus would provide a clear gradient of humus content).
2. The excessive presence of large stones constricted to one specific depth.

The addition of soil to the site was carried out before the planting of the tree, which means that the incident occurred more than 100 years ago. The site has been church ground for many centuries, and there was a preference for building church buildings in Denmark on hills and highly elevated ground. The reason for the soil fill is not clear; however, it is possible that the soil was moved to the site to create a more level ground on which to build.

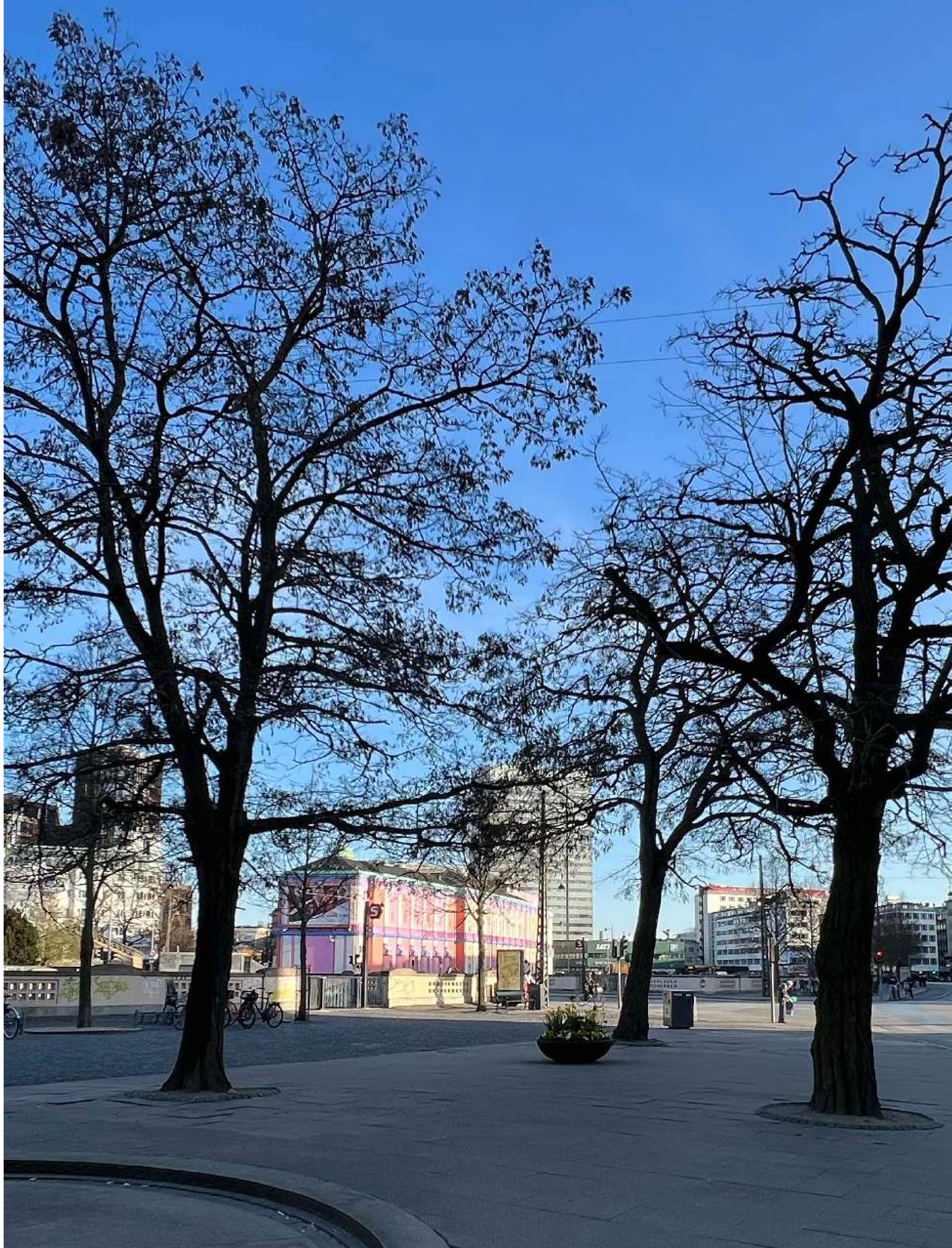
Furthermore, the soil texture is characterised by a high content of silt and clay. Although NOT compressed, gas exchange to deeper soil layers is restricted. The lower humus-rich horizon is not completely anaerobic, but gas exchange is not sufficient to prevent anaerobic processes, which may be anaerobic respiration or fermentation. More-or-less phytotoxic compounds and gases are released depending on the microorganisms and prevalent chemical elements in the soil. Nitrogen and sulphur will often be used for anaerobic digestion, and sometimes gasses with an unpleasant odour are produced (methane, sulphurous compounds, etc). Fermentation may release alcoholic substances. It is anticipated that phytotoxic substances were released due both to the high humus content and to periods in which anaerobic reactions took place in the soil.

Site Selection

Except for the artificial humus enrichment in the soil, beech is a suitable choice of tree species. The final or desired image, a fully grown tree, is suitable and realistic.

Tree Revitalisation

The soil down to a depth of 80 cm is actually "good mull". The only problem is poor vertical gas exchange between the atmosphere and the deeper soil layers. Thus, any technique that permanently provides an effective input of oxygen and export of CO_2, NH_4, SO_4, and H_2 will change a detrimental soil layer into a suitable growth media. Please refer to Chapter 2.4 Tree Site Improvement and Remedial Measures and consider either vertical mulching or radial trenching as adequate techniques. Finally, read Fite et al. (2016) in Chapter 2.4 Tree Site Improvement and Remedial Measures. In this specific case, 100 mm diameter vertical holes were drilled for every square metre around the tree up to a distance of 8 metres. A plugged drain tube was installed up to 50 mm below the soil surface, and the holes were then filled with FLL type 2 substrate mixed with 25% compost. FLL type 2 substrate is a ready-to-use tree substrate. As the remediation was realised in 2022 and this publication is of 2023, it is too early to assess the impact of the remediation.



1.7.3. Case Study: Planting and Transplanting Trees

Wim Peeters

INTRODUCTION

This case study illustrates the how and why of a situation in which the only way to conserve trees was to transplant them.

SEE TOGETHER WITH:

Tree Function and Structure, Tree Development and Growth Stages, Soil Science, Tree and Shrub Planting and Aftercare

A. DESCRIPTION OF THE CASE

Site

Two large plane trees (*Platanus sp.*) that stand in the vicinity of Dok Noord in Ghent (Belgium) need to be transplanted. Dok Noord is a neighbourhood undergoing development, with a lot of old buildings being demolished and new ones being constructed. As shown in the photo, the building which is covered by plants will be demolished and rebuilt, leaving no space for the trees in the new design. Thus, only two options remain: cutting the trees down or transplanting them. The city of Ghent chose the second option to maintain both the trees, their ecological value, and their ecosystem services. The value of trees increases exponentially with their size; therefore, conserving existing trees is always preferable to cutting them down and replacing them with young trees.

Figure 1 (K. Dupon). The trees in their original location in front of the building to be demolished.

The case can be divided into two parts: a research and consultancy assignment on the transplantability of the trees, and the actual research assignment including aftercare.

Assignment 1: Consultancy Phase

The consultancy assignment includes a transplantability study, which includes the preparation of a report explaining the advice. In the preliminary study, the transplantability of the two plane trees was investigated. Their new location is just 200 metres further to the centre of a square with enough rooting space, as shown in Figure 2.

The first task was to map out the below-ground space of both the old and new sites. This involved a structural soil analysis, which meant carrying out a visual soil assessment, finding utility lines, and detecting the exact location and branching of the root system. This was largely done manually (Figure 3). Because the trees had been raised in the past, the fieldwork also mapped how well the root system had responded to that situation. In addition, the specific characteristics and prospects of the specific tree species were also examined. The second task was an examination of the condition and vitality of the trees and the nature of their branching. The third task was an analysis of the route by which the trees could be transported, and any factors that might affect their transportation were taken into account. The fourth and final task was to consider any financial constraints the company ordering the work might have. The costs of transportation were weighed against the costs of planting new trees of the same size. In practice, the latter proved not to be an option, as trees of the same size are not available and are hardly transportable over longer distances.

Figure 3 (K. Dupon). Manually digging the soil to assess the root system and the soil.

Based on all these results, a timetable and strategy were drawn up for transplanting the trees. All the data was mapped and collected in a report for the client and/or builder.

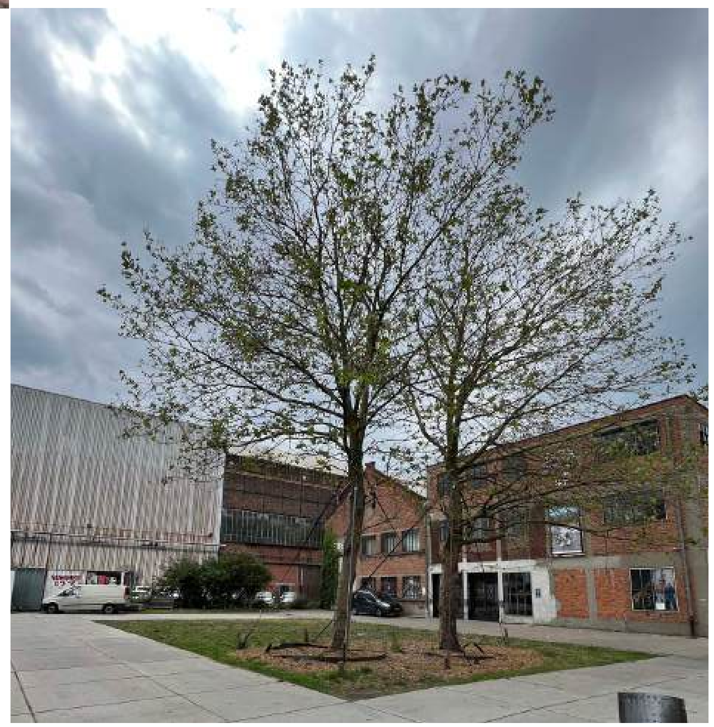


Figure 2 (B. Roobroeck). The trees at their new location in the centre of the square.

Assignment 2: Transplanting and Aftercare

We explain this by describing the actions that were taken in chronological order.

April 2022

The entire root ball was cut off at the desired depth, retaining some thicker roots. In this way, a fully compact root ball could be formed that, by retaining a few thicker roots, minimised planting shock. A root-proof cloth was placed around the root ball to prevent it from growing wider again. The existing root ball was loosened by using pneumatic air injection, whereby a phosphate fertiliser was injected. This fertiliser ensured that root growth was further stimulated. The root ball was then covered with well-matured compost and wood chips.

May to October 2022

Moisture sensors were installed around the root ball of the trees, measuring and transmitting moisture levels at all hours. The trees were fitted with an automatic irrigation system controlled by the soil moisture sensors. On average, the trees received a weekly watering of 50 litres per m^2 of root ball.

Late August

The building next to the trees was demolished, freeing up the trees. As the trees had a smaller root ball due to preparation for transplanting, pruning was necessary to ensure stability.

Autumn 2022

Now that the new planting location had been definitively determined, the soil on site could be examined. This showed that it was full of stone rubble that had to be excavated and removed. 40 m^3 of substrate was provided per tree.

December 2022

The tree was effectively transplanted. Because there was too much rubble in the soil, it was not possible to build a system to support the tree under the root ball. So, the tree had to be lifted using a sling around the trunk. This made the density of rooting enormously important. The preparatory work ensured that the root ball was very densely rooted on the outside, allowing all the soil to be carried integrally with the root ball.

Figure 4 (K. Dupon). Moving one tree at a time from the old to the new location.

Figure 5 (K. Dupon). Planting the trees at their new location.

April to October 2023

Watering was done weekly according to the levels of soil moisture. It was crucial to match the specific need for watering to the actual need as indicated by the soil moisture levels. Due to technical limitations, it was not possible to install an automatic irrigation system at this location.

Evaluation at the end of summer 2023

Although the tree had very thin foliage, no branches had died. The mulch layer applied at transplanting had all but disappeared by the end of June 2023. The mulch layer was then replenished. Inspection of the superficial rooting found that the tree was forming plenty of new roots in the mulch layer. We can therefore assume that the tree initially reduced its leaf volume after transplanting in response to the root loss and that the tree is primarily investing in forming new roots.

B. Explanation of the Case

Tree Function and Structure

To assess the transplantability of trees, it is necessary to assess both the above-ground and below-ground structures. Transplanting is one of the most unnatural things that can happen to a tree and this process causes it a great deal of stress. It also requires a considerable investment. So, it is crucial that the tree is not only well prepared but can also be sustainably preserved after transplantation. Structural problems, both in terms of the structure of the crown and root system and possible infestations, should be recognised as early as possible so that the chances of successful transplantation are optimised from the start. Although time consuming, manual digging partly revealed the root architecture, such as the type, thickness, and density of the roots. Through the knowledge of root architecture, methods to make the root ball and mitigate plant shock were possible. These seemingly simple actions are sometimes the difference between success and failure.

Soil Science

Knowledge of the soil and soil conditions in both the old and new locations is an absolute must for successful transplanting. At the old location, digging holes revealed the root system and its depth. At the new location, an analysis of the soil revealed that the existing soil quality was inferior because of soil compaction and lack of soil life. Know that it is not just about ensuring that the new growing site is suitable for the tree; it should also be suitable for water management. For example, the soil must be able to provide sufficient water in periods of drought, and in cases of excessive rainfall, excess water must also be drained smoothly. By altering the soil texture (adding more clay) and structure (adding more organic material), the water buffering capacity rises.

Tree and Shrub Planting and Aftercare

As described, a transplantability study was carried out, which conforms with the guidelines of the European Tree Planting Standard (ETPLS). This means that all the topics below were covered:

1. Time of planting: in winter, when the tree was inactive.
2. Transport: although only 200m, the route needed to be checked. The trees were lifted with a crane and put on a deep loader.
3. Root management: through a root ball but not cutting all the roots immediately to mitigate the stress.
4. Site and soil amendment: as described above.
5. Planting pit adjustments: as described above.
6. Tree placement/planting: with a crane, with special care taken of the stem base as most of the lifting force was concentrated on that part of the tree.
7. Anchorage systems: an underground system with 3 cables per tree, securing the root ball and tree.
8. Stem and crown protection: during lifting.
9. Mulching: adding mulch and replenishing.
10. Water supply systems: not feasible for automatic irrigation, but soil moisture sensors monitored the water buffer and notified the manager.
11. Tree pruning at planting: minimal formative pruning for practical, stability, and physiological reasons.

1.7.4. Case Study: Tree Assessment

Kamil Witkoś-Gnach

INTRODUCTION

This case study shows the basic tree assessment procedure of a small-leaved lime tree situated on a heavily used regional road in a rural area. This specific tree, standing amidst a historical avenue, exhibits several distinctive characteristics that demand careful evaluation and prompt action.

SEE TOGETHER WITH:

Diagnostic Features,Tree Assessment

A. DESCRIPTION OF THE CASE

The mature tree under consideration stands alongside a busy regional road, forming an integral part of a historical avenue. This avenue holds ecological significance, as some of its trees provide a habitat for the hermit beetle, Osmoderma eremita. Despite its landscape, historical, and ecological value, this tree has endured various challenges.

Basic Tree Assessment Procedure

The decision to subject the tree to an individual assessment was made during a routine drive-by check. During this initial observation, it became apparent that the tree was in a state of heavy decline, with several fungal fruiting bodies prominently visible on its trunk. This alarming finding prompted the immediate initiation of an individual assessment to comprehensively evaluate the tree's health and determine the necessary course of action.

Preparation: Health and Safety Considerations for Inspecting Trees Alongside the Road

Ensuring the safety of the tree inspector is paramount when assessing trees along a heavily trafficked rural road with limited space for manoeuvring. Below are the essential preparations and safety measures that must be considered before conducting the assessment:

- **Heavy-Use Traffic Awareness:** Acknowledge the presence of heavy traffic in the rural area and be prepared for the associated risks. Recognise that the road's proximity to the tree may expose you to vehicular hazards, including speeding vehicles and sudden lane changes by drivers.
- **Informing the Road Authority:** Prior to the inspection, communicate with the relevant road authority to notify them of the assessment. Request the emergency phone number of the road authority in case of unforeseen emergencies or accidents during the assessment.
- **Visibility and Safety Gear:** Prioritise visibility to approaching vehicles. Before venturing near the road, wear a high-visibility jacket or vest to make yourself easily seen by drivers. Whenever possible, approach the tree from the outer edge of the treeline to minimise your exposure to oncoming traffic.
- **Aural and Visual Awareness:** Avoid using headphones or any other items that may impede your hearing or peripheral vision. Being attentive to your surroundings is critical for your safety, especially near a busy road.
- **Vehicle Parking:** Park your vehicle in a safe and designated parking area nearby. If such an area is not available, coordinate with the road authority to ensure a secure spot for your vehicle. Ensure that your vehicle's position does not obstruct traffic flow or pose a hazard to other road users.
- **Emergency Preparedness:** Carry a fully charged mobile phone for communication in case of emergencies. Familiarise yourself with the location and accessibility of emergency services.

By diligently adhering to these safety measures and taking precautions, the tree inspector can minimise the inherent risks associated with assessing trees alongside a busy rural road. Prioritising safety not only safeguards the inspector's well-being but also enables a more effective and secure evaluation of the tree's condition.

Figure 1(K. Witkoś-Gnach). Fungal fruiting bodies present on the trunk.

Figure 2 (K. Witkoś-Gnach). The crack along the trunk.

Figure 3 (K. Witkoś-Gnach). Extensive dieback of the crown.

Tree inspection

A basic assessment method is employed to inspect the tree, involving a combination of visual observation and other sensory cues, complemented by tools such as a probe, mallet, and binoculars. The entire assessment process is meticulously documented using a tablet equipped with specialised tree management software.

During the inspection, the tree is thoroughly examined from ground level, considering all available angles to ensure a comprehensive evaluation of its condition and structural integrity.

Site considerations

Firstly, the site where the tree grows is evaluated. There are a number of key points to consider:

- Proximity to Road: The trunk of the tree is positioned just 0.5 metres from the road verge, exposing it to potential hazards associated with road traffic, including pollution, the risk of vehicle impact, and salt spray during winter road maintenance.
- Crown-Raising Procedure: Historically, the trees in this avenue underwent a heavy crown-raising procedure which involved the removal of large-diameter limbs (over 15 cm in diameter). The impact of this procedure on the tree's health and structural integrity requires examination to gauge its significance.
- Soil Modification: The soil around the tree has been repeatedly lowered to facilitate improved water flow away from the road. This modification affects the tree's root system and its ability to access essential nutrients and water.
- Lack of Regular Maintenance: Alarmingly, the tree has not received regular assessments or maintenance, rendering it susceptible to various stressors.

Diagnostic features on tree

The tree presents several diagnostic features that indicate its deteriorating physiological condition and mechanical integrity:

- Tinder Fungus Fruiting bodies: On the trunk, fruiting bodies of the tinder fungus (*Fomes fomentarius*) are visible at different heights (approximately 2 metres, 4 metres, and 6 metres) on different sides of the trunk. These fungal growths have been observed for several years, indicating an ongoing issue.
- Longitudinal Crack: A prominent longitudinal crack, approximately 4 metres in length, runs from the base of the trunk upwards, further compromising the tree's structural stability.
- Extensive Wood Decay: The trunk displays extensive wood decay, as evidenced by the ease with which an arborist's probe can penetrate the trunk.
- Mechanically Damaged Roots: The area around the tree shows signs of mechanically damaged roots, further impairing the tree's ability to access nutrients and water.
- Dead Branches and Limbs: Throughout the crown, numerous dead branches and limbs are observed, including some that have broken-off and are hanging, rendering the main crown predominantly lifeless and indicative of the tree's severe decline.
- Leaves that are scarcer and smaller than usual are present throughout the crown.

Result of the Assessment

Upon a thorough assessment and analysis of the aforementioned factors, it has been determined that the removal of the tree is imperative and has been assigned a high priority level. The diagnostic features evaluated during the assessment were found to be sufficiently comprehensive within the scope of this assessment, rendering further investigations unnecessary and impractical.

All actions regarding the tree's removal will be conducted in consultation with the relevant nature conservation agency, ensuring compliance with environmental and ecological regulations. To safeguard the potential habitat of the hermit beetle, an entomologist expert will be enlisted to provide specialised guidance during the tree removal process.

B. EXPLANATION OF THE CASE

Management History

In this case study, understanding the tree's management history is of great importance. The original planting of the tree avenue was driven by significant landscape and ecological considerations, reflecting a commitment to preserving natural beauty and biodiversity. Historical documentation confirms the avenue's existence for over a century, underscoring its cultural and environmental significance.
However, in recent decades, the pressures stemming from road maintenance have taken a toll on these trees, resulting in extensive damage. The approach to tree management during this period was marked by an imbalance and a deviation from best arboricultural practices, ultimately leading to harm inflicted upon the trees on multiple fronts.
The profound soil modifications carried out exceeded the tree's capacity to cope with the alterations. The use of heavy machinery, such as diggers, for soil removal in an attempt to improve water flow had direct consequences, including the physical removal of tree roots and mechanical damage. Indirectly, these activities altered the soil level and resulted in the removal of valuable soil, further diminishing the tree's ability to access essential nutrients and water.

Over the years, the avenue's trees underwent a crown-raising procedure that extended beyond standard arboricultural practices. This involved the removal of major limbs in the lower sections of the crown, leading to substantial dysfunction within the main trunk. The pruning wounds left behind exposed a significant portion of the trunk, compromising its structural integrity. Perhaps most critically, the tree avenue suffered from a lack of regular inspection and maintenance by a qualified tree assessor. The absence of proper assessment overlooked the fundamental principle that trees should be assessed before any further management activities are undertaken.

Tree Assessment Analysis

The assessment of the tree followed a standardised protocol, prioritising safety while conducting individual inspections from various angles and at ground level. The findings from this comprehensive assessment provide a detailed picture of the tree's overall health and structural integrity.

From a distance, it became evident that the tree's crown was in a state of severe decline, readily distinguishable from the neighbouring trees. The crown displayed numerous dead limbs and branches, accounting for more than half of the crown volume. Notably, the current leaves were noticeably smaller and scarcer, signalling a significant physiological deterioration. A species-specific approach considered the potential for regrowth in response to reversible decline. However, the absence of recent regrowth indicated a high level of stress and dysfunction beyond recovery, suggesting that the tree was rapidly approaching the end of its life cycle. The extensive presence of dead wood within the crown already exhibited signs of weakness, with some limbs broken or hanging perilously above high-traffic areas, posing a safety hazard.

Inspection of the trunk revealed multiple fungal fruiting bodies, particularly of the tinder fungus. This type of fungus causes rapid wood decay, a process that is particularly rapid in softwood species like the small-leaved lime. The removal of limbs had exacerbated the wood decay, with the location of fungal fruiting bodies indicating decay at multiple levels within the trunk. Additional sound testing using a mallet confirmed the extensive decay. Furthermore, the longitudinal crack on the trunk displayed visible wood decay. A non-typical probe test on the trunk revealed that the probe could be easily driven into the trunk, indicating an advanced stage of wood decay.

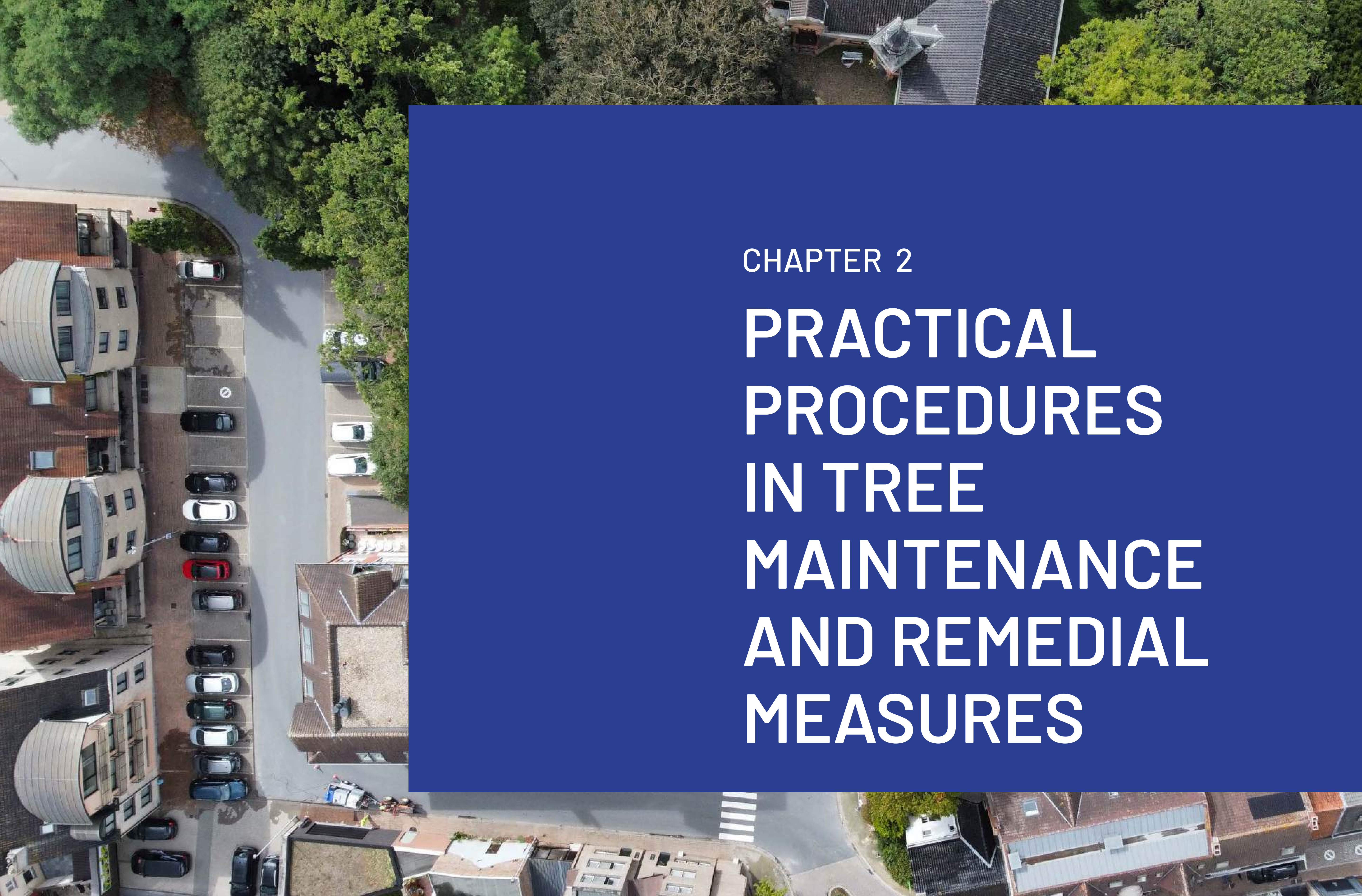
The investigation of the root system revealed severe damage, with the main roots cut approximately 0.5-1 metre away from the tree. Importantly, this occurred within the critical tree root protection zone. Substantial alterations to the soil around the tree were also evident.

Summary of Findings

The physiological condition of the tree was deemed critical, with the entire tree in a state of decline and approaching the end of its life. The mechanical integrity was also critical, as all parts of the tree, including the root system, trunk, and crown, exhibited significant weakening. The absence of compensatory growth indicated that the current stage of decline was irreversible.

In conclusion, the tree assessment revealed a dire situation, with both physiological and mechanical aspects of the tree's health in a state of critical decline. The combined factors of extensive wood decay, damaged roots, and a severely compromised crown underscored the urgency of addressing the tree's condition and the importance of preserving the safety of those in its vicinity.

Figure 4 (K. Witkoś-Gnach). The tree failed in an autmn storm. Luckily it fell allong the road and there were no damages. Despite the warnings and notices raised by a member of public the road athority ignored the obvious signs for over a year.



CHAPTER 2

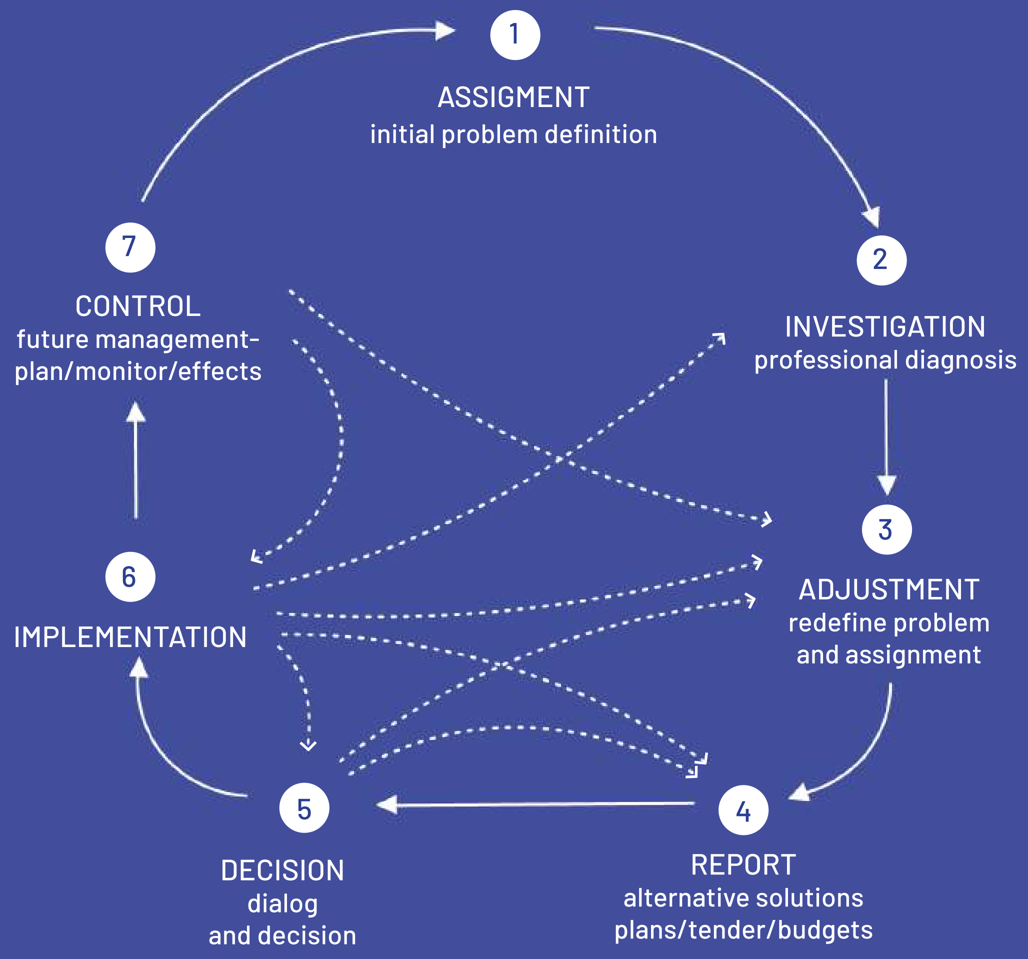
PRACTICAL PROCEDURES IN TREE MAINTENANCE AND REMEDIAL MEASURES

INTRODUCTION

Whereas Part 1 focuses on the theoretical foundations of arboriculture, this section looks at how this theory can be applied in a number of practical work cases that an ETT may typically encounter. Thus, the material in the following chapters will provide some guidelines for proper task management. This is where we go inside the head of a tree specialist to understand their thinking patterns when addressing a specific problem. As we conceptualise the thinking process, we always encounter the same pattern, which is a never-ending loop of steps that are taken while the assignment is being worked on.

So, whenever a new practical tree care job is to be carried out, it is useful to follow a general work process that protects you from delivering fundamentally flawed work. It is also important that there is a clear and well-defined structure in the reports and written correspondence, as this will dramatically enhance the level of professionalism.

THE FOLLOWING STEPS CAN BE USED METHODOLOGICALLY AND ARE DISCUSSED IN THE CHAPTERS BELOW. OF COURSE, PLEASE BEAR IN MIND THAT THIS DIAGRAM IS A GUIDE, NOT A STANDARD.



1. Assignment: Make sure that the job is ordered in writing. Make sure that the client is informed in writing about your basic requirements, remuneration, the work you will undertake, and relevant rules or regulations covering health and safety, biodiversity, and so on. It is a good idea to include a permanent referral to your business details (such as registration number, legal address, and so on) in your email signature, together with a link to your homepage. Also ensure an agreement between yourself and the client regarding price variations, milestones, timetables, and deadlines.

2. The scope and limits of the assignment are often defined by the client. Remember to communicate to the client that the definition of the problem and, therefore, the assignment may need to be adjusted after the initial in-depth investigation of the problems. Take care not to issue price guarantees or fixed prices until you have carried out an investigation at the location.

3. Investigation: Take care not to "jump too hastily" to a specific solution and implementation strategy. Carry out a proper investigation to clarify the significant factors and mechanisms to avoid a biased diagnosis. Also consider any practical obstacles, security, or traffic issues which may have an impact on the problem.

4. Adjustment of problem/assignment: A proper investigation often reveals new aspects of the problem/assignment. Make sure that an adjusted assignment is clarified and accepted by the client.

5. "Plan of approach": Report back to the client in writing and suggest alternative solutions. If relevant at this stage, the most reliable alternative could be specified by 1) what needs doing; 2) the resources necessary; 3) the timing of the plan; 4) the budget/tender; and 5) what the delivered product should be. Basically, make the plan of approach SMART. You will find out more about this topic in Chapter 3.1. Performance Description. A complete management plan, looking at least 10 years ahead, may be relevant but depends on the assignment.

6. Decision process: The client and relevant stakeholders consider the alternative solutions. Eventually, budgets/tenders for specific solutions may be requested, which may involve having to revise aspects of the solutions proposed. When the client decides to accept a given action, this should always be confirmed in writing before implementation is initiated.

7. Implementation: The job is carried out. New knowledge or problems may be exposed during the implementation, which may alter the diagnosis and change our understanding of what the most appropriate solution is. This may invoke a new round of making adjustments to the assignment, finding alternative solutions, and decision-making from the side of the client (the dotted lines in the figure).

8. Control/monitoring and future management plan: At this stage, control is carried out to ensure that the applied treatment solved the problem outlined in the assignment. This may be detectable immediately or after several years. If long-term effects are expected, a plan for monitoring should be suggested and organised. Too many arboricultural tasks are carried out without monitoring to check that the desired outcome is achieved, which is basically wasteful. A professional approach could, therefore, include a plan for future management.

2.1. WORK SITE SAFETY AND RISK ASSESSMENT WHEN CARRYING OUT TREE WORK

Peter Hjelmqvist & Daniel Daggfeldt

GENERAL OBJECTIVE

An ETT is expected to have a broad understanding of the many aspects of worksite safety and the risks associated with tree care operations. This includes identifying and mitigating risk; understanding which EU, national, and local legislation affects occupational health and safety; and who is responsible, both within the organisation and out in the field, regarding the working environment.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- understand the requirements and processes involved in risk assessment for tree work;
- undertake a risk assessment for a tree worksite and make an overall safety plan for a complex tree care operation;
- identify safe equipment, working procedures, and training requirements for tree planting, tree climbing and/or the use of mobile elevating work platforms, the use of a chainsaw from mobile elevating work platforms and/or rope and harness, tree pruning, tree dismantling, tree felling, the installation of bracing and propping systems, chippers, stump grinders, other relevant machinery, first aid, etc. (in accordance with technical regulations);
- observe safety regulations as set out by relevant trade/professional associations or other relevant authorities;
- ensure all equipment is regularly maintained;
- supervise the safe, correct, and environmentally conscious use of materials, hand tools, machines and products, and take corrective measures where necessary with special attention to the framework of healthy, safe and environmentally conscious work;
- select the right techniques and equipment to work safely in trees, with special attention to rope techniques, aerial work platforms, scaffolding, and ladders;
- ensure compliance with current national and European regulations on the use of positioning harnesses, work platforms, scaffolding, and ladders, with special attention to the current code of good practices for the use of chainsaws at heights;
- supervise the correct use of collective and personal protective equipment for tree work; and
- define the work and safety procedures for the use of material and equipment for tree work.

SEE TOGETHER WITH

Tree Assessment, Legal Regulations for Carrying Out Tree Maintenance, Professional Organisations and Trade Unions at European and National Levels

ESSENCE OF THE TOPIC

There are many inherent risks to carrying out tree work. Risks can be associated with the equipment used, such as chainsaws, stump grinders, and elevated work platforms; or with the tree itself, such as dead wood, cracks, fractures, and so on. Moreover, complex worksites, in which there may be subcontractors who need to be informed and coordinated, can also present risks. Risk can never be eliminated; however, the core strategy of risk management is to reduce the level of risk to an acceptable level. The baseline of this strategy is a systematic thought-through approach in which risks are identified and measures are implemented that cover all work activities and all levels of staff. An effective technique or tool for achieving this strategy is to repeat the following four-step circular process:
investigate risks – risk assessment – risk mitigation – control, where control will lead us back to investigate.

This process is repeated until the outcome *acceptable level of risk* has been achieved and becomes a protocol. It is crucial, though, that this process stays live. Risk mitigation is not a one-off task but a process that permeates all operations, from the early planning stage to follow-up and control once the work is done.

A. Work Site Safety

Work site safety is so much more than working carefully with sharp tools around climbing ropes. The aim of a healthy and safe work environment should influence decision-making throughout the entire organisation.

Ensuring work site safety means not just being concerned with avoiding accidents and their related injuries (including those caused by poor ergonomics), but also ensuring good mental health in an inclusive and equal workplace.

The systematic approach can be used both at a large scale to see if policy documents, reporting, and auditing are working to achieve the desired outcome, and at a more detailed level when performing an on-site risk assessment after a changed condition or criteria.

Working with trees in a safe way not only includes understanding biomechanics in order to be able to read the tree, but also being able to identify external risks on the work site such as traffic, public access, and interfering utility lines and pipes. Given the complexity of these multiple and often overlapping risks, tree care operations are naturally affected by several health and safety laws and regulations covering both operations and equipment. To have a safe and healthy work site, we need to reduce the risks to an acceptable level.

KEY TERMS

Work site safety: ergonomics, health and safety, work environment

Risk mitigation: hazard, risk, risk assessment, risk mitigation

Systematic approach: safety plan

Legal framework: traffic environment, personal protection equipment

B. Risk Mitigation

B.1. What is Risk?

A risk is the probability of a dangerous event or exposure occurring and the consequences if it occurs, in the form of injury or ill health. If we simplify it down to the multiplication 'probability × consequence = risk', one will easily realise that if either of the factors are eliminated or brought close to zero, then the risk is also eliminated.

The risk of damaged property can be approached in a similar manner, where the consequence is replaced by, for example, capital loss. When plotting the risk formula into a graph, we obtain a risk matrix (see Figure 1). This effective table helps to simplify the risks by dividing them into categories.

B.2. Identifying Risks

The first step in risk management is identifying hazards and the associated consequences by applying the matrix. In tree work, the potentially hazardous event could be a branch failure due to a compromised structure. Depending on the probability of failure and the consequences if it were to fail, the risk may be anywhere between almost none and very high.

Examples of what affects the **probability of failure:**

- vitality and structural condition of the assessed part of the tree;
- exposure to adverse climatic conditions and recent or planned changes to the tree's environment;
- species specific properties.

Examples of what affects the **consequences of failure:**

- size/weight of the assessed part of the tree;
- presence of target and frequency of presence;
- 'value' of the target.

A high probability of failure situated in a rarely visited remote woodland will have an extremely low consequence for us and hence no risk. On the other hand, if the identified target is a very frequently used bus stop, even a low probability of failure will result in a higher risk, which will require mitigation. The process of identifying risks is therefore a combination of looking for potential targets and dangerous events. This can be within the organisation where dangerous machinery, traffic, or the weak mechanical structure of a tree may pose a danger to the operator or climbing arborist. Tree-related risks can also impact public domains when a failure may interfere with utility lines, obstruct traffic, or strike a member of the public. At all events, there needs to be both probability and consequence to form a risk. Note that in Chapter 1.5.2. Tree Assessment we discussed the difference between risk management and tree assessment. The latter is part of risk management.

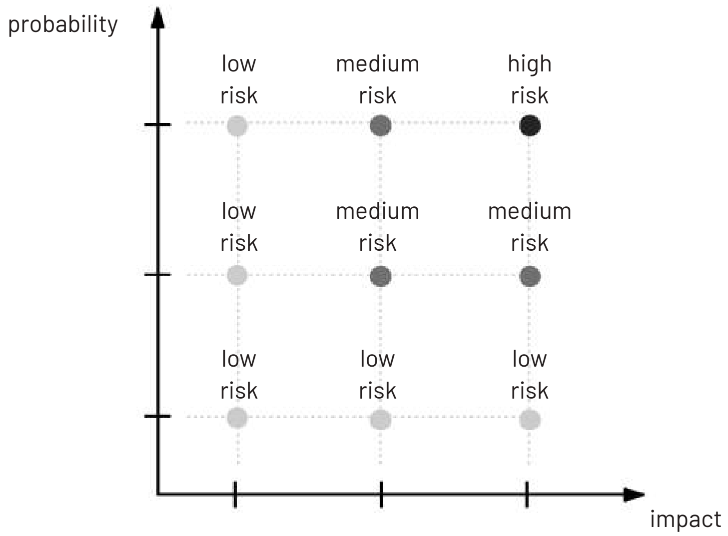


Figure 1. Risk matrix. (Adapted from Kaya 2018)

B.3. Risk-Benefit Analysis

After identifying the risk or risks associated with the action, machinery, etc, it is necessary to weigh the risks against the benefits in order to establish working procedures and provide justification for why the levels of remaining risks are acceptable. Risk-benefit analysis evaluates the need for risk mitigation. This risk-benefit analysis is also applied in the flowchart from the tree assessment standard ETAS and chapter 2.3 Tree Care and Remedial Measures. For more information about this analysis, we refer you to Chapter 1.5.2 Tree Assessment.

C. Systematic Approach Strategy for Risk Mitigation

As we described above, it all comes down to having a systematic approach/strategy to minimise the risk, which changes the risk-benefit analysis/balance in favour of the benefits. In practice, this can be done by implementing and repeating the following four-step circular process: *investigate risks – risk assessment – risk mitigation – control.*

C.1. Investigate

The first step, which is about identifying the risks to produce a risk-benefit analysis, was explained in the previous chapter (B).

Figure 2. The wheel of systematic approach to healthy work environment in four-steps.

C.2. Risk Assessment

The term 'risk assessment' is often used to describe the entire process, but more precisely, it is the second step in the four-step process described above. It is when we decide how severe a risk is by combining the identified probability and consequences. In this step, the risks are also prioritised according to their severity, and if they are found to be at an unacceptable level, a measure to eliminate or mitigate them to an acceptable level is decided. A common approach for evaluating identified risks at work is by setting up a risk list or risk table, in which the risk sources and hazards are listed and evaluated. One risk source can be connected to multiple hazards and targets and hence generate more than one risk. Probability and consequences are quantified for each one according to our risk matrix, and their sum represents the quantified risk, so probability x consequence = risk. Measures to bring the risks down to acceptable levels are also described above. Often, the suitable measures are dictated by the relevant rules and legislation regarding the listed hazards, operations, or equipment. In practice, risk assessment within a company or organisation for a working site is divided into generic and specific risk management.

C.2.1. Generic Risk Assessment

All the risks that are identified when looking at the entire organisation are added to and analysed in the generic risk assessment as a part of the strategic planning and mapping of all processes and tasks executed within the organization. Depending on the national legislation and often the size of the organisation, there are different demands regarding the documentation and revision of this process.

During the safety rounds and inspections, the sources of risk and hazards are identified, evaluated, and documented. Suitable measures are then put in place to eliminate or minimise the risk of any that generate an unacceptable level of risk.

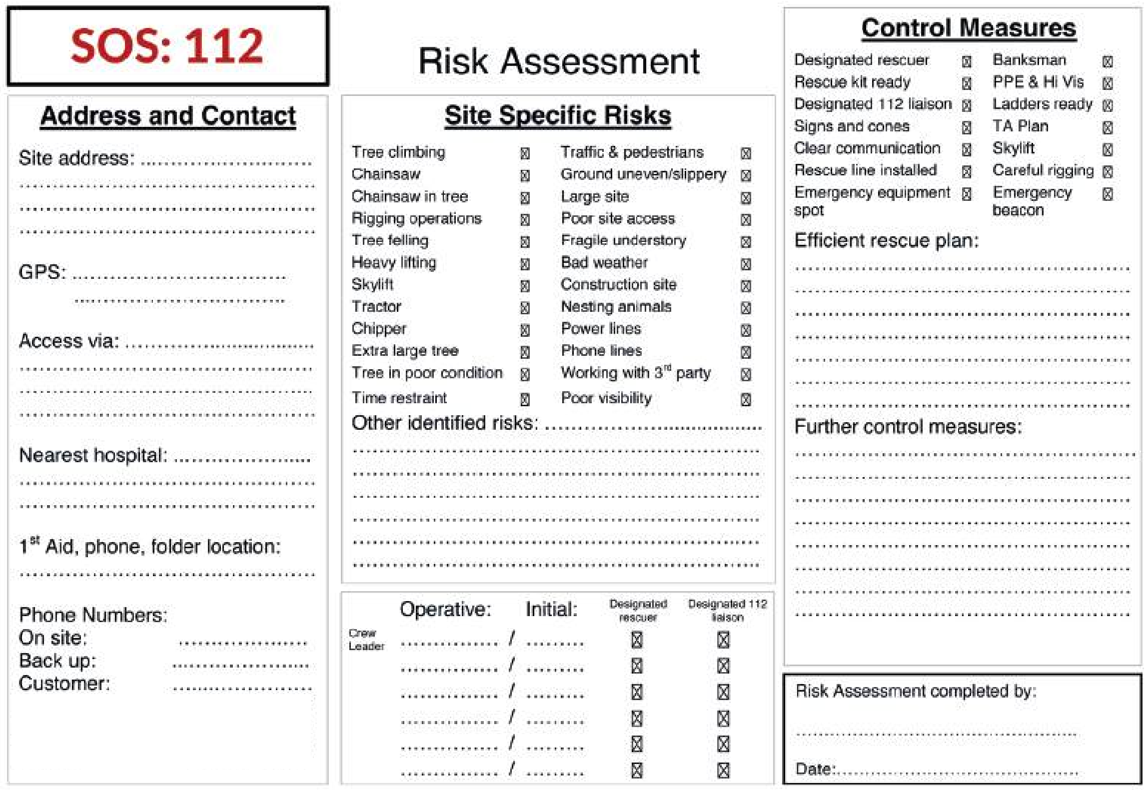
Risk source	Hazard	Target	Risk type	Probability 1-5	Consequence 1-5	Risk	Measures
Chain saw	Cut	Operator	Work environment	2	4	8	Risk minimised by the use of PPE and relevant training and experience.
Work near traffic	Traffic accident	Operator and/or public	Work environment and public safety	2	5	10	Risk minimised by hi-viz, shut-off work area, and relevant training.
Fuel for machinery	Pollution	Environment	Environ-mental	2	2	4	Risk minimised by routines around fuelling spots and spill trays.
...	...	...	...	...	...	...	...

Table 1. Generic risk analysis, example of generic risk assessment for tree care operations. All identified risks are to be dealt with in the table. Probability and consequence are quantified, and the product is a quantified risk.

This is recommended even when there is no strict demand for documentation. If anything ever goes wrong, a traceable process will be helpful in finding out what went wrong and how we can avoid a similar accident from occurring again. For example, *was the hazard missed in the process, or was one of the measures not sufficient or maybe neglected? Maybe all the measures had not been communicated with all the co-workers?* Feedback and re-evaluation are key features of risk management and should be done regularly, especially after accidents, incidents, and near misses. It's the analysis of the 'ouches' and 'whoopsies' that prevent the serious accidents.

C.2.2. Site Specific Risk Assessment

During the strategic planning of operations, all possible risks are identified, and measures are suggested. These measures are then implemented in the site-specific risk assessment. One approach to this is to have a checklist to go through of which risks and measures are relevant for the task or the site. This document is also a good place to note relevant information that is part of risk management; who's on site and who does what, access to first aid and emergency services, GPS location, etc. The site-specific risk assessment can be in digital or paper format. What is important is that it's done and that all the workers involved are aware of it and its content and conclusions.


SOS: 112

Risk Assessment

Address and Contact

Site address: ...

GPS: ...

Access via: ...

Nearest hospital: ...

1st Aid, phone, folder location: ...

Phone Numbers:
On site: ...
Back up: ...
Customer: ...

Site Specific Risks

Tree climbing ☒ | Traffic & pedestrians ☒
Chainsaw ☒ | Ground uneven/slippery ☒
Chainsaw in tree ☒ | Large site ☒
Rigging operations ☒ | Poor site access ☒
Tree felling ☒ | Fragile understory ☒
Heavy lifting ☒ | Bad weather ☒
Skylift ☒ | Construction site ☒
Tractor ☒ | Nesting animals ☒
Chipper ☒ | Power lines ☒
Extra large tree ☒ | Phone lines ☒
Tree in poor condition ☒ | Working with 3rd party ☒
Time restraint ☒ | Poor visibility ☒

Other identified risks: ...

	Operative:	Initial:	Designated rescuer	Designated 112 liaison
Crew Leader	...	...	☒	☒
	...	...	☒	☒
	...	...	☒	☒
	...	...	☒	☒
	...	...	☒	☒
	...	...	☒	☒

Control Measures

Designated rescuer ☒ | Banksman ☒
Rescue kit ready ☒ | PPE & Hi Vis ☒
Designated 112 liaison ☒ | Ladders ready ☒
Signs and cones ☒ | TA Plan ☒
Clear communication ☒ | Skylift ☒
Rescue line installed ☒ | Careful rigging ☒
Emergency equipment spot ☒ | Emergency beacon ☒

Efficient rescue plan: ...

Further control measures: ...

Risk Assessment completed by: ...

Date: ...

Figure 4. The site-specific risk assessment often also serves as a document where, in addition to identified risks and measures, on-site workers will also find contact details and emergency procedures.

C.2.3. Tree Climbing and Working at Heights

When tree work involves climbing, we need to be aware of the obvious risks connected with working at heights and working suspended on ropes. Not only the risk of falling, but also the more complicated rescue procedures if anything happens up in the tree or work platform. Most countries in Europe have similar legislation around climbing and work positioning. It is allowed when safer work methods, such as work platforms, are not justified; however, a risk assessment must state that the work can be performed in a safe manner and approved equipment must be used. All workers involved should have relevant training for their tasks and equipment used, including rescue techniques. A rescue plan should be in place so that any member of the staff can be evacuated in the event of an emergency.

C.3. Mitigation

Step 3 is the action of mitigating the risks. The foundation for this involves policies and routines where communication is key. Just like a tree needs a vital root system in healthy soil to maintain a sound structure, our health and safety approach needs a base to stand on.

If we look at the process at large, the foundation for achieving a sound working environment is a health and safety policy and its accompanying routines and procedures. These documents can serve as a road map for the process.

Our Work Environment Policy and routines tells us:

- where we are;
- where we want to go; and
- how we get there.

The policy and routines not only need to be regularly checked against each other, but also against the feedback and reporting from the daily operations. This feedback and revision ensure that the policies, routines, and documents are still valid and that they are a realistic approach to reaching the desired end result.

National legislation will state whether this type of documentation must be a written document and how often it should be audited and revised. In Sweden, for example, work environment legislation has different levels of demand for documentation depending on the number of employees within the organisation. This also affects the level of sanctions if you fail to show documentation of appropriate measures; the number of employees will determine the magnitude of the fines. The severity of consequences is another parameter that affects the demand for documentation, proof of measures taken, and the level of sanctions.

Once policies and routines are in place according to legislation and industry standards, they are connected to the daily operations of the organisation or workplace. Through communication and participation, and by identifying or acquiring knowledge and competencies, tasks and responsibilities are then delegated within the workforce. It is important that all employees are aware of who holds responsibilities for what and what competencies and measures are required to maintain safe operations. It is always the employer that is ultimately responsible for ensuring that work is carried out in an approved and safe manner, but the decision-making and control can be delegated to anyone within the organisation with suitable competence and training. Employees, on the other hand, are required to follow established routines and use supplied PPE, etc.

C.4. Control

This stage of the process is where we actually start mitigating the risks and implementing the policies and routines outlined in the previous chapter. This is done in the generic risk assessment and later in the site-specific risk assessment, where all the identified risks are mitigated by stating what, who, and how. What is the problem, who will solve

the identified risks are mitigated by stating what, who, and how. *What is the problem, who will solve it, and how is it to be done?* The solution is then tested and controlled against the original risk. This will also produce feedback on the earlier processes being used, such as policies and current competences within the organisation.

It is incremental in that the policies and routines also include reporting and feedback systems for when the measures are actually tested. A plan of approach is worth nothing if it is not practically possible.

Conditions change, and predictability is key to safe work processes, which is why risk assessment never stops. By thorough planning and good communication, we will foresee many but not all risks. Incremental improvements, therefore, identified and implemented in the risk assessment, are part of an ongoing process that is carried out from the early planning stage to right before placing a cut while pruning. Re-assess and re-evaluate your work continuously. By noting what doesn't go according to plan, we will be able to mitigate and change our plan of approach and, in the end, have a more predictable and safer work environment.

D. Legal Framework, Responsibility and Liability

The goal or essence of health and safety at work is to prevent employees from becoming ill or injured at work and to prevent work-related accidents. This is also stated in EU Directive 89/391/EEC – OSH "Framework Directive". National law based on this directive can be found on the EUR-LEX web portal, National laws implementing the OSH directive (https://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:31989L0391)

As mentioned above, the employer always has work-site safety liability and is responsible for making sure the employees can carry out their work duties without being injured or sick. That means, among other things, giving instructions regarding their work duties, informing them about risks at the workplace, avoiding injuries and accidents, and providing safe tools and personal protection equipment.

The employee, in return, has the responsibility of making sure to follow the regulations and safety rules, making the correct use of tools and machinery, and always informing the employer of any shortcomings or situations that can present a danger at the workplace.

The employer can appoint health and safety responsibilities in the organization. Such a distribution of responsibilities should be clear so that everyone knows what is required of them. Within an organisation, it is common to allocate duties to representatives and team leaders.

National and regional law may override the EU directive but only in the event that it is stricter, i.e., Directive 89/391 EEC is the base line. The same goes for local restrictions within an organisation or particular worksite. It may be stricter but not weaker than national and regional law and could, for example, state that all employees at a specific site should wear hi-viz clothing and helmets, even though the risk assessment has not identified the need for this PPE everywhere.

The European Framework Directive on Safety and Health at Work (Directive 89/391 EEC)

- The Directive aims to establish an equal level of safety and health for the benefit of all workers.
- The Directive obliges employers to take appropriate preventive measures to make work safer and healthier.
- The Directive introduces as a key element the principle of risk assessment and defines its main elements (e.g., hazard identification, worker participation, introduction of adequate measures with the priority of eliminating risk at source, documentation, and periodical re-assessment of workplace hazards).

SELF-CHECK QUESTIONS

1. Explain why active reporting is important for the systematic implementation of health and safety policies in the working environment.
2. What is the role of a safety representative?
3. Who has the main responsibility for health and safety in a tree care company?
4. What needs to be considered when planning tree work close to a busy road?
5. Who is usually responsible for on-site risk assessment?
6. What is the significance of the target in risk assessment?
7. Give two examples of when risk is mitigated by amending the consequences?
8. Give two examples of when risk is mitigated by amending the probability?
9. Describe the legal outlines for your country of documenting the health and safety work in an arboricultural company.

TERMINOLOGY

close call – a near accident or incident that could have caused harm
deviation report – reporting of accidents, incidents, and close calls aimed at improving health and safety measures and policies
MEWP – mobile Elevated Work Platform, a device for lifting people and equipment to work safely at height; can be truck-mounted, towed, or tracked; boom-lifts are most common for tree work
PPE – personal Protective Equipment is equipment used to minimise exposure to hazards; e.g., helmets, gloves, and goggles.
risk assessment – identifying hazards and finding measures to eliminate risk of harm
safety representative – safety representatives can be elected by the employees, trade unions or works councils, or appointed by the employer, depending on the country; they represent the workers in the work environment and health and safety matters; they take part in health and safety inspections and safety rounds
safety rounds – a walk through where managers, supervisors and safety representatives observe a workplace to identify risks and how mitigation is functioning; frequency is set by policy and regulations.
systematic work environment management – the procedures ensuring that health and safety matters are dealt with on a daily basis; a continuous, circular process giving feedback to health and safety policies
traffic control – temporarily changing or stopping the flow of traffic through or adjacent to a work site. Traffic control is heavily regulated

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https://www.av.se/arbetsmiljoarbete-och-inspektioner/arbeta-med-arbetsmiljon/systematiskt-arbetsmiljoarbete-sam/?hl=systematiskt%20arbetsmilj%C3%B6arbete%20en%20v%C3%A4gledning
UK *HSE, Health and Safety Executive, arboriculture and forestry: Resources such as case studies, video clips, research reports and leaflets can help you protect your health and safety and that of your employees.* Retrieved from: https://www.hse.gov.uk/treework/resources/index.htm
UK *ICoP for Arboriculture: Tree Work at Height (Edition 2, May 2020)*
https://www.trees.org.uk/Trees.org.uk/media/Trees-org.uk/Documents/ICoP/ICoP-Tree-Work-at-Height-May20-web.pdf

ESSENTIAL READING

To achieve safe and heathy work operations it often comes down to following industry best practice, government guidelines and equipment manufacturer's manuals. These may differ between countries.

ADDITIONAL READING

EU https://osha.europa.eu/en/safety-and-health-legislation/european-directives
European directives on safety and health at work (EU)
EU https://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:31989L0391
List of relevant health and safety legislation in the member states.
UK ICoP for Arboriculture: Tree Work at Height (Edition 2, May 2020)
Industry Code of Practice for Arboriculture Tree Work at Height
SE Systematic Work Environment Management (AFS 2001:1Eng), provisions
Provisions and recommendations on work environment management.

2.2.
CASE STUDY: WORK SITE SAFETY AND RISK ASSESSMENT WHEN CARRYING OUT TREE WORK

Peter Hjelmqvist & Daniel Daggfeldt

INTRODUCTION

This case study involves a standard tree pruning operation in an urban area based on a management plan. The main risks identified with the pruning operation are the trees' partly compromised structures; the close proximity to traffic; the presence of fixed or stationary objects that could be damaged, such as a stone wall and a church building; and the need for climbers to be working in the trees with chainsaws and handsaws. The old lime trees have high historic, cultural, and ecological values.

SEE TOGETHER WITH:

Tree Function and Structure, Tree Development and Growth Stages, Ecology and Biodiversity (Nature Conservation and Environmentally Friendly Practices), The Amenity and Monetary Value of Trees, The Social Value of Trees

This case mainly relates to the chapters Work Site Safety and Risk Assessment when Carrying out Tree Work, Selecting and Applying Appropriate Tree Care Techniques and Tools, Tree Care and Remedial Measures

A. DESCRIPTION OF THE CASE

The general process of the systematic approach to a healthy work environment follows the flow chart from 2.1. Work Site Safety and Risk Assessment When Carrying Out Tree Work, figure 2.

The following steps from the chart should be considered by the contractor at all times during the process, from assignment up to implementation:

1. carrying out an assessment of whether the technique chosen in the pre-work evaluation is appropriate;
2. deciding on safe systems of work that define the methods to be used to carry out the work;
3. ensuring there are adequately trained and proficient operators to undertake the work;
4. performing a site-specific risk assessment;
5. ensuring adequate emergency planning, including resources in the event of the need for aerial rescue, first aid, and/or evacuation; and
6. producing a clearly communicated plan that covers points (a)–(e).

Southeast of Stockholm, in the small coastal village of Dalarö, there are four old, pollarded lime trees (*Tilia × europaea*) in the yard of the local church. The trees have been inspected and found to be partly decayed due to heavy pruning in the past. The church is worried that they can collapse onto a historic stone wall, the church, and a road leading down to the ferry landing around the corner, which is very busy in the summer. The consultant recommends a weight reduction by lowering the limes by approximately 30%, and, at the same time, carrying out pollarding of the remaining growth. The trees have unusually high and different levels of pollarding points, which indicates that they have been topped in the past and then managed as pollards. Decay has developed in the old topping cuts.

The trees are protected by the following laws:

- The Swedish environmental code (12 kap. 6§ miljöbalken) based on its age, girth, and extensive hollowing.
- Government listed building (Statligt byggnadsminne).
- The Cultural Environment Act (Kyrkligt kulturminne 4 kap Kulturmiljölagen).

Figure 1. (D. Daggfeldt). The four pollarded lime trees on the border of the church yard next to the road (on the left) and the orientation satellite image with marked trees (on the right).

<table>
<tr><th>Tree no.</th><th>Species (common/latin)</th><th>DBH diameter at 1.3 m [cm]</th><th colspan="3">Notes (general notes, structural defects, pruning history, protection level etc.)</th><th colspan="2">Management recommendations</th></tr>
<tr><td>7</td><td>European lime Tilia × europaea</td><td>73</td><td rowspan="4">multi-stemmed</td><td rowspan="2">pollard</td><td rowspan="4">veteran tree/ protected tree</td><td rowspan="4">Weight reduction by approx. 30% height reduction</td><td rowspan="4">pollarding</td></tr>
<tr><td>8</td><td>European lime Tilia × europaea</td><td>67</td></tr>
<tr><td>9</td><td>European lime Tilia × europaea</td><td>90</td><td>pollard, severe decay/ hollowing, stem crack</td></tr>
<tr><td>10</td><td>European lime Tilia × europaea</td><td>84</td><td>pollard</td></tr>
</table>

Table 1. Generic risk analysis, example of generic risk assessment for tree care operations. All identified risks are to be dealt with in the table. Probability and consequence are quantified, and the product is a quantified risk.

Systematic Approach Strategy for Risk Mitigation

Investigate

The assignment was assessed by the company's production manager by looking at:
- the suggested work specification;
- the trees to be worked at; and
- the properties of the site.

The following plan of approach was established based on the above:
- The trees will be worked on by an arborist using a rope and harness (A MEWP was considered, but the approach was dismissed due to the limited space to operate it in and the close proximity to the road).
- Arisings will be stacked on site to be later picked up by a lorry.

The following risks were identified with the assignment:
- The work will be carried out in close proximity to traffic, which means there is a risk of being hit by traffic.
- Tree climbing – risk of a fall.
- The use of handsaws and chainsaws – risk of cutting oneself or equipment.
- The poor condition of the trees – risk of trees failing while being climbed.
- Traffic and pedestrians – risk of damage to vehicles and people.
- Fragile surroundings – risk of damaging trees, wall, streetlights, etc.
- Nesting animals – risk of damaging biodiversity, such as destroying habitat for roosting bats.

The procedures used for risk mitigation were:
- trained and experienced tree climbers;
- PPE and Hi vis clothing;
- signs and cones to control the traffic;
- clear communication on site between climbers and groundsmen; and
- an efficient rescue plan: emergency equipment spot, rescue line installed in trees, designated rescuer, rescue kit ready, and designated 112 liaison,

Control measures
An active system in place for staff reporting: deviations, close calls, accidents, risk observations etc.

Figure 2 (D. Daggfeldt). After the weight reduction the limes where pollarded where epicormic growth was removed. Then more than one climber could work in the same tree. Extensive decay was present around the pollard points due to heavy pruning in the past. A mobile platform was considered at the beginning of the work.

Figure 3 (D. Daggfeldt). Before and after tree pruning.

2.3. TREE CARE AND REMEDIAL MEASURES

Peter Hjelmqvist & Daniel Daggfeldt

GENERAL OBJECTIVE

This chapter serves as a guide in the decision-making process when assessing trees for tree care measures and common remedial measures such as pruning, cabling and bracing, planting, staking and guying, tree removal, pest and disease management, and interventions with the tree's surroundings.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- carry out inspections and aftercare/establishment operations;
- describe the biological/arboricultural optimal pruning plan for common street-, park- and open landscape trees;
- apply the best pruning operations within the available funds and resources and adapt to other limiting factors;
- explain why proper early pruning is necessary to achieve specific goals concerning the architecture of the tree;
- produce and implement a tree management plan; and
- instruct, supervise, and control tree pruning work, as well as ensure that the pruning work meets accepted standards.

SEE TOGETHER WITH:

What is the role of an ETT in modern arboriculture? Tree Development and Growth Stages, Soil Science, Diagnostic Features, Tree Assessment, Pruning, Tree Revitalisation, Work site safety and risk assessment when carrying out tree work, Selecting and applying appropriate tree care techniques and tools, Performance Description

KEY TERMS

General framework: control measures, loop, tree assessment

Explanation framework: cost-benefit analysis, intervention, non-intervention, management decisions, management recommendations, pre-assessment actions, risk-benefit analysis

ESSENCE OF THE TOPIC

Tree care is an essential part of maintaining the health, aesthetics, and ecosystem services (values) of urban trees. As we saw in Chapter 1.6.1. Pruning, most actions have a permanent effect on shifting the natural development of a tree. Hence, the essence of tree care and remedial measures is that the actions or decisions taken must be well supported through a holistic methodology that considers numerous preconditions. To ensure that all variables are considered when making decisions on tree care, one can follow a set flow of actions: a decision-making process that points out what tree care and/or remedial measures should be chosen in a specific situation. Be aware that working your way through such a decision-making process is not a one-time event but must be repeated every time tree care is considered, as the situation can change over time. In other words, this process is continuously looped by feedback and control measures.

A. General Framework of Tree Care and Remedial Measures

Many factors and preconditions must be taken into account before interventions in trees are carried out. Like all living organisms, trees react to the environment and actions taken on them. Since most interventions are irreversible, we will find that sometimes allowing the tree to follow its natural growth and recovery patterns may be the best course of action.

The proposed framework helps in finding a supported solution to choosing the right tree care and remedial measures. It basically comes down to answering three questions:

- Is there a need for an intervention or not?
- If so, what kind of intervention is needed?
- How 'intense' should this intervention be?

The answer to the first question of whether intervention is required is based on the nature of the diagnostic features described in Chapter 1.5.1 Diagnostic Features Part A.2. and can be carried out by expanding the flowchart from the tree assessment standard EAS (see Figure 1). We will get back to this step further into the process when weighing up costs, benefits, and risks. Knowing this, the first consideration for an ETT should always be: What are the consequences of no intervention? Both sides of the cost-benefit analysis will change in magnitude as we move down the decision tree and may therefore need to be re-assessed continuously throughout the process.

Question two determines which intervention is needed. This can be an intervention for the tree itself, such as improving tree health or structure; or for us as a society, such as mitigating risks or managing interference with infrastructure. It is therefore imperative to know the why and how of the intervention in order to choose the right method. For example, if a tree is considered a problem due to crown spread, a pruning specification that is not in line with arboricultural principles or species-specific properties may result in a tree with low vitality. This could, depending on the situation, cause it to be a hazard to its surroundings, thereby necessitating an even more costly management solution or even removal. There are many methods available for intervention, and choosing the right one depends on training, common/national practices, standards, and experience.

The third and final question is about determining the 'intensity' or 'dose' of the recommended intervention. This, of course, also depends on the tree's surroundings and the objectives of the management. For example, if two trees have the potential for a large branch to break, but the first tree is located next to a frequently used pathway and the second tree is located in a deserted corner of a park, then the benefits of leaving the branch on the tree will have to be weighed against the risks of losing or damaging a part of the tree through branch failure as well as the consequences of the failed parts of the tree hitting a target on the path.

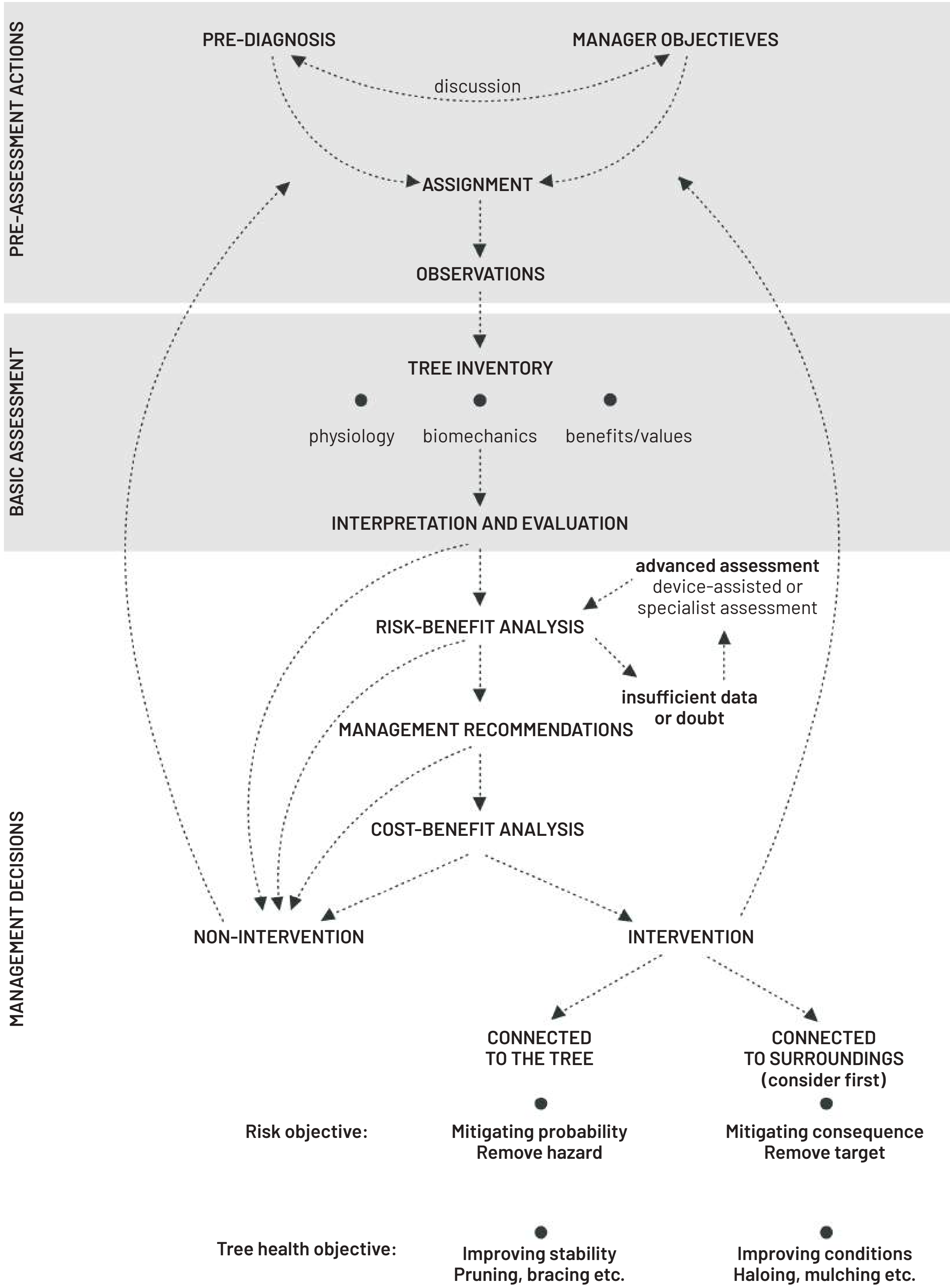

Figure 1. This flowchart has been based on a draft of the upcoming European Tree Assessment Standard. All tree work specifications are influenced by multiple variables, such as objectives, the current situation (inventory, plans, etc.), and the budget. The experience and knowledge of an ETT will take these into account and recommend a suitable approach. .

The management recommendations will specify the pruning for the first tree to be more intense due to the higher level of risk than the one with no target and hence no branch failure-related risks for the public. The objective decides the intensity.

There are several loops in the decision tree. Not only will we need control measures to check that the result meets the desired objective, but we will also need to make sure throughout the process that the decisions made do not conflict with each other. For example, will leaving dysfunctional wood for biodiversity purposes cohere with risk management, and will raising the tree's crown to avoid a conflict with infrastructure cohere with sustainable tree vitality? The end result is, in a way, a continuous loop, which ends when a decision is made not to intervene when the level of risk along with the expected development, response, and vitality of the tree are all at acceptable levels.

B. Explanation of the Framework

To further explain the flowchart, we will elaborate on significant points in the framework. The ambition is not to explain all the different types of tree care, such as pruning, bracing, cabling, revitalisation, etc. For pruning, bracing, and cabling, there are the European Arboricultural Standards available on the EAC website, and many member states have several guides and standards on different tree care topics. Tree revitalisation is described in depth in Chapter 2.4. Tree Revitalisation. The main purpose of this framework is to develop a thinking pattern or a roadmap to ask the right questions in any given situation and to come up with a sustainable solution for management.

Pre-assessment Actions

When following the flowchart above, our first step is defining the assignment. As with all agreements between parties, a well-defined assignment will minimise the risk of misunderstandings and surprises throughout the project. This is achieved through discussing the desired result or end goal, or in other words, what the objective of the potential tree care is. The baseline information is gathered, and limitations are set. If there is no current tree inventory for the site, this needs to be done to get an insight into the current conditions. More information on defining the assignment is described in Chapter 3.1. Performance Description.

Basic Assessment

The tree inventory with its set of parameters, as we saw in Chapter 1.2.1 Soil Science and Chapter 1.5.1 Diagnostic Features, leads to observations in three domains:

- Physiology: type of epicormic growth, defoliation, discolouration, root activity, life stage, etc.
- Biomechanics: fractures, dysfunctional wood, fungi, etc.
- Benefits/values: cracks and holes for biodiversity, eco-system services, etc.

The sets of parameters of the inventory will eventually shift the observations to an interpretation that forms an analysis or evaluation. For example, based on defoliation, the orientation of epicormic shoots, root decay, and the appearance of specific fungi at the buttresses, the basic assessment concludes that a tree is not stable. But the tree is also recognised as being the only large solitary veteran tree in the area, which implies that the tree has a high biodiversity and cultural value. This makes it necessary to weigh the different needs and values against each other.

Risk-benefit analysis

The risk-benefit analysis is an analysis that weighs risks such as members of the public being struck by falling branches against the benefits and values (ecological, social, and economic) associated with mature trees in the urban environment. In the example of the large solitary veteran tree, we have a safety risk due to stability reasons on the one hand and high biodiversity values on the other. Taking this analysis into account, a management decision needs to be made. If more information is needed to make the risk-benefit analysis, a more detailed assessment can be executed (advanced assessment), which may be of the tree itself (e.g., tomography, a pull test, or aerial inspection) or of the surroundings (e.g., soil analysis or visitor frequency of the site). Remember that the basic idea here is to ensure that the benefits outweigh the risks, finding an acceptable level of risk for the situation that maximises the benefits.

Management recommendations

After reaching a decision that ensures that the benefits outweigh the risks, the outcome will often be a set of management options, all with a different price and a different result. Suppose in the example of the large solitary veteran tree, we choose to keep the tree for biodiversity reasons. Consequently, since the tree is not stable enough to support itself and has associated safety risks, the following management options are possible:

1. do nothing to the tree itself and restrict access to the growing site;
2. carry out severe retrenchment pruning in order to assure that the probability of failure is minimised; or
3. carry out light retrenchment pruning to mitigate the risk, combined with improving the growing site.

Cost-benefit analysis

Once the recommended measures have been presented to the manager or tree owner, a management decision needs to be made. This is where the desired objective of the assignment is weighed against the expected outcome of the measures combined with the cost of performing the recommended tree care. In the case of the solitary veteran tree, we can choose Option 3 which is a compromise between Options 1 and 2. Remember that the basic idea here is to outweigh the cost with the benefits, while in the risk-benefits analysis, we outweighed the risk with the benefits. To make this analysis and come to a sustainable decision, a combination of experience, training, and dialogue with all the stakeholders is required. Note that there is not one right answer.

Non-intervention

As already discussed in Chapter 1.6.1 Pruning, almost all interventions have a permanent impact on the tree, which means, therefore, that any decision to carry out this work should be well supported. There are many different reasons why we can end up deciding not to do anything. It may be that there is no need for intervention, but this decision can also be reached if the costs or risks of carrying out the work outweigh the benefits.

Note that in the flowchart, there are shortcuts to the decision to not intervene after each of the decisions of interpretation and evaluation, risk-benefit analysis, management recommendation, and cost-benefit analysis. This very simple concept of doing nothing is harder than it seems. The arborist may be eager to do something to show his/her skills, create job opportunities, and be in control. Moreover, the stakeholders may be keen for action.

Moreover, the stakeholders may be keen for action to be taken. It is also important to note that non-intervention is not a permanent solution; a job can be done later but it can't be undone. Hence, there is a loop to the pre-assessment actions from the non-intervention decision. Control and follow-up schemes are always important, no matter what we decide to do or not to do.

Interventions

Going further along the flowchart, we divide the interventions into objectives connected to the tree and objectives connected to the surroundings. In the first objective, the tree occupies a central role in the decision-making process. In the second, the decision-making process focuses on the surrounding area, such as removing paved surfaces around the trees or pruning heavy, high-risk branches next to a bus stop. It is important for an ETT to not only have a holistic approach of looking at the tree itself, but also at its surroundings. This is an essential element of the definition of the ETT as described in the beginning of the study guide (What is the role of ETT in Modern Arboriculture?). Tree care interventions in practice tend to focus mostly on risk mitigation where the tree is not at the centre of the decisions. An arborist should always strive to put the tree first. In the example of the large solitary veteran tree, putting the tree first could mean addressing the risk by removing the target of the hazard by enlarging and fencing off the growing site and looking at the actual probability of a failure damaging the structure of the tree when deciding on pruning. Also, take into account what the consequences of not dealing with the risks are. As you can see in the flowchart, this idea of intervention being connected to the tree or its surroundings has been conceptualised into risk objectives and tree health objectives.

When mitigating risks, we can focus on the consequences by removing the target or by reducing the probability of damage to the target by removing the hazard. Likewise, when improving tree vitality or structure, we can improve growing conditions (de-compaction, mulching, land use, etc.) or do work on the crown (pruning, bracing, etc.). In practice, although we can generally categorise the work to be carried out as being focused on either the tree or its surroundings, in practise, of course, many interventions will often affect both. These mixed interventions can be seen as a sliding scale which represents the intensity of – or the balance between – the work connected to the tree and the work connected to the surroundings.

For example, the dosage or intensity of a pruning specification may differ significantly depending on whether the objective is clearance from a tram line or weight reduction to prevent branch failure. For clearance pruning, there is an outside parameter deciding where we place the cut; however, for weight reduction, the biomechanical structure of the tree will define the final cut placement.

Naturally, some objectives, such as promoting the longevity of a tree, will end up in both categories. A healthy tree will not only re-iterate and thrive but also keep supplying its surroundings with habitat, shade, and maintain a sound structure without loose branches that could pose a risk to the public. Remember that non-intervention, unlike intervention, is not permanent. There is a feedback loop to the pre-assessment actions where the current status is checked. This irreversibility should be kept in mind when the intensity of tree care is set. A small dose can always be increased, but a large dose cannot be decreased in hindsight.

REFERENCE LIST

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SS 990001-2:2020 Tree care –Processes and methods for tree pruning- Part 1: Requirements for providers. Retrieved from: https://www.sis.se/en/produkter/mathematics-natural-sciences/biology-botany-zoology/ss-990001-22020/

ESSENTIAL READING

The text in this chapter summarises many years of scientific work and practical experience within different fields of science. The present text is essentially new and other than the tree assessment standard (ETAS), there is nothing similar.

EU European Tree Assessment Standard. Retrieved as a draft from: http://www.europeanarboriculturalstandards.eu/etas

Reference work on tree assessment.

ADDITIONAL READING

The present text is essentially new and there is nothing similar to be found elsewhere. Apart from the recommended European Cabling and Bracing Standard and the European Pruning Standard there are also several national standards on pruning and other tree care operations These will also be relevant to professionals planning and executing arboricultural work.

EU European Cabling and Bracing Standard. Retrieved from: http://www.europeanarboriculturalstandards.eu/

Reference work on cabling and bracing trees.

EU European Pruning Standard. Retrieved from: http://www.europeanarboriculturalstandards.eu/

Reference work on pruning trees as it explains the pruning matrix.

EU European Tree Planting Standard. Retrieved from: http://www.europeanarboriculturalstandards.eu/

Reference work on tree planting

EU European Tree Worker Handbook. Retrieved from: https://www.eac-arboriculture.com/etw-handbook.aspx

Reference work on tree work / tree care

EU Trees – a Lifespan Approach. Retrieved from: http://drzewa.org.pl/en/publikacja/trees-a-lifespan-approach-contributions-arboriculture-from-european-practitioners/

Reference work on arboriculture

UK Common sense risk management of trees. Retrieved from: https://ntsgroup.org.uk/wp-content/uploads/2016/06/FCMS024.pdf

Guidance on trees and public safety in the UK for owners, managers and advisers

US An Illustrated Guide to Pruning 3d edition by Edward F. Gilman

Tree pruning handbook

UK Ancient and other veteran trees: further guidance on management. Retrieved from: https://vetree.eu/en/page/94/Training+products

Handbok on veteran tree management

2.4.
TREE SITE IMPROVEMENT AND REMEDIAL MEASURES

Christian Nielsen

GENERAL OBJECTIVE

This chapter guides the planning and practical implementation of a revitalisation project that will help to improve the health, growth, and life expectancy of ancient urban trees by reducing problems with the soil and poor root vitality.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- through dialogue with the client, help with a preliminary definition of the problem and influence the content of the initial assignment. Please refer to the chapter introduction for legal and economic aspects to be aware of;
- carry out a professional diagnosis of the health problems that the tree is suffering from. Often, a specialist must be consulted for complicated soil/root interactions;
- formulate alternative solutions to improve the health of the tree, taking work safety, biosecurity, and habitat protection into account.
- organise and implement the task; and
- try to arrange a monitoring of tree increment to evaluate the effects of revitalisation.

SEE TOGETHER WITH:

Tree Development and Growth Stages, Soil Science, Diagnostic Features, Tree Assessment, Tree Revitalisation, Tree Care and Remedial Measures.

KEY TERMS

General framework

Explanation framework: fine-root turnover, flaws in the carbohydrate-balance

Hints: soil gas exchange

Technical aspects: anaerobic soil respiration, "root-friendly" soil horizon, waterlogging

ESSENCE OF THE TOPIC

This chapter provides guidance on how to organise a tree revitalisation project from the first contact with the client through implementation and final control of the desired results. The flow of the process is described and sketched in the flowchart on the next page.

As we saw in Chapter 1.6.2. Tree Revitalisation, tree revitalisation aims at improving the tree's water and carbohydrate balance, which stimulates the tree's regenerative and protective processes. This essentially comes down to the improvement of the growth media. The essence of tree care and remedial measures for tree site improvement is that the actions or decisions must be well supported through a holistic methodology, as described in Chapter 2.3. Tree Care and Remedial Measures. This decision-making process helps in making effective and sustainable tree revitalisation decisions. Be aware that such a decision-making process is not a one-time event but must be repeated every time the question of tree care arises as the situation can change over time. In other words: this process is looped in time.

A. General Framework of Tree Care and Remedial Measures

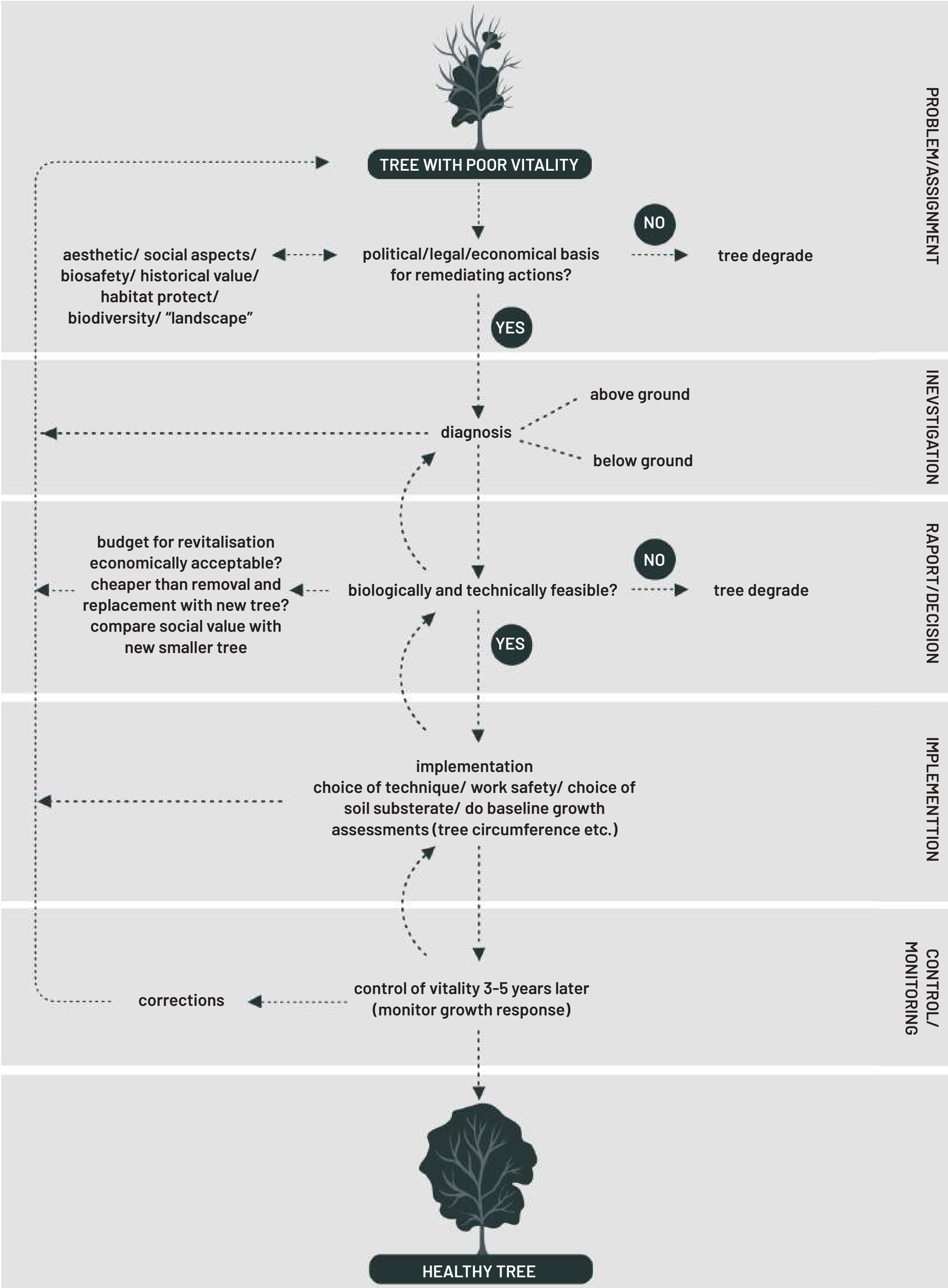
In Figure 1 you will find a flowchart on how to approach a tree revitalisation project. Note that this flowchart is a guide and not a standard and the flowchart presented in Chapter 2.3 is also applicable to tree revitalisation. We will keep them both as neither of them is a standard and both illustrate beautifully the general concept and essence explained in chapter 2.0.0.

B. Explanation of the Framework

Let us explain in more detail what the flowchart is all about. We will do this by elaborating on significant points in the framework. It is not our ambition to explain all the different types of tree revitalisation techniques and methods; however, since there is no European Tree Revitalisation Standard, we will try to describe the most common kinds of remediation work. The main purpose of this framework is to develop a thinking pattern or a handhold that can be used to help us ask the right questions in any given situation and to come up with a sustainable solution. This flowchart helps remind us of all the important questions and prompts us to find good answers to them. Notice the possibility of looping every step back to the previous step, which is an essential aspect of Part 2 of this study guide. This 'going back to the previous step' is, in reality, a common situation, as the result of one step has an impact on the previous step. For example, the diagnosis can reveal that bats are living in the tree. As bats are protected by European law, that can change the assignment, as now the tree must be kept at all costs. Notice also the 'big loop' which can 'shortcut' some steps, since some steps in the flowchart do not apply to all trees with poor vitality.

B.1. Problem Definition and Assignment

The problem with poor tree vitality is commonly identified by the client (but may also be identified by an ETT during a larger survey). Most clients may recognise a problem but may not have sufficient knowledge to properly diagnose it. Thus, during the initial contact, an ETT should stress the necessity of a thorough investigation and also help the client to perceive the potential full extent of various remedial actions. If the client has a sufficient legal and financial basis for remedial work, then an assignment should be formulated in writing. Note that the preconditions (habitat value, aesthetics, social value, etc.) should also be clearly formulated in order to start the next steps.



REVITALISATION

is both relevant for amenity trees and for veteran trees because no matter whether the purpose is to improve the tree's aesthetics or protect biodiversity, a prolongation of the remaining life span of the tree is desirable. It is important to realise that the nature conservation value of veteran trees can be dramatically enhanced by improving the carbon balance of the living parts of trees.

B.2. Investigation/Diagnosis

The tree may have many different kinds of damage or health problems, which means that the problem should be investigated both above and below ground. There may be unstable bifurcations in the stem; large dead, broken, or pruned branches; stem hollowness; severed roots; fungi attack; crown decline symptoms, and so on. Many of these kinds of problems can be handled directly by employing specific measures (pruning, cabling, fertilisation, etc.) to deal with the specific symptoms – see the relevant sections in Part 1 and 2. The best way to diagnose the problem is to follow the questions in the flowchart in Chapter 2.3 Tree Care and Remedial Measures until you arrive at a basic assessment (interpretation and evaluation).

The revitalisation process aims at improving the carbohydrate balance of the tree. Poor carbohydrate balance commonly causes symptoms of poor vitality, as described in Chapter 1.1.2. Tree Development and Growth Stages, Chapter 1.2.1 Soil Science, Chapter 1.5.1. Diagnostic Features, and Chapter 1.5.2. Tree Assessment. An improved carbohydrate balance will improve increment in general, enhance twig and leaf mass, improve leaf colour, enhance root regeneration and, above all, improve the maintenance of barriers for decay within the living woody body. Older trees always have more-or-less hidden wounds in roots, stem, and crown, where the woody body degenerates and dies back. A central purpose of revitalisation work is to slow down the speed of decay and degeneration. Or put it in the terms of urban forest managers: to enhance the remaining life span of the tree by several decades.

The purpose of the investigation is to identify the most critical factors and mechanisms that limit the carbohydrate balance. These may either be flaws in carbohydrate production (input=photosynthesis) or mechanisms that heavily consume carbohydrates (output). Sugar production in old trees is very often limited by poor water balance, which very often comes back to poor water uptake, which again commonly relates to poor root architecture (poor horizontal AND vertical extension of the root system). Excessive carbohydrate consumption is often found in the fine-root turnover complex (see Chapter 1.6.2. Tree Revitalisation).

A correct diagnosis is very important in evaluating the feasibility of a revitalisation project and suggesting the proper measures to be taken. It will often be necessary to involve a soil/root specialist in the project in order to ensure a correct diagnosis.

Tools:

- Mallet
- Binocular/drone for the study of the crown structure and foliation. e.g.:
- Iron rod for analysis of stem hollowness and for detection of soil compression (test horizontally or obliquely in every major soil horizon)
- Spade and hand shovel

Figure 1. The flowchart of tree revitalisation project to improve the health of urban trees. (Adapted from C.C.N. Nielsen 2023)

- Camera and measuring tape, pen, paper etc. for documentation
- Field tools for pH assessment of major soil horizons
- Brush to clean root samples
- Botany magnifying glass (10x) for the study of the root surface

B.3. Reporting/Decisions

Improvement of a tree's biology is always possible. However, is it possible within certain economic restraints? As we saw in Chapter 2.3 Tree Care and Remedial Measures, the question that needs answering is, 'What are the results of a cost-benefit analysis?'
The answer relies on several steps of analysis:

- Describe the biological/technical measures. Can you formulate alternative measures?
- Can you provide rough cost levels for each alternative and the long-term monitoring of effects?

Here is an example of the cost-benefit analysis applied to tree revitalisation: the costs for improving a tree during its life span should be compared with the monetary and social values of the tree. This evaluation may also include the costs for the replacement of the old tree with a new one including costs for site improvement.

The report should also be formulated in a way (or at least contain a summary) that is suitable for dialogue between your client and other stakeholders (politicians, community etc). Two courses of action that are always options are 'do nothing' or 'remove the tree'.

B.4. Implementation

Signs and symptoms that support, contradict, or extend the original diagnosis are likely to show up during the implementation of the revitalisation operations. Please register such observations. After the operation has ended, it is a good practice to carry out a baseline assessment of stem circumference for later, simple control of the remedial measures carried out.

B.5.Control

It is good practice to monitor and control the process so that the anticipated positive effects on tree vitality are achieved. The first signs of improved vitality are often an improved density and colour of the foliage; however, it may take 3 to 5 years before there is any visible evidence of improvement. If the tree does not respond to the revitalisation as expected, explanations for this should be searched for. A revised diagnosis and supplementary work might be necessary.

C. Hints Regarding Diagnosis / Investigation

Before attempting any improvements, carry out a diagnostic analysis, including

- above-ground factors involved in tree degeneration (see Chapters 1.5.1 Diagnostic Features and 1.5.2 Tree Assessment);
- below-ground problems.

Below-ground problems are commonly related to one or both of the following factors:

- Limited root space
- Poor soil quality

Determination of a tree's root space – horizontally and vertically – is very difficult in an urban environment. Not least because tree roots tend to exploit every found macropore and therefore "run wild" in many unexpected directions. Such a job is for specialists. Having said that, obvious limitations to root expansion close to the tree should be acknowledged. Root spread in park soils *may* be less complicated.

An attempt should be made to evaluate the soil quality, even though this also constitutes a challenge, because practically all available theories and textbooks on soil assessment relate to more-or-less natural soils in forestry or agriculture. Good instructions for urban soil assessment are missing. Urban soils are affected and often deteriorated by humans and are exposed to different problems compared to "natural soils". The texts of Urban (2008, chapter 7) and EPA (2011) provide some inspiration, but they are not sufficiently "hands-on". Great care should be taken not to use "copy-paste" guidelines: Table 14 in Cappiella et al (2006) is an example of guidelines that should only be followed after a thorough analysis. Therefore, in order to help you undertake an urban soil evaluation, we have compiled some key questions that can help you build up an idea of its condition.

Former land use should be noted if possible – particularly with respect to contamination of the soil with pollutants and heavy metals. If the soil is polluted, soil exchange could be a relevant option.

Is the soil a recipient for de-icing salt from nearby streets or pedestrian paths? Does the soil have a sufficiently coarse texture and structure to "wash out" salt from the soil column?

The hydrology of the site should be considered. Does the site seem to have natural vertical drainage through the soil, or is surface runoff the primary mechanism of rainwater disposal? Will the site be suitable for stormwater management? Can the site receive roof water for improved growth conditions?

The soil assessment is always a must. This job is not easy because the soil as growth media for tree roots is a complicated ecosystem (refer to Chapter 1.6.2. Tree Revitalisation).

D. Technical Aspects

Soil biodiversity and old root channels – particularly valuable in deep clay horizons

Deep clayey soil layers may contain old root channels (macropores), which are extremely important for drainage, gas exchange, and new root expansion. Such soil horizons are created over thousands of years and are crucial for soil biodiversity and soil health. Please take care not to ruin such deeper soil layers.
Rough or gentle techniques for soil work

1. Pneumatic tools (air pressure and vacuum): When the old soil is loosened with an air spade and removed by vacuum, it is possible to work close up to the trees with comparatively little damage to the root system. Roots smaller than 1-2 mm will be lost, but they regenerate quickly. However, please be careful not to damage the root bark with close-up air pressure.
2. Backhoe/ripper drainage plough, etc: When using tools that sever roots, the "critical root zone" (CRZ) should be respected (see Chapter 1.6.3). Although it means that it is harder to work closer to the tree, it may still have a significant effect.
3. Combination of backhoe and manual shovelling: Combining the backhoe work with careful manual soil removal around roots makes it possible to remove soil closer to the tree.

Before using techniques 2 and 3, gather data about root distribution to formulate the CRZ.

General root protective measures:
By root work, please note the following:

- always keep exposed roots moist and protected against sun and light, e.g., with wet burlap;
- try not to damage roots thicker than 30-40 mm;
- whenever such larger roots are severed, they should be treated with a clear cut to stimulate regrowth and prevent decay;
- fine roots will commonly get lost during root exposure, which is a minor problem as fine roots regenerate vigorously given the right growth conditions.

Critical Root Zone (CRZ)

When using one of the rough methods to sever roots, the CRZ must be considered (refer to Chapter 1.6.3. for references to CRZ). Either by doing a prior analysis of root spread or by starting the work at a greater distance from the tree and then gradually approaching the tree. When digging or ripping no (or very few) roots being thicker than 3-4 cm should be cut in the CRZ. Please note that the CRZ varies a lot among tree species and strongly depends on how deeply rooted the soil is.

Correction of soil chemistry

During soil work, low or high pH may be corrected – although this is not an easy job. Ideally, soil samples should be titrated in a soil lab to provide us with an idea of the pH buffer in the soil, but in the real world, it is very difficult to hit the right dose and get the dose correctly mixed with soil particles. Furthermore, it may take time for the soil to achieve a new pH balance after the addition of either lime or sulphur. One way of minimizing the risk from chemical amelioration is to add our corrective material to spatially limited spots, lines, or sections. Another method for reducing the risk of "chemistry running wild" is to use coarse material, for example, coarse lime instead of common agricultural fine-textured lime. An unbalanced nutrient situation may be corrected by using proper fertilizers. Please also consider the risk of killing roots with overdoses of fertilizers.

E. Technical Solutions

Whereas Chapter 1.2.1. explains soil processes and soil assessment and Chapter 1.6.1. reveals the problems, the following is about finding the appropriate solutions.

Deep Ripping

Soil compression in the topsoil is easier to deal with: Mechanical tilling, frost and thaw, and root activity will commonly counteract compression of the topsoil. But vehicles with an axle load of more than 5 tonnes will compress the soil to a depth of 60-70 cm. Loosening of the subsoil is a much larger challenge. Loosening with a backhoe is generally very effective. Ripping with 70-100 cm-deep "ripper tines" or a chisel may also be effective. The soil should be dry during the treatment. The macropores created in soils with a high clay content may close again when clay particles are leaked downward during water infiltration. Sandy soils are more likely to gain from deep ripping in the long term. On clay soils, deep-rooting crops may be considered (canola, alfalfa, and lupin) to enhance the creation of deep macropores.

Soil Drainage

Water input in large parts of northern Europe is between 600 and 1000 mm of precipitation per year. Between 300 and 450 mm of water is commonly lost from forest ecosystems via evapotranspiration. Thus, between 300 and 600 mm of rain must drain off urban landscapes. This may happen in three ways:

- surface runoff (e.g., to sewer systems),
- horizontal drainage within the soil to low-positioned recipients, or
- vertical drainage through the subsoil.

At any site where trees are growing, it is useful to spend a little time considering these basic hydrological issues – not least to consider how much water will be available for the trees at various soil depths.

Where water stagnates and accumulates in the subsoil, the soil becomes waterlogged. Rainwater contains oxygen, but the content of oxygen in soil water is gradually reduced to a critically low level within a few days (within a maximum of a week). Thus, stagnating soil water quickly becomes anaerobic and toxic to fine roots. After being waterlogged for months, woody roots also tend to die, but resistance to waterlogging varies tremendously between tree species.

Accumulated free water in the root zone is commonly detrimental to tree health. Where a risk of waterlogging in the subsoil is present, drainage of the subsoil is necessary for good tree growth. Moreover, where the outlet of drain tubes is not under water, drain tubes also enhance gas exchange to the subsoil, and we do see that root growth is particularly intensive close to drain tubes in such situations. Trenches with course gravel covered with geotextiles may be used instead of drain tubes. Finding a recipient for the drain water often constitutes a challenge for the drainage of urban soils.

Soil Profile Rebuilding (Backhoe Treatment)

Where urban soils contain different layers of varying root friendliness, remixing the soil may be useful. This is efficiently carried out with a backhoe. This operation may, at least, break up compressed soil layers. Please refer to Day (2016). Before carrying out such a profile rebuilding, it should be carefully considered whether the soil texture and structure will be suitable after remixing. Sometimes the supplementary supply of soil materials may be beneficial (e.g., coarse sand if too clayey, clay if too course material, the addition of compost or mull in the upper 25 cm, aeration tubes, etc.).

Replacement of Soil

Poor urban soils are commonly replaced by a specific urban tree soil substrate before the establishment of new trees. But soil replacement may also be an option around an older standing tree. When done close to the tree where the intensity of coarse roots (>3 cm) is high, removal of the old soil must be carried out using pneumatic tools (Fite 2016). Where replacement is carried out at larger distances from the trees, normal digging equipment may be used for removal.

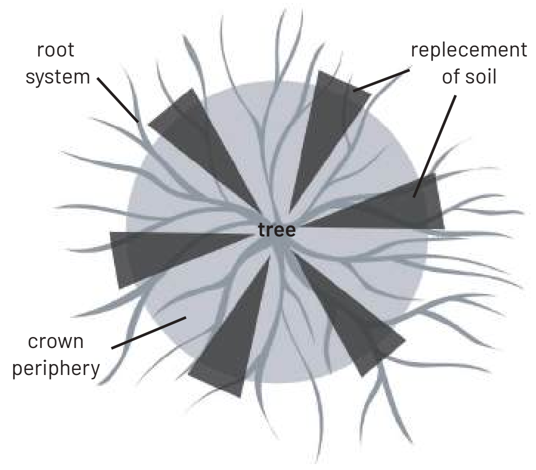


Figure 2. Replacement of soil. (Adapted from C.C.N.Nielsen).

Please consider the CRZ. Besides the common root protection guidelines above, please note the following:

- The anchorage/stability of the tree must be maintained during the operation. Therefore, only replace the soil in sections of the root zone (see Figure 1). The best time for this kind of operation is late winter/early spring, in order to provide the roots with a growing season for root regrowth in the new soil.
- Use refill material that is suitable for the site, minding the traffic load, etc.
- Actions should be taken to ensure proper soil moisture, at least during the first growing season after soil exchange.

Air Tilling

This method can be used to loosen compressed topsoil. It may also be used to mix compost down into the upper soil. Please refer to Fite (2016).

Pneumatic Creation of and Filling of Macropores with Compost (or other material)

A method now widely used in the Netherlands and Belgium is an attempt to loosen up compressed soil by means of soil picks (a tool similar to an air spade) and high air pressure. This operation must be accompanied by the insertion of a material that prevents the created macropores from closing after mud filling, particularly in soils with high clay content. Air pressure creates only a few widespread macropores. This method does not resolve and loosen compressed soil, but it improves the drainage and gas exchange in the soil to an unknown depth. Depending on the character of the inserted material (crushed lava, biochar, compost) the macropores may be more or less permanent.

Radial Trenching

This is either an air tilling or a soil replacement procedure involving radial trenches going radially outward from the tree. Depending on the depth and width of the trenches, this concept is an intermediate technique between the real "soil exchange" and "air tilling" and "vertical mulching". Please refer to Fite (2016).

Vertical Mulching (with or without aeration tubes)

Vertical mulching is the creation of vertical holes in the soil, which, after refill, serve both as channels for vertical root growth and as ventilation channels for O_2 (down) and CO_2 (up). Vertical mulching may be appropriate where root growth is restricted to a shallow band of topsoil; however, it is not helpful in all cases.

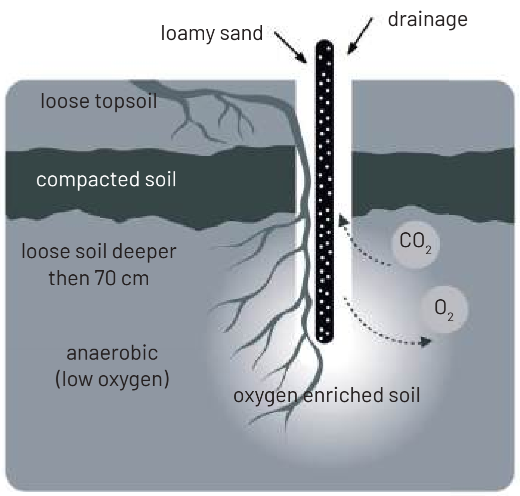


Figure 3. Vertical mulching. (Adapted from C.C.N.Nielsen)

In anthropogenically compressed soils, the major limitation of the vertical expansion of the root system is a lack of oxygen in the subsoil. In such situations, compression may be restricted to the upper 60-80 cm of the soil. If the subsoil below this compressed layer is "root friendly" (or is enhanced in root friendliness by e.g., liming or fertilisation), roots may expand below the compressed layer and thus improve the water balance and health of the tree.

However, vertical mulching is not always a proper solution. If the subsoil is waterlogged or otherwise not root friendly, the benefits of vertical mulching may be limited. Some effect may arise from the improved soil gas exchange in the proximity of the vertical borings.

Root Collar Excavation / Studies of Root Health

One common problem in arboriculture is "planting too deep". This commonly leads to poor root expansion and, not infrequently, fungal infections. The health of the root flare may be improved by a "root collar excavation". Please refer to Fite (2016). The health of supporting horizontal roots after attack by *Meripilus giganteus* or *Armillaria mellea* may also be clarified by air spade removal of the topsoil around the stem base.

SELF-CHECK QUESTIONS

1. Mention typical signs of poor water- and carbohydrate balance (carbohydrate=sugar, starch, etc.).
2. At what distance from the tree will you investigate the soil profile in order to evaluate vertical root distribution?
3. Are you capable of carrying out a diagnosis of the "root friendliness" of soil horizons down to ~1 metre depth?
4. List the technical methods for replacing urban soils close to trees and present the pros and cons of each method.
5. List the methods that can be used to loosen or drain urban soil and discuss their pros and cons.
6. Consider the availability and costs of various tools in your region for root work (air spade, vacuum, backhoe, etc.).
7. How can exposed roots be protected after soil removal?
8. Define the criteria for CRZ.
9. Describe artificial urban tree soil substrates that are suitable for soil replacement around trees.
10. Discuss the pros and cons of using vertical mulching versus radial trenching.

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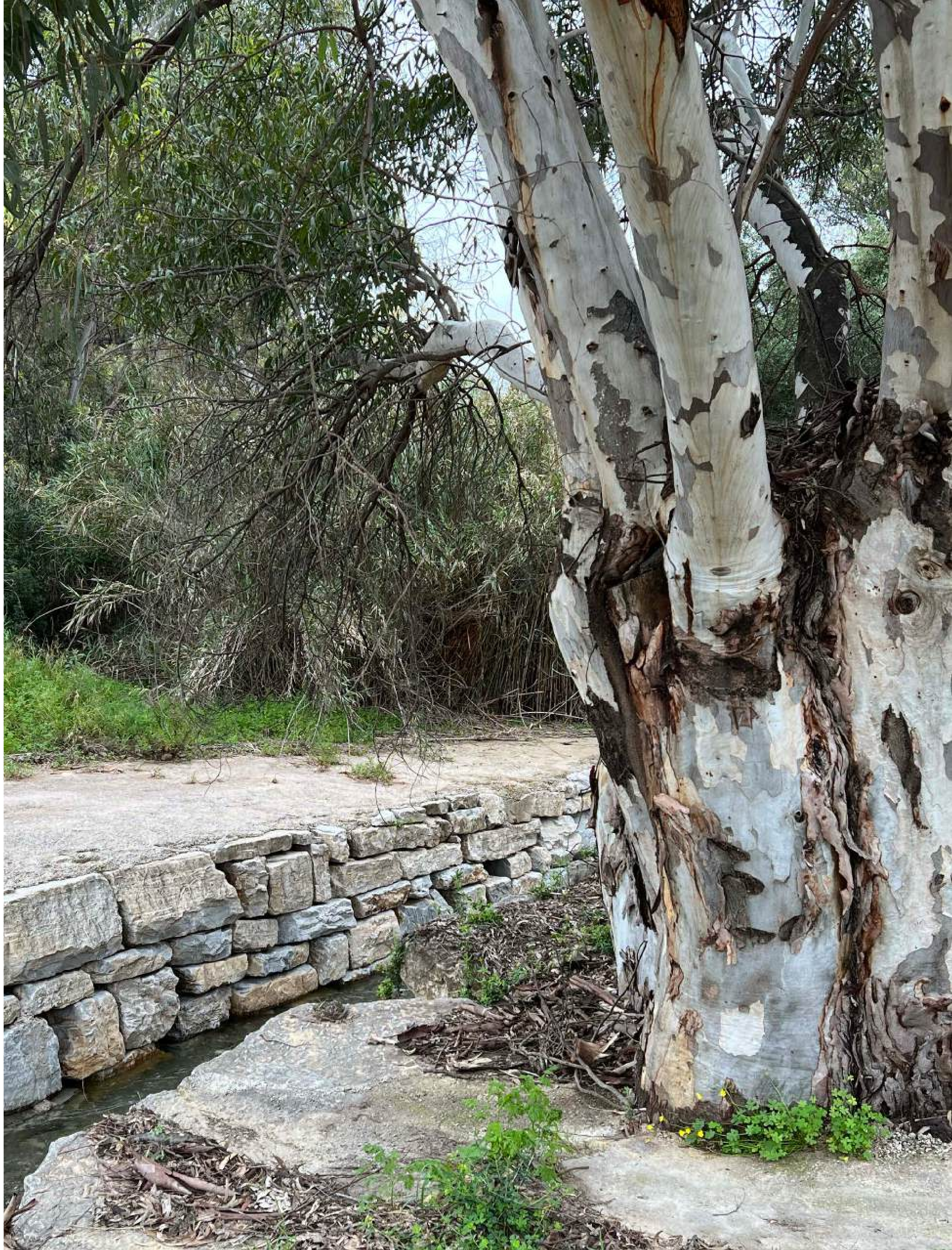

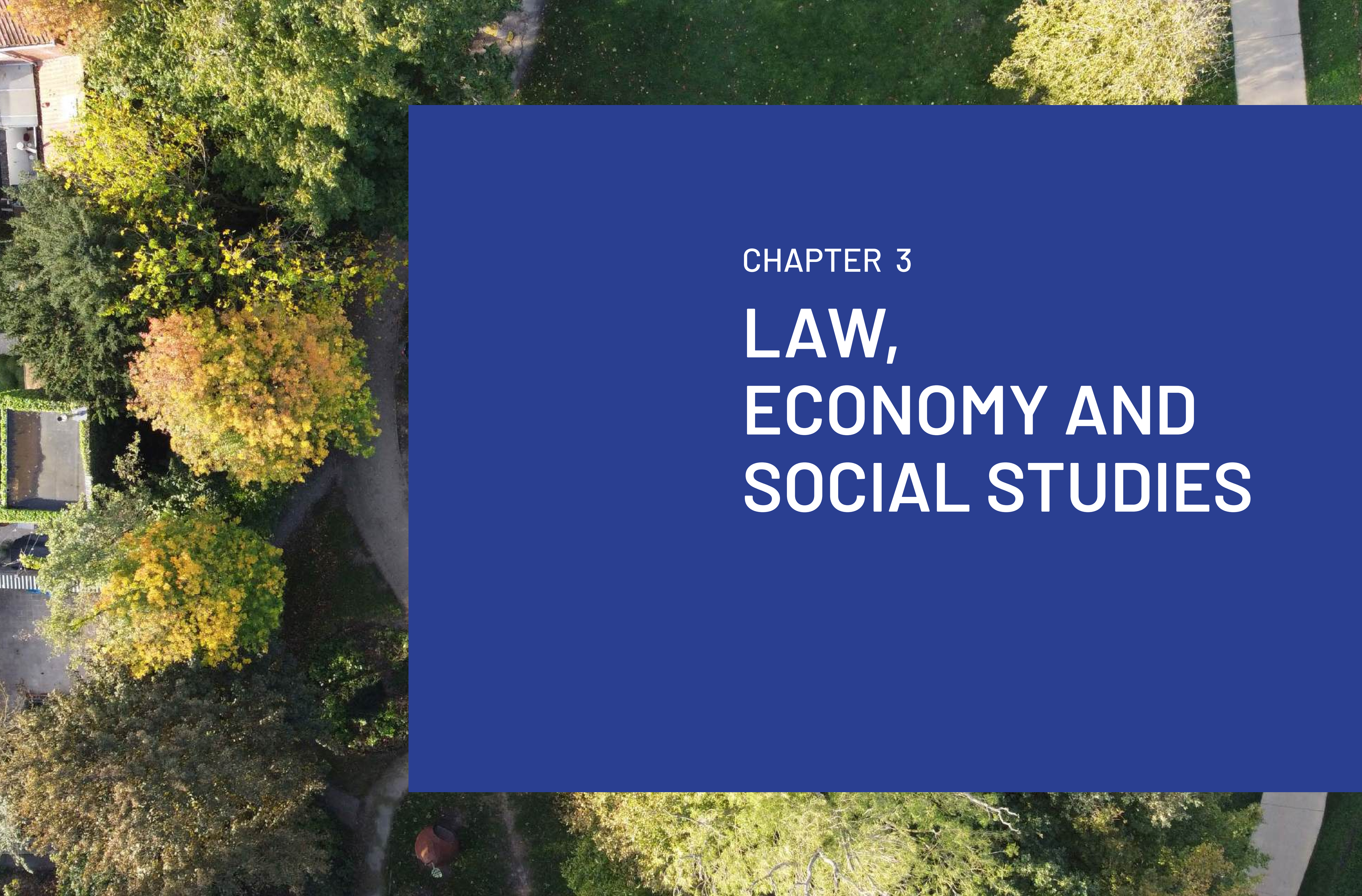

CHAPTER 3

LAW, ECONOMY AND SOCIAL STUDIES

INTRODUCTION

As we saw, Part 1 covers the theory and foundations of tree management; while Part 2 focuses on the practical procedures involved in tree maintenance and remedial measures where experience and fine-tuned thinking patterns are essential. Part 3, however, is about the law, economics, and social studies. In other words, the material in the following chapters focuses more on the management aspect of dealing with trees than on the trees themselves. We described the consultancy or advisory role of an ETT in the Introduction to Study Guide The Role of the ETT in Modern Arboriculture, and we elaborate on this more in Part 4. As you will see in Part 3, the interdisciplinary nature of tree management transcends traditional boundaries, which means that the ability of the ETT to adjust tree management to the demands of tenders, calculations, regulations, and project management is, in a sense, a true mark of professionalism.

We focus on these topics, therefore, to ensure that you are familiar with the common methods employed in these areas of tree management.

3.1. PERFORMANCE DESCRIPTION

Bregt Roobroeck

GENERAL OBJECTIVE

Provide a comprehensive understanding of how to make performance descriptions of complex assignments.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- describe the contents of a works specification and its legal and economic significance;
- describe the legal requirements concerning the workforce and sub-contractors on the work site and on the employer's premises;
- describe the liability regulations covering the safety of people and property on the work site and on the employer's premises;
- take note of the instruction to draw up specifications;
- analyse the assignment; and
- ask or search for additional information if necessary.

SEE TOGETHER WITH:

Calculations, Offers and Costing, Setting Up of Legal Transactions, Legal Regulations for Carrying out Tree Work, Professional Organisations, Communication and Reports

ESSENCE OF THE TOPIC

Tree assignments which require an ETT are, in general, characterised by their complexity. They involve multiple actions, dealing with stakeholders, budgets, and time restrictions. Metaphorically, it is like solving a puzzle. One strategy that can be used to deal with this complexity is to break down the sophisticated assignment into smaller problems, thereby creating logic and structure so the puzzle can be solved faster. To achieve this, a plan of approach and a timeline are useful. They can be viewed as an instruction manual for solving the puzzle. The plan of approach, more commonly known as an action plan, should be logical, highly structured, concise, and nicely visualised in a timeline.

KEY TERMS

complexity: divide, formulating, SMART, SMARTER, subdivide, user story

analysis: unforeseen circumstances

plan of approach: action, action plan, chronology, GANTT chart, methodology, phase, sub-activities

timeline: Deliverables, milestones

A. BREAKING DOWN THE COMPLEXITY

A.1. Define the Problem or Assignment:

When doing advisory assignments or consultancy, it is not always crystal clear what the client wants and, therefore, what the assignment exactly is. Usually, in practice, the client has a problem that he/she wants solved; however, the problem has not been defined exactly as this more difficult than we commonly think. Defining and clarifying the problem, and thus the assignment, might take several attempts. A good strategy for this is to set up the user stories of the stakeholders and (re) formulate the assignment in a SMART way. A user story is a short, simple description of the needs of an end-user. It is not a functional description, but it makes it clear what an end user wants or needs, and why it is needed (the goals or objectives). By asking the client 'what exactly do you want', the client is encouraged to think very practically. This could lead to rephrasing and restructuring the initial problem/question in a SMART way, thereby defining precisely the problem with goals or objectives. SMART stands for specific, measurable, achievable, relevant, and time bound.

- Specific: The assignment or objective should be clearly stated, so anyone reading it can understand what will be done and who will do it.
- Measurable: The assignment or objective includes how the action will be measured. Measuring your objectives helps you determine if you are making progress. It keeps you on track and on schedule.
- Achievable: The assignment or objective is realistic given the realities faced in the community. Setting reasonable objectives helps set the project up for success.
- Relevant: A relevant assignment or objective makes sense; that is, it fits the purpose of the grant, the culture and structure of the community, and it addresses the vision of the project.
- Time-bound: Every assignment or objective has a specific timeline for completion.

In the extended version, SMARTER, two more criteria are added:
- Evaluated: An appraisal of the goal to assess the extent to which it has been achieved.
- Reviewed: Reflection and adjustment of your approach or behaviour to reach a goal.

Note that this step helps to formulate the questions of the assignment based on the user stories. It is therefore logical that at the end of the assignment, the questions are clearly answered. This seems evident, but in practice this is often not the case when reports are formed.

A.2. Subdivide the Problem or Assignment:

In the previous chapter, we pinpointed exactly the problem or assignment. This can be simple, like a visual tree assessment for a single tree; or complex, like a tree management plan (TMP) for 50 trees in a park. This step is about dealing with complexity. Breaking down complexity into smaller problems is a fundamental problem-solving strategy that simplifies large assignments. By dissecting the assignment into manageable components like clear questions, it becomes easier to comprehend, analyse, and address each part individually. This approach promotes clarity of thought, accountability, and minimises the risk of errors, as smaller problems are generally easier to tackle with precision. In the example of the TMP of the trees in the park, the following questions break down the complexity:

- What is the current state of the 50 trees in the park (below and above ground)?
- What do the stakeholders want?
- What are the short- and long-term goals for achieving what the stakeholders want?
- What actions are needed to achieve the goals?
- What resources (time and money) are needed to achieve the goals?

It is the same strategy as we described in Chapter 4.2 Structured Tree Management where we address three main questions:

- What do we have?
- What do we want?
- How are we going to achieve it?

Note that defining and subdividing the problem/ assignment is required in order to make a plan of approach.

B. Analyse the Assignment

When the assignment is more clearly formulated, as discussed in the chapter above, we can better analyse the assignment and see if it is realistic and/or feasible. This step has 2 aims:

- to keep unforeseen circumstances to a minimum, so the assignment does not overshoot its time and budget; and
- to answer the question as to whether the assignment is feasible for the contractor.

This analysis is, of course, very specific for each assignment, contractor, or company, but it is worth thinking about questions like the following:

- Does your company have the expertise necessary to do the job?
- Does your company have the resources (employees, machines, etc.) to complete the job?
- What are the regulations and restrictions of the assignment?
- Are the deadlines for the project feasible, and are they realistic for your company?
- How can unforeseen circumstances you cannot control, like bad weather, be taken into account?
- What is the environmental impact of your methodology?
- How will you communicate with the stakeholders?

B. Plan of Approach

B.1. General Methodology

A plan of approach, often used in various fields such as project management, consulting, and research, is a structured document outlining how a project or assignment will be executed. Its structure typically follows a logical sequence, allowing for clear communication and effective implementation. Simply put, it is a step-by-step plan for execution. When defining and subdividing the assignment, the plan of approach will be easy to generate as the SMART methodology makes it very specific, and the steps to be executed are essentially the subdivision of tasks. If we use the analogy of the puzzle, then the plan of approach is a step-by-step instruction manual for solving the puzzle. In reality, the previous step – analysing the assignment – is usually done together with the plan of approach as the latter is, in essence, a structured thinking exercise.

B.2. Specific Methodology: The Action Plan

Crucial in making a plan of approach is to categorise the subdivided problems or assignments into work packages, phases, or activities, which together go to make up the plan of action. That plan must be logical, structured, and to the point. For example, the assignment of preparing and supervising 460 public tree pruning and maintenance works is divided into the following activities

	Activities	Description	Outcome	Timeline
PHASE 1 - consultancy activities				
1	Desk research		Materials to commence field work and other tasks.	Week 1
2	Tree survey			
2.1	GIS mapping and marking (tagging) trees	Due to a lack of a detailed plan, it is necessary to localise and identify individual trees to allow for unambiguous identification of trees and avoiding potential mistakes.	A map of the trees on site, and individual tree tags placed on trees.	
2.2	Field work	It is necessary to assess all trees individually to assign proper maintenance measures. In particular, a detailed approach is necessary for monumental trees. This information is needed in order to acquire permits from external stakeholders to allow work on trees.	A database with the necessary information on the trees.	Week 2-5
2.3	Report	A final report which includes all the information of the tree survey.	A full report in the database that will be provided to the client to allow tree management.	

which can be seen in the table above (only Phase 1 is visible):

- Phase 1: Consultancy activities, which cover desktop research and tree survey.
- Phase 2: Setting up the tender, which covers the technical details of the job.
- Phase 3: Supervision of the works, which covers the field work and reporting.

As shown in the table, the assignment is highly structured, as the activities are divided into different phases and each phase has sub-activities. Furthermore, logic is present because of the chronology of the task and the logical sense of the activities. For example, reporting is not possible if the fieldwork is not performed. Last but not least, the action plan is to the point because the activities are described concisely, and the outcome or deliverables are listed together with the timeline. Activities which for some reason remain unclear should not be ignored but be taken into account.

Try not to 'guestimate' how many resources (time and money) should be available but describe the unclear/unforeseen tasks as best as possible and as a scenario. For example, if this situation occurs, then an expert will need to be consulted, although the extra work of the consultancy has not been included in the action plan and timetable.

We explicitly want to emphasise that although this table is a good example, it is by no means a standard or template on how to make a plan of approach/action plan. It does, though, illustrate the logic, structure, and hands-on character that can be made by organising the work into a table. It is therefore highly recommended to use tables like a Gantt chart. Note that working in such a table is also extremely efficient for making offers because each action is well described with the deliverable, which is a good way of working to define the actions per unit. It is always easy to multiply that action by the number of repetitions. For example, in the case of the 460 park trees that require maintenance, defining the price for one tree (per unit) and then multiplying by 460 makes it clear for the client. If the situation changes, such as fewer trees being pruned, then the calculation is easy to make. You can see more on calculations and offers in Chapter 3.2 Calculation, Offers and Costing.

D. Timeline

The final part of a good performance description or assignment is a clear timeline that is the visual representation of all the chronological steps organised along a linear time axis. Although timelines are very straightforward, in practice they are often badly made. Good timelines consist of more than just the time needed for every phase or work package. They also contain information on:

- Milestones
- Deliverables
- Communication with the client

SELF-CHECK QUESTIONS

1. What do we mean by breaking down complexity?
2. A good plan of approach/action plan can be screened by checking three criteria. Name and explain them.
3. What is the role of a timeline and what items are essential?

PRACTICAL EXERCISES

1. Make an action plan for a job description according to the methodology described above. You can use your own template in MS Excel or MS Word. Focus on breaking down the assignment into smaller phases and determine the deliverables, milestones, and communication.
2. (Re)formulate the assignment in a SMART way.

TERMINOLOGY

deliverable – something, such as merchandise, that is or can be delivered, especially to fulfil a contract (examples of deliverables include reports, documents, software products, server upgrades, or any constituent component contributing to the broader project's completion)

milestones – sub-goals in a project that are necessary to accomplish in order to achieve the final goal, usually defined so that the team can see the progression of the work and its approaching completion; often divide the whole project into several stages, and it is good practice to ensure that the periods between them are not too short or too long (in a case of 460 park trees, a logical milestone is the end of the fieldwork)

EXCERCISE: SMART GOAL

Use the sheet below to check whether your goal in the plan of approach meets the SMART principle.

Go through the steps in the sheet below, checking that the formulation of the objective meets the SMART aspect and reformulating the objective to better meet the principle.

Steps of the exercise	Enter your answer
Preliminary goal: Write down the target as you initially define it.	
Is it specific? *If not, reformulate it to be more specific.*	
Is it measurable? *If not, reformulate it to make it more measurable.*	
Is it achievable? *If not, rephrase it so that you can imagine who will perform it.*	
Is it Realistic? *If not, reformulate it so that it can be achieved with the resources at hand.*	
Is it time-related to the time you have in the project? *If not, reformulate it so that it can be achieved within the timeframe envisaged.*	
SMART objective: *Enter a goal here that meets the SMART principle*	

REFERENCE LIST

No references were used for making this text.

ESSENTIAL READING

The text in this chapter summarises many years of practical experience and is more a methodology or thinking pattern that cannot be found in books applicable to arboricultural practices. We cannot recommend any essential or additional reading list.

3.2. CALCULATIONS, OFFERS, AND COSTING

Kamil Witkoś-Gnach

GENERAL OBJECTIVE

Provide a comprehensive understanding of how offers function and how to perform calculations and costings for a job.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- describe the contents of a works specific and explain even spread costing and make relevant calculations;
- calculate tender prices for:
  - tree planting,
  - tree transplanting,
  - tree care,
  - tree removal,
  - the monetary value of a tree/damage done to a tree,
  - crown stabilisation systems and installation,
  - tree assessment,
  - tree protection during construction, and
  - consultancy (not executing);
- calculate intermediate costing, and plan ahead with regard to the need for machinery, manpower, and technical resources, including post-calculation;
- carry out a costing exercise and prepare an offer that meets the specifications stated in the tender; and
- analyse the project scope and specify potential technical and financial risks.

SEE TOGETHER WITH:

Performance Description, Setting Up of Legal Transactions, Legal Regulations for Carrying out Tree Work, Professional Organisations

KEY TERMS

The base: communication, estimation, roadmap, time management

Cost types: equipment costs, labour costs, material costs, overhead costs, profit margin, subcontractor costs

Offer: 10 steps, basic cost estimate, comprehensive cost proposal, cost per unit, cost table, detailed project budget, miscalculation, mistakes, value added taxes (VAT)

Post-calculation: methodological registration

ESSENCE OF THE TOPIC

The essence of calculations, offers, and costing lies in a systematic approach to determining the financial aspects of a project. Calculations play a crucial role in estimating the costs involved, considering variables such as labour, materials, and overhead expenses. By breaking down the project into smaller subtasks and utilising tables or systems, the estimation process becomes more organised and accurate.

Offers are the means by which the estimated costs and pricing are communicated to stakeholders, including clients or customers. It is essential to include all necessary cost categories, including taxes and VAT, in the offer to ensure transparency and consistency. Furthermore, the offer should align with the plan of approach, which outlines the project's scope, timeline, and resources. Hence, a good offer is logical, complete, and detailed, resulting in good communication with the stakeholders.

A. The Base: A Detailed Work Plan

A detailed work plan serves as the foundation for a successfully executed project. It provides a clear roadmap, outlining the tasks and objectives that need to be accomplished. Additionally, a detailed work plan enables effective time management, ensuring that the tasks are completed in a logical sequence with a SMART verifiable description of the end result per project phase, thereby optimising resource allocation (for more information, see Chapter 3.1 Performance Description).

Arranging tasks in chronological order is a crucial aspect of work planning. This approach ensures a logical flow of activities, allowing for a smooth progression throughout the project. Moreover, a chronological work plan aids in resource allocation and optimises efficiency.

Cost estimation plays a pivotal role in effective financial management. It involves the process of forecasting and quantifying the financial resources required for the successful completion of a project. Accurate cost estimation enables one to set realistic budgets, allocate resources effectively, and make informed decisions. A thorough understanding of cost estimation techniques and their application allows organisations to plan and execute projects in a financially responsible manner, mitigating the risk of cost overruns and ensuring project success.

When making an estimate, it's important to clearly define the roles and responsibilities of the workers involved in the project. This allows for a more precise assessment of the skill level and effort required for each task. It ensures that workers with specialised expertise or higher responsibilities receive appropriate compensation, as they may require a different wage rate than general labourers. By specifying workers' roles, the estimate becomes more comprehensive, reflecting the specific labour requirements and enabling a more accurate assessment of costs.

B. Cost Types and Categories

When creating offers, there are several cost categories to consider, all of which help ensure that all relevant costs are accounted for in the offer and that an accurate representation of the total financial requirements is provided. Here are some common cost categories that should be taken into account when creating offers:

- Labour Costs: This category includes the costs associated with the labour required to complete the project. It encompasses salaries, wages, overtime rates; and any other additional compensation.
- Material Costs: Material costs cover the expenses for all the necessary materials and supplies needed to execute the project. This includes the cost of purchasing or sourcing materials, transportation fees, and any applicable taxes or tariffs. These costs may vary greatly depending on the nature and scale of the project.
- Equipment Costs: This category includes the costs associated with renting or purchasing equipment needed for the project. It covers rental fees, maintenance and repair costs, fuel or energy expenses, and any other expenses related to the use of machinery or tools.
- Subcontractor Costs: In some projects, subcontractors may be hired to perform specific tasks or provide specialised services. Subcontractor costs include the fees or rates charged by subcontractors for their services, as well as any associated expenses, such as travel costs or accommodation.
- Overhead Costs: Overhead costs encompass various indirect expenses necessary for the operation of the business and the execution of the project. These costs may include administrative expenses, insurance premiums, legal fees, rent or lease payments, utilities, and other general expenses. Overhead costs often go unnoticed, but they can have a significant impact on the overall project cost. Understanding and accounting for overhead costs such as insurance, rentals, and administrative expenses is essential for setting realistic budgets and pricing structures, thereby ensuring all necessary expenses are considered.
- Profit Margin: The profit margin is the amount added to the total costs to ensure the business or contractor generates a profit from the project. It is typically calculated as a percentage of the overall costs and reflects the desired profit level for the work performed.

Projects rarely go exactly as planned, and unforeseen costs can arise due to unexpected events like equipment failure, weather disruptions, or sudden changes in market prices. It is wise to allocate a contingency budget to address these situations, providing a buffer to handle unforeseen expenses. These contingencies need to be taken into account.

C. Preparing the Offer

C.1. Complexity of the Offer

When creating offers, the complexity and scale of the task at hand can vary significantly. Different projects require different levels of resources, expertise, and coordination. Therefore, it is important to consider the scale of the task when determining the type of offer to be presented.

Basic cost estimate: For simple and straightforward projects, a basic cost estimate is suitable. These offers typically involve a single cost category, such as labour or materials. Examples include simple tree consultations and basic assessments. The focus is on providing a clear breakdown of the costs involved in a concise and easy-to-understand format.

Comprehensive cost proposal: When the task becomes more complex, involving multiple cost categories, a comprehensive cost proposal is necessary. These offers cover a broader scope of

work and require detailed estimates for each cost category. Examples include a tree assessment of a population of trees, a survey of planting sites, and simple tree pruning operations. The proposal can include labour costs, material costs, equipment expenses, subcontractor fees, and overhead costs.

Detailed project budget: For large-scale projects with significant complexity, a detailed project budget is essential. These offers encompass extensive planning, coordination, and various cost categories. Examples include large-scale tree planting and large-scale tree management plans. The budget includes many cost categories that are meticulously calculated and presented in a comprehensive manner. The detailed project budget serves as a financial roadmap, guiding stakeholders through the project.

C.2. Preparing the Offer in 10 Steps

Preparing a detailed cost table for an offer requires careful planning and execution. Here is a step-by-step guide to help you create a comprehensive cost table:

Step 1 – Start by identifying the key cost categories that are relevant to the project. These categories may include labour costs, material costs, equipment costs, subcontractor fees, overhead costs, contingency funds, and profit margins. Customise the categories based on the specific needs and requirements of the project.

Step 2 – Analyse the scope of the project and break it down into specific tasks or work packages (these should be identified in the plan of approach). Estimate the quantities or units for each task, such as the number of hours or days required, quantities of materials needed, or equipment usage. This breakdown allows for a more accurate estimation of costs.

Step 3 – Determine the cost per unit for each cost category. For example, calculate the hourly rate for labour, the cost per unit of materials, or the rental fees for equipment.

Step 4 – Multiply the quantities by the corresponding unit costs for each task to calculate the subtotal for each cost category. This provides an estimate of the individual costs associated with each task. This step helps in understanding the distribution of costs across different aspects of the project.

Step 5 – Consider overhead costs, such as administrative expenses or insurance, and add them to the subtotal. Additionally, allocate a contingency percentage to account for unforeseen expenses or risks.

Step 6 – Determine the desired profit margin for the project and calculate the amount of profit based on the total estimated cost. Add the profit amount to the total to account for the business's profitability. This step ensures that the offer includes an appropriate margin for the company's financial goals.

Step 7 – Take into account any applicable taxes or Value Added Tax (VAT) and calculate the corresponding amounts based on the total cost. Ensure compliance with tax regulations and accurately incorporate the tax figures into the cost table.

Step 8 – Organise the cost table in a clear and structured format. Display the cost categories, task descriptions, quantities, unit costs, subtotals, overhead costs, contingencies, profit margin, taxes, and the final total. Use appropriate headings, columns, and formatting to enhance readability and understanding.

Step 9 – Include explanatory notes or additional information as needed to clarify any specific cost items, assumptions, or conditions.

Step 10 – Review the cost table thoroughly to ensure accuracy. Double-check calculations and validate the data used. Seek input from relevant stakeholders or colleagues to validate the cost estimates and address any potential errors or omissions.

C.3. Common Mistakes

Preparing offers requires careful attention to detail and consideration of various factors. However, several common mistakes can occur during the process. Here are some common mistakes to avoid:

- Calculation errors: Calculation errors can have a significant impact on the accuracy of an offer. Mistakes in adding up costs or miscalculating quantities can lead to inaccurate estimates and potential financial losses. Double-checking calculations and using reliable tools or software can help minimise these errors.
- Lack of alternatives for outsourcing: Relying solely on a single outsourcing option can be risky. If the planned outsourcing is unavailable or falls through, it can disrupt the project's progress and timeline. It is important to have backup options and alternative suppliers or subcontractors identified in advance to mitigate these risks.
- Ignoring weather conditions: Weather conditions in arboriculture can have a considerable impact on project timelines and costs. Adverse weather, such as heavy rain, snow, heavy wind, or extreme temperatures can prevent work from taking place or significantly prolong the duration of certain tasks. Considering weather forecasts and incorporating potential weather-related delays into the offer helps to set realistic timelines and manage client expectations.
- Neglecting delivery and storage costs: When preparing offers, it is essential to consider delivery times, as well as the costs of transportation and storage for materials and equipment.
- Inadequate consideration of seasonal variations: Different seasons can impact working speed and resource requirements. For example, in summer, there may be more leaves to transport or longer working hours due to increased daylight. Failing to account for these seasonal variations can lead to underestimating labour and time requirements, causing delays and additional costs.
- Underestimating branch removal: Underestimating the number of branches to be removed during tree care or similar projects is a common error. Typically, the actual volume of removed branches is around 25% higher than estimated. Failing to consider this can result in inadequate resources, leading to inefficiencies and unexpected expenses.
- Lack of awareness and understanding of environmental issues and community relations: Environmental factors such as nesting seasons or noise regulations can impact project timelines and methods. Additionally, neighbour-related issues like noise complaints or interference can disrupt work progress. Being aware of and addressing these environmental and community-related challenges in the offer helps manage potential conflicts and avoid costly delays.
- Poor and unprofessional communication skills: Inadequate communication can lead to misunderstandings, delays, and disputes. Clear and effective communication with clients, subcontractors, and team members is essential throughout the process of preparing the offer. This includes proper documentation, regular updates, and addressing any concerns or questions promptly (see Chapter 4.1 Communication and Reports).

D. Post-calculation

Budget monitoring and post-calculation are essential aspects of responsible project management for ETTs. These processes play a vital role in evaluating the financial performance of a project and identifying any deviations from the original cost estimates.

After completing a job, it is common for ETTs to overlook the post-calculation phase. However, this calculation is crucial as it helps determine the actual operating result of the project. The post-calculation assesses whether the actual costs align with the expectations of the initial offer. To achieve an accurate post-calculation, documentation of all resources used, such as materials, machines, and labour, is necessary. Ideally, this documentation should follow the structure of the original offer.

One of the critical components in post-calculation is recording the time spent on the project. By tracking the number of trips made, the number of people involved, and their hours worked, the ETT can gain insights into the project's actual costs and performance. This data becomes invaluable for future cost estimations and project planning.

Regularly conducting post-calculation allows the ETT to refine their cost estimations over time. As the cost per unit is gradually adjusted based on real data, subsequent offers become more accurate, detailed, and less susceptible to unforeseen expenses. This iterative improvement process enhances the overall efficiency and financial management of future projects.

SELF-CHECK QUESTIONS

1. How do you estimate costs for tree work in a tender? Provide examples of different types of tree work that would be included in the estimate.
2. When preparing an offer for cross-border contracts within the European Union, what additional considerations should be taken into account?
3. What are the main considerations when preparing a cost table for an offer? Name at least three key elements that should be included.
4. What is the role of overhead costs in an offer, and why is it important to include them?

PRACTICAL EXERCISES

1. Make an offer for a job description according to the 10 steps described above. You can use your own template in MS Excel or MS Word. Focus on breaking down the job into smaller workstations and determine the price per unit.
2. For the above offer, carry out a post-calculation by using the same template. Answer the question of whether the offer was correctly compiled.

TERMINOLOGY

contingency – something that might possibly happen in the future, usually causing problems or making further arrangements necessary
estimate – roughly calculate or judge the value, number, quantity, or extent of
insurance – a contract in which an insurer indemnifies another against losses from specific contingencies or perils
salary – fixed amount of money paid to someone for the work the person is employed to do, usually calculated on a monthly or yearly basis
unforeseen costs – expenses that are incurred as a result of failing to identify all of the factors that make up the overall cost of a project.
wage – fixed amount of money paid to someone for the work the person is employed to do, usually calculated on an hourly, daily, or weekly basis.

3.3.
SETTING UP OF LEGAL TRANSACTIONS AND LIABILITY RIGHTS

Bregt Roobroeck, Wim Peeters & Ben Bergen

GENERAL OBJECTIVE

An ETT has a basic understanding of liability and how it is managed in their daily work. Furthermore, an ETT should know how to set up a contract that covers issues related to liability.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- explain the unanimous declaration of intent (as a prerequisite for the legally valid settlement of a contract);
- explain the legal classification of the tree as a construction;
- explain the basics of liability law, particularly with respect to damage caused by trees, and quote the regulations concerning liability in connection with injury to trees;
- explain and assess procedures for securing evidence; and
- explain the liability concerning consultancy work.

SEE TOGETHER WITH:

Legal Regulations for Carrying out Tree Work

ESSENCE OF THE TOPIC

The essence of setting up legal transactions and liability rights lies in establishing unambiguous, structured, and enforceable agreements or frameworks to communicate the liability to the stakeholders. Although liability comes in many forms and is not at the heart of the ETT's technical knowledge, it is a means by which they can legally operate in daily situations. The best way to set up such legal frameworks or agreements is through contracts.

KEY TERMS

Liability rights: balanced, civil liability, contractual liability, criminal liability, legal liability, non-contractual liability, risk liability

Setting up a legal contract: Agreement, clauses, involved parties, legal language, terms and conditions, validity

In order to set up the contracts, it is important to understand contractual and non-contractual liability. In essence, the contract will help ensure fairness, accountability, and predictability by defining the rights, obligations, and potential consequences for parties involved in transactions or activities and promote trust, stability, and the overall functioning of legal systems.

A. Liability Rights

A.1. Liability in Arboriculture

Liability refers to the legal responsibility for someone's actions or omissions that result in harm or damage to others. In the context of law and business, it means being held accountable or legally obligated to compensate for losses, injuries, or damages caused to another party due to negligence, breach of contract, or unlawful conduct. For arborists, liability refers to the legal responsibility and accountability concerning the care and maintenance of trees. This seems obvious but has some strange effects in practice. By law, in most European countries, the owner of the tree is liable for damage caused by the tree if it has been given insufficient care.

Note that, mostly, there is no risk liability. This means that the owner is only liable if the tree becomes a risk to people and/or property if, for example, they fail to deal with a dead branch. When in doubt, therefore, the owner will call in an expert to clarify matters. Arborists, and ETTs in particular, will assess, manage, and deal with the risk and are, therefore, liable if damage occurs during or after the assessment or tree work. As you may have noticed, the following problem appears:

The liability shifts from the owner to the arborist because the owner of the trees has called in an expert to deal with the risk. The owner has done his job of taking care of the tree. Because of this shift, arborists tend to overcompensate by removing more than the acute risk, which could be harmful to the tree itself. For example, if the risk is one large branch that can fall on the neighbour's garden shed or house, the arborist overcompensate by removing multiple (healthy) branches just to be sure. This shifted liability creates a stress field between implementing the minimum care to minimise the impact on the tree and eliminating the risk. ETTs are tree specialists and should be able to find that balance. Do not make the mistake of thinking that arborists, and particularly ETTs, are insurers. Note that it is up to the client who outsources the responsibility to check the competence of the inspector, tree expert, or arborist. Failure to do so may also hold the owner (jointly) liable. If the tree fails, the inspector, tree expert, or manager can be held accountable. In doing so, it is important that he/she can prove the correct judgement has been made. Any tree inspection carried out after a tree has failed will not have sufficient weight to prove the tree inspector had made the correct decision.

In these cases, the question to be asked is whether mistakes were made during the inspection. Were all elements assessed correctly based on the knowledge before the person carrying out the inspection? If the report clearly shows that all observations were assessed correctly, then there is little discussion. The systematic listing of all observations is one of the elements by which the tree expert protects himself against possible liability afterwards. The terminology used is also very important. You can use the research results to determine that a tree has no indications that, with current knowledge, there is a danger that could lead to an unacceptable risk. To conclude, arborists perform technical risk assessments, while insurers assess the legal aspect. You can tackle this problem by setting up a legal framework (e.g., a clause), like a contract, with your insurance company on the one hand and with your client on the other. Be aware that this is not the complete picture, as we have not addressed all liabilities, such as employee liability, privacy liability, and so on.

A.2 Difference in Types of Liability

Above, we explained liability as a general concept, but which kinds of relevant liability do we have? Depending on the classification, there are different types of liability. You can make the distinction between civil liability versus criminal liability or contractual liability versus non-contractual liability. Considering the scope of this chapter, we focus only on the latter classification.

A.2.1 Contractual Liability

Contractual liability refers to the legal obligation that arises when parties enter into a contract. In the context of contracts, liability refers to the responsibility of parties to fulfil their contractual obligations. When one party fails to meet its obligations as outlined in the contract, it may be held liable for any resulting damages or losses suffered by the other party.

A.2.2 Non-contractual Liability

Non-contractual liability refers to the legal obligation one party has to compensate another for harm or loss caused by wrongful conduct, even in the absence of a contract between the parties. Unlike contractual liability, which arises from a breach of a specific agreement, non-contractual liability arises from a general duty imposed by law to avoid causing harm to others. An example of this is the liability for your own actions or mistakes which are usually covered by civil law. It is logical that you are liable for making a big mistake, such as felling a street tree without traffic regulation. You are also liable for another person's actions if that person works for you as an employee or subcontractor.

B. Setting Up a Legal Contract

As we saw above, it is absolutely necessary to know who is liable for which actions. We briefly explained there is civil liability and (non)-contract liability. In this part, we focus on setting up a contract from a legal perspective. There are numerous templates or AI chatbots that can help you set up a contract, and they are great, but the key message is that the contract should be tailor-made and revised by a legal expert.

B.1. The Contracts of the Contract

An agreement starts when at least two parties agree to do something for each other. In principle, an agreement can be oral; however, it is preferable to make a written agreement, as this gives you more security and prevents conflicts.

An agreement, and thus a contract, contains at least the following elements:

- The involved parties and all their data:
    - Official names of the legal entities
    - Type of legal entity such as a public government, partnership, etc.
    - VAT number
    - Official address
    - etc.
- The subject: what the contract is about and what purpose it serves. For example, if you rent a skylift to dismantle a tree crown, your contract with the rental company will be a rental contract for the purpose of lifting big objects. Another example is when you prune trees in a private garden. The contract will be a construction contract with the purpose of carrying out tree work. This is essential for detecting which laws and regulations apply to the contract.
- The period of validity: it seems like an obvious detail, but forgetting to put a start and end date of the validity of the contract can have serious consequences and can be exploited by the opposing party during a conflict.
- The obligations: this is mostly the technical (tree-related) part of the contract.
- The procedures to start, finalise or terminate the contract.
- The possible conditions and compensation in the event of early termination.
- Clauses for damages, responsibilities, or conflicts: liability clauses are tools designed to manage overall risk by limiting a party's potential liability. Note that these liability clauses have their limits. If you repeatedly make the same small, intentional, or large mistakes then the liability clause is invalid for obvious reasons. Describe your damages, responsibilities, or conflicts/scenarios (what...if...) very clearly so no confusion is possible. Emphasise that the scenarios are not limited. Of course, the contract should be well-balanced for both parties. A party morally cannot set up numerous clauses where they distance themselves from all liability and the opposite party has full liability. For damages, disclaimer clauses are widely used to lower or exclude liability. This would not be a good deal for the opposite party.
- The responsibilities of all the parties.
- Terminology: if relevant, you can define certain terms to unambiguously clarify what is meant. This can be placed at the top of the contract.
- etc.

CONTRACTUAL LIABILITY VS. NON-CONTRACTUAL LIABILITY

Imagine an ETT is summoned to inspect a deteriorating tree in an urban area. In order to assess and solve the problem, excavation work near the root system needs to be done. As we all know, power lines and tree roots occupy the same area, so the excavation is delicate work. In the contract set up by the power line company, actions such as root investigation and soil replacement are well described. However, what happens if the contractor damages power lines during digging and 10 city blocks have no electricity? Although the contract assumes that the contracted party is fully liable for any damage to the power lines during the digging work, based on principles of property law (damage to property calls for compensation), the ETT can negotiate a clause wherein the liability for damaging or cutting power lines is limited.

An example of how to do this is to ensure that a supervisor of the power line company is present during excavation works and helps to detect the power lines based on the plans and experience. This shared liability is an example of a more well-balanced contract.

A LIABILITY CLAUSE FOR TREE ASSESSMENT

A visual tree assessment is a snapshot. It is used to assess the current condition, vitality, and susceptibility to breakage based on visual characteristics. However, trees are living beings that grow, decay, or even break down. Moreover, a large part of the tree, especially the roots, is underground. The extent to which and the speed with which a tree decays cannot always be clearly quantified, just like the peak loads a tree has to cope with during a storm. Therefore, no conclusive guarantee can be given that trees assessed as safe on visual or further examination cannot fail. However, with regular inspection and good management, risks can be reduced to an acceptable level.

The two first parts, namely the parties involved and the relevant laws and regulations they are subject to, form the basis of the contract as they determine the type of contract. For example, if one party is a public organisation like a municipality, the contract will logically be a tender. In Chapter 3.4 Legal Regulations for Carrying out Tree Maintenance, we explain the methodology to assess this.

In principle, you are free to include whatever you want in a contract. Having said this, European and national legislation provides certain restrictions towards the protection of, for example, private individuals and legal provisions in government contracts to prevent malpractice and unethical behaviour. An example is labour law when working with staff. Note, also, that despite European legislation and law, the contract should always be written in accordance with the national law of one party. This is, of course, obvious if both parties have their legal entity in the same country. If this is not the case, however, it is commonly written in the national law of the most powerful party. In a legal contract, the most powerful party is typically the party with the greater bargaining power or leverage during the negotiation process. For example, a municipality that publishes a tender is the most powerful partner.

B.2. Roadmap for Setting up the Legal Contract

Setting up a legal contract involves a series of steps to ensure that all the parties involved clearly understand their rights, responsibilities, and the legal implications of the agreement. Here, we suggest a roadmap to guide you through the process of setting up a legal contract. Of course, if you want to submit a tender, the contract is mostly non-discussable.

THE ROAD MAP

FOR SETTING UP THE LEGAL CONTRACT

1

DETERMINE THE TYPE OF AGREEMENT:

- Identify the parties: Clearly define who the parties involved in the agreement are. Include their full legal names and addresses.
- Specify the transaction: Clearly state what the agreement is about. Be specific about the goods, services, or property involved in the transaction.

2

DEFINE THE TERMS AND CONDITIONS:

- Scope of Work: Clearly outline what goods, services, or property will be exchanged. Be specific about quantities, quality standards, and any other relevant details.
- Payment Terms: Specify the total amount, payment schedule, methods of payment, and any late payment fees or discounts for early payments.
- Delivery/Performance: Define the timeline for delivery of goods or performance of services. Include milestones and deadlines, if applicable.
- Responsibilities: Clearly state the obligations and responsibilities of each party involved in the contract.

3

INCLUDE LEGAL LANGUAGE:

- Legally Binding Language: Include a statement indicating that the agreement is legally binding and enforceable in a court of law.
- Dispute Resolution: Specify how disputes will be resolved, whether through arbitration, mediation, or litigation in a specific jurisdiction.
- Confidentiality: If applicable, include a confidentiality clause to protect sensitive information.

4

CONSIDER SPECIAL CLAUSES:

- Indemnity: Specify if one party will compensate the other for losses or damages incurred due to specific events.
- Termination: Define the conditions under which the contract can be terminated by either party.
- Non-compete: Include a non-compete clause if one party is restricted from competing with the other party within a specific time frame or geographic area.

5

LEGAL REVIEW AND REVISION:

- Legal Review: If the contract involves complex legal matters, consult with a legal expert who specialises in the relevant field to review and provide guidance on the document.
- Negotiation: Allow room for negotiation. The parties may need to revise the terms and conditions until a mutually agreeable version of the contract is reached.

6

SIGN THE CONTRACT:

- Signature: Once all parties are satisfied with the terms, the contract should be signed and dated by all parties involved. Consider having witnesses or notarisation if required by local laws.

SELF-CHECK QUESTIONS

1. What is liability?
2. Explain, with some examples, what the difference is between contractual liability and non-contractual liability.
3. What do we mean by a well-balanced contract?
4. What is a clause?

PRACTICAL EXERCISES

1. Set up a clause for damage liability when digging for tree roots near utility lines.
2. Set up the terms and conditions of a work, e.g., felling a tree along the road as part of a public tender.

REFERENCE LIST

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ESSENTIAL READING

World Routledge Handbook of Urban Forestry
Edited by Francesco Ferrini, Cecil C. Konijnendijk van den Bosch, Alession Fini
Reference work on urban forestry

UK Risk perception and Arboriculture. Guidance on trees and public safety in the UK for owners, managers and advisers by David Ball (the National Trees Safety Group), https://ntsgroup.org.uk/wp-content/uploads/2016/06/Risk-perception-and-arboriculture.pdf
Although an older publication, it is still valuable to learn how risk perception on trees works from a professor on risk management.

UK Common sense risk management of trees by the National Trees Safety Group, https://ntsgroup.org.uk/wp-content/uploads/2016/06/FCMS024.pdf
Very good work regarding structure and text on risk assessment

3.4. LEGAL REGULATIONS FOR CARRYING OUT TREE MAINTENANCE

Bregt Roobroeck

GENERAL OBJECTIVE

Trees and tree work are affected by many different fields and levels of legislation; including but not restricted to agreements in contracts, conservational protection, liability for tree owners and health and safety regulations. An ETT has a basic understanding of how EU directives influence national law which forms the framework for local rules and regulations. More detailed knowledge is expected in certain areas, such as legislation covering worker safety and the environment, which can be different in each European country.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- explain the content, structure, and legal importance of regulations governing construction contracts;
- explain the contents and legal importance of specific standards, legislation, and contractual constituents as they affect tree care operations;
- know civil law where it concerns involved parties;
- show a basic understanding of public law;
- show understanding of the aims and principles of environmental law and legislation as far as it is relevant to trees in urban and rural areas;
- understand traffic regulations relevant to arboricultural work;
- have a basic understanding of contract law and industrial law;
- explain the relevant social insurance system;
- explain the content and legal importance of safety regulations relevant to arboricultural operations and draw conclusions about the practical applications of safety regulations as applicable to everyday working scenarios;
- draw conclusions about the practical applications of safety regulations as applicable to everyday working scenarios;
- know the basics of employment law, social legislation and collective agreements; and
- know the basics of regulations governing working at height and lifting and lowering.

SEE TOGETHER WITH:

Setting Up of Legal Transactions and Liability Rights

ESSENCE OF THE TOPIC

When carrying out jobs such as tree pruning along a road or felling a tree in a garden, it is crucial for an ETT to have a good working knowledge of the multiple laws and regulations that apply to the work being done. In essence, laws and regulations determine how agreements are made and how the contracts are set up. For this purpose, it is useful to have a basic understanding of the law and how to apply methods to define which legislation applies to each particular assignment.

Although ETTs are not lawyers, it is still quite straightforward to process to unravel and understand the relevant rules and regulations. By simply asking the following questions, the situation becomes clearer:

1. Which parties are involved in the assignment?
2. What is the subject matter or topic of the assignment?

KEY TERMS

Law system: decree, directive, European law, hierarchy of international law, municipal regulations, national law, treaty, regulation, United Nations

Legal branches: civil law, criminal law, financial law, private law

Proces of qualification: defines your rights and obligations as workers and employers

Checklist: These can include a wide range of legal topics, from employment laws to environmental concerns, contracts, industrial relations, and worker safety regulations. Industries vary widely and the policies for each is as unique as the business to which it relates.

This process is known as qualification, and it helps to detect the relevant legal branches and narrows down the scope of searching for relevant laws and regulations. Based on those two questions, the relevant laws and regulations will be made specific in the legal contract (Chapter 3.3 Setting Up of Legal Transactions and Liability Rights). See the contract as an octopus where the body is the most applicable legal branch. For example, in the case of tree pruning along the road, the relevant legal body would be public law. The tentacles can be seen as connections to other legal branches like road safety and industrial law (chainsaw, climbing restrictions, and on). In other words, the contract mostly ends up being a mix of clauses from different legal branches. Do not forget, of course, that if things get too complicated, you should seek the advice of a legal expert.

In this study guide, it is impossible to examine the different kinds of law in detail because it is vast, complex subject, and different in each country of Europe. It is up to the local certification center to provide an overview of laws and regulations involved and evaluated. In this chapter, we focus only on the basics of law and the methodology to find out which laws and regulations are applicable for your specific assignment.

A. The (Hierarchy of the) Legal Systems

In order to understand the laws and regulations that apply to work in and around trees, it is necessary how the law systems are structured and how they work.

There are numerous legal systems in the world which influence laws and regulations at local level. For European citizens, there are three large-scale levels around which law is structured; namely international (United Nations), European, and national level. The subsidiarity principle suggests that matters ought to be handled by the smallest, lowest, or least centralised competent authority rather than a central authority. As consequence, more local governments must apply the laws and regulations of the overarching governing bodies, such as the UN or the EU. Be aware that strategies are not the same as laws and regulations. For example, the Biodiversity Strategy for 2030 is a strategy to achieve a goal; the laws and regulations are just instruments to meet that goal.

A.1. International Law

International law, also known as public international law or the law of nations, covers the set of legal principles, norms, and standards that govern the relationships between sovereign states and other entities officially acknowledged as international actors. without going into detail, modern international law arose in the aftermath of World War II with the creation of the United Nations in 1945. The UN Charter laid out rules whereby countries agreed to uphold human rights, respect borders, and settle disputes through negotiation and arbitration rather than conflict. Two examples are the Sovereignty Principle and the Universal Declaration of Human Rights. It basically means that all the UN countries acknowledge this set of laws and regulations. It is important to note that at a more local level, such as the EU or national level, these laws and regulations still apply. Moreover, they need to be embedded into these more local levels. Agreements of the UN are embedded in conventions or treaties. An example is the 1993 Convention on Biological Diversity (CBD), which forms the basis of biodiversity policy of the EU.

A.2. European Law

Most EU countries (called member states) have a legal system based on the Civil Law system, which is a complex system of laws and treaties that govern the relationships between the EU institutions, member states, and individuals or businesses operating within the EU. The legal system of the European Union is primarily based on 3 aspects:

1. EC treaties. A treaty is a binding agreement between member states and must be followed. A treaty must be signed by each individual member state. In many cases, ratification is required afterwards: the government of the participating country still has to approve the treaty. This is not relevant for an ETT.
2. Regulations: Regulations are directly applicable laws that are binding in their entirety and automatically become law in all EU member states without the need for national legislation. They are used to ensure consistency across the EU, especially in areas where uniform rules are necessary, such as competition policy and consumer protection. An example is the EU Regulation 2016/2031 on protective measures against pests of plants, with the Phytosanitary Certificates being the most tangible outcome.
3. Directives: Directives are legal acts that set out specific goals that all EU member states must achieve. However, it is up to the individual countries to decide how to implement these goals into their national laws. Member states have the freedom to choose the form and method of implementation, allowing for adaptation to national legal traditions and administrative systems. The most known are the Birds and Habitats Directives that form the cornerstones of EU biodiversity policy. The directives for the EU are more about fixing the goal; the way to achieve it is up to the member states.

A.3. National Law

As a consequence of the above hierarchy, national law is inevitably a mix of international and national law. A lot of EU directives are implemented in national legislation such as decrees or Royal Decrees in Belgium. For example, the Water Framework Directive 2000/60/EC sets out rules to halt deterioration in the status of EU water bodies and achieve good status for Europe's rivers, lakes and groundwater. This directive, developed in 2000, was transpose into Belgian legislation through the decree Integral Water Policy of 18 July 2003.

To make this more complicated, at the level of cities and municipalities, municipal regulations also apply.

B. Legal Branches

A legal branch of law refers to a cluster of legal issues, principles, and regulations around the same topic. Among branches of law, two primary branches emerge: private law and public law. Be aware that in practice, laws can be applicable to both, such as procedural law. The distinction between them lies primarily in the parties involved in the legal relationship at hand. It is not the scope of this study guide to address all types of law, but some branches are very relevant and will be explained in the subchapters.

B.1. Private Law

Private law governs interactions between private individuals, legally equal parties such as buyers and sellers who have specific rights and responsibilities. It consists of civil law, commercial law, international private law, and intellectual property law like copyright and patent regulations. The most relevant and largest part of private law is Civil law.

Civil law defines the rights and responsibilities of mainly individuals like citizens in their day-to-day interactions with each other. More specifically, civil law deals with issues such as personal injury, contracts, property, inheritance, family law, labour law, and social security law.

In essence, civil law is the baseline law when working with clients, although it is very specific for each country. In the textbox on the next page you will see the example of Flanders, Belgium.

B.2. Public Law

Public law refers to the body of law that governs the relationship between individuals and the state, as well as the structure and operation of the government itself. It establishes the legal framework within which governments operate, outlines the rights and duties of government institutions, and regulates the interactions between the state and its citizens. Public law is essential for maintaining order, protecting individual rights, and ensuring the proper functioning of public institutions. It consists of constitutional law, administrative law, financial law, criminal law, procedural law, environmental law, and international law. Usually, when performing an assignment with a public organisation such as a local government, the following laws are the ones that most relevant to contracts and liability:

- International (environmental) Law: Laws such as the European Bird and Habitats Directive and the Convention of Bern can be in force. An example can be found in Chapter 1.2.3 Ecology and Biodiversity. Another example is Regulation No 1107/2009 on Plant Protection Products for managing pesticides.
- Criminal Law: A public party such as a municipality can ask if you or your organisation have a criminal record.
- Financial Law: A public party such as a municipality can ask if your organisation has the financial capabilities for performing the assignment.

C. The Process of Qualification

When setting up a contract or performing an assignment, you need a methodology to understand which laws and regulations apply to the work to be carried out.

One important step is the qualification of the contract. This is the process which determines the mutual rights and obligations of the contracting parties.

AN EXAMPLE OF CIVIL LAW: FLANDERS (BELGIUM)

The main tree related aspects in the Civil Law related to tree pruning and felling are related to excessive neighbour nuisance:

- Trees can only be planted at a minimum distance of 2 meters from the boundary between 2 properties, private or public. There is a statute of limitations after 30 years: the felling of wrongly lanted trees (closer than 2 m) cannot be claimed from 30 years after they were planted onwards. The right to claim that such a tree should be felled is also subject to the general principles of 'abuse of law': a neighbour cannot claim these rights if the downsides of felling the tree are disproportionately high compared to the benefits obtained.
- A neighbour can claim that the tree owner should prune away all the branches overhanging the property boundary. After 60 days' notice without response, the neighbour can prune the branches himself (or have them pruned) and charge the owner for this work.
- A neighbour can claim that the tree owner cuts away all roots crossing the property boundary. After 60 days' notice without response, the neighbour can cut the roots himself (or have them cut) and charge the owner for this work.
- Note that there is no statute of limitations when it comes to the right to prune overhanging branches and cut away roots: these rights stay valid after decades or centuries. However, these rights are also subject to the general principles of 'abuse of law': a neighbour cannot claim or execute these rights if the damage to the tree is disproportionately high compared to the benefits obtained. Judges have the power to give a ruling that takes the public benefits of the tree into account.
- A neighbour can claim 'excessive nuisance' from a tree, if this nuisance exceeds the normal nuisance that can be expected in that environment (different in urban areas compared to the countryside). This is a very vague legal description, which gives the judges greater scope in their deliberations. Tree pruning is often imposed by judicial decision after such claims, based on excessive shade, leaf fall, etc. However, judges have to take into account the public benefits of the tree in their decisions.

It involves two steps:

1. The determination of the parties (stakeholders).
2. The determination or establishment of the content of the contract and the mutual rights and obligations it entails (this is the interpretation of the contract).

C.1. The Determination of the Parties (Stakeholders)

Identifying the parties involved in a contract is the foundational step in any legal agreement. This involves not only understanding who the primary parties are but also recognising any secondary stakeholders who might be affected indirectly. These stakeholders could include employees, shareholders, subcontractors, or even clients of the contracting parties. Clarity about the identity of these stakeholders is crucial, as it defines who holds responsibilities and rights under the contract.

In some cases, especially in complex business transactions, there might be multiple parties involved, each with varying degrees of influence and responsibility. Legal entities, such as corporations or partnerships, must be correctly identified, including their registered addresses and representatives. Additionally, individuals involved should be specified by their full legal names and titles. Properly identifying stakeholders ensures that the contract's obligations and benefits are correctly distributed among all relevant parties.

C.2. The Determination of the Content of the Contract

Once the parties are identified, the next step involves establishing the contact of the contract. This process is intricate and demands meticulous attention to detail. It consists of the precise definition of terms, conditions, and clauses that outline the mutual rights and obligations of the involved parties. Interpretation of the contract involves understanding the explicit statements as well as implicit implications, ensuring that there is a shared understanding between all stakeholders.

- Defining Terms and Conditions: Clear definitions of terms used in the contract are paramount. Ambiguity in language can lead to disputes. Hence, all technical, legal, and industry-specific terms must be defined explicitly within the document.
- Stipulating Rights and Obligations: The contract should comprehensively outline the rights and obligations of each party. This includes what each party is expected to do (obligations) and what they are entitled to receive (rights) under various circumstances. These must be detailed and specific to avoid misunderstandings.
- Addressing Contingencies: Contracts should anticipate contingencies, outlining the course of action if unexpected events occur. This might include provisions for termination, breach of contract, force majeure, or any other unforeseen circumstances.
- Compliance with Applicable Laws and Regulations: A crucial aspect of contract establishment is ensuring that the content complies with relevant laws and regulations. Contracts that violate legal standards can be rendered void or unenforceable.
- Dispute Resolution Mechanisms: Including mechanisms for dispute resolution, such as mediation, arbitration, or litigation procedures, can significantly streamline conflict resolution, saving time and resources for all parties involved.

D. Non-limitative Checklist

As an ETT, you have to check every law and regulation is followed to avoid damage, safety risks, and reduce your liability while doing your job. A checklist to go through can be helpful to see what applies to your assignment. Below you can find an example of a checklist who helps you to structure your own checklist appliable to legislation in your country. This study guide explicitly points out that this checklist is non-limitative and not finetuned for a specific country. It is just to show an example of what a checklist could be. The main topics are mostly the same across the EU.

1. Nature conservation, forestry, countryside:
    - understanding which work is allowed in protected areas;
    - endangered species;
    - felling of woody plants growing outside the forest;
    - substitute planting and general planting;
    - special protection of plants and animals.
    - etc.
2. Heritage protection:
    - veteran trees;
    - special status trees.
    - etc.
3. Civil Law:
    - contract with involved parties who you are working for;
    - law concerning neighbors;
    - civil liability;
    - privacy.
    - etc.
4. Public Law:
    - Tender process
    - etc.
5. Work and safety (including traffic regulations):
    - environmental legislation as far as they are relevant to trees in urban areas: nature protection and heritage protection;
    - permission for pruning/cutting trees;
    - impact of the work on traffic and traffic regulations;
    - permission for digging in a public area .
    - etc.
6. Application of industrial law, company law, labour law, and social legislation:
    - working at height or lifting and lowering regulations;
    - European chainsaw standards;
    - risks inherent in work that conflicts with what is stipulated in labour and social legislation.
7. Certifications (not required by law, more good practice)/permits (legally mandatory): licenses for sky-lifts, heavy trailers, ECC, ETW, ETT

If some of these regulations or laws are suitable for your case, you have to be sure that you act accordingly and know how to regulate yourself if necessary. Regarding liability, it is important that you can always show that you have done everything in your power to prevent damage in accordance with current knowledge, so that when something goes wrong, you can prove you have done everything to avoid injuries and damage. The scheme below can be helpful.

1 WHICH LEGISLATION APPLIES

2 HOW SHOULD/CAN I FOLLOW IT?

3 HOW TO REGULATE OR ACT IF SOMETHING GOES WRONG?

AN EXAMPLE OF QUALIFICATION: CZECH REPUBLIC

The pruning of trees is ensured by their owner or another authorised person (the owner of a tree is the owner of the plot on which the tree grows). The pruning of trees and their inspection is a professional activity. Interventions on trees are irreversible; therefore, it is necessary that they are done by competent persons. Activities associated with the pruning of trees are therefore operations requiring an adequate qualification. There is no state-regulated qualification system or recommendation that defines the minimum qualification of people working on trees. The recommended qualification for persons pruning trees at height is a successfully passed certification test for:

- Czech Certified Arborist – ground worker. The recommended qualification for persons pruning trees off the ground and at heights is the successful completion of one of the following certification tests:
    - Czech Certified Arborist – Tree Climber,
    - Czech Certified Arborist – Platform,
    - ISA Certified Tree Worker Aerial Lift Specialist,
    - ISA Certified Tree Worker Climber Specialist,
    - European Tree Worker,
    - European Tree Worker – Platform.

Specific certification schemes are being developed for use in specialised areas of tree care, such as the maintenance of trees along roads and railways.

SELF-CHECK QUESTIONS

1. Explain the hierarchy of legal systems.
2. What is civil law?
3. Is an EU directive immediately applicable in national legislation? Explain why or why not.

PRACTICAL EXERCISES

1. Set up a small contract between a client and apply the process of qualification by asking the two questions.

REFERENCE LIST

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ESSENTIAL READING

The text in this chapter summarises many years of practical experience and is more a methodology or thinking pattern that cannot be found in books applicable to arboricultural practices. We cannot recommend any essential or additional reading list.

3.5.
PROFESSIONAL ORGANISATIONS AND TRADE UNIONS AT EUROPEAN AND NATIONAL LEVELS

Ben Bergen

GENERAL OBJECTIVE

To have a general knowledge of professional organisations and trade unions at European and national levels.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- show an understanding of the aims and responsibilities of the relevant arboricultural, horticultural, and forestry associations and governing bodies;
- show an understanding of the aims and responsibilities of other relevant and influential associations, governing bodies, and various public services that can affect city trees.

ESSENCE OF THE TOPIC

Arboricultural professional organisations and trade unions are organised at the European and national levels to improve the condition and number of trees in urban areas by facilitating the education and certification of arborists. Key to this story is the spreading of often newly developed knowledge concerning tree care and tree management. Further, by endorsing a code of ethics and by representing a huge number of professional arborists, these organisations have a greater impact on policy.

A. European Arboricultural Council

The European Arboricultural Council (EAC) is the biggest arborist organisation in Europe. Their objective is to improve the health and care of trees of environmental importance by ensuring the highest levels of professionalism in arboriculture. Explicitly, the EAC wishes to improve:
- The profession
- Research on urban trees
- Education and training in arboriculture
- Safety practices with pruning tools and chainsaws
- Tree management
- Disease and pest control
- Tree planting in urban conditions
- Harmonisation of tree care procedures in Europe

All members of the EAC are national representative arborist organisations of different countries in Europe with the same objectives. The EAC organises and regulates the European Tree Technician and Tree Worker certifications.

This certificate has a validity of 3 years. By demonstrating sufficient annual training, you can apply for an extension or recertification. The aim is to keep the quality of the certificate high and encourage people to undergo lifelong training. In addition, they produced the European Arboricultural Standards, good practices, and code of ethics. The EAC also publishes literature around tree care and promotes good tree management throughout Europe.

Worldwide, ISA (the International Society of Arboriculture) is the biggest arborist association. Through research, technology, and education, the International Society of Arboriculture (ISA) promotes the professional practice of arboriculture and fosters a greater worldwide awareness of the benefits of trees. Besides all this, they organise international tree-climbing competitions. In essence, both organisations have more or less the same goals, but the EAC is the dominant organisation in Europe, while the ISA is the leading organisation in the rest of the world.

B. Organisation of Arboriculture in Europe

On the website of the EAC (https://www.eac-arboriculture.com/members) you can see which countries are members of the European Arboricultural Council (EAC). Under the name of the country, you see the national representative for each country. When you click on his/her name, you will get more information. In preparation for the ETT exam, you have to search for those organisations that are actively involved in the work of arborists and tree care in your own country. There are, for sure, more than just those that are members of the EAC. It is, however, not the scope of this study guide to give an overview of how the arboricultural sector is organised in each EU country. We only show an example of Belgium in the textbox. The key message is to illustrate that every country has a unique structure within which arborists are organised.

ORGANISATION OF ARBORISTS IN BELGIUM

Belgium is a small but politically complex country, consisting of 3 regions (the Flemish, French, and German-speaking parts), each with its own government working autonomously and independently. There are several professional arborist organisations:

- Bomen Beter Beheren, covering the Flemish part;
- Arboresco, covering the French part;
- BAAs, the official representative of Belgian arborists;
- Others that are affiliated with trees.

Bomen Beter Beheren

As a professional non-profit organisation, Bomen Beter Beheren (BBB) unites mainly practising and consulting arborists as members. BBB organises activities such as an annual tree trip, field trips, and other social events, and is also the official organiser of ETW/ETT exams in Belgium, including the French and German-speaking parts of the country.

Arboresco

Also a non-profit association within the Wallonia-Brussels Federation, it brings together tree climbers, researchers, students, and gardeners. Arboresco fights against preconceived ideas and tries to disseminate information to professionals in the sector to promote pruning that respects the biology, architecture, and aesthetics of trees. They perform similar tasks to BBB.

Belgian Arborist Associations

The Belgian Arborist Association (BAAs) is the national arboricultural association. In fact, this organisation is a joint venture between Bomen Beter Beheren and Arboresco. BAAs was set up to represent the Belgian arborist industry in international affairs, mainly through its organisation of the Belgian Tree Climbing Championship. BBAAs is an associate partner of the International Society of Arboriculture. BBB is the national representative in the European Arboricultural Council.

BOMEN BETER BEHEREN	ARBORESCO	BAAs
Pursuases a valued urban tree forest	Pursuases a higher respect for the tree	Organizing Belgium climbing competition
Organizing seminars	Organizing seminars	ISA associated seminars
ETT and ETW certification		

Others

Although the national organisations are the most common and easy-to-find arboricultural organisations, there are several others that are affiliated with trees:

- Inverde (part of Natuurinvest) is the leading arboricultural training centre in Flanders and a daughter organisation of the Flemish government's Nature and Forest Agency. Inverde organises professional training for practising and consulting arborists, both one-day and longer training.
- Urban Forestry Lab (VIVES): educates tree managers and carries out research on urban forestry;
- Vereniging voor Openbaar Groen (Association for Urban Greenery);
- Agentschap Natuur en Bos (Flemish government's Nature and Forest Agency);
- Instituut voor Bos- en Natuuronderzoek (Forest and Nature Research Institute);
- Agentschap Wegen en Verkeer (Flemish government's Traffic Agency);
- Agentschap Onroerend Erfgoed (Flemish government's Heritage Agency);
- Cities and villages, being the owner/manager of many urban amenity trees.

SELF-CHECK QUESTIONS

1. Which are the national organisations with objectives related to urban forestry?
2. What is the link between the EAC and the ISA, and what are the differences between these organisations?

TERMINOLOGY

Trade Union – an organisation which unites and organises, for example, arborists and represents their interests

Code of Ethics – rules or guidelines stating what can and cannot be done; these can include behaviour, practical implementation, and standards

REFERENCE LIST

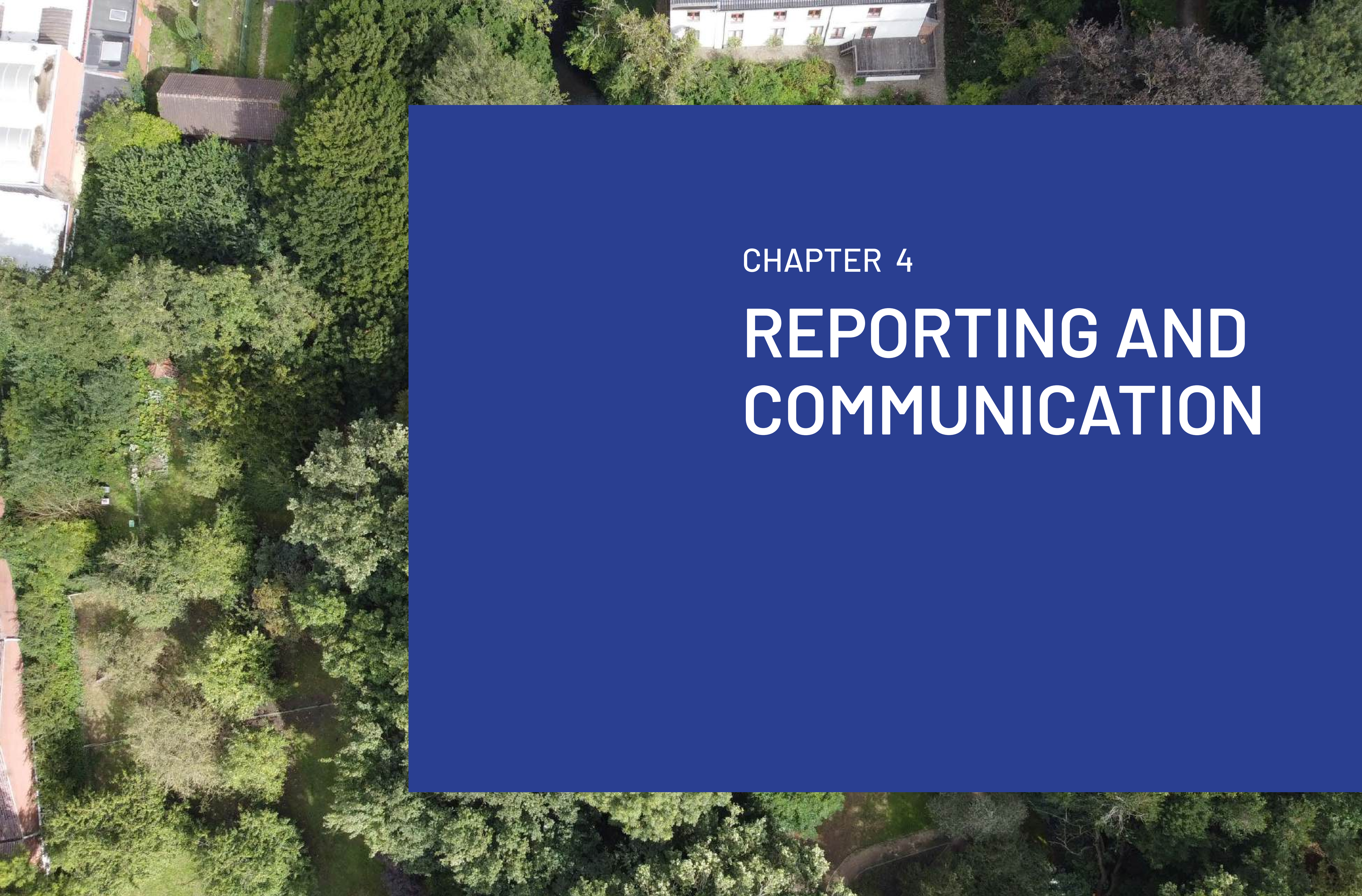
Website of the European Arboricultural Council https://www.eac-arboriculture.com
Website of the International Society of Arboriculture https://www.isa-arbor.com
Erasmus European Arboricultural Standards (2022). Tree pruning: national annex Belgium. Retrieved from: https://ec.europa.eu/programmes/erasmus-plus/project-result-content/e45dfccd-51a5-4612-9215-2dc94de2ca64/Tree_pruning_-_national_annex_-_Belgium.pdf

ESSENTIAL READING

EU How the EAC works: www.eac-arboriculture.com
The starting point for finding all the necessary information on how arborists are organised in Europe, including certifications, newsletters, knowledge, etc.
World How the ISA works: www.isa-arbor.com
The starting point for finding all the necessary information on how arborists are organised worldwide.

ADDITIONAL READING

Read the information on the webpage of your official national arborist organisation. These organisations are listed on the official EAC website.



CHAPTER 4

REPORTING AND COMMUNICATION

INTRODUCTION

In an era in which there is a continuous stream of information, and where everybody is a stakeholder of the urban forest with (critical) opinions, it is necessary to justify any conclusions and/or advice that you give, something that we addressed in Parts 1, 2, and 3. This chapter is all about how to transfer that information to the stakeholders. To do this, Part 4 covers three areas of competencies related to structuring communication, documenting work, preparing plans of action, and explaining how the tree management is being carried out. Do not underestimate the role of an ETT as an advisor or consultant, where structured communication is a key requisite of a professional. To assist you in this, the following chapters focus on managerial, verbal, and social skills and knowledge.

4.1.
COMMUNICATION AND REPORTS

Beata Pachnowska

GENERAL OBJECTIVE

Provide guidance on how to communicate clearly and effectively with the various stakeholders in an arboricultural project – from identifying them to communicating the results of the work orally or in written form.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- communicate professionally, both orally and in written form;
- adapt the style of communication according to the target audience;
- take the input of all the stakeholders into account to ensure the best possible result according to best practices;
- communicate with the stakeholders while the work is being undertaken;
- identify the stakeholders and take the initiative to inform or consult all involved and interested parties as the point of contact in the field;
- communicate effectively about the assignment, adhering to the company's policies and enhancing the company's image; and
- describe findings, advice, execution, site follow-up, etc. in a structured manner in a document.

SEE TOGETHER WITH:

Performance Description, Tree Assessment, Structured Tree Management, Advisory and Consultancy

KEY TERMS

Communication process: channel, communication (one-way/two-way), communication process, communication scenarios, encoding, decoding, (key) message, noise, receiver, sender

Stakeholder analysis: arboricultural project, internal/ external stakeholders, key representatives, key project messages, professional stakeholder-driven communication

Documentation and reporting: analysis, assertiveness, conclusion, data (primary and secondary), data transforming, methodology, raw data, recommendation, storytelling

Context: multifaceted, tree life span, probabilistic events / accidents and uncertainty, public attitudes

ESSENCE OF THE TOPIC

Every operational process in arboriculture involves not only trees and machines but first and foremost, people. Their needs, expectations, or decisions affect the fate of trees and the actions of those responsible for trees. These various actors or observers involved in arboricultural processes can be called stakeholders because they can influence or be influenced by a given process, just like shareholders and customers in companies. An ETT interacts on a daily basis with a wide variety of stakeholders in the environment – both institutions and individuals – and it is important that he/she knows how to perform a stakeholder analysis in order to identify, recognise, diagnose, and interact with them appropriately.

Many of the people and groups involved in the work of tree care and management are not from the industry. The ETT is the link between them and the professional arborists. This means that communication, including reporting to various stakeholders, may require translating or decoding tree-specific technical vocabulary into clear, transparent, and flexible language for those and the general public. This can best be done by telling a story aimed at answering questions related to the task so that the message is as clear as possible to the stakeholders while at the same time being credible, competent and professional. The essence of good communication means exchanging information between sender(s) and recipient(s) and removing noise by using effective messaging channels. This aspect of the ETT's work is demanding: one needs to define and identify stakeholders, recognise and understand their needs, and deliver answers and solutions in a way that is comfortable for them. Therefore, it is important for the ETT to know the basics of communication theory, be able to analyse the project environment, understand the principles of preparing documentation and reporting, and use them in practice.

A. ETT in the Communication Process

A.1. Communication in a Nutshell

The communication process for project management purposes can be depicted in the popular interaction model. It takes into account the two sides of communication – the sender and the receiver – as well as the message conveyed to the receiver by the sender. The message is encoded, often in a common language, and transmitted through an established channel. The receiver can receive the message by decoding it (that is, for example, by reading it in a language he/she understands well), often responding to it using an analogous communication process. Feedback can be used to confirm receipt of a message, to check that the recipient has understood it, or to clarify the message.

Communication models usually include another factor: interference in the process of transmission and reception of the message, resulting in misunderstanding due to either the use of unfamiliar terminology or physical interference (e.g., illegibility of the text or ambient noise), – called noise. "Noise" is related, for example, to the multiplicity of messages, the illegibility of the message, the differences between recipients and senders, the multichannel nature of the message, and differences in the way it is encoded and decoded. It is worth remembering that senders send multiple messages, some of them unintentional, and receivers receive multiple messages, some from other senders. Individual messages can influence each other, interfere with each other, and interact with the prior knowledge, attitudes, experiences, and situational goals of both parties in the process.

Communication can occur in all the relevant message channels, such as verbal communication like oral discussion; written reports, telephone; email; social media; and outdoor advertising, such as posters at construction sites. Each of these channels and means can be agreed upon with the client, and the messages can serve a specific purpose. The ETT, moreover, can be involved in them in one of the many roles he/she plays. Note that non-verbal communication, such as the appearance of company cars and employees, staff behaviour, or the appearance of documentation, can influence verbal communication both in a positive and negative way.

Good communication processes mean exchanging information between sender(s) and recipient(s) and removing noise through effective message channel(s).

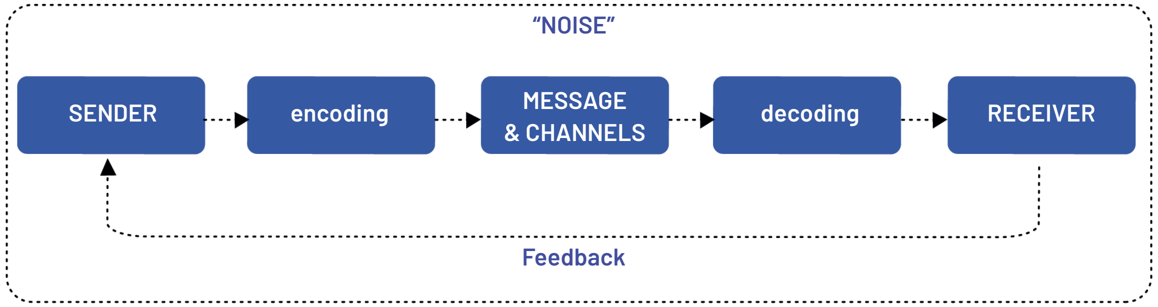


Figure 1. Communication process according to the interaction model

<table>
<tr><th>ETT as a sender</th><th>ETT as a receiver</th></tr>
<tr><td>tenderer</td><td>author of the request</td></tr>
<tr><td>delegating employees</td><td>the person commissioning the work</td></tr>
<tr><td>preparing documentation e.g.,
work reports or tree evaluations</td><td>accepting the consultant's expert
opinion on the tree</td></tr>
<tr><td colspan="2">manager/supervisor of tree workers
leading arrangements with contractors
communicating with the public e.g., passers-by</td></tr>
</table>

Table 1. Examples of ETT roles in the communication process.

A.2. The Role(s) of the ETT in the Communication Process

In an arboricultural project, an ETT can be involved in a number of communication processes and roles, depending on the stage of the project and the stakeholder group with whom he/she is sending and receiving information. Of course, in some cases, an ETT can be part of a message channel(s) sharing the information gathered from others.

In these areas the ETT can be:

- an advisor – e.g., ongoing assistance with stand management;
- a consultant – e.g., assessing the condition of trees, preparing a tree replanting project;
- an executor – e.g., managing the implementation of a specific project;
- a representative – e.g., as a supervisor of the work of other contractors.

He/she will perform different tasks and interact with different stakeholders. In each of these roles, the ETT can act on behalf of the company/organisation, during which time care is needed to ensure a good image and consistency with the organisation's public relations (PR). It is worth ensuring that the role and responsibilities, as well as the relationship to other parties in the process, are clearly identified in the contract, along with the channels of contact.

A.3. The Communication Strategy

A communication strategy involves developing and implementing a comprehensive plan to effectively convey information, raise awareness, and engage recipients regarding the trees and the work being carried out. The strategy can be elaborated or short, but always tries to ask and answer the following questions:

- Who are you talking to?
- What are the key messages?
- What are the resources?
- How, where, and when should you communicate?
- What are the expected results?
- How can you control the results?

First of all, it is essential to define the target audience by performing a stakeholder analysis. Second, clarify what you want to communicate. It is best not to have more than 2-5 key messages to keep it clear. A key message could be that trees grow and become big or that sometimes trees need to be felled. Experts in any field wildly overestimate the average person's familiarity with their field.
With resources we mean skills, people, money and time. The how, where and when makes the strategy SMART (described in Chapter 3.1. Performance Description). Essentially, it involves envisioning a good outcome for the process and then controlling it.

An important element of communication is to identify the specific representatives of the group concerned who can be parties in the process. These are either official representatives of the group in question (e.g., a company representative, a site manager) or people taking on the role of representatives, e.g., community opinion leaders (such as a representative of the residents of the area or an opinion leader of a 'green' social media group).

Models of communication with different stakeholder groups indicate variation in the intensity and content of the relationship, usually on a two-dimensional matrix of involvement in the project and real impact on the project.

Together with the intensity and content of the relationship, it is interesting to know if the communication with the stakeholders is one-way or two-way. One-way communication, for example transmitting information for educational purposes or capacity building, means that there is little interaction with the stakeholder. Two-way communication is about consultations where feedback is desirable to make more informed,

		Interest in the project	
		low	high
Impact on the project	small	Observe/ minimal involvement	Maintain contact, inform
	large	Maintain contact, show results	Broad communication

Table 2. Communication across stakeholder groups with different priorities for the project.

COMMON COMMUNICATION SCENARIOS

Pre-prepared scenarios and aids to the communication process can be useful. Having ready answers makes it easier to give answers to passers-by, the media or clients, especially when stressed about public speaking.

Examples of areas of such scenarios are indicated below:

1. Description and explanation of the fundamentals of trees, including not only their value but also their dangers. Example topics: the role of trees in controlling urban temperature; the importance of root damage to tree statics; the importance of hollow trees and fungal fruiting bodies; and the importance of ecosystem services.
2. Description and explanation of the typical work carried out on and around trees. Examples: Explanation of why young trees are pruned, what mulching involves, and why living trees might have to be cut down.
3. Description and explanation of key information about the specific project being carried out – to be agreed on with the client beforehand. This includes, for example, information about the head of the organisation carrying out the work, contact details of the representative, project objectives, project time, expected project results, and project cost.
4. Description and explanation of the role of ETTs – in general and specifically in a given project. Example: core competencies of the ETT, the relationship of the ETT to the tree worker, and the tasks of the ETT in a given project.

Use short answers for passers-by, additional arguments for leaving a tree, explanations for building contractors, and information for cleaning services.

Restrictions: project information, objectives, and contact details should be agreed with the client. As a minimum, it will be helpful to write a concise communique about the project in question. As well as being an aid for public speaking, it can be given as a 'handout' to the media and other stakeholders, as well as be used to create information material (message boards, the internet).

custom-made decisions. Moreover, communication can be bottom-up (from executors or the public to decision-makers) or top-down (in the opposite direction).

A.4. Conclusion

To conclude, communication to stakeholders should be:

- clear: be strategic about the key information you want to communicate;
- adapted to the audience: adapt media and language to your target public;
- transparent: offer context, disclose methods, sources, errors, and margins of error;
- planned but flexible: be prepared but responsive and open to change.

B. Stakeholder Analysis

As mentioned above, stakeholder analysis is the backbone of the communication strategy. In an arboricultural project, many groups of stakeholders can be distinguished, including internal stakeholders – those connected to the project – and external stakeholders – those not directly connected to the project, but influencing it (real or potential). Their diversity may require considerable communication skills on the part of the ETT. The ETT should be able to define the stakeholder groups of the ongoing project, recognise them and their most important representatives in practice, and adapt his/her communication to their specificities, taking into account their place in the project. This is all done in a stakeholder analysis.

The identification of stakeholder groups and their representatives is done in various ways, and methodologies have been developed to help with this. In large projects, for example, the organisation commissioning the work may have already carried out a stakeholder analysis, which it can make available to the ETT. The ETT can therefore check whether the stakeholders are identified. If they are not, or this is not available, the ETT can use a general scheme of arboricultural projects to identify and label the stakeholder groups. Figure 4 shows examples of these stakeholder groups. The ETT can take any role in the diagram, for example, a tree manager, a tree worker, and so on.

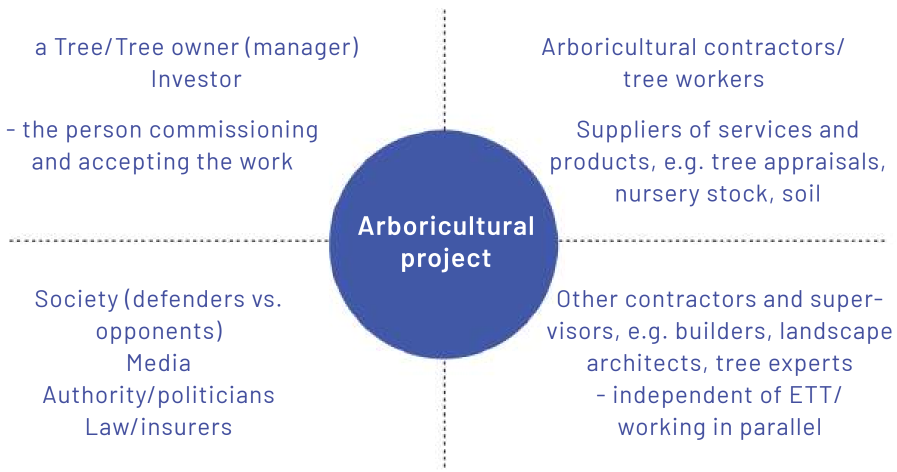


Figure 2. Examples of stakeholder groups in an arboricultural project.

Professional stakeholder-driven communication requires several steps recommended in the literature and by experts. In ETT practice, there will probably not be a need for communication plans and their control, but a few preliminary steps in the stakeholder analysis can be helpful in day-to-day work, as listed below:

- identification of groups that will be affected by the project;
- prioritisation of stakeholder groups according to their relationship to the project (e.g., interest in the project, influence on the project, attitudes);
- identifying key representatives in stakeholder groups;
- identifying the types of communication needed;
- development of key project messages;
- filtering out the noise;
- creating a timetable for the communication plan;
- preparation of the means of communication;
- conducting communication;
- track the effects of stakeholder communication and amend accordingly.

One specific stakeholder is the client – the one who submits the tender request, commissions the work, and approves the work as done (note: in reality, these may be different people in different departments of the client's institution). That person may represent different groups related to the tree/stand, for example, the landowner, the site manager, the investor, a community organisation (e.g., a tree protection association or foundation) or the law (e.g., the court or the police), depending on the content of the project and its purpose.

C. Documentation and Reporting

An important element of an arboricultural project is the creation of documentation and reporting, i.e., the collection, processing, and communication of information relevant to the ongoing project, including facts, results of analyses, as well as conclusions, interpretations, and recommendations. Preparing documentation often begins with a request for a proposal where problems, needs, assignments, and preliminary conditions for acceptable solutions are described by the potential client. Usually, a proposal is the first part of documentation prepared by the ETT (see more in Chapter 3). When the assignment is confirmed by an agreement, the process of documentation is a fixed aspect of all the stages. Note that it is essential to tell a story.

ETT's documentation should:

- have a good structure and thus tell a story with:
  - **a beginning:** an outline of the demands of the assignment;
  - **a middle:** data gathering and analysis, as well as preparation of conclusions and recommendations; and
  - **an end:** concluding how the demands of the report were met.
- be comprehensible: speak the language and formulate answers in a way that is understandable to the stakeholders;
- be stakeholder-minded: the stakeholders want something custom-made, so fulfil this desire and don't go beyond the scope of the assignment;
- be professional: use appropriate and up-to-date tools, ensure and maintain a good level of execution, check the last version before delivery, and use your expertise in proper areas.

The process that leads to the development of documentation is shown in Figure 3.

Figure 3. Documentation preparation process

C.1. The Beginning: Assignment

The starting point for the process of preparing documentation on arboricultural processes are the recipients of the documentation; it is often their expectations (expressed in the detailed guidelines written in the tender conditions, established in the evaluation forms/tree evaluation applications, or communicated verbally) that determine the scope of the data to be collected in the field and set the framework for the report. This is an important step: to understand well the assignment described in the request and to answer any questions, calculate costs and timescales, and conduct the work needed. Be prepared that sometimes the stakeholders don't really have a clear idea of the assignment that they want to assign. So, what is the need behind the request? Formulating these needs and questions is crucial in conducting investigations, preparing the work, and making the report. The aim of the assignment should be defined and added explicitly at the beginning of the report. In some cases, reformulating the assignment can be necessary, and the ETT should be ready to help the client with this task (sometimes it can occur during the process). To put it more simply, what is the question behind the question? More information can be found in Chapter 3.1 Performance Description.

C.2. The Middle: Data and Analysis Processing

In order to ensure transparency for the stakeholders, it is always important to describe both the methodology and the analysis.

C.2.1. Methodology

It is good to have a plan for gathering data, performing the analysis, and writing the report. Visualising the final documentation frame helps to plan the process, tools, and time accordingly. The basic idea of reporting the methodology is to be transparent. It should be written in such a way that a colleague can perform the task without any extra information.

A good plan will include:

- a timetable with a clear deadline (preferably earlier than the task deadline);
- formatted documentation;
- input – necessary or anticipated data, analyses;
- people, and their roles in the documentation;
- other necessary resources (tools, materials);
- the process of input collection and data processing, taking into consideration both the schedule and available resources.

The process usually requires field work combined with desk work. It includes both secondary data, e.g., from reports, maps and earlier studies, as well as primary data, collected for the first time for the purpose of the report. The source of the data and the type of data should be indicated in the report. Primary data may be collected independently by the preparer of the documentation or by other people involved in the project.

The field data collection can involve a tree assessment (see Chapter 1.5.1 and 1.5.2) and require a specific toolkit and equipment. Documentation of the execution of the work often includes data on man-hours and equipment, consumption of materials, fulfilment of requirements and obligations, and the performance of tasks. Evidence of the work is gathered, such as photo documentation, measurements, notes, and recordings.

For field data, the documentation usually includes:

- the time, place, and conditions under which the data was collected (e.g., weather conditions, access restrictions, season);
- accuracy level (e.g., to the nearest metre);
- the method of data collection and the tools used;
- the significance of the conditions or data collection methods on the results and conclusions;
- information about the broader context, e.g., historical conditions, further surroundings, and plans for the site.

For cited data, the source should be added and the time of access, if applicable (especially important for online data that changes frequently).

C.2.2. Data, Analysis, Conclusions, and Recommendations

We can include different types of content in the documentation:

- Data: facts that exist and are verifiable independently of the collector. Whatever does not meet this condition should be considered as conjecture or a hypothesis.
- Analyses and their results: results of data processing (e.g., recalculation, combination, reduction)
- Interpretation, conclusions, and judgements based on the data and their analyses in the context of broader models and knowledge.
- Recommendations: suggestions or advice for specific actions based on the collected data, analyses, and conclusions in relation to the problem and the goals of the recipient.

Example: The appearance of the soil around a tree may suggest compaction – this is a hypothesis. By verifying it, for example, with a penetrometer, it is possible to obtain factual information – the result of the measurement. The level of soil compaction can be used to analyse the factors causing the tree to die. The conclusion can be effect causation (the state of the tree is the effect of soil compaction), and the subsequent recommendation would be to improve site conditions.

Each type of information in the documentation should be separate and clear to the recipient. This can be achieved by, for example, dividing the report into separate subsections.

There are different methods of gathering the data: observation, interviewing, direct measuring by special tools, experiments, and analysis of existing documentation. Artificial intelligence and machine learning are increasingly being used in these processes, although in arboriculture, these innovations are still a relative novelty.

Data should be reliable, accurate, and legible, something which also applies to the 'inputs'. Below are some helpful hints.

- Measurements: When collecting data, do so according to standards (if any), record deviations from the standard, and make notes to aid memory. Record measurements as soon as they are taken. Memory is unreliable.
- Documentation by image: The photographs should help visualise crucial aspects of the report. Retake important photographs (e.g., required in the order) to be sure.
- When transforming data, always keep the original: prepare a special folder or offline box with notes, files, etc. Keep them at least to the end of the job (+ warranty period).
- Graphics (graphs, drawings, etc.) should be clear and easy to read.
- The image of employees or tools shown in the documentation should be controlled and adequate to the assignment (e.g., show health and safety rules are being observed and respect is being shown for the subject of the assessment and the environment).
- Privacy and personal data not related to the project (e.g., registration numbers of bystanders' cars) should be removed from the documentation.

- The data should have a documented source. The data collection in the field - as much as possible - should be able to be replicated by others, and the process and tools employed should be clear for replication purposes.

Usually, the gathered data are transformed or organised to be more useful. Raw data from the field can be punched into scoresheets or special applications; notes can be scanned; and photos can be gathered, named, and resized to be more conveniently documented. Transforming data also means cleaning and removing any unnecessary, redundant, or false data and files.

Data and analysis are used to find answers to the questions posed at the beginning of the process. While analyses should be carried out in an objective manner, their results are sometimes interpreted subjectively. Therefore, it is important to remember that data, analysis, interpretations, and conclusions are different types of information and should be clearly distinguished from each other in the documentation. Recommendations are the most subjective element.

Analyses are used to extract meaning from data to answer a question. They often help reduce the amount of data needed for storage or processing. Tabulation, recalculation, and coding can serve this purpose. In arboricultural processes, it is common to use analysis with graphics, such as maps and photos. Sometimes special models (statistical or theoretical) are used. If so, cite the source, make sure the licence is up-to-date, and check whether the data used are adequate for the analysis. Conclusions should be related to the problems and tasks, so try to ensure that they contain answers to all the questions posed, are logical, and are understandable for the audience. Recommendations, if they are part of the task, should be justified using the collected data and analysis. Of course, they should be consistent with the conclusions and relate to the problem posed. If several alternative solutions are considered in the recommendations, then the recipient will be better able to make a decision if the pros and cons of each of the suggestions are clearly listed (more about this in Chapter 4.3 Advisory and Consultancy). The end result is usually a report - written, in electronic form, and/or in print. See more tips in Section E of the chapter.

C.3. The End: Report

Documentation is used to collect and analyse data in order to get answers to the questions posed and to communicate them to the audience. Many clients begin reading reports with the conclusions and recommendations and then often stop there. A good report helps the recipient navigate the journey from the questions to the answers and allows them to check the route the author has taken to lead them there. The report should be clear, readable, and easy to use for the recipient: the style, language, and wording - clear, correct, and appropriately used, the technical or scientific vocabulary used should be appropriate to the recipient's level of understanding; and, where necessary, explained.

Both the form and content of the report are indicative of the author and the organisation/company they represent. If an ETT or EAC logo is used, then it denotes expertise, which is of great value. The recipient, knowing the certificate, expects the document received to conform to the expected quality. If, in a country, the ETT certificate is known and associated with expertise, this will also be the expectation of the recipients.

Another important aspect is the responsibility to uphold the image of the profession; the report writer, by giving advice or recommendations, becomes an ambassador for the profession. The report influences the image of the certificate or organisation - the affiliation referred to in the report. By signing as an ETT, for example, the author of the report indirectly takes responsibility for the image of ETTs in the environment. Of course, only those certifications and affiliations to which we are entitled should be used.

The report is not necessarily conclusive, although some audiences may expect it to be. The research or analysis results obtained may be inconclusive and lead to several possible options. The report writer can then juxtapose these options, showing the advantages and disadvantages of each for further discussion. The ETT may also recommend one of the options with appropriate justification. The report may be mainly informative, but it often also has persuasive elements: the aim may be to convince the recipient to apply the recommended solutions. The author must be prepared to defend the reported opinion in a professional and cultured manner, albeit with some assertiveness. Recipients do not need to be familiar with the technical issues, so questions and doubts on their part are possible. More on this in Chapter 4.3 Advisory and Consultancy.
The writer of the report should understand the information contained in it and be able to explain it to the recipient, although it is not necessary to know the whole process of obtaining the test results or calculations. For example, when reporting data from a sonic tomograph examination, it is necessary to know the methodology of the examination and to be able to interpret the tomogram; however, it is not necessary to know exactly all the calculations leading to the results, although it undoubtedly helps to know how to spot possible deviations.

There are no uniform standards for grammar/style of writing, although sometimes for an expert's report it is expected to write in the first person and

IMPORTANT ASPECT OF THE REPORT

- Page numbering (it is also good to enter the name/date of the report in the footer).
- Cover page: who, for whom, subject of the report (project name, location), date of work/deadline for completion of the report.
- Table of contents: in electronic documentation, preferably interactive, with page navigation.
- Chapter headings that clearly indicate their content and are visible in the table of contents.
- Introduction: background to the work and its general purpose, location and general information about the site, scope of work, information about the contractor and client, information about the author of the report, contact details.
- Description of the working methodology; tools used; specialised equipment, if any; explanation of terms used in the document; and sources of information used in the assessment.
- Results: facts, evidence gathered, results of evaluations or studies organised according to a clear key.
  - Evidence collected during fieldwork;
  - Own observations and experiences general;
  - Data from other sources - with reference to source (note copyright and avoid plagiarism).
- Conclusions and interpretations of the results obtained should be separated from the results.
- The context of initial hypotheses may be important.
- Recommendations for further action - separated in a separate point/chapter
- List of sources used or referred to by the author(s)

not the passive voice. However, it is always advisable to strive for comprehensibility and rather simple sentences. The written document should be reviewed for content consistency, visual legibility, and linguistic correctness before being handed over to the recipient.

D. Context of Communication in an Arboricultural Project

The ability to communicate and document the results of work, both orally and in writing, is crucial in any field for managing processes or projects, including the management of other people. General principles relating to communication or documentation, but adapted to the specifics of the industry, can be applied here. The specifics of arboricultural projects cover several areas relevant to the subject matter of this area, including the following contexts:

- Probabilistic events/accidents and uncertainty. Trees and their behaviour are difficult to predict, and accidents involving trees can be serious. Decisions involving trees are subject to a high degree of uncertainty, both in terms of the tree itself and its surroundings. Risk acceptance may vary from country to country, but liability for accidents is usually attributed to the owner of the land with the tree or its manager. This necessitates demonstrating due diligence in planning, conducting, and inspecting the work and documenting it in detail. Communication and reporting are thus important for evidence.
- Public attitudes towards trees: Some people have serious concerns about trees, and they are likely to negatively assess the effects of their presence, e.g., leaf litter or shade. On the other hand, many of the public are positive about the presence of trees in their surroundings, recognise their value and are active in preserving trees and increasing their numbers. This results in the presence of diverse public stakeholders in arboricultural projects – both individuals and their groups, e.g., community organisations (non-governmental organisations – NGOs) or celebrities and their communication (e.g., through social media). With socially significant trees or monoliths (e.g., charismatic trees), an arboricultural project can become a political issue, with even local authorities or other politicians as stakeholders.
- Tree lifespan – influences the lifespan and validity of a project and its consequences. It causes difficulty in restoring a lost tree, but also a commitment; a planted tree affects its surroundings and its management for many years. This results in the fact that arboricultural projects can have long-lasting consequences, which means they need to consider future stakeholders as well as the current ones. Moreover, documentation should be kept for at least the minimum required period (often defined by law), as it is often necessary to consult reports or documents prepared by predecessors, carry out searches to retrieve them, or carry out research to help reconstruct the history of the tree.
- Multifaceted – arboricultural projects can be stand-alone (e.g., performing tree protection) or accompany others (e.g., construction projects), and often involve multiple processes and tasks not always related only to trees (e.g., underground infrastructure, traffic, structures). The operator of such projects (e.g., ETTs) may have contacts with other contractors and must familiarise themselves with their documentation and make appropriate arrangements well beyond their own industry.

E. Tips and Tricks on Reporting

- Adjust the report size and format to the assignment and client's expectations. It can be a one-page memo, a short summary of the work carried out, or a multi-page detailed study. It is a good idea to find out what the client's expectations are in this respect and to clarify this at the commissioning stage.

- Adjust the report to the existing document: The report may require the use of client-specific design, the use of branding or colour, minimum sizes for photographic documentation, and attachments may be necessary, e.g., separately attached and signed photographs or source files.
- Mark/label the report and other parts of the documentation and its carriers. Name the files unambiguously and describe the media/carriers to facilitate archiving. As a rule, the documentation should be labelled, e.g., with the name of the contractor and signed by the author/team of authors.
- Hard copies cost money and time and produce a higher carbon footprint. The cost should be included in the job price and schedule. Sometimes a copy in electronic form is sufficient and useful. If a hard copy is required, it is good to make a scan/electronic copy of the signed paper documentation and attach it to the digital files. This usually includes a covering letter redirecting the documentation to the final addressee, e.g., the site officer, or secure packaging of the media and hard copies. When sending documentation by e-mail, it is a good idea to ask for an acknowledgement of receipt and to keep this together with a copy of the mailing in the tree evaluation documentation catalogue.
- Delivery of the documentation often does not mean the end of work. Presentation, consultation, and clarification are important parts of the work of completing the project. Even if it is not included in the contract, it is worthwhile to offer help/clarification or a presentation of the results to the recipient. Sometimes recipients come back to the report after a long time, so it is worth archiving your own version of the documentation in a clear way so that you can refer to it quickly, if necessary, even after many months. This will also come in handy if you are working on the site again or doing other work for the same recipient.
- Check if the report answers the recipient's question. Ask yourself what the recipient needs and if you have covered it in the report. The content of the report should answer the questions asked; be based on facts that can be demonstrated and defended, e.g. in a trial before a court of law (as appropriate for national or professional acts); include both the data and their interpretation with a clear breakdown; and be limited to the subject of the work and to the author's area of expertise.
- Make the report visually accessible, and easy to navigate and read. Make a clear division of the content types and give informative titles indicating clearly what the part is about and how it is relevant to the content. The contents page should detail the page numbers and be accurate. Use appendices for additional data that could distract from the main content. Adjust the layout, pagination, font type, and size to make the navigation easier. Use clear names of species (both common and scientific), tools, processes, etc. For more difficult or technical terms, prepare a glossary or description in the text/ footnotes. Proofreading should always be done, if possible, by someone who is not involved in the documentation.
- Keep the executed documentation for at least the guarantee period stated in the contract or order, or in accordance with applicable law. It is applicable for raw data, analyses, and reports. Another guideline for the retention period of the documentation may be fiscal records – a report is proof of the performance of a service, so if it was paid for, it is worth keeping it to show the work to the fiscal authorities in case of an audit. Trees are long-lived, and one has to reckon with the possibility of reaching for the results of an assessment even after several years or decades. Current archiving options allow for long-term digital storage without cost or loss of quality, so it is worth adopting a long retention period. It is always worth making a digital copy of the archive.

SELF-CHECK QUESTIONS

1. What is specific to arboricultural projects in the context of communication with the public? Please think also about public opinions and attitudes towards trees.
2. What are the most important elements of the communication process?
3. What is a stakeholder analysis?
4. What is the structure of a good report?
5. What do we mean by storytelling?
6. What roles can the ETT play in the communication process?
7. What are the most important stakeholder groups of the arboricultural project?
8. What is the difference between data, analysis and conclusions?

PRACTICAL EXERCISES

1. As an ETT, you oversee tree work on one of the city's main streets. What information do you find useful to prepare in advance to facilitate communication with residents of the nearby buildings and passers-by?
2. Imagine that you are an advisor to your client (the owner of the park area). You have been asked for advice on what parts of a tree assessment should be included in a report. Consider also the minimum content of the report, the form of submission, and the duration of storage.
3. You are working in the field doing a basic assessment of a tree. An elderly lady approaches you, introduces herself as the occupant of the house next to which the tree is growing, and says that the tree is dangerous and needs to be cut down. As a professional, how do you react? How do you answer?
4. You have received test results from the mycology laboratory indicating that *Fusarium* fungi have been identified in a sample of tree leakage at the site in question (3 trees out of the 10 tested). What further steps will you take to communicate the test results to the commissioning officer?

TERMINOLOGY

assignment – a task or a piece of work that is given to someone to do, often for a limited period of time, e.g., a tree care task on a group of trees

communication process – the process of sending and receiving different information, usually including the channels/means used, as well as the encoding and decoding of the message

object's image – image of the object (e.g., an expert, certificate, organisation, company) existing in the immediate environment, mainly among customers, including a set of (usual) positive associations evoked when hearing the company or seeing its logo, created by the company for that purpose and/or spontaneously built in the mind of the customers or other stakeholders

report – a spoken or written description of an event, situation, or results of a process, e.g., a tree assessment process and results

stakeholders – an interested person directly involved in the process or one remaining an external observer and often a commentator on it or having an influence on the process or their results

target audience – the particular group of people to which the communication (e.g., speech, report, article, or programme) is directed

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US Documenting Evidence: Practical Guidance for Arborists by ASCA
A guide for collecting and documenting information and then using that evidence to help form opinions, make decisions, or develop recommendations.
US A Consultant's Guide to Writing Effective Reports by ASCA
A manual for the consulting arborist's use in report writing. This guide provides a step-by-step process from the initial organisation of information through to the final presentation of the report. Included are three report models that utilize the principles and strategies provided.
US A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas by Matheny N.P., Clark J.R (1994)
A guide for documentation of the evaluation of hazard trees.
US A Consultant's Guide to Writing Effective Reports by ASCA
Describing the process of report writing, from the initial planning and organising of the content through the final packaging and presentation of the finished report.
US Example Report Book for Consulting Arborists, 3rd Edition, by ASCA
Tips on how to format your written reports by providing you with sample cover letters and Consulting Arborist reports submitted to meet the graduation requirement for ASCA's Consulting Academy as well as real-life reports submitted by Consulting Arborists to their client.
US Guide to a Professional Consulting Practice by ASCA
Guidance for setting up a consulting practice, as well as information on the role of Consulting Arborists and how they perform their duties.

4.2.
STRUCTURED TREE MANAGEMENT

Beata Pachnowska & Bregt Roobroeck

GENERAL OBJECTIVE

To learn what a tree management plan (TMP) is, what it is for, what it consists of, and the principles for preparing one. In addition, to learn how to prepare and execute the basis of a successful TMP, namely, a well-defined inventory, supplemented by a tree assessment or advanced tree diagnosis.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:

- understand the tactical and strategic potential of a tree management plan;
- support the implementation of a tree management plan by giving input on the aspects related to the tree(s);
- define and describe the inventory that will act as the basis for a tree management plan; and
- perform an inventory and/or define and describe the parameters for the inventory and tree assessment.

SEE TOGETHER WITH:

Ecology and Biodiversity, Amenity and Monetary Value of Trees, Diagnostic Features, Tree Assessment, Performance Description, Communication and Reports, Advisory and Consultancy

ESSENCE OF THE TOPIC

The essence of tree management plans is to enable trees to reach their maximum lifespan, as the (beneficial) functions of trees only start to become significant after three, four, or five decades. This means that it is crucial to have stable growing conditions and goals that surpass the lifespan of local political visions and day-to-day tree care issues that can result in conflicts between the needs of human beings, trees, and associated organisms. In order to communicate across multiple different local government administrations and ensure a stable environment in which trees are allowed to grow to an old age, we need to implement a sustainable, long-lasting communication tool(box) or framework such as a tree management plan. As knowledge, techniques, visions, and plans tend to shift over long periods of time, it is crucial that the plan be both robust and flexible. The best way to create robustness is through a thorough data-based analysis carried out by tree experts that involves all the stakeholders. That data is based on an inventory, which is crucial to the TMP. Good inventories should, firstly, use parameters that have multifunctional analysis opportunities, which means that we can perform two or more analyses with just one parameter. Secondly, only those parameters that are strictly relevant should be inventoried, as fieldwork is expensive, time-consuming, and can quickly be outdated.

Flexibility in the TMP can be achieved by adopting a built-in framework which is not completely fixed.

KEY TERMS

Tree management plan (TMP): tree management, tree maintenance, strategy, tactical plan, management of trees, micro/meso/macro scale

TMP components: vision, goals, objectives, actions, main plan, implementation plan, monitoring plan, communication plan, inventory, analysis

TMP development: key players, stakeholders, target groups, needs, tree(s) owner, decision maker, consultations

Tree inventory: survey, sample, tree parameter(s), assessment, I-tree, scoresheets, GIS, arbotag, dbh, ALS, complete, partial, or specific inventory

As we know, trees affect multiple stakeholders, so a tree document consisting of what we would need to do with the tree(s) and how we intend to achieve it needs to be communicated to all the stakeholders. So, in essence, tree management plans are robust communication plans that can be strategic, visionary, or management driven. Note the scale dimension such plans have: micro (tree or small group of trees), meso (site, e.g., a park) or macro (city).

A Deeper Look at Tree Management Plans (TMP)

A.1. Definition and Scope

A tree management plan is a strategic or tactical document that provides guidelines for the management of trees in a particular area. In contrast, a tree care plan for a single tree, e.g., a particularly valuable or protected tree, refers to that specific tree and may include a detailed action plan over a longer period. When prepared for a smaller site, e.g., in the context of a new building, it will be more specific, detailed, and operational. When it concerns a city or other large site, it will be a more strategic document at a rather general level, requiring further specification for individual trees or groups of trees.

A tree management plan usually addresses three main questions:

- What do we have?
- What do we want?
- How are we going to achieve it?

To answer the questions, a detailed analysis is conducted (or updated) in several areas. Its preparation requires specific data from a tree inventory existing documents, plans, and expectations. The preparation should take into account the general, objectives for the site, applicable standards for tree work or maintenance of urban greenery, as well as legal regulations, both local and external, e.g., national. A tree management plan, like any document with more general (strategic) objectives, needs to be implemented with the approval of the responsible decision-makers (just as is the case with an operational plan).

A.2. Types of TMP

A.2.1. Strategic Level: Policy/Conceptual Work flow in the Long Term

At the strategic level, a TMP is focused on long-term goals. These are more general and are related to general challenges, principles, and objectives, sometimes connected with other long-term plans like a city strategy, an adaptive tree stand, or plans to achieve a specific percentage of canopy cover. This planning covers a time span of at least ten years.

In strategic plans (5 to 10 years or longer), tasks will be described more as guidelines and principles; the schedule will be more like a timeframe; and instead of a budget, there may be sources of funding, estimated costs, or ways to develop the budget in subsequent years. This time horizon will probably result in the TMP being included with other strategic documents concerning urban forests, city management plans, and urban planning.

A.2.2. Tactical Level: Management in the Shorter/ Medium Term

At the tactical level, a TMP is a short-term framework of tree management that comprises a set of daily operations as well as risk management, conflict resolution, and problem-solving. This planning usually covers a few years, after which the results are reviewed, and a new plan is devised and implemented.
A tactical plan with a short time horizon (up to 5 years) may specify tasks to be performed and a more specific time and financial schedule.

A tree management plan can also refer to different scales of activities: macro (city scale), meso (site scale), and micro (at the scale of an individual tree or small group of trees). ETTs are usually included in the TMP at the meso or micro scale, but there is more and more demand for their input in macro-scale level plans as well.

A general overview of the types of TMP and their scales is given in the following table:

	Macro scale	Meso scale	Micro scale
Strategic TMP	Long-term strategic plan for big areas like a city or region e.g., Urban Forestry Strategy.	Long-term strategic plan for a specified site e.g., Local residential company XY Tree Strategy.	Long term tree XY care guidance (e.g., connected with a reshaping of a veteran tree crown over the next 20 years).
Tactical TMP	Medium-term management plans for an area connected with rebuilding a water retention system.	5-year maintenance plan for the trees in the context of a new building.	An action plan for a tree e.g., crown reduction or site improvement.

Table 1. Timeline vs scale of TMP matrix with examples. In grey – macro scale – not fully relevant to the ETT level.

A side document on operational-level plans is developed to cover defined tasks to do in the short term, usually one year. It can be an appendix to a more general TMP, as it may change yearly.

A.3. The Role of an ETT

Participating in the preparation of a tree management plan and its implementation is one of the most important tasks facing those managing green spaces with trees. An ETT is a natural partner for this task because of that person's breadth of competence in tree biology, management, and other subjects in arboriculture, as well as his/her good background as a consultant. The ETT can either be involved in building the plan or just be a user of it, such as a contractor. In the latter case, the ETT needs to familiarise him/herself with the TMP, understand it, and critically evaluate it in relation to the work being carried out or supervised. As mentioned above, ETT competencies could be more appropriate for projects at the meso and micro scales.

The prepared plan should be implemented by the decision-maker, e.g., the site manager, and by the contractors. As stated in the plan, monitoring of its application and effects should be carried out and updates made accordingly.

The ETT is expected to handle the TMP as a work leader or contractor. By TMP, we mean both the master plan and the preliminary documentation (e.g., the inventory), especially at the tactical level. On receipt of the document, the ETT should familiarise himself/herself with its contents, paying particular attention to:

- inception time;
- duration/update;
- relevance – whether or not it relates to the site or trees that are the subject of the work;
- relevance to current standards, regulations, or industry guidelines;
- content – whether it covers the subject matter of the work/order, or whether it requires additional clarification;
- duties/requirements – not included in the scope of the assignment but arising from the TMP.

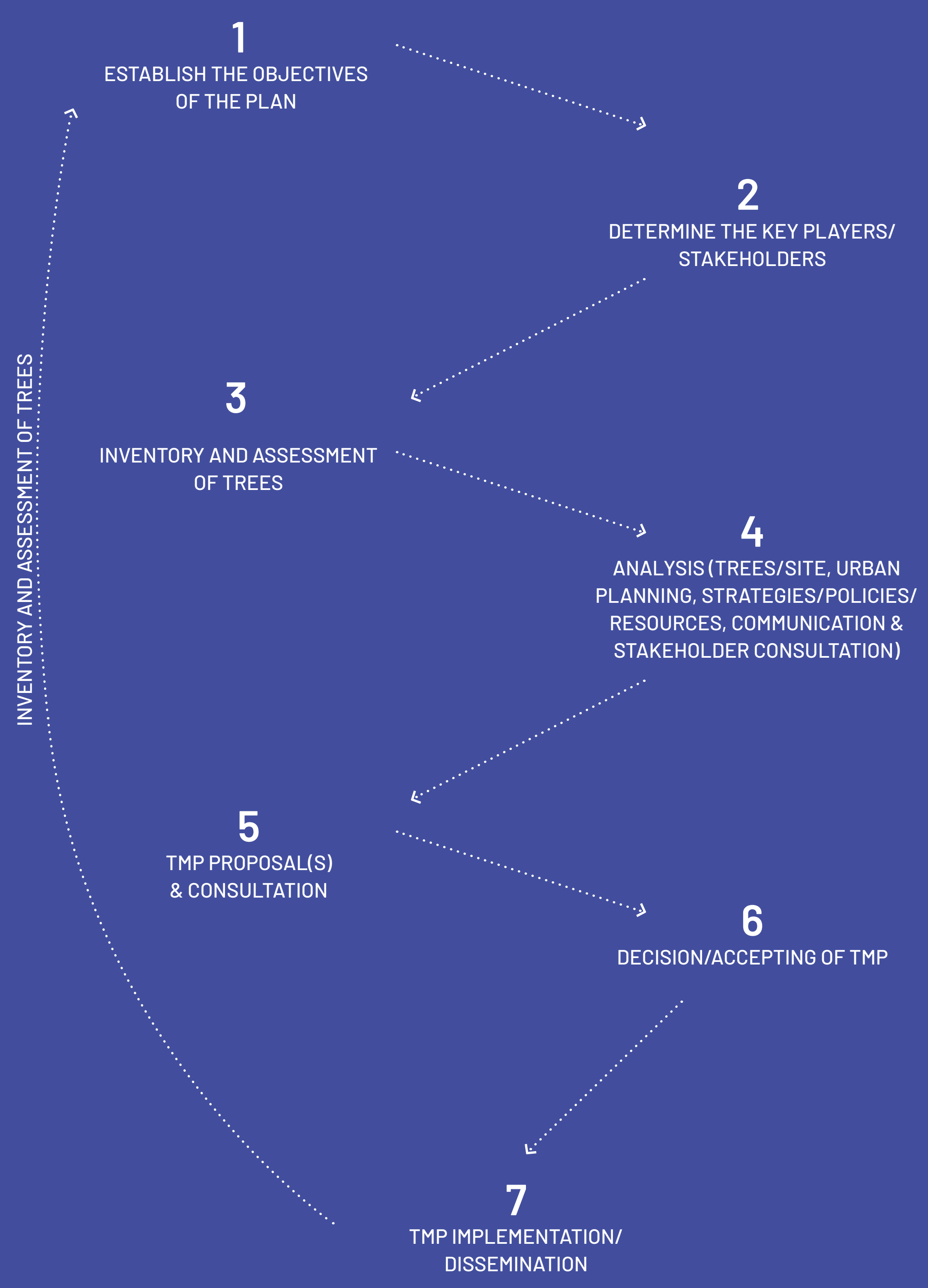
Any inconsistencies are worth catching and clarifying before work starts.

B. The TMP Development Process

An example of the steps in building a tree management plan is shown on the next page.

The starting point for the process of developing the plan is to clarify the objective and the target audience. When there may be multiple audiences and objectives, it could be helpful to analyse the stakeholders and, once they are defined, determine who should be directly involved in developing the plan and whether anyone else needs to be consulted. It is also important, if it is a group process, that the TMP development has "an owner" and that the process is properly managed. In addition to defining the substantive framework (the content of the plan), it is important to establish the formal framework. The document should be readable, inviting, and adapted to the audience. Therefore, those developing the TMP should determine the proper language; how to present graphics, maps, etc.; the format of the study; and the software needed to produce it. Rules and hints on how to disseminate the TMP to different target groups can also be included in the communication plan. A key step in building a TMP is to analyse the initial documentation and collect data on the trees covered by the plan (this can be an inventory, general tree canopy data, detailed tree data and assessments, etc.), more fully described in Section D (Tree Inventory).

THE PROCESS OF DEVELOPING A TMP



Due to its general nature, the TMP is usually not long (a few or a dozen pages) and does not contain details of individual trees; these details can be placed in separate documents (e.g., tree databases). The operational details of how to proceed for either specific trees or the site need to be specified in a separate document with detailed guidelines, e.g., annual tree maintenance plans agreed with contractors or ad hoc tree work orders requiring safety improvements for the surrounding area. The budget can also be included in the plan, although it does not need to be included in the contents of a plan that is available to all.

A tree management plan should be in written form, include multi-stakeholder agreements, and be publicly available. This means, therefore, that its visual form and the availability of a format for different media are also important.
Communication with stakeholders should be conducted to find the best solutions. Depending on the scale, it can be:

- meso-micro scale: meetings and interviews;
- meso and macro scale: public consultations may be necessary, e.g., meetings with representative groups and interviews with interested community members, leaders, and tree-care experts. Use public polling methods and social media to assess larger samples of the population (online, by telephone, mail surveys, and interviews in public areas or door-to-door).

The TMP should include the following sections or topics:

- Introduction – e.g., description of the contents of the plan and general assumptions on which it is based;
- Description of the area/site concerned (e.g., city, campus, park);
- Details of the persons/positions responsible for its preparation, implementation, and decisions;
- Dates of the creation, adoption, and validation of the plan;
- Objective(s) of the plan;
- General site conditions and other guidelines influencing tree management (e.g., nationally accepted standards, minimum requirements for contractors, local conservation policies);
- Description of activities on and around trees; recommended, acepted, and prohibited;
    - Description of the work on the trees (e.g., pruning, felling, reinforcement, care, watering, fertilising mulching) and their remains (e.g., dead wood) and different groups of trees (e.g., according to age or value);
    - Tree protection and biosecurity measures;
    - Method of inventory, tree assessment, data storage, and updating (including baseline data, e.g., initial tree inventory and assessment);
    - List of prohibited practices;
    - Planting plan with a list of preferred and/or prohibited species.
- Places to make the plan and other related documents available;
- Timetable of activities (planned, may also include activities underway or already done), including dissemination and communication;
- Guidelines for monitoring, reviewing and updating the plan; and
- Other elements to assist the user, e.g., a dictionary.

Developing the content on other topics are beyond this publication but can, as with the ones described above, involve the assistance of an ETT as a consultant.

C. Components of a TMP

The final content of the TMP depends on the time horizon and scale as well as the starting point ("what we have"). The plan is prepared on the basis of background documents, e.g., a contract, order, or management resolutions or decisions (e.g., when it is an internal process). It must take into consideration national legislation, local requirements, and the internal regulations of the recipient of the plan for both the site, the trees, and other organisms affected.

C.1. Inventory

Data is needed for the preparation of the TMP, either already available or specially collected/prepared in the areas listed below. If these areas do not need to be analysed, there is no need to spend any time on them.

- Tree(s)
- Urban planning
- Resources and costs
- Policies
- Communication

Good data is the foundation for analysis, and an ETT should know what data is needed, how to find it, and, in some areas, how tree parameters should be used in the inventory process. The TMP must be based on cooperation with other city departments, public agencies, utility providers, policy makers, NGOs, and the general public, even if the tree is on private land. Trees can be a common element that ties different groups together; however, as these groups may have different desires, it is extremely important to inventorise the stakeholders. See also Chapter 4.1. Communication and Reports, for more information. Specific relevant stakeholders are those in general area management, greenery management, media, and utility providers, as they can possess their own plans and management policies.

C.2. Analysis

The analysis is the foundation that helps us understand the current status of the area and explore the needs of management. Depending on the type and scale, the TMP may require a different size and scope of analysis, at least in the areas described below. The aim is to understand what is needed and identify the most efficient and accurate schedule and budget for the entire project. Of course, the analysis has to be based on reliable parameters, the current characteristics of the tree(s), and a good understanding of the needs of the community and the trees. The whole analysis is carried out in order to evaluate the current status, needs, and resources that will be necessary. Usually, limitations and restrictions are also included. The following domains are commonly analysed in urban areas:

C.2.1. Trees and Site Analysis

This area is naturally part of the responsibilities of ETTs. First of all, it is necessary to check whether the site already has a valid tree inventory. If there is not one available, then a complete inventory or an update should be performed. Depending on the objectives and scale, it should be possible to perform a complete, comprehensive inventory or a partial inventory, e.g., on a sample of trees. The scope of the inventory is described in Section D of this chapter. In the next step, an assessment of the condition of the trees can be performed to obtain an understanding of the resources, a picture of the threats to the trees and the environment, and resources that might be needed to carry out the work. A baseline analysis will also provide an estimate of how well indicators/assumptions from other plans or strategies are being achieved. Then the data obtained should be compiled and analysed to provide a picture of the current status of the trees covered by the plan under preparation. Common areas of analysis include the following:

- History and land use changes: a review of the history of the urban forest will help explain how it arrived at its current composition and condition. Compare aerial imagery for past and current land uses. Consult your local museum, historical society, or tree-care and non-profit organisations to learn about heritage trees and past community urban forestry efforts.
- Climate and site condition analysis: some environmental factors require consideration in making resource management decisions. Assess factors that are relevant to your site, such as climatic conditions that can impact plant selection and the condition of existing trees. Soil conditions can be an important aspect for other analyses and programmes.
- Population characteristics (the current composition and condition of the tree population): This can include variables such as the number of trees, species, trees posing a threat, the relationship to grey infrastructure (structures, streets, power lines, etc.), blue infrastructure (reservoirs and watercourses, water retention, etc.), and its place in the green infrastructure (i.e., in the context of other green elements such as lawns, flower beds, green walls, or roofs). See more on this topic in Chapter 1.2.3. Ecology and Biodiversity.
- Maintenance programmes: a population analysis provides information on the work that needs to be done on the trees as well as which work is of high priority. This will provide a basis for determining long-term staffing needs and estimates of the time required to perform the necessary maintenance. Typical work includes removal, pruning, cabling/bracing, green waste utilisation, insect and disease treatment, guard repair, mulching, watering, as well as, increasingly, dead wood management and site revitalisation.
- Planting programmes: selecting the tree species and designating planting locations are significant components of TMPs. Decisions about what kind of tree to plant and where to plant it are critical due to the long-term impact of these decisions. Analysis of the current state at a meso or macro scale can help determine the species composition of the current stand and the plant selection plans, taking into account threats like pests or climate change. The tree inventory reveals the number of vacant planting sites as well as the size and types of these locations. The TMP looks at this data to develop an overall planting strategy and address many issues related to the planting and care of new trees. The analysis identifies the areas with the greatest need for improvement, helps in the choice of species appropriate for the available spaces, discusses specific maintenance plans for newly established trees depending on the characteristics of the site, and provides technical information about proper tree planting techniques.
- Threats and control of insects, diseases, and invasive species: Analysis helps us discover current problems and prevent future ones. Nowadays, there are more and more introduced problems such as Dutch elm disease, the emerald ash borer (*Agrilus planipennis*), or the Asian long-horned beetle (*Anoplophora glabripennis*). Statistical analysis can help evaluate populations of invasive species (like *Ailanthus altissima*) or changes in the population of native species. Analysis can help in proactive and preventive actions in this area.
- Budget needs: the aspects above can help in estimating the budget needed to cover the cost of the necessary resources, work, and materials prioritised according to the assessed needs. The budget should be analysed and estimated according to the timescale and scope of the future TMP. This information gives an idea of the size of the financial commitment necessary and how to take steps in subsequent years to attain the level of funding required.
- Cost-benefits analysis: public trees are increasingly treated as valuable municipal resources, and their benefits are calculated in monetary value (e.g., in i-Tree software – see more in Chapters 1.3.1 and 1.3.2). The services that trees provide include pollution control, energy reduction, storm water management, property values, wildlife habitat, education, and aesthetics. All these benefits can bebalanced with costs for maintenance, and these aspects should be included in the tree analysis part of the TMP.

C.2.2. Urban Planning Analysis

Trees occupy and require space both above and below ground; they affect water relations, soil, light, and shade; they can influence other elements of the urban infrastructure; and they are part of the compositional layout. Urban planning information, especially development plans, is very important for the TMP, especially for new planting. The remit of the ETT does not include urban studies, but he/she should know what information should be checked and obtained for planning the management of trees in the area.
In particular, this could be:

- local land use plans – not just setting the framework for new buildings but also for greenery, including trees.
- planned developments – may include the need to plant or remove trees from a site, or may affect the cutting regime (e.g., clearance in connection with a road under construction).

C.2.3. Strategic/Policy Analysis

This area of analysis serves to check for injunctions, prohibitions, and indications that may be relevant to the content of the TMP. The analysis should cover existing regulations, agreements, bylaws, policies, standards, principles, and guidelines relevant to the trees covered by the TMP, including current and past TMPs if they are or were present, such as urban forestry master plans. Some of these regulations are likely to be well known and frequently used by the ETT, e.g., those that govern the protection of historic sites, nature conservation laws or trees, laws that preserve protected species, and standards and norms for work on and around trees. Within these scopes, the ETT should feel free to move around and provide his/her input in the process of building or updating the TMP.
Other types of regulations with a different scope may be outside the remit of the ETT, but he/she should be ready to read and consider the regulations. Some of the regulations may require additional queries or the inclusion of other persons competent in certain fields, e.g., water or road law. For the purpose of TMPs at strategic level, strategic plans for cities (e.g., the general strategy of the city, country, or region) may be useful, even if they are not directly related to trees. It is useful to keep in mind the boundaries of ETT's competence and to report the need to include other people or parties if necessary.

C.2.4. Resources and Costs Analysis

This covers the additional needs of the people involved with the short- and long-term care and maintenance of the trees in the specified area. The ETT is competently equipped to estimate the resource needs of tree work plans and to assess existing resources, although for full analyses he/she may need additional data, e.g., from finance departments, in which case his/her role is to indicate what information may be needed for the analysis and to assist with the use of this information. Remember that in Chapter 1.3.1 Amenity and Monetary Value of Trees, we emphasised that money is the universal language. Insight into this language is therefore crucial for the TMP. The following topics can be part of the analysis:

- policies and plans currently existing for the area (analysis described in B.2.3.);
- people in all target groups involved, especially local greenery management and contractors;
    - ability to schedule and track projects and maintenance;
    - communication and coordination between departments with respect to tree issues;
    - municipal tree ordinances;
    - staff competencies in the execution of the plan;
    - training and education for tree-programme staff;

- tools: software, machines, equipment available directly or by contractors;
- materials: water, mulch, planting material;
- processes: e.g., waste;
- financing: sources of TMP funding, incl. works, staff, machines, education, promotion, materials etc.;
- "power": the force to convince decision-makers to accept the TMP and urge executors to implement the TMP.

In this part of the analysis, it is worth gathering the costs of potential and necessary actions and services in as much detail as possible (e.g., pruning trees by tree size, plant material, and species), as it will help calculate the costs of the work defined by the TMP. If necessary, estimations can be made based on proposals from the market.

C.2.5. Communication and Society Needs Analysis

This part covers the exploration of public perceptions and behaviours related to trees in specified areas, including:

- understanding about the planting and care of newly planted trees;
- attitudes towards the protection of existing trees and their proper management;
- public knowledge about the benefits of trees and sustainable urban forest management practices.

The analysis could be related to local education and promotion programmes, social media content, and opinion leaders who could be involved in the process of developing and promoting the TMP. Analysis should also include the channels and media that are available to and used by decision-makers/local authorities, which can be used to gather data for the inventory, disseminate the results, promote the TMP, or gather comments from the key targets. Additionally, it should determine what the key messages are and if they are well communicated to the stakeholders. The methods of gathering data and communication processes are described in Chapter 4.1. Communication and Reports.

C.3. Strategic Planning: Vision, Goals, Objectives, and Actions

The strategic planning of the TMP includes the development of goals, objectives, and actions that will lead to the achievement of your vision for the future of the area. The key part of the strategy is a vision for the area.

This vision can be a result of urban planning and the strategic and communication analysis. It should meet expectations, political aims and targets, the needs of society, and take into consideration style and trends. External factors like the European Commission or national plans can influence visions and goals at local levels. The vision should be clear and described in one phrase, such as, for example, "the greenest city in Europe", or "a fully sustainable town".

The strategic plan helps to execute the vision by defining more concrete goals, objectives, and actions based on the information that has been analysed and the needs that have been identified. Goals are statements that spell out the overall general outcomes to achieve. For example, for the vision "the greenest city in Europe", the goals could be "a 30% canopy cover", or "a good range of healthy trees in terms of species and generations". For the vision of "a fully sustainable town", the goals could be something like "no invasive tree species planted in public areas". It is key to define the goals very accurately so that they can be key performance indicators, or KPIs. KPIs are a quantifiable measure of performance over time for a specific objective and are really helpful in achieving goals. They are defined by more concrete objectives and actions. More on setting up a strategic roadmap is to be found in Chapter 3.1 Performance Description.

AN EXAMPLE OF STRATEGIC PLANNING:

- The Vision "Sustainable town greenery" can be defined by

- The Goal "Species mix in accordance with best practices and standards." The analysis and inventory of the tree population results in 50% of species 1 (*Tilia*), 30% of species 2 (*Fraxinus*) and the remaining 20% of other species.

- The Objective could be "Improve species diversity" and
- The Action "Prepare the standard for new planting using the rule "10-20-30".

(The rule says that city tree population should include no more than 10% of any one species, 20% of any one genus, or 30% of any single family, as proposed by Santamour (1990)).

A TMP requires at least the following work categories:
- plan and implement tree plantings;
- maintain existing trees;
- manage hazards associated with trees;
- remove trees; and
- recycle or dispose of green waste and wood from pruning and removals.

At a macro-scale, it can include information about the type of trees (e.g., street, park, facility, or heritage) or the age of trees (e.g., young, mature, ageing, or ancient).

A strategic plan can not only cover a tree maintenance plan but also other aspects, including staff, organisation, tools, and processes:

- tree assessment, maintenance tools, and processes (purchasing new tools, updating existing tools, digitalisation of processes);
- staffing (competencies – education, certifications, training and education for TMP staff);
- financing (developing and maintaining adequate funding to implement a TMP);
- organisation (improving coordination between city departments or other parties connected with the area or tree with respect to tree issues);
- policies and regulations (keeping track of updated tree and tree-related policies, e.g., implementing the newest arboricultural standards);
- decision making (creating a new tree communication and decision platform, e.g., a specific tree board for cooperation among all the stakeholders);
- recycling/ waste management/ dead wood management (closing the system, circular economy, leaving green waste on site to decompose, etc.);
- safety (defining the risk acceptance of different sites depending on their usage, risk-benefits balance, and accepting specific rules for risk acceptance, e.g., ALARP rule in management).

The ETT can also be an advisor or consultant in the areas above.

C.4. Tools

In order to achieve the strategic goals of the vision, which are based on a thorough analysis, we need tools or instruments to be implemented in our day-to-day workflows. For example, in a civil tree test, a complaint-decision flowchart or pruning matrix, and so on. In the scope of this guide, we don't go any deeper into the development of these tools. Note that tool implementation is a two-step process that involves implementation and monitoring, as described below.

C.4.1 Implementation

This plan is to execute the TMP and define who will take action, as well as when and how, i.e., which tools and measures are needed to execute the work. It is important that implementation is part of the project, and the financing required should be planned in advance, with the source of the funding clearly stated. Implementation plans include a specific timetable, clearly defined responsibilities for the tasks assigned to the people or departments, funding sources, and budgets (an implementation matrix). This plan should define priorities (e.g., valuable and hazardous trees could be the main priority, new planting in parks the last one), and timelines (realistic with respect to the seasons and surroundings), usually divided into phases.

Implementation includes communication with the target groups defined in the analysis stage. The communication plan should be part of the main TMP.

An ETT can be in charge of executing parts of the plan connected with tree maintenance, assessment, safety, or tools, but the ETT can also assist the decision-makers in the implementation of other parts of the plan, at least regarding communication.

C.4.2 Monitoring

The purpose of monitoring is to control the effects and biases of TMP implementation and make amendments if necessary.

To do this, we need a monitoring plan with a system or matrix that can be used to check the effectiveness of the work being performed, including any revisions to the original work plan. It helps to evaluate if the goals are to be met, the work is executed properly, and the quality of the work meets the required standard. If KPIs are being used as we discussed in the chapter above, then, obviously, these indicators need to be included in the monitoring plan as well. An alternative is an implementation matrix with columns for who is responsible for monitoring, when to collect data, and what data to collect. Here too, the ETT can be a part of the team or a leader of the TMP with regard to those aspects that involve trees, tools, and processes. The monitoring plan should include a regime for updating and allowing changes (who, when, and what changes can and should be made). Please remember that monitoring also costs money, and the budget should cover it.

D. Inventory of Trees as a Fundamental Basis of the TMP

D.1. Definition and Scope

Tree inventories are a statistically reliable survey of the trees under ownership and/or being managed. They are used to determine the location and the exact or estimated measurements of quantity, quality, health, and trends of the tree in a specific area, as well as a description of other attributes, such as potential planting sites, the presence of utilities, and hardscape features. It is a tool that can be used to aid management planning and as a background analysis for a TMP or a tree assessment.

Tree inventories are often understood as a simple physical inventory according to set criteria, but in many studies and guidelines, they are understood more broadly as a tree assessment (close to the idea of a tree inspection discussed in Chapter 1.5.2 Tree Assessment). Less often, they include advanced diagnostics, in which case the physical inventory is the first step in a broader tree assessment. A tree inventory provides precise data on the location of a tree and allows it to be found on maps and in the field and to be clearly identified by others. It enables us to gather information about a tree (e.g., treatments carried out, protection installed, recommendations) based on a single ID, which helps us to build up a tree history and management plan at a micro-scale.

It provides a lot of data on individual trees and their communities, e.g., the number of trees in an area, canopy cover, or areas available for new planting. The tree inventory also helps in the preparation of action plans in the event of accidents or emergencies (e.g., underground network failures), costing, and planning activities for the tree and the surrounding area. The inventory data can be used to calculate the value of trees and their ecosystem services, e.g., with digital tools such as I-tree; and to communicate their value to decision-makers, authorities, the public, or the media.

D.2. The Role of the ETT

The ETT should know how to use a completed inventory to decide on how to work on trees, prepare other documents, and carry out the inventory and tree inspection themselves according to the mandated criteria. The ETT should also be able to commission the inventory, oversee the inspection, and give his/her approval. Last but not least, an ETT should be able to set up an assignment and determine the parameters for the inventory. The tricky part is choosing the right parameters. Proficiency in scoresheets, e.g., MS Excel, the ability to read maps, or a basic knowledge of GIS and mobile applications, as well as knowledge of professional or ad hoc-built software designed for carrying out tree inventories, are all skills that could be indispensable for carrying out this work.

D.3. Components of the Inventory

A physical inventory of trees is always done in written form (digital or analogue) in a way that allows it to be verified. It usually includes a graphical representation on a map with a descriptive (e.g., tabular) overview of the inventoried trees with basic data about them collected in the field. The tree is also marked with a unique ID and, often, a permanent arbo tag.

CHOOSING PARAMETERS FOR INVENTORIES

When commissioning or carrying out an inventory, be sure you know how it has been defined and establish the scope and parameters of the trees to be collected during the inventory/assessment. Inventories, especially field surveys, are highly time-consuming and thus costly. Hence, for an inventory to be effective and efficient, it must have the right parameters. The aim is to cover all the necessary parameters, but nothing that is unnecessary or – even – not allowed. The parameters should have multifunctional analytic usage, meaning that with one parameter, two or more can be analysed. For example, when determining the tree species of an urban forest, we can also analyse the risk of disease spreading based on location, the period of pruning, and the potential height of the tree(s).

Depending on the objectives and budget, the completeness and detail of the data collected can vary. It usually includes at least the following parameters: location of the tree, species, trunk diameter or circumference, as well as other established tree size parameters (e.g., height, crown span). In a broader sense, the inventory can include the results of the tree inspection: assessment of vitality, condition, stability (see Chapter 1.5.2 Tree Assessment and Chapter 1.5.1. Diagnostic Features) and even maintenance needs and priorities, in which case it always includes photographic documentation. It can also include proximity to other objects (like pavements, utility lines, traffic signs, damaged paved surfaces, and pests). Sometimes potential planting sites are included.

An example is given in Table 2.

No	Tree ID/ Arbotag No.	Location_ coordinates	Species_ local name	Species _ latin name	Diameter OR Circumference_ at XX cm/dbh [cm]
a	b	c	d	e	f
1	123456	41°53′ 30″N 12°30′ 40″E	Field maple	*Acer campestre*	210

Height [m]	Crown diameter [m]	Date_ inventory	Author_ inventory	Notes
g	h	i	j	k
14	18	2022-08-22	John Assessor	photos 1.1-1.4

Table 2. Example of table with basic tree inventory data, basic – columns a-f, and additional – columns g-j.

- The location of trees can be determined with the help of GPS, by laser scanning, or geodetically, depending on the accuracy required. Today, digital maps and GIS (Geographical Information System) tools are usually used. Depending on the arrangements, different systems and ways of recording coordinates can be used. The worldwide uniform WGS_84 (World Geodetic System '84) can be written traditionally in degrees, minutes, and seconds (e.g., Rome 41°53′ 30″N and 12°30′ 40″E), or in decimal notation (41.891667, 12.511111 respectively) – both are used, e.g., by Google Maps or in other established systems.
- Tree measurements can be taken traditionally (tape measure, diameter gauge, rangefinders), but digital and remote instruments (e.g., LIDAR, 3D measurements, electronic callipers) are becoming more widely used. A typical measurement is the diameter at a set height of trunk circumference (the common height is 100 cm or 130 cm – breast height, called DBH), but be sure to check current guidelines or requirements. The available inventory manuals give precise guidelines on how to take measurements of the trunk and crown and other tree parameters (such as the crown base).
- The tree species is defined and described according to the nationally accepted nomenclature. Usually a scientific (Latin) name is also required; both may need to be referred to in an accepted plant inventory. For some trees, it may be necessary to specify the cultivar as well; for others (e.g., ornamental fruit trees), the genus may be sufficient. There are many keys or manuals for identifying tree and shrub species, even in a leafless condition.
- Other tree characteristics (e.g., vitality assessment) can be performed based on accepted evaluation scales, either set by a national standard or established by contract. If a national or international standard exists, the tree assessment can be based on that standard, making communication and use of the results much easier. In addition, during the tree assessment, the following data can be recorded:

- hazard risk
- raised roots
- pruning needs
- watering needs
- native or invasive species
- heritage trees
- site conflicts, such as powerlines above or constrained roots in planters
- pavement damage
- short life span
- damage to the tree (and the reason for the damage)
- high maintenance needs
- value

Data in the field can be collected traditionally on paper forms; however, nowadays it is more common to use ready-made applications for digital mobile devices (tablets or smartphones). The collected data are usually processed and stored digitally in special applications or calculation sheets. Modern remote technologies (e.g., LiDAR) allow inventories to be taken from a bird's-eye view - in this case, tree crowns are most often inventoried (e.g., Crown Map of Poland https://www.mapadrzew.com/), whereas tree heights are calculated from ground level - in this case, trunk circumferences are also inventoried at breast height or at 130 cm. The precise location and species of the tree are also noted.

D.4. Full or Partial Tree Inventory?

The tree inventory can be complete or partial, depending on its purpose, budget, and scale.

For important areas on a meso scale (e.g., a group of trees, parks, squares), the inventory usually includes all the trees in it. On a macro scale (when greenery management plans are being developed for a large area, e.g., in an urban forest or an entire city), an inventory of all the trees may be difficult or impossible due to different ownership rights, access to trees, or costs. In such cases, a partial or specific inventory can be used, either by carrying out an inventory on a sample of trees (e.g., randomly selected parts of the site), the most valuable sites, the most sensitive ones (e.g., busy city streets, areas around schools or playgrounds), or by using other estimation methods (e.g., remote methods), for the entirety of the trees. The more complete the inventory and the more data collected about a particular tree, the more accurate the basis for further analysis and planning. This is, however, a very expensive task. Another aspect is updating the inventory; the more data we have, the more we have to update. So, what is needed and updated is a multi-aspect decision in which an ETT can be a good partner, having the relevant competencies and ability to discuss all the pros and cons.

Note that modern technology like remote sensing LiDAR, multi- and hyperspectral imagery, artificial intelligence, drone technology, the Internet of Trees, and so on allows us to continuously survey aspects of complete urban forests like canopy cover and health. So, inventories are not all about placing dots in a GIS file and will shift towards new GIS data layers for calculation.

Complete Inventory	Surveying the entire tree population in a given area. It is especially useful for building a complex TMP with intensively managed areas, such as parks, streets, and campuses, but is costly in time and labour.
Partial Inventory	Gathers data from a sample (or samples) and then extrapolates the information to apply to a larger area. The sample can be chosen on a statistical basis (randomly, typical, or proportionally). Only as a base for more general visions or general plans.
Specific topic/ problem inventory	Gathering data about a specific problem or condition for work contracts or work schedules. It should be conducted by properly competent staff.
Specific parameters inventory	Gathering only chosen data using specific tools, e.g., canopy coverage with ALS.

Table 3. Types of tree inventories according to their completeness.

SELF-CHECK QUESTIONS

1. What are the essential parts of a tree management plan?
2. Explain the differences between a strategic and tactical TMP.
3. What kinds of analysis are needed when preparing a TMP?
4. For what purpose is a tree inventory carried out?
5. List the main key players of a TMP at an urban scale (macro scale).
6. Describe the main steps of the process of TMP development.
7. List a set of parameters to be collected in the inventory for a TMP at a meso scale.

TERMINOLOGY

inventory – a tree inventory gathered in the field, usually including species, location, identification, and the location of the tree

strategic tree management – a framework for the long-term management of a tree or a group of trees/site with trees

tactical tree management – a short-term framework of tree management, comprising a set of daily operations as well as risk management, conflict resolution, and problem-solving

tree assessment – an assessment of different tree diagnostic features, including evaluation of vitality, condition, or stability at a basic or advanced level

tree management plan – a standard management plan for the site or a specific selected tree

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Examples of tree management plans available on the Internet. Retrieved from:
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ESSENTIAL READING

ENG https://ufmptoolkit.net/
This website provides a "how-to" approach to develop an Urban Forest Management Plan (UFMP). The toolkit will lead the reader through a planning process. Good examples of plans at meso and macro scale for specific areas and cities.

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4.3.
ADVISORY AND CONSULTANCY – HOW TO GIVE GOOD ANSWERS IN RESPONSE TO AN ADVISORY ASSIGNMENT

Beata Pachnowska

GENERAL OBJECTIVE

To gain knowledge of the roles and tasks of a consultant and advisor in arboricultural processes. And to be able to prepare a plan of action that meets the needs of the client and takes different solutions and recommendations into consideration.

SPECIFIC OBJECTIVE

A European Tree Technician is expected to:
- give advice in response to an advisory assignment;
- make recommendations and support the client in deciding on the details of the advisory task and the priorities to be set;
- gather all the relevant information needed to carry out a consultancy assignment;
- analyse the information obtained and, in the advice, take into account the condition of the trees, the soil, the surroundings, and the anticipated future development;
- identify possible alternatives and their associated consequences;
- formulate a recommendation that integrates all the relevant information; and
- make recommendations on the possible alternatives and support the client in deciding on the execution of the assignment and the priorities to be set.

SEE TOGETHER WITH:

Performance Description, Communication and Reports, Structured Tree Management

KEY TERMS

Difference between advice and consultation: problem, request, solution, problem-oriented approach, specific solutions, specialised expertise, assisting the client, non-quantifiable work

Basics of advisory and consultancy: problem/project-oriented approach, objective perspective, stakeholder collaborations, up-to-date competences, recommendations, implementation, facilitating, information, data, action plan, plan of approach, alternative solutions, biases

ESSENCE OF THE TOPIC

The consultancy and advisory role of an ETT becomes more important as urban tree management becomes more highly specialised and complex. For this reason, stakeholders in urban green infrastructures like municipalities, cities, and project developers rely more on specific tree knowledge for services, better known as consultancy and advisory work. The first, consultancy, is more task-oriented towards solving a problem and proposing a programme of action in response to perceived challenges, whereas advisory work is more advice-oriented and involves collaboration between the client and a person considered an expert in his or her field or industry, often on a long-term basis. An ETT can perform both roles. In addition, the ETT can also implement the proposed solutions as a project manager, thereby controlling the implementation process. When doing consultancy or advisory work, the ETT should work methodologically.

A. The Difference Between Consultancy and Advisory Work

Consultancy is a role and set of tasks oriented towards solving a problem and proposing a programme of action in response to perceived challenges. Consultancy usually involves collecting data, analysing it, documenting the activities, and presenting the results in the form of a report. The problems are often already fairly well-defined by the client (sometimes with the help of a consultant), and the consultant refines them.

The consultant is usually independent of the organisation for which he or she works, providing services as an independent supplier. The relationship with the client may be quite formal, and the selection of his or her services may be subject to tendering procedures. In this case, a consultant is a person hired for a project from outside who has experience and specific competence in a particular field and who provides a specialised service in response to a specific request. He or she performs such a service, often based on specially gathered information, e.g., a specialised tree survey and/or a search of available sources and their analysis. This usually culminates in solutions proposed in a report. The consultant is usually paid, and his or her assignment may end once the work is handed over and accounted for.

Advisory work is defined as collaboration with a given client or a person considered an expert in his or her field or industry, often on a long-term basis. In some countries, it may be industry-limited, requiring conditions to be met, e.g., an examination for membership of a professional chamber or a licence (e.g., tax advisory). It is not necessarily linked to a specific project but rather to a broader perspective of the client's problems, which are, sometimes, strategic in nature. The role of an advisor is usually understood as assisting in the selection of final solutions/decisions and may also include discussing possible solutions being considered by the client/decision-maker along with their implications. The advisor does not necessarily do the quantifiable work, i.e., preparing specific documents or giving opinions and recommendations. His/her advice may be verbal only or in the form of notes prepared for meetings. The advisor is invited or hired because of his/her experience and authority. So, the ETT's opinions may therefore be subjective and based on the knowledge or practice they have gained during their working lives. Recommendations are not necessarily required to solve a problem; they may even precede the perception or definition of problems commissioned to the consultants. The advisor may be associated with a given client for many years, becoming part of the organisation, and the relationship may also become more informal. Viewed from this perspective, the advisor can support the client's decision-making, and the documentation and reports prepared by the consultants can help with this.

As the core of the main processes and tasks of both roles are similar, both advisory and consultancy hints will be described together in the following chapters. Just be aware of the distinction and take it into account while analysing requests, needs, and assignments.

B. ETT Consultancy and Advisory Role(s)

Proposing solutions or assisting clients in selecting solutions are significant areas of work for the European Tree Technician. Consultancy and advice may become increasingly important as arboriculture and the concepts associated with it develop. Also, as there is rapid development in the technologies and tools available, the number of potential solutions may be rather dynamic, significantly, for example, in price, complexity, execution time, or with regard to ecological aspects. The ETT can become a 'guide' to these solutions for the client – the tree manager or owner - and must therefore know these solutions, be able to explain them, show their benefits and limitations, and, in an advisory role, help the client make a choice that takes into account the existing tree management plan or the available budget.

In arboriculture, it is rare to find a distinction between a consultancy and an advisory role. The ETT is likely to act as a consultant, responding to already defined problems and providing suggestions for solutions. The most experienced ETTs, in senior positions, may also step into the role of long-term advisor (counsellor), supporting clients in understanding problems and making decisions. Both consultancy and advisory services can be industry-specific or cover a wide range of industries. However, consultancy often involves specialised expertise in specific domains, such as management, finance, or technology, whereas advisory roles can have a broader focus that encompasses strategic, financial, or operational guidance across various industries.

An interesting and important aspect of the ETT's work (like that of many other advisors or experts) is to what extent his/her judgements or advice are intended to be unambiguous and to what extent they leave the final decisions to managers or tree owners. This is important, for example, in the context of assessments for litigation purposes or defining tasks for contractors, where unambiguity and concreteness are required. When undertaking assessments or preparing schedules, the ETT should ascertain what is expected and adjust the plan of approach accordingly (see Chapter 3.1 Performance Description for more information).

The competencies required then are not only technical knowledge and skills but also general ('soft' social or analytical) and specialised decision-making skills. The key output of an ETT as a consultant is a – usually written – response to a reported problem with a proposal for action. To do this, the consultant will usually not only analyse the query itself but other available data as well, often requesting it from the client before preparing an initial proposal or offering to obtain it as part of the service. As an ETT consultant, he or she will take the client's point of view and, from this perspective, may evaluate the tree management plan, the results of expert opinions, or recommendations from others. In this work, competencies related to analysing the situation, seeking information, planning, and making decisions based on the data provided are helpful. In terms of planning and goal setting, the SMART methodology can be useful (see Chapter 3.1 Performance Description). Whatever the role and expectations of the client, the ETT works in accordance with the law, industry standards, and the EAC Code of Ethics, while keeping in mind a holistic approach to trees and their environment. The main strengths of ETTs, as well as examples of competencies that can be executed in consulting and advising roles, are described in the table on the next page (Table 1).

Expertise	The ETT possesses specialist knowledge, expertise, and experience in arboriculture. They should have an in-depth understanding of tree species, growth patterns, diseases, and environmental factors that affect trees.
Problem-oriented approach	The ETT is well prepared to identify and analyse tree-related problems, such as disease, pests, or structural issues, and develop practical solutions and strategies to maintain or improve tree status.
Perspective: objective and wide	An objective viewpoint, based on an unbiased assessment of tree conditions and recommendations based on scientific knowledge and best practices in arboriculture.
Project-oriented approach	The ETT often works on a project basis, with clear plans, timelines, budgets, and deadlines in cooperation with other tree-related branches, such as utilities, architecture, and tree watering, all of which give a wider and more objective perspective on tree-related issues, such as road traffic signs.
Data: defining, gathering, and analysing	The ETT is able to collect data and analyse it to evaluate tree conditions and tree structure. An ETT can conduct soil tests, analyse pest and disease patterns, and interpret environmental factors to make recommendations for tree care, prepare plans of action, or develop tree management plans.
Collaboration between stakeholders and clients	The ETT works closely with different clients and stakeholders. Both the stakeholder's analysis and communication processes are helpful tools. They assess the site, evaluate tree health, and engage in discussions with clients to develop tailored solutions that meet their needs.
Professional and ethical standards	The ETT's work is based on professional and ethical standards, including the EAC Code of Ethics. They observe the best technical practices in treework, respect environmental regulations, and provide transparent and honest recommendations to their clients.
Up-to-date competencies	Due to continuous learning and renewing his/her certification on a regular basis, the ETT stays updated with the latest research, techniques, and regulations in arboriculture (through training courses, lectures, and conferences), ensuring they provide up-to-date advice and consulting.
Communication skills	Part of the ETT's job is to understand, explain, and communicate complex tree care concepts, assessment findings, and recommendations in a clear and understandable manner to the various target audiences.
Recommendations and implementation	The ETT guides clients on appropriate tree maintenance at a micro, meso, or macro scale, giving actionable recommendations based on their analysis and expertise.

Table 1. The main strengths of ETTs and examples of competencies that can be executed in consulting and advising roles.

C. The Basics of Consultancy and Advisory Work

There are many approaches to learning how to be a good consultant, but not so many on how to be a good advisor. It is most important, however, to develop all the competencies that are necessary for both roles. Here are the eight fundamental objectives of consulting, arranged hierarchically according to Arthur N. Turner in Harvard Business Review (1982). The list is a very useful description of the consulting role, which could be relevant to an ETT, too:

1. Providing information to a client
2. Solving a client's problems
3. Making a diagnosis, which may necessitate re-definition of the problem.
4. Making recommendations based on the diagnosis.
5. Assisting with the implementation of recommended solutions.
6. Building a consensus and commitment around corrective action.
7. Facilitating client learning, that is, teaching clients how to resolve similar problems in the future.
8. Continuously improving organisational effectiveness

Within each of these objectives, the following may be required:

Provision of information	**TIP:** Data alone is not yet information. Data becomes information when it is interpreted in the context of a question, relates to the problem/question and allows for its solution. *E.g., the height of a tree given in metres is a piece of data. It becomes information when it answers the question "How tall is the tree?", but it is not information when the question is "Is this tree old?"* The client expects information to be provided, i.e., answers to his/her questions, but often requires raw data as well - sometimes even specifying the type and structure of the data. The ETT should, most importantly be able to identify what data is required and how it should be interpreted. He/she can respond on the basis of his/her own knowledge and experience by carrying out field research, querying existing data (e.g., official data), and also by making use of expert support. When analysing a request to provide information, it is worth checking whether the relevant data is already available (to hand) and whether it can be transformed into information to answer the customer's question.

Solving a problem requires a good definition of the problem. Alternative solutions are often possible.	**Tip:** A consultant is someone who finds solutions to problems. The clients outsource this because they don't know how or are not able to solve them themselves. The problems that an ETT may encounter can be very diverse in terms of the content and the degree of difficulty. The ETT deals with trees both at a micro-level and meso-level, and could also work on trees at a macro-level (parks and urban forests). Within this, he/she can deal with a selected aspect, e.g., just a care plan for an existing tree or an overall tree stand management plan. A typical problem may be to prepare an action plan for a development site and work out how to reconcile the development and the existing tree stock, or to identify the causes of weakened street trees and prepare a remedial action plan. In order to solve the problem, it is necessary to do the following: • Get a good definition of the problem and what is meant by a solution. • It is worth assuming that the client does not always know exactly what they want, and help is required to assist them in clarifying these needs. It is a good idea to find out what solutions have been adopted in the past, what has worked well, what the solution to the problem means, what solutions are unacceptable to the client, and what the boundary conditions are for potential solutions (e.g., maximum expenditure accepted in the project, prohibition on cutting down a tree). • Analyse the causes of the problem. Sometimes the causes of a problem are obvious, but the consultant should be prepared to gather all the available information. In the event that there are hypotheses that are beyond those suggested by the client or the experience of the ETT, it could be advisable to invite other specialists and/or find similar cases with which to compare the problem. • Seek solutions and alternatives. It is good not to be limited to the traditional or most commonly used solutions. Looking for alternatives allows you to see new options and possibilities. Creative techniques such as denial ('What if we do the opposite? E.g., instead of cutting down trees, let's fence them in'), exaggeration ('How about doing something for 30 years instead of 10?'), or downsizing ('Let's make something 10 times cheaper') could be helpful. *Example: A road reconstruction project with a cycle path involving the removal of an avenue of mature trees was modified so that the cycle path was moved, and the avenue was retained.*

Effective and reliable situation assessment and diagnosis.	**Tip:** Objectivity is required of the consultant. Consultants are often expected to take the perspective of the party they are assisting, but they should have a broad and objective view of the situation. An external consultant, in addition to having specialist knowledge, may be more objective than the client or closely related consultants. Cooperation with the client is necessary but must not distort information or conclusions (e.g., a dendrological report must not omit information on the root system of trees on a site that is unfavourable to a building project).
Recommendations including a plan based on either a specific approach or alternative approaches.	**Suggestion:** Every decision requires an analysis of at least two alternative approaches (e.g., accepting and implementing the proposed solution or not doing so), but we often have more options and paths to take to reach our goal. **Example:** *The Veteran Trees Specialist consulting level certification requires the preparation of two alternatives and the recommendation of one of them with justification.* The consultant concludes his work with a written report that includes recommendations for further action; however, this does not always include a detailed plan of action. The ETT should be able to prepare such a plan of approach (which is described in the next subchapter), but whether this is expected must be agreed upon with the client when deciding on the scope of the assignment. Among the required competencies of the ETT is the ability to prepare alternative solutions and to show their advantages and disadvantages to the client so as to facilitate the client's decision-making.
Selection and implementation of accepted solutions.	The solutions and action plan proposed by the consultant can only be implemented if the decision-makers accept them and have the necessary resources. The ETT's task may be to help select and implement the solution. It may sometimes also be necessary to convince the management or team of contractors also involved in the project. An ETT proposing an alternative solution may benefit from the support of other professionals and good examples of similar solutions that have been tried elsewhere. **Example:** *In one of the cities in Belgium, during the construction of an underground city car park, the developer's advisor questioned a design that severely interfered with the root system of a mature tree. The proposed solutions were costly and required additional protection for the tree, but the alternative solution was to abandon the construction. The support of the local authority and the city's general policy of minimising the negative impact of the development on the trees were crucial.*

Communication and commitment.	Communicating solutions and preparing plans requires appropriate forms of communication. This means that the results of the work must be presented so that they are interesting and properly understood. It is advisable to check: • the client's existing knowledge of the research and the proposed solutions. If weak, the plans should be described further (e.g., work methodology, technologies, tools); • the likelihood of the customer accepting the solutions proposed (whether they have already been applied, what assessments have been made, and how successful they have been); • the willingness of the client and team members to learn. Do they have a willingness to learn new methods? How willing are they to participate in or observe the work (e.g., when using new technologies to improve the soil conditions of trees or to test their stability in the ground)? • the client's willingness to take risks and be open to novelty. How conservative has the approach to working on and around trees been to date? What can reduce the sense of uncertainty when deciding on new solutions?
Education during the project.	In any project, the acquisition of new knowledge or skills may be needed; something that applies to all stakeholders. A consultant or advisor, despite his or her specialised competencies, also acquires new knowledge and can invite clients to do so, too, by providing them with the results of his or her work, encouraging them to participate in the processes involved in finding the information, analysing this information, or carrying out the work. The proposed solution and plan of action, based on the preliminary findings, may include the client's participation during the various stages of implementation.

D. What to Include in a Consultancy or Advisory Proposal

The ETT will probably be asked repeatedly to give advice on tree topics, to solve problems related to trees and/or their surroundings, or to participate in tree projects. These requests will involve dealing with a particular problem on an external consultancy basis. Some may be related to the need for advice, permanent or ad hoc. Recognising these expectations of the type of advice and the content of the advice itself is an additional competence that may be expected from the ETT. Opinions and recommendations can include a holistic approach to trees and their surroundings, covering a wide range of assessments and actions. In addition to assessing the condition of the tree itself, ETTs are expected to include their opinion, expertise, or advice on the following:

- habitat – soil conditions, restrictions on root development;
- surroundings – other trees, infrastructure, future development opportunities, or constraints;
- organisms associated with tree(s);
- the value of trees; and
- safety issues.

Information on these individual elements is described in Part 1 of the Study Guide. The proposed activities on and around trees may include standard solutions (cf. Part 2 Study Guide), but the ETT may also be invited to work on projects where it is necessary to go beyond existing practice and innovation. In such situations, it is a good idea to consult the advice being prepared with others in the industry (with the agreement of the project owner – the client), in order to avoid the psychological 'paternal effect' – of defending one's own ideas even against rationality and the tendency to confirm one's own choices and views. You can read more about errors in decisions and judgements in the publications by David Kahneman and co-authors indicated in the recommended additional reading list.

Preparing a plan of approach related to existing regulations, standards, and the factors that limit or define the scope of the task is more the role of the consultant than the advisor, as defined in Chapter B above. Part 3 of the Study Guide on delivering up-to-date knowledge provides useful information on this topic. The Chapters 4.1 Communication and Reporting and 4.2 Structured Tree Management can help the ETT prepare and conduct work connected with TMPs and communication processes connected with most ETT tasks.

Carefully read the request sent to you and the attachments, if any.	Check that they are readable and that electronic files can be opened and saved. Check that the files uploaded are relevant to the case.
Define the client's needs and expectations regarding the response and future work.	Sometimes an enquiry is perfunctory or vague, in which case it might be necessary to clarify the actual objectives and needs.
Check that the enquiry and the client's needs are in accordance with current legislation, accepted arboricultural or other industry standards, the EAC Code of Ethics*.	ETTs are expected to be familiar with relevant regulations, of which clients are not always aware.
Check what data you need to answer.	Revisiting the information that you have can help you identify what is missing, including the information you need in your plan to price the work involved (e.g., an inventory).
Check what competencies are needed to answer.	It is good practice to respond within your area of competence, seeking support from others if necessary. In addition, some work and recommendations may require special skills.
Check that the offer prepared and the assignment or contract are consistent with each other.	It is particularly worth looking at the timing and scope of the work.
Once the information has been gathered and the analysis performed, prepare an initial response and match it with the defined needs of the client.	Check step by step whether you have the answers to all your questions, whether other solutions are available, and what their significance is for the trees and the environment.
Draw up a definitive answer.	It is advisable to check the documents for accuracy before sending them.

THE EAC
CODE OF ETHICS

The EAC Code of Ethics was officially published in January 2021 and applies to all certified ETWs and ETTs. It includes general principles developed to promote the arboricultural industry in a professional manner throughout Europe and other countries in the area of performing arboricultural work, including safety for people and trees, honesty in presenting one's competence, and offering services. The principles described in the code can be a guideline for the content of consultancy and advisory services provided by an ETT.
In accordance with the ETWs and ETTs codes of ethics, the ETWs shall:

- offer their arboricultural services in an unbiased, confidential, truthful, and responsible manner;
- comply with the accepted Best Practice Standards relating to arboricultural matters and national laws and policies within their working area;
- be aware that:
- trees are living organisms that deserve our respect;
- trees have numerous benefits for the environment and are essential for our wellbeing;
- any intervention to a tree will have an effect on the life and further development of the tree;
- apply safe working practice and procedures and use officially approved equipment at all times to ensure a safe working environment for themselves, all co-workers, and the general public;
- not misrepresent themselves by selling services or skills they do not possess, but rather seek more qualified assistance;
- exercise their professional judgement impartially to the best of their skill and understanding;
- avoid conduct that could cause a conflict of interest with any client, employer, employee, other professionals, affiliated trades, or members of the public;
- have the necessary insurance to realistically cover any potential damage or injury claims;
- be aware that they are a part of a professional collective aiming for the well-being of trees and to always consider the best interests of biodiversity in their work; and
- be aware that any operation carried out may affect the image and prestige of the arboricultural profession.

For the full text of the Code see: https://www.eac-arboriculture.com/policy-and-report.aspx

SELF-CHECK QUESTIONS

1. What is the difference between the role of an advisor and the role of a consultant?
2. What are the tasks of a consultant in the arboricultural process?
3. Who is bound by the EAC Code of Ethics?

PRACTICAL EXERCISES

1. Your old friend, an ETW, has called you to find the best solution for the site improvement of a veteran oak in a public park. You met him twice in the field, spent in total 5 hours evaluating the tree site and tree and you are ready to prepare the report and recommendations. What could be your proposal, and what would be the valuation of your work? Explain why.
2. As an external advisor, you are to assist in the process of developing the city's TMP in phases based on the city's tree inventory. Your task is to help prepare the conditions of the tender, the job description for those carrying out the inventory, and to assist in the selection of the final contractor. Estimate the workload and price the task in terms of time and money. Indicate the constraints for accepting the task if it concerns your city.

TERMINOLOGY

advisory – the act of giving advice, information, or warnings, and assisting the decision-maker in making choices and decisions
Code of Ethics EAC – a set of principles adopted by the European Arboricultural Council governing the ethical dimension of ETW and ETT work
consultancy – the activity of giving expert advice on a particular subject, usually provided as a paid service external to the contracting authority

REFERENCE LIST

Agency for Healthcare Research and Quality, Six Tips for Making a Quality Report Appealing and Easy to Skim. Retrieved from: https://www.ahrq.gov/talkingquality/resources/design/general-tips/index.html
Haughey D. (2014). A Brief History of Smart Goals. Retrieved from: https://www.projectsmart.co.uk/smart-goals/brief-history-of-smart-goals.php
Turner, A.N., *Consulting Is More Than Giving Advice.* (1982). Harward Business Review. Retrieved from: https://hbr.org/1982/09/consulting-is-more-than-giving-advice

ESSENTIAL READING

US A Consultant's Guide to Writing Effective Reports, asca
Describing the process of report writing, from the initial planning and organising of the content through the final packaging and presentation of the finished report.
US Example Report Book for Consulting Arborists, 3rd Edition, asca
Tips how to format your written reports by providing you with sample cover letters and Consulting Arborist reports submitted to meet the graduation requirement for ASCA's Consulting Academy as well as real-life reports submitted by Consulting Arborists to their client.
US Guide to a Professional Consulting Practice, asca
Guidance for setting up a consulting practice, as well as information on the role of Consulting Arborists and how they perform their duties.
US Documenting Evidence: Practical Guidance for Arborists, asca, 2014
A guide for collecting and documenting information and then using that evidence to help form opinions, make decisions or develop recommendations.
US Thinking Fast and Slow by Kahneman D.,2019
Description and explanation of psychological traps of thinking which can influence decision and consulting processes described by a social psychologist
US Noise. A flaw in human judgment. By Kahneman D., Sibony O., Sunstein C.R, 2022
General knowledge about noise in social processes and individual judgments that also influence assessment and communication processes.

PROMOTION AND ALIGNMENT OF EUROPEAN TREE TECHNICIANS (ETT) QUALIFICATION IN EUROPE
ETT 2020 ERASMUS+ PROJECT WORKING GROUP

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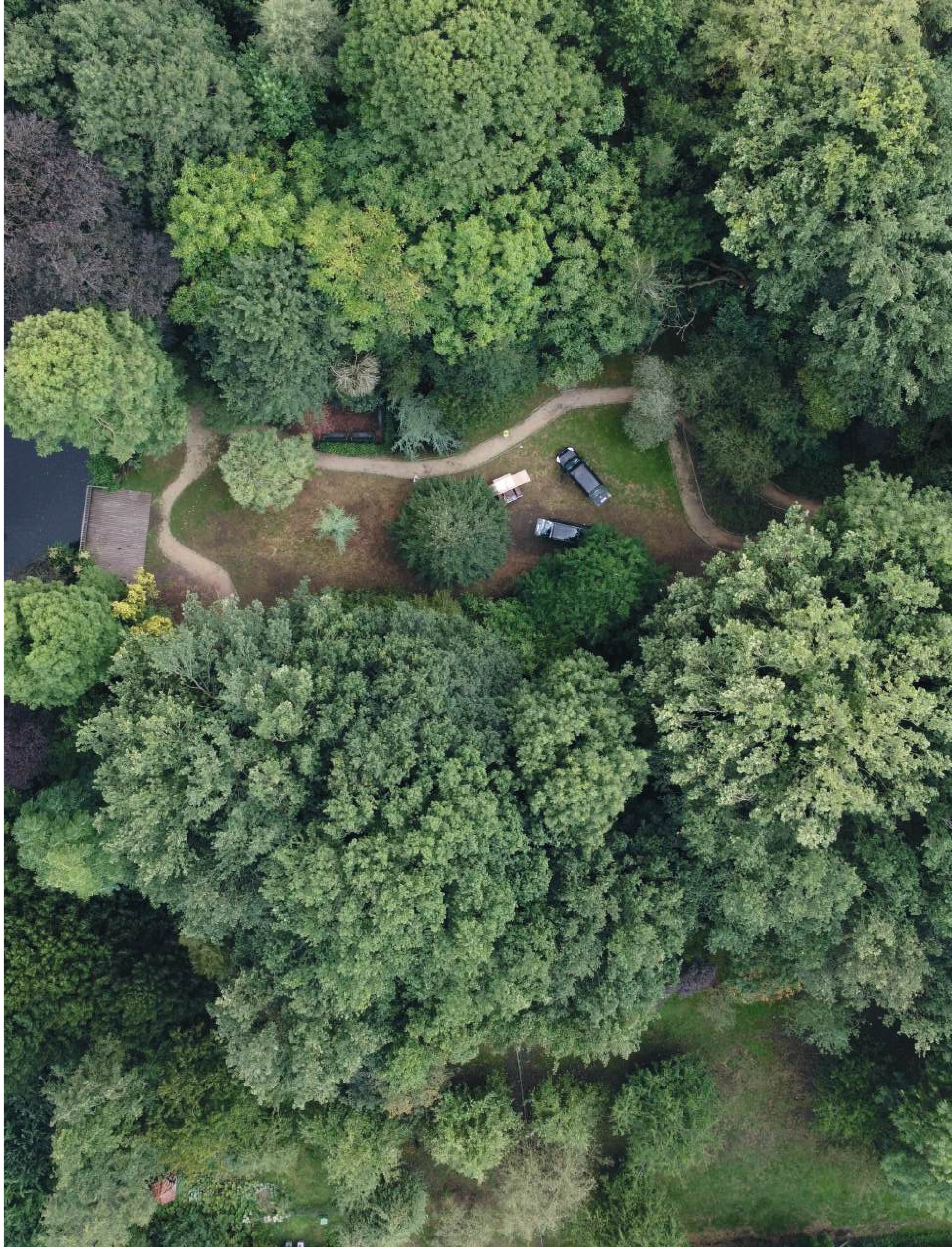

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