DESIGN, IMPLEMENTATION AND MANAGEMENT
of naturalistic
Permanent Polycyclic Tree farms

Enrico Buresti Lattes e Paolo Mori
(Editors)

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FOREWORD

This manual deals with Permanent Polycyclic Tree farms (Permanent Polycyclic Planted Forests[1]). It is therefore necessary to state what Polycyclic Tree farms are. The following can be a useful definition:

*A **Tree farm** is **Polycyclic** if it has, in the same plot of land, at least one of the following characteristics:*

- *Blocks (see definition) with Main Trees of different productive cycle.*
- *Blocks with Main Trees of equal rotation cycle length and Dual-role Trees of short cycle.*
- *Blocks where Main Trees have equal rotation cycle length, but with harvest times delayed each other for at least 20% of the Blocks after some time of at least 30% of the production cycle length (e.g.. plantations for only wood biomass or only poplar rotary-cut veneer production in which with a 10-years cycle you can harvest 50% of the plantation every 5 years).*

This definition covers most of the cases of Polycyclic Tree farms: those well tested and placed in demonstration areas of LIFE InBioWood, those whose tests are in progress and those conceptually possible but not tested so far.

A further element has to be considered to mark out the field of interest of this issue: the Arboriculture for Wood production (Tree farming) can be planned and managed according to **either naturalistic or agronomic criteria**. The first criterion aims at supporting the Main Trees vigour and shape, taking advantage mainly of their natural dynamics. This approach results into economic and environmental benefits, both locally and globally. On the other hand, following an agronomic criterion, the Main Trees vigour and shape are driven by external inputs (i.e. tillage, fertilization and phytosanitary treatment). Nevertheless, in general we can say that there are advantages and disadvantages for both approaches.
This publication mainly focuses on **Naturalistic Polycyclic Tree farms**, while other kinds of plantations will be referred to only when we need a comparison. Naturalistic design

1) *Tree Farm is a tree-covered area managed for the production of timber, similar to FAO definition for Productive Plantation within the category of "planted forests" (www.fao.org/forestry/plantedforests/67504/en).*

patterns of LIFE+ InBioWood take into account a review of experimentation on Polycyclic Tree farms performed up-to-date in Italy together with their results.
Chapter 1 describes the reasons why naturalistic Polycyclic Tree farms have been tried and the first positive results achieved. Chapters 2 to 5 provide the theoretical and practical basis useful to design, plan and manage this type of tree crops which is then examined in detail in chapters 6 to 9. As for planning and management, only the main operations are described, while we consider in detail the Tree farm design, the true distinctive element of naturalistic Polycyclic Tree farms. Further, a short series of examples is introduced in Chapter 10.

Polycyclic Tree farms have been realized for less than 20 years, a long period of time considering agricultural cycles but quite short in terms of wood crops. Nevertheless, many positive results have already been obtained, in good general agreement in all the Tree farm properly designed, implemented and managed. Topical knowledge has been consolidated, though the field is quite broad and many productive and environmental variables need to be accounted for. There is still a wide range of skills to be achieved. In order to add new pieces of knowledge supporting naturalistic Polycyclic Tree farms, during the LIFE+ InBioWood several scientific studies where performed by researchers and specialist in biodiversity, CO_2 storage, phytoremediation for nitrogen pollution due to intensive agriculture, economic and financial analysis. Products obtained with this kind of Tree farms will be compared with those obtained with competing kinds of plantation.
Some studies have already been completed (or near to) before the redaction of this manual: they are included in chapters 11 to 13. Others studies will be completed by the end of the project and will be published elsewhere but they will be anyway available on the website of LIFE+ InBioWood (*www.inbiowood.eu*).

Picture: Paolo Mori

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THE PATH TOWARDS POLYCYCLIC TREE FARMS

As mentioned above, Polycyclic Tree farms adopts strategies capable of replacing management and external inputs with natural ecosystem dynamics favourable to the achievement of the main objectives of the Tree farming. Besides getting benefits for the entrepreneur, this way of wood production gives rise, as a consequence, to environmental and social benefit that occur both in local and global scale (see Chapters 11 and 12 below).

The experimental and demonstration activities developed within LIFE+ InBioWood, originate from the need to overcame production and environmental limits evidenced by previous wood production systems in conventional plantations. The goal is to begin to reduce and, if possible, to eliminate problems identified in previous production systems and define some general criteria to established a new type of Tree farming. Thus, by correcting from time to time the errors and looking for the most effective solutions, the theories and experiments led gradually to the practical realization of Polycyclic Tree farms (Buresti Lattes *et al.* 2001, Buresti Lattes and Mori 2009, Buresti Lattes *et al.* 2014). This manual aims to provide basic knowledge in order to design Polycyclic Tree farms: to this purpose, a brief review of the issues identified in the previous production systems can be appropriate, while looking for solutions and taking into account the first results of the new method.

1.1 Economic and financial drawbacks

1.1.1 Pruning costs

In the traditional medium-long cycle Tree farms, the large number of plants required massive pruning. This practice is necessarily applied even on trees that will be cut by subsequent thinning, in order to ensure strong and relatively constant diameter growth of plants selected for completing the production cycle (see section 1.1.3). The pruning of plants that won't produce commercial products represents an unnecessary cost weighting the financial statement of Tree farm. It has to be noticed however that this problem does not exist in the traditional poplar or woody biomass plantations (Picture 1.1).

1.1.2 Tillage costs

Soil tillage represent one of the main economic cost of management: it is requested at least 1-3 times per year, depending on the area where the plantation has been established. In poplar plantations, with intensive agronomic criteria, soil tillage should be conducted for 8-10 years, almost for the entire production cycle (Picture 1.2). For medium-long cycle Tree farming plantations, with agronomic criteria, 4-5 years of intense tillage are necessary to contain weed competition against tree species.

For the traditional medium-long cycle tree farms it need intensive soil tillage (2-3 time per year) for 4-6 years to contain weed competition against tree species. This type of tillage soil can be made for 8-10 years in the most dense plantations.

1.1.3 Thinning costs

One of the features of valuable timber is to have relatively constant diameter increment. To achieve this, it is necessary that the plants could come at the end of the cycle and produce expected revenue (Main Trees) by developing their crown free from competition of surrounding plants.

During the application of EEC Reg. 2080/92 and of RDP 2000-2006 most medium-long Tree farms showed 5 to 6 meter plant spacing (25-36 m^2 per plant, i.e. from 400 to 277 plants per hectare).

Considering that to obtain 35 to 45 cm diameter with large and almost constant growth these species needs surface areas between 81 and 144 m^2 for each single tree. This means that from one hectare of land, exploiting the full potential of development of the various species, one can't get more than 69-123 Main Trees. Hence, in high density Tree farms (25-36 m^2) there is the need of eliminating between 54 and 82% of the plants, with thinning operations that have almost always proved financially negative. Again, traditional poplar plantations and very short rotation plantations for energy are free from this drawback.

1.1.4 Long delay between investment and revenue

Tree farming can become a true economic resource, not only for tree farmers, but for the whole community. Tree farms could provide adequate income expectations for tree farmers, ideally without public financial support.

Starting from this assumption it is important to consider in addition to the technical results of the Tree farming also the financial ones, not only revenues, but also weight of costs compounding to the end of productive cycle and/or costs discounting to the beginning of productive cycle with revenues (NPV, Net Present Value). Particularly important are the production cycle length and the sequence in which costs and revenues are distributed over time (see Chapter 13). In principle, if quantity and quality assortments product being equal, shorter the period between cost and revenues better will be the financial result.

1.1.5 Poor product's variety

Almost all the Tree farming in Europe in recent decades has been possible only thanks to public financial support. However, the European Commission has strongly influenced the evolution of Tree farming, by granting a support, but distinguishing between Tree farming medium-long cycle (greater than or equal to 20 years), short cycle (8-12 years in poplar), and very short cycle for biomass (from 1-2 to 5-7 years) and therefore pushing beneficiaries to choose one out of this three categories. This policy makes easier the control by

Picture 1.1 - Example of pruning operation (Picture: Claudio Bidini).

Picture 1.2 - Poplar plantation, with soil tillage still 10 years (Picture: Paolo Mori).

public bodies but simplifies the commercial offer from tree farmers, especially for owners of medium and small-size lands.

1.2 Technical drawbacks

1.2.1 planted area inadequate to the planned goal (requiring too many pruning and expensive thinning)

Medium-long cycle plantations without definitive distance (e.g. 5 or 6 m plant spacing with 25-36 m^2 land available for production), need to prune a large number of plants that will be then eliminated with unavoidable thinning. Often the tree farmer feels some psychological resistance to eliminate plants and doesn't carry out thinning, with a consequent loss in the value of the material produced. This issue does not affect short and very short cycle plantations (Picture 1.3).

1.2.2 Definitive distance (slow land exploitation)

Who, rather recently (RDP 2007-2013) has planted trees in medium-long cycle at definitive distances, providing between 81 and 144 m^2 surface for each Main Trees, could realize that much of the surface area was not used by trees for many years, in some case for decades. Planting only Main Trees in medium-long cycle at definitive distances you will lose the opportunity to exploit a significant part of the production area. This issue does not affect short and very short cycle plantations

1.2.3 Poor and irregular diameter growth

In medium-long cycle Tree farms, high density and no thinning, result in a significant reduction of diametrical increments. In addition to this, some timber downgrading, the extension of the production cycle will produce a relevant negative impact on costs.

1.2.4 Design stiffness

The strong limits of monocyclic[2] Tree farming are to not taking advantage of the whole production area relatively quickly and not beneficing of the synergy between plants of various species including some with rapid development.

***2)** This type of arboriculture, essentially, has been the subject of public support in EEC Reg 2080/92 and RDP 2000-2006 and 2007-2013.*

Picture 1.3 - Walnut Tree farm non-thinned, with high competition between trees (Picture: Paolo Mori).

1.3 Environmental drawbacks

1.3.1 Heavy use of pesticides

Poplar growing, despite selecting new clones, remains closely linked to 'I-214' most popular and best paid clone. For this reason, almost all poplar plantations in Northern Italy use 'I-214'. This has led to a gradual spread of diseases of this clone and an increased need of carrying out a variety of phytosanitary treatments, often administered 3-6 times per year, for almost the entire production cycle. Some specific treatments are used in very short cycle poplar plantations for biomass production, while usually these treatments are not administered to medium-long cycle species. The use of pesticides affects both air and water quality. Further, their use is generally performed with agricultural machines emitting CO_2 into the atmosphere (Picture 1.4).

1.3.2 Intensive tillage

The poplar plantations with intensive agricultural practice, as mentioned before, usually need soil tillage for almost the entire production cycle. This results in altering GHGs (Green House Gasses) emissions caused by agricultural machinery for soil working.
This impact affects for at least 4-6 years also in the agronomic medium-long cycle Tree farming plantations (Picture 1.5).

1.3.3 Use of fertilizers

The use of fertilizers during the production cycle affect poplar plantations in intensive agronomic practice. This practice results in pollution of waterways. Further, the fuel needed to produce and administrate them increases CO_2 emissions.

1.3.4 Water for irrigation

Many poplar plantations owners, especially with plants in alluvial areas or near rivers, irrigate their plantations whenever rainfall is insufficient for the needs of the plants. This impacts on the water cycle and, in many cases, on carbon emissions caused by the use of pumps powered by fossil fuels. This practice is not usual for Tree farming plantations of medium-long cycle and, generally, for biomass in very short cycle.

1.3.5 Quick release of stored soil carbon

When monocyclic Tree farms reach the end of the production period they undergo clear-cut harvesting, stumps removal and further soil tillage. This leads to rapid volatilization of carbon stored in the soil back to atmosphere. This affects the climate change.

1.3.6 Habitats clearance

Over the years or decades needed by a Tree farming to complete its productive cycle, a habitat for insects, birds, amphibians or micro-mammals is created. The end use of monocycle Tree farms with clear-cut harvesting, stumps removal and soil tillage, results in an abrupt clearance of that habitat.

1.3.7 Landscape upset

The final clear-cut harvesting of a monocyclic system suddenly

Picture 1.4 - Phytosanitary treatments in a traditional poplar plantation (Picture: Luigi Torreggiani).

Picture 1.5 - Cherry Tree farm in Basilicata (Italy) with tilling still to 10 year (Picture: Paolo Mori).

changes landscape as perceived by the local population in terms of the line of the horizon, masses and colours.

1.3.8 Microclimate upset

Every tree plantation affects, more or less depending on density extent and composition, the local microclimate. The final harvest of a monocyclic system determines an abrupt change of the microclimate.

1.4 Problem solving criteria

The problems identified above prompted the Istituto Sperimentale per la Selvicoltura di Arezzo (today, Council for Agricultural Research and Analysis of Agricultural Economics - Forestry Research Centre (CREA-SEL)) and Compagnia delle Foreste (CdF), to develop and test strategies aimed at solving them through a new way of planning and managing Tree farms. Below we indicate the main criteria adopted, the tenth of which apply only to Potentially Permanent Polycyclic Tree farms (3P Tree farms).

Criterion 1: take advantage of the natural dynamics and competition between plants of different species and ability of some species, both trees or shrubs, at fixing nitrogen.

Criterion 2: Exploit as much as possible the production area by planting in the same management unit species characterized by:

- markedly different growth rate (medium-long, short and/or very short cycle);
- different lighting requirements (shade-tolerant under the partial coverage of light-loving plants);
- both shallow and deep root systems, in order to explore different soil layers.

Criterion 3: differentiate, within the same land plot, both production times and assortments, in order to reduce commercial risks.

Criterion 4: combine plants of different species in the same land plot, distribute them uniformly or in clusters, in order to prevent the spread of disease.

Criterion 5: define already in the design the space needed by Main Trees (see Chapter 3) of each species in order to achieve the expected commercial diameter, then place plants at reciprocal distances able to avoid thinning before reach the productive goal.

Criterion 6: minimize the number of Accessory Trees replacing them whenever possible with Dual-Role Trees (see Chapter 3). These latter have to usually belong to fast growing species, which, if placed at suitable distance from Main Trees, are capable simultaneously of exerting positive competition and produce income before the competition would become negative.

Criterion 7: establish high density Tree farm, to cover ground quickly with crowns, control weeds and create a microclimate favourable to better control of the water cycle and the containment of wind effects.

Criterion 8: choose species and planting stock so that each plant has a specific role in ecological dynamics of the Tree farm. In other words it is necessary that each plant "pay the place", that is, create conditions of benefit in terms of increased production or easier conduction.

Criterion 9: allow the crowns of Main and Dual-Role Trees enjoy full light through careful design and gradual exploitation or thinning. This gradual approach will be dictated by the need to take advantage, as long as possible, the favourable conditions for crowns lateral protection and soil shading.

Criterion 10: perform only partial harvesting on 3P[3] Tree farms, in order to contain the loss of CO_2 stored in soils, the disappearance of habitats, the landscape and microclimate abrupt changes.

1.5 Experimentation

Taking into account problems and criteria described above and treasuring the ISSA (today CREA-SEL) experimental experiences, gained thanks to the early works of 1978 (Buresti 1984), the Polycyclic Tree farms experience started as early as 1997 (Buresti Lattes and Mori 2006, Buresti Lattes *et al.* 2008). The first experimental areas were established in Casal Buttano (CR), approximately 25 ha in 1997, and San Matteo delle Chiaviche (MN), of about 60 ha, since 1998. Other 5 areas have been activated successively, three of which in San Matteo delle Chiaviche (MN) for another 17 ha, and 2 near Legnago (VR) for about 57 ha overall (2012-2014). In Legnago approximately 52 ha (25 ha in open field and 45 km in rows) are part of the LIFE + InBioWood (LIFE12 ENV/IT/000153), designed and developed by the Association of Arboriculture for Wood Sustainable for Economics and Environment (AALSEA in Italian) and Compagnia delle Foreste with demonstration purposes. All the above mentioned Tree farms now form part of the AALSEA network of experimental Tree farms. Each of them is followed by a scientific director who is responsible for monitoring the Tree farm development and verifying the agreement between design expectations and field results. The 18 years of experimentation in the Tree farms listed above led to the first positive results, described in the next paragraph.

3) See definition in section 3.3.

1.6 First results

1.6.1 Economic and financial results

1.6.1.1 Reduced pruning costs

In Temporary Polycyclic Tree farms (TP[4] Tree farms) the cost of pruning decreased from 24% to 82%, compared with monocyclic Tree farming of medium-long cycle with plants of the same species or different species (mixed), at a spacing of 5 and 7 m (25-49 m_2 per plant).

1.6.1.2 Reduced soil tillage costs

Soil tillage, to be performed 1-3 times a year, depending on the Tree farm land plot ecological characteristics, have been limited to the early 3-4 years; later on, crown shadow from Main Trees, Dual-Role Trees and Accessory Plants significantly reduce, and sometimes prevent, weeds growth.
This saves about 5-6 years of tillage costs respect to the agronomic intensive poplar plantations.

1.6.1.3 Reduced thinning costs

In TP and 3P Tree farms expensive thinning is almost unnecessary, while exploitations can be done instead. In this way new space is granted to crown, for longer cycle plants remaining in the Tree farm. So, the tree farmer is pushed to thinning at the right time, since such intervention may draw earlier income before if compared with longer cycle systems.

1.6.1.4 Reduced delay between costs and early income

The presence of Main Trees, in short and/or very short cycle, reduces delay between costs and time that you can get the first income, significantly reducing the weight of “costs” on the balance sheet of the Tree farm.

1.6.1.5 Increased variety of products

The simultaneous presence of plants of different species, with different production objectives (e.g. walnut for sliced veneer, poplar for rotary-cut veneer and plane tree for firewood) allows to differentiate, both in time and variety, the commercial offer into local, regional and national markets.

1.6.2 Technical results

1.6.2.1 Strong and regular diameter growth

In Polycyclic Tree farms, thanks to the fact that the Main Trees crowns are always well lit and that the microclimate inside the system is favourable to their growth, you can aim to get strong and relatively constant diameter increment up to physiological limit allowed by species. In TP experimental Tree farms, (AALSEA, San Matteo delle Chiaviche -MN), the 17 years old walnuts, after the poplar harvesting, have already exceeded the average diameter of 31 cm with a maximum of over 35 cm, without irrigation and fertilization (Picture 1.6 and 1.7).

1.6.2.2 Greater design flexibility and better productive area exploitation

Polycyclic Tree farms show how you can combine species with different growth speed so as to increase productivity in the same time. For example, where before you could only get 100 walnuts for hectare (100 m^2 available to reach a diameter of 35-40 cm in 20-25 years), you can now get 100 walnut and 100 poplars, without any of the two species is affected by the negative competition of the other. In other types of polycyclic tree farm, especially 3P Tree farms, you can also combine 3 different production cycles also adding very short cycle (5-7 years) for wood biomass.

1.6.3 Environmental results

1.6.3.1 Reduced use of pesticides

In TP experimental Tree farms of AALSEA, at the end of poplar clones (‘I-214’, Neva, Adda and Lena) production cycle, were applied very low amounts of pesticides. In one case were applied 2 treatments in the first year and 1 in the second year, always against willow borer (*Cryptorhynchus lapathi* L.), as a preventive measure. Subsequently there have been no other phytosanitary treatments because there were no sufficiently serious disease or pathologies infestations of insects. It is assumed that this result is due to the mix of species and the low degree of light competition by poplars.

1.6.3.2 Reduced soil tillage intensity.

Soil tillage, limited to the first 3-4 years, has reduced the carbon footprint related to emissions of agricultural machinery (Chiarabaglio *et al.* 2014).

1.6.3.3 No fertilizers

In experimental polycyclic Tree farms AALSEA have been obtained diameter increment totally comparable to those of traditional intensive Tree farms, but avoiding use of fertilizers during the production cycle. This was possible due to the design choice addressed at including N-fixing trees and shrubs that can bring a significant increase of nitrogen in the soil (Tani *et al*. 2007).

1.6.3.4 No water for irrigation

No irrigation was used in poplars experimental polycyclic Tree farms of AALSEA. This had no effect on plants development that showed strong diameter increment up to 10th-11th year, time they were harvested. At that time poplar average diameter was 45.2 cm to 130 cm, with the same production cycle length of a traditional agronomical system.

4) See definition in section 3.3.

Picture 1.6 and 1.7 - Walnut tree grew up on a Naturalistic Polycyclic Tree farm, 37 cm in diameter and age of 17 years (Picture: Paolo Mori).

1.6.3.5 Low release of stored soil carbon

In 3P Tree farms harvesting is expected to be always partial. Therefore, part of the productive area is protected by crowns of plants that have yet to conclude their production cycle. This reduces the possibility that all the carbon stored in the soil returns to the atmosphere (CO_2) in a few months.

1.6.3.6 Reduced habitat perturbation

In 3P Tree farms partial harvesting contain habitats and landscape disturbance. For the same reason also the local microclimate experiences a reduced disturbance compared to traditional systems.

Picture: Paolo Mori

2 OBJECTIVES OF TREE FARMING

Technical and financial objectives are the key references for both technicians and tree farmers at each stage of design and managing Tree farms for wood production. Below we will describe the overall objectives of Tree farming. Designer and tree farmer will then decline overall objectives into specific objectives related to tree farmer needs and pedo-climatic conditions of the plot where Tree farm will be established.

2.1 General objectives of Tree farming

Design Tree farming plantations means pursuing in each technical choice and management action three objectives closely linked to business results:

- get timber assortments with market-required characteristics;
- get timber assortments in the shortest possible time;
- minimize the production costs.

2.2 Market-driven characteristics of timber assortments

Timber assortments provided by a Tree farming plantation can be divided into 2 main categories: valuable timber and wood biomass.

Valuable round timber

Valuable timber is the one getting higher prices, because it can be used for the production of veneer (sliced veneer or rotary-cut veneer) or sawn timber. Best paid trunks must be:

- of wood **species able to produce valuable timber** (Figure 2.1);
- **straight** and **cylindrical** (to optimize yields during primary processing) (Figure 2.2);
- **without branches for at least 250 cm in height** (standard size below which is practiced a downgrade and a consequent depreciation of assortments) and with a diameter at least of 30 cm for poplar and 35 cm for other broadleaves (measured at 130 cm from the ground) (Figures 2.3a and 2.3b);
- **showing regular diameter growth** (to optimize the drying timber) (Figure 2.4);

- **homogenous in colour** (to minimize waste during the first processing) (Figure 2.5);
- **with knots and scars enclosed in a central core as small as possible**. This core should not extend above 33% of the final diameter of the log to be sold (to optimize yields in the primary process) (Figure 2.6).

The lack of one or more of these features will downgrade the log value (Figure 2.7).

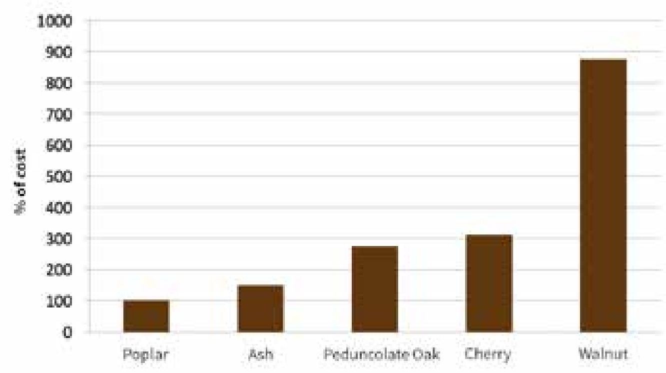


Figure 2.1 - Comparison between prices of various species, made 100 the poplar wood price. These ratios are merely aimed at evidencing important differences between different species. However, that ratios can change significantly in time. It is therefore important to be well informed, both before planting that before clear-cut harvesting at the end of a production cycle.

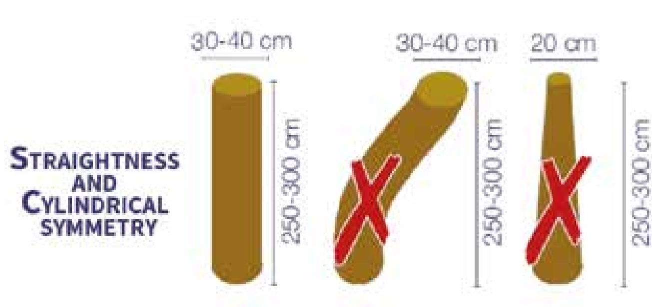


Figure 2.2 - A valuable log, to enter the high-end market segment must be straight and cylindrical. In the centre and on the right of the figure, are shown the curvature and excessive taper causing downgrading of timber assortments.

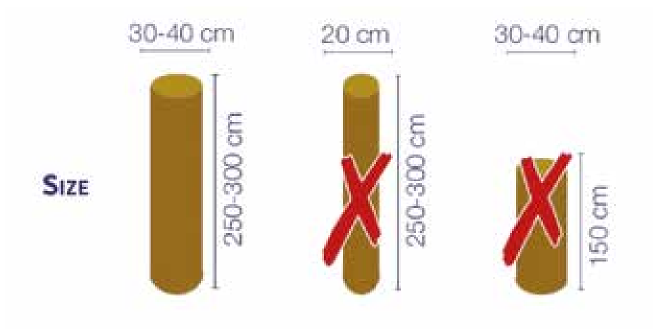


Figure 2.3a - A valuable log, to enter the high-end market segment must be longer than 250 cm and must have a diameter greater than 30-40 cm (depending on species). In the centre and on the right of the figure, are shown smaller log below the minimum dimensions, therefore, will be downgraded.

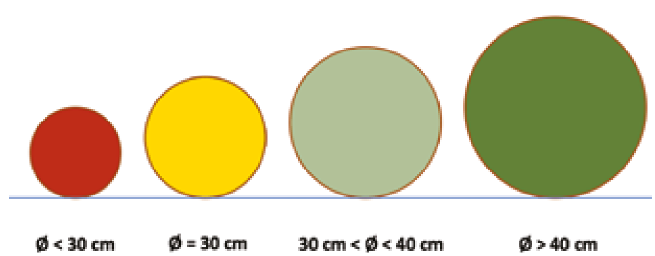


Figure 2.3b - More than 30 cm in diameter to 130 cm from the ground, the greater the diameter and higher will be the timber evaluation.

Figure 2.4 - Growth rings must have regular diameter increments. Groups of different sized rings result in a downgrading of the material since you may experience stability problems during seasoning.

Figure 2.5 - Generally, as the colour is homogenous the easier it will be for processor use the log. The exceptions are special processing, at certain times or in certain geographical areas, in which you also enjoyed the contrast of colour. This second case, however real, is much harder to find on the market.

Woody biomass

This material does not require special technological or esthetical characters in each stem. However, it is important to take into account two aspects that may significantly affect the final price of biomass produced:

Figure 2.6 - The presence of knots may restrict the types of processing. The type of pruning and timeliness with which this is done, can limit the presence of knots.

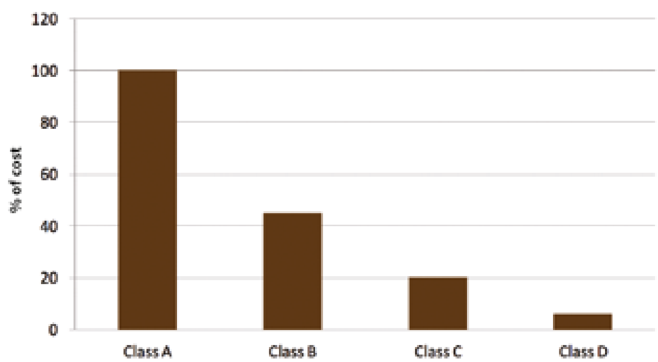


Figure 2.7 - Approximate representation of the percentage change in price on the basis of quality class (walnut).

- the market favour for each kind of wood;
- the type of transformation: reduction in woodchips or firewood (Figure 2.8).

2.3 Reduce production time

For the same quantity, quality and wood assortments prices, the product delivery speed considerably affects the balance sheet of a Tree farming plantation. The advantage of shorter production cycles is determined mainly by three concurring factors allowing to:

- reduce cost weight of implementation and management in the balance sheet at the end of the cycle (Figure 2.9);
- get soil availability ahead of time for starting new production activities;
- promptly invest the net revenues obtained at the end of each production cycle.

All this converges into a financial statement of the business as more profitable as shorter is the production cycle (see Box 2.1).

2.4 Reduce production costs

The Tree farming has characteristic of times of production which rank with long times in high-forests and those relatively short of most of agricultural crops. Generally in Tree farming plantations should range between 5-7 years of woody biomass short cycle up to 40 years for the valuable timber of medium-long cycle species.

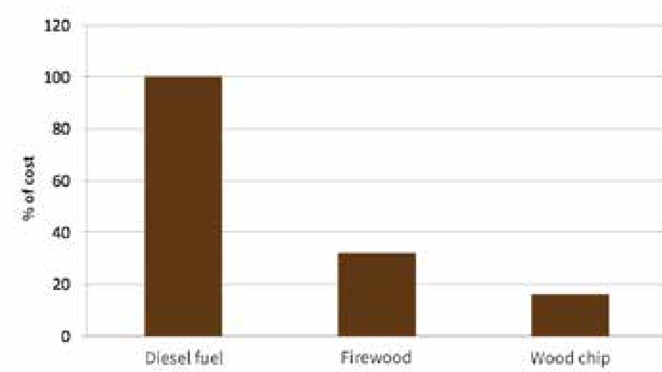


Figure 2.8 - Comparison between oil and various wood fuels prices (with equal energy obtainable) made 100 the cost of diesel fuel.

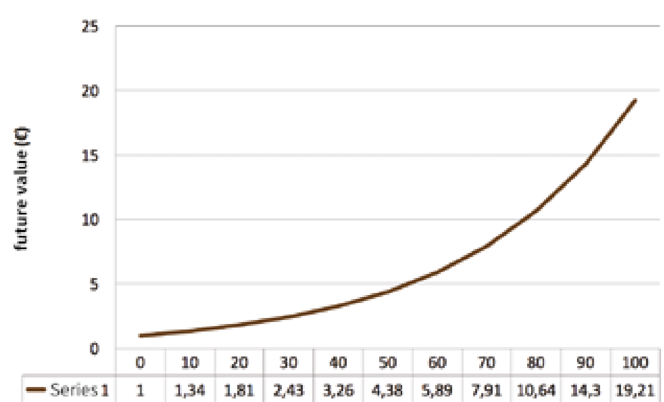


Figure 2.9 - Growth of value of 1 € , incurred at the production cycle start, in a period of 100 years (r = 3%).

Such important time ranges make it especially important to pay close attention to implementation and management costs of Tree farms, looking for the right balance between the pursuit of valuable assortments and the expenditure restraint, to reduce the weight in the final financial results.

Nothing different from any other business. The innovation that has been proposed in this LIFE InBioWood, with the 3P Tree farms, is particularly addressed to the design and management strategies that, using a few favourable natural dynamics, could reduce costs at constant quantity, quality and production time.

BOX 2.1
DURATION OF PRODUCTION CYCLE AND FINANCIAL RESULTS

At the same gross revenues the production cycle length, which is necessary to obtain the desired production of wood assortments, affects the balance sheet of wood Tree farms in a much more important way commonly thought. The following example, entirely theoretical, keeps artificially fixed gross revenues and the cost of implementation and management so as to highlight how the length of production cycle can it affect the length of the production cycle on the balance sheet. Gross revenues are considered at the end of each production cycle. Implementation and management costs, to simplify the example, were first discounting at the beginning of the cycle and postponed to the end of cycle (e.g. Table 2.1) to underline the importance of duration of production cycle on balance sheet of Tree farming. In the example are considered 3 cases of duration of production cycle length: 20, 30 and 40 years respectively.
In this simulation was assumed that the financial resources necessary for the implementation and management were originated by a bank loan (at 3% a year). Higher values for interest rates would of course change the simulation output, but the differences determined by the length of the cycles will remain important anyway.. The length of the period of 120 years reported in Tables 2.2 and 2.3 was chosen in order to make possible matching the conclusion of the 3 cases considered.

Length of the production cycle (years)	Discounting planting and management costs (€)	End of rotation cycle cost (€)
20	5.000,00	9.030,56
30	5.000,00	12.136,31
40	5.000,00	16.310,19

Table 2.1 - Weight variation of costs on the balance sheet according to the length of the production cycle (debit interest rate 3%).

Length of the production cycle (years)	Gross revenue year 20 (€)	Gross revenue year 30 (€)	Gross revenue year 40 (€)	Gross revenue year 60 (€)	Gross revenue year 80 (€)	Gross revenue year 90 (€)	Gross revenue year 100 (€)	Gross revenue year 120 (€)
20	20.000		20.000	20.000	20.000		20.000	20.000
30		20.000		20.000		20.000		20.000
40			20.000		20.000			20.000

Table 2.2 - Sequence of gross revenues over the course of 120 years according to the length of the production cycle.

Length of the production cycle (years)	Total costs discounting to start of rotation (€)	Gross revenue at the end of rotation cycle (€)	Gross revenue year 20 (€)	Net revenue year 30 (€)	Net revenue year 40 (€)	Net revenue year 60 (€)	Net revenue year 80 (€)	Net revenue year 90 (€)	Net revenue year 100 (€)	Net revenue year 120 (€)
20	9.030,56	20.000	10.969		21.931	32.907	43.876		54.845	65.814
30	12.136,31	20.000		7.864		15.728		23.592		31.456
40	16.310,19	20.000			3.690		7.380			11.070

Table 2.3 - Variation of net revenues during the first 120 years versus length of the production cycle. The cost of build-up and management have been attributed to each production cycle. It is clear from the table that at the same cost and revenue with a production cycle of 20 years one could get a financial result at 40 years which is about 6 times the one obtained from the production cycle of 40 years. At the 60th year the 20-year cycle has produced a value that is approximately 2.1 times greater than with a 30-year cycle. At constant values, these financial differences maintain the same ratios over time.

Picture: Paolo Mori

3

NATURALISTIC POLYCYCLIC TREE FARM ELEMENTS

3.1 Role of plants

3.1.1 Main Tree

A plant is attributed the role of Main Tree when provides at least one of the main products for which the Tree farm was designed.

In the case of **valuable assortments production** (e.g. logs for sliced and rotary-cut veneer or upper grade of sawn timber) for each tree that we want to consider Main Tree will be provided:

- a production area assuring the achievement of the expected commercial diameter (Figure 3.1);
- the highest level of hierarchy than any other tree or shrub is attributed to them, within the assigned production area unit, called "Block" (see section 5.1);
- individual care are guaranteed to them, aimed at achieving all the features of the expected commercial timber, as far as allowed by the particular species and the surrounding environment.

Some differences can be observed, in the first 3-5 years of planting, in the Main Trees of medium-long cycle of species not having clones or genetic selections for the wood production. These species are characterized by a high degree of genetic variability that can determine a strong in-homogeneity in Main Trees, both in vigour and shape. To reduce this negative effect and increase probability of having vigorous and good shape plants in each specific plot, we can use "**double tree technique**" (Buresti and Mori 1999, Buresti *et al*. 2001, 2002, 2003). This involves planting trees in pairs near the position where we would get a Main Tree. The trees in pairs should be planted on the line, at a distance of 0.5-1 m from each other, symmetrical with respect to the point where you would find the Main Tree (Figure 3.2). The selection of the plant more vigorous and with a better shape must be carried out during the first 3-5 years. During this period both plants are not Main Trees, but **Potentially Main Trees** and, until the moment of selection, both should be pruned.

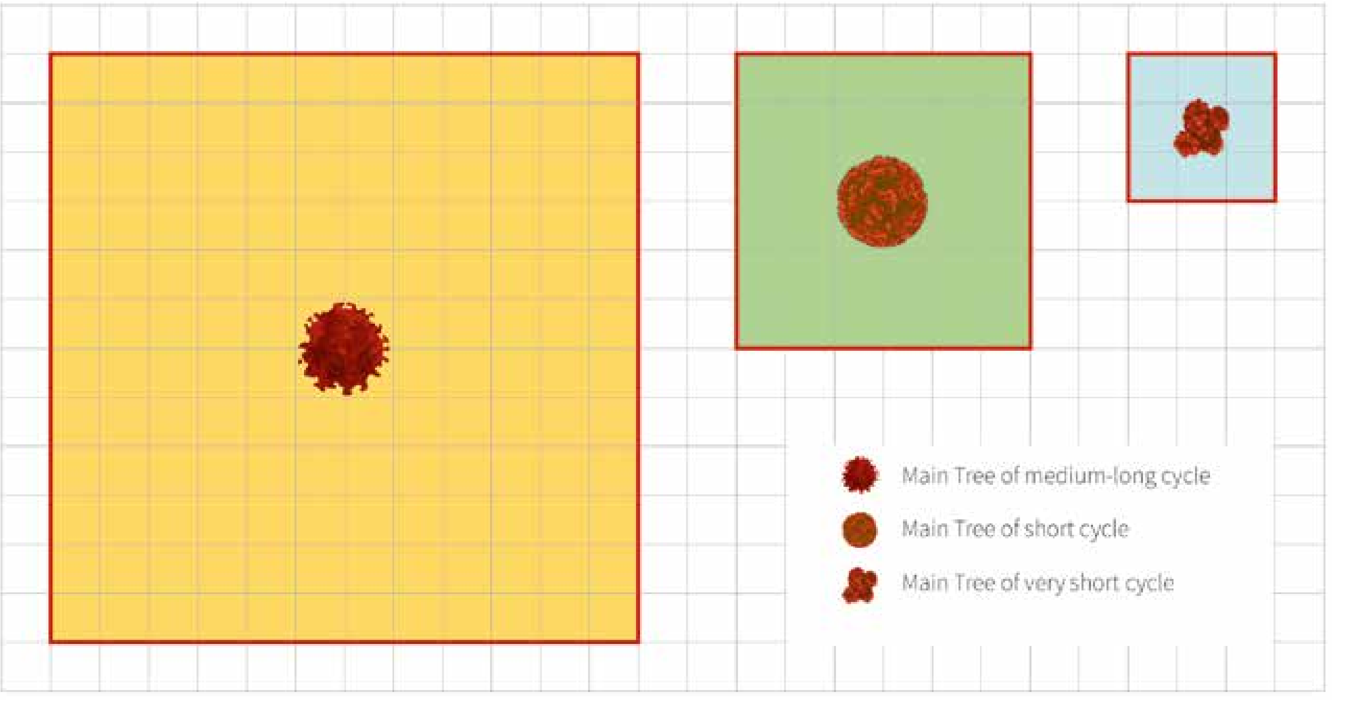


Figura 3.1 - Examples of Main Trees of medium-long cycle species, short and very short, with respectively an area of 144 m^2, 36 m^2 and 9 m^2 that produce logs with a diameter of 40-50 cm (medium-long cycle), 30-32 cm (short cycle) and 8-12 cm (very short cycle), with maximum possible growth for each species related to fertility and management. In the figure each square represents an area of 1 m^2.

For **woody biomass production** in order to a plant of a particular species could be considered Main Tree, it requires that:

- its production area is large enough to allow reaching the harvest diameter without any thinning (Figure 3.1);
- the highest level of hierarchy, within the area units assigned (Block[5]), than any other shrub or tree;
- individual care operations are not applied.

3.1.2 Accessory Plant

A plant is attributed the role of Accessory Tree or shrub when it makes easier the planting management.

The Accessory Plants are so named because their presence is not essential in order to obtain the desired production. TheAccessories Plants can be inserted in the design of Tree farm to get "services", single or combined, such as:

- reduce soil tillage;
- provide a suitable shape at Main Trees to make pruning easier;
- improve soil fertility;
- determine micro-environmental conditions for a better Main Trees development and, if present, Dual-Role Trees.

The Accessory Plants offer an advantage to the tree farmer, but they have also a cost that affects the financial balance sheet of the Tree farm. So when you decide to put them it is important to:

- select suitable species to get at least one of the "services" expected from plants with accessory role;
- give them the last level in the hierarchy respect to Main Trees and Dual-Role Trees;
- place them at appropriate distances to achieve the desired effect during a suitable period of time, before their presence might turn into negative competition against Main Trees and Dual-Role Trees (Figure 3.3).

Accessory Plants have NOT to be pruned, first to avoid a costly operation, useless for the purposes of expected production, second because the pruning could even reduce or eliminate benefits of Accessory Plant. If the competition for light between Accessory Plants and Main or Dual-Role Trees would be too strong, the first, being on the bottom level of the hierarchy, must be thinned or totally removed.

5) See section 5.1.

3.1.3 Dual-Role Tree

Is attributed the "Dual-Role" to the tree that in addition to influencing the architecture of Main Trees and to provide the services expected of Accessory Plants, also produce fine valuable assortments and/or biomass required by the market. In order a plant of a certain species could be regarded as Dual-Role Tree, it requires that:

- it has a production cycle considerably shorter than the cycle of Main Trees in the Block[(6)] in which they are inserted (in whole or in part) or are able to tolerate shading.
- it has, for long enough, a production area suited at achieving the desired objective without ever being harvest before reaching at least once (in the case of biomass for fuel) the commercial diameter. The area available of Dual-Role Trees can be entirely or partly within the Block of a longer cycle of its Main Tree (Figure 3.4) or in part within a Block with Main Trees with the same production cycle length (Figure 3.5);
- we attribute to it, within the surface unit assigned to one or more Main Trees (Block), the second level of hierarchy, subordinate only to the Main Trees present in the Block (Figure 3.6). This means that in case of competition between the Main Trees and Dual-Roles Trees, the latter have to be felled;
- we submit it to individual care aimed to achieve, as soon as permitted by species and by the environment in which it is inserted, a commercial log with expected features. The individual care should not be made to all the Dual Role Trees for wood biomass production.

6) See section 5.1.

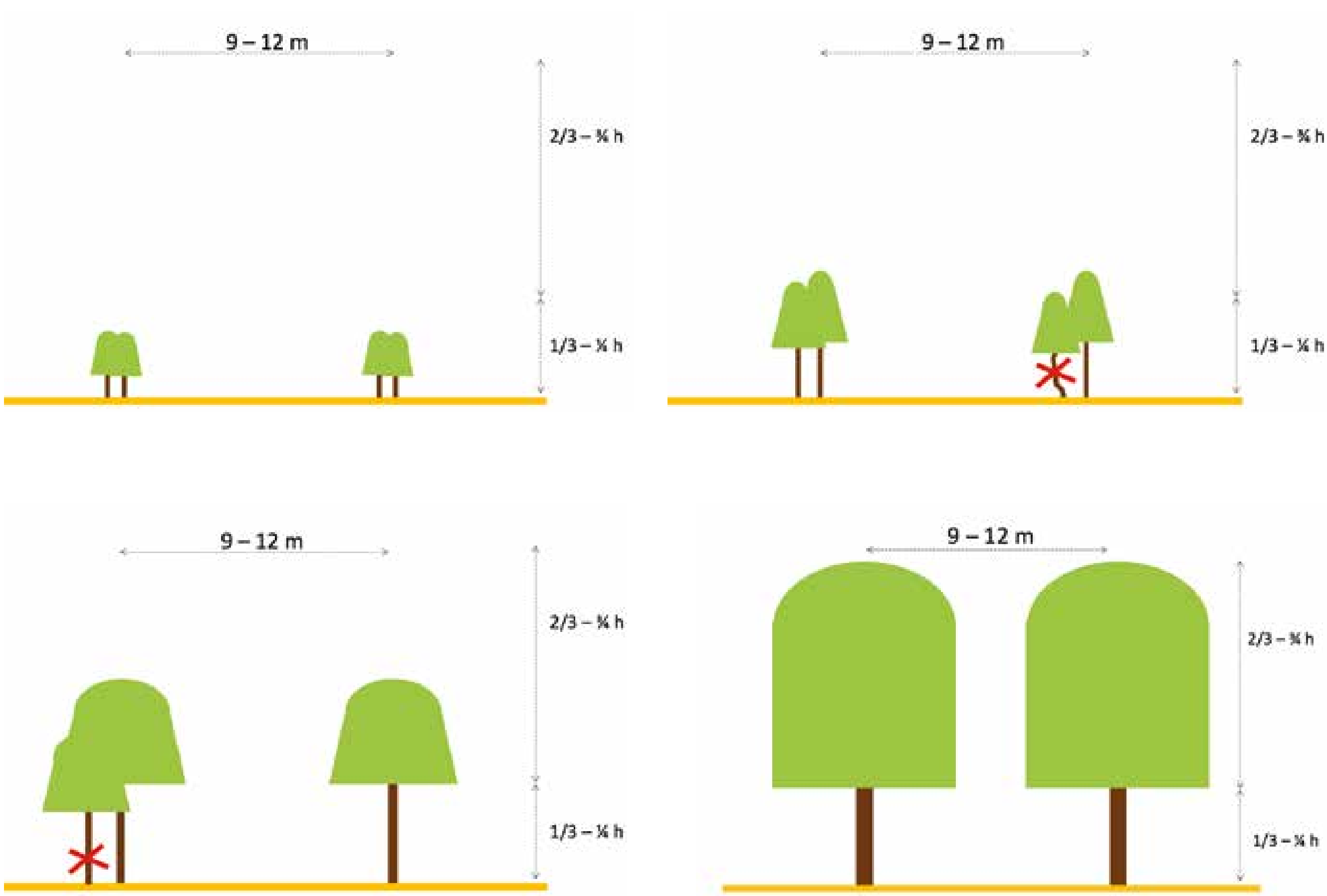


Figura 3.2 - Example of two double trees evolution of Potentially Main Trees that, following the selection, will give rise to 2 Main Trees. In this example it is assumed that the selection within the couple took place at different times, but is also frequently the case that the selection is made during the same cut in both couples.

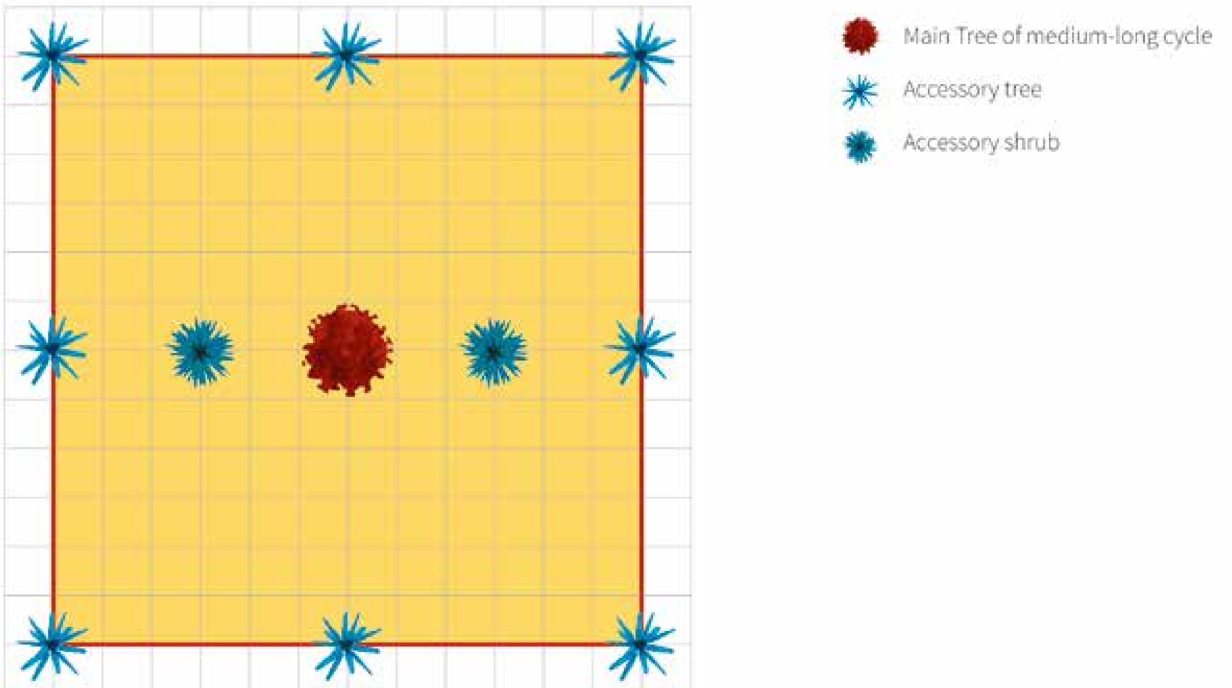


Figure 3.3 - Example of sized Block for a Main Tree in a medium-long cycle, with Accessory Trees and shrubs.

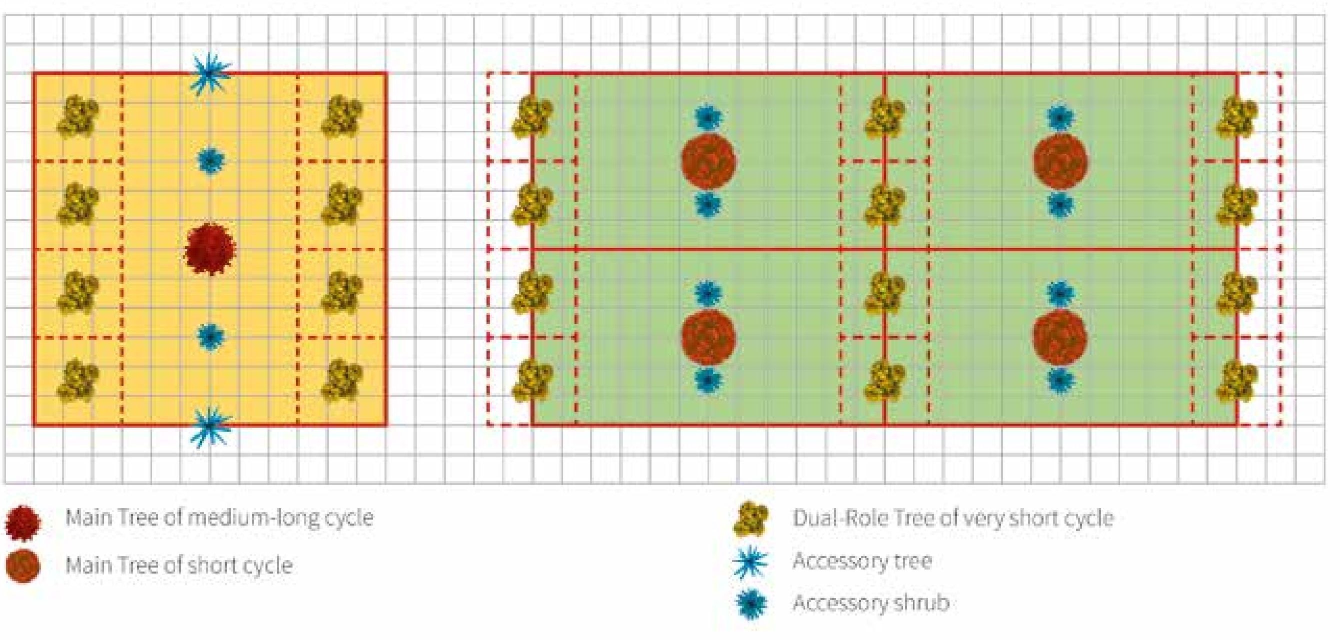


Figure 3.4 - Example of Dual-Role Trees with very short-cycle (4-7 years) with production area located completely inside a single Block medium-long cycle (left) and with production area within 2 Blocks with short-cycle Main Tree (right). The continuous red line marks off the surface of the Block of the Main Tree. The dotted line marks the part that may be temporarily occupied by crowns with Dual-Role Trees. The dotted line outside the Block shows an area that will be necessary for a good crown development of Dual-Role Trees in adjacent Blocks.

For example the poplar Main Trees, placed at suitable distance, can simultaneously produce timber for rotary-cut veneer and, like Accessory Plants, induce a straight stem in walnut, making pruning and by shading the ground so as to reduce the need of tillage.

3.2 Production cycles

3.2.1 Tree farm type and production cycles length

- **medium-long cycle Tree farm** => over 20 years (e.g. for species like walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), ash (*Fraxinus* spp.), oaks (*Quercus* spp.), maples (*Acer* spp.) or *mountain ash* (*Sorbus* spp.));

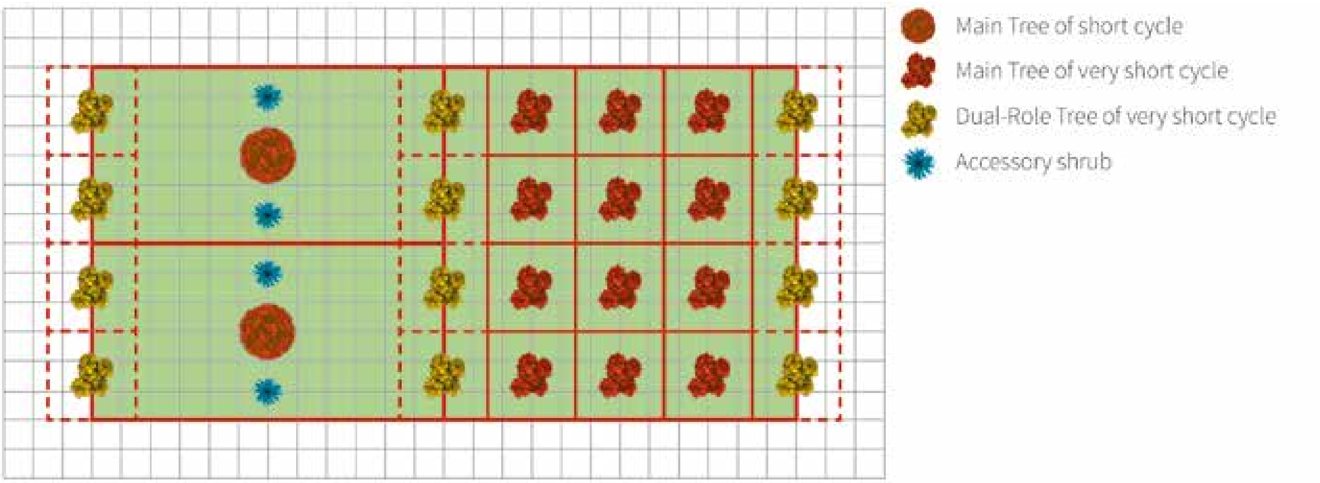


Figure 3.5 - Example of Dual-Roles Trees in very short-cycle with production surface only partially inside the Block of a Main Tree longer cycle.

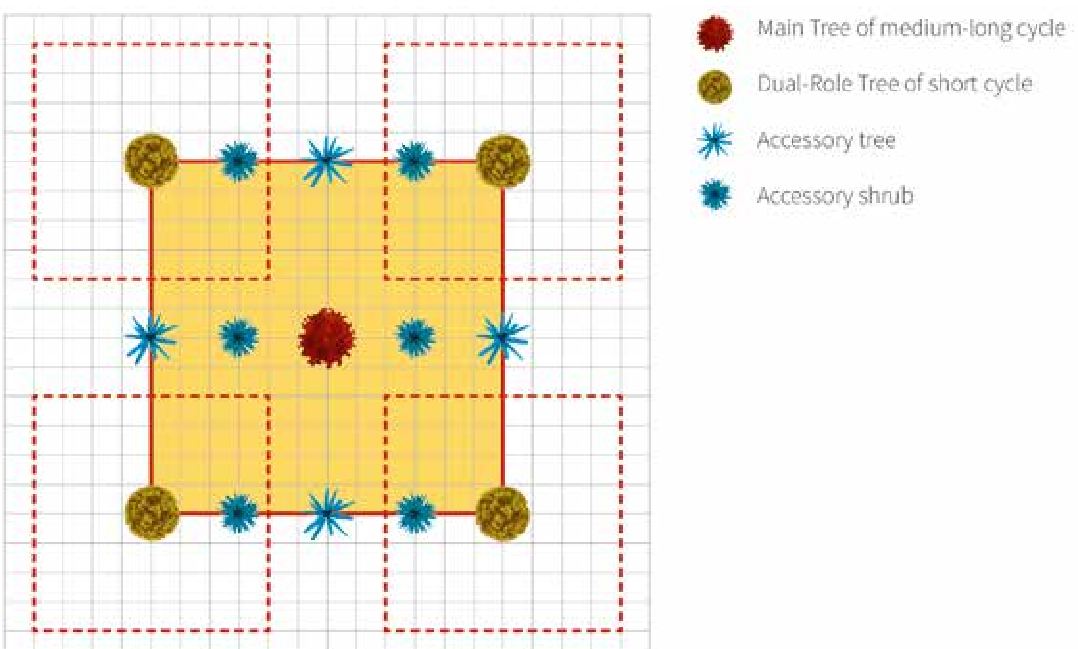


Figure 3.6 - Example of Block sized for a Main Tree in medium-long cycle, in which are inserted Dual-Roles Trees and Accessory Trees and shrubs. The yellow background and the continuous red line define the sur-face and the limits of the Block that, at the end of the cycle, will be fully occupied by the Main Tree. The dotted line marks the part that may be temporarily occupied by Dual-Roles Trees. The dotted line out-side the Block shows an area that will be necessary for a good crown development of Dual-Role Trees in adjacent Blocks to that considered.

- **short cycle Tree farm** => from 8 to 12 (15) years (e.g. poplar logs for rotary-cut veneer);
- **very short cycle Tree farm** => from 4 to 7 years (for producing woody biomass).

3.2.2 Tree farm type and number of production cycles

In Tree farming is possible to use both Main tees in one production cycle and Tree farms which have, on the same plot, Main Trees of different species and with different production cycles lengths. We can consider to this purpose two categories of Tree farms, depending on the number of production cycles simultaneously occurring on the same plot.

Monocyclic Tree farm

It is a Tree farm where Main Trees have the same duration of production cycle.

For example, are monocyclic very short cycle Tree farms for woody biomass production. The same is for medium-long cycle Tree farm with Main Trees of a single species or with two or more species that reach the productive target at the same time.

Polycyclic Tree farm

It is a Tree farm where, in the same plot, Main Trees have different production cycles[7].

Therefore every Tree farm where there are at the same time, in the same plot and in any combination, Main Trees with medium-long, short and/or very short cycle, is considered polycyclic. We need to distinguish Agronomic Polycyclic Tree farms (PPA in Italian) (Figure 3.7) from Naturalistic Polycyclic Tree farms (PPN in Italian). **A Polycyclic Tree farm** (see section 3.3) **will be considered of "Naturalistic type" when with Main Trees are also present Dual-Roles Trees and/or Accessory Plants** (Figure 3.8). The minimum number of plants of various roles when the Tree farm starts, in a Naturalistic Polycyclic Tree farm, is 600 per hectare.

3.3 Type of Polycyclic Tree farm

Polycyclic Tree farms can be distinguished on:

- **Temporary Polycyclic Tree farms** (or TP Tree farms), when they support only Blocks containing Main Trees with production cycle of the same length, Dual-Role Trees and optional Accessory Plants (Figure 3.9). At the end of the production cycle all the surface of the plot will be covered by Main Trees crowns (Figure

7) Theoretically it can be considered polycyclic a Main trees plantation with production cycle of the same length, but planted deliberately in 2 moments from each other over time at least for 20-50% of the production cycle length.

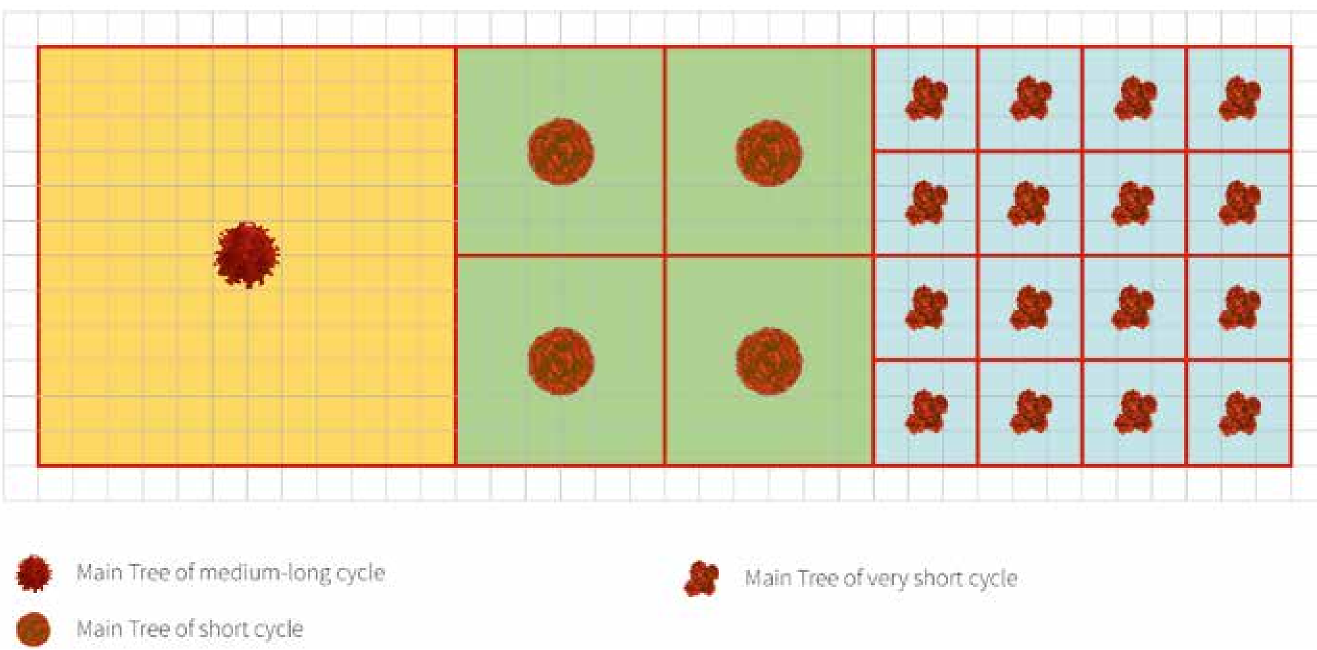


Figure 3.7 - Example of Tree farm scheme of 3P (see par. 3.3) Agronomic Tree farm (PPA), composed of monocyclic Blocks where there are Main Trees with different production cycle lengths. The combination of short-cycle and very-short cycle Blocks should occupy an equal area respect to medium-long cycle ones. In the absence of medium-long cycle, the same criterion has to be used for short cycle and very short cycle Blocks. This will allow maximum flexibility of choice about the next kind of woody production at the end of each growing cycle.

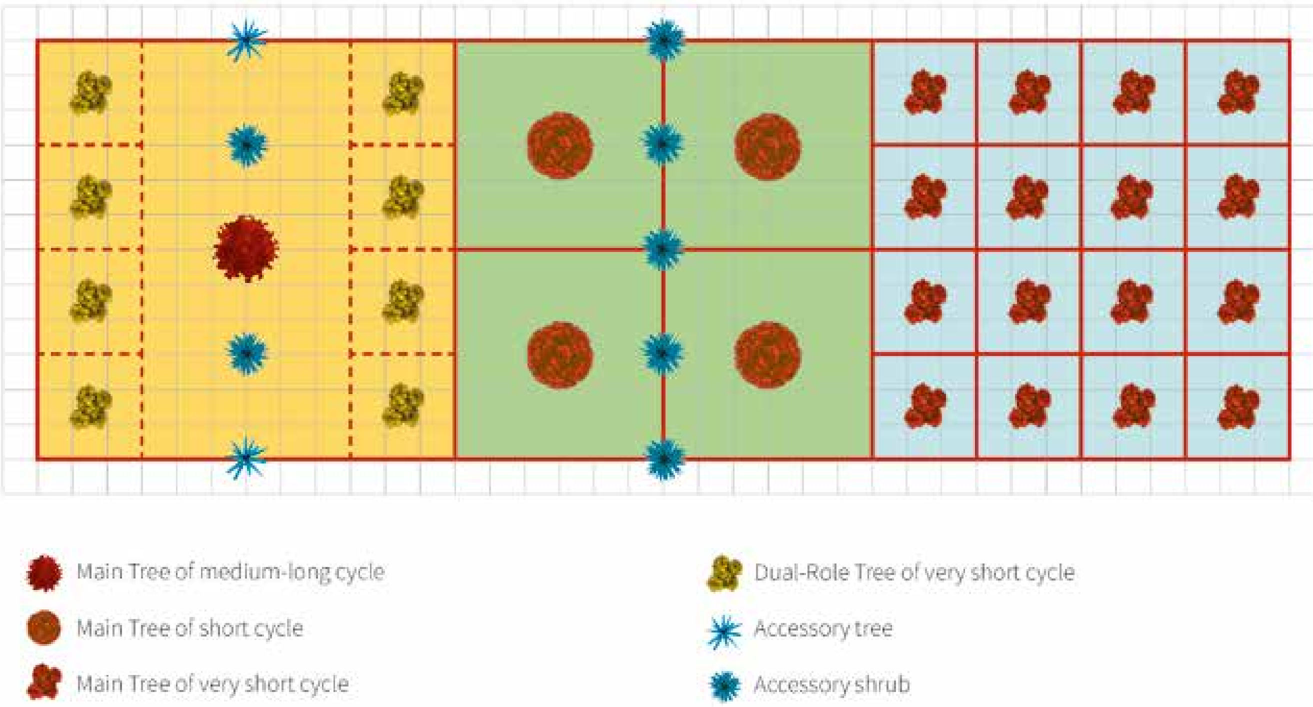


Figure 3.8 - Example of Tree farm scheme example of 3P Naturalistic Tree farm (PPN), composed of monocyclic Blocks where there are Main Trees with different production cycle lengths. Within the medium-long cycle were inserted very-short cycle Dual-Role Trees and Accessories Plants, both trees and shrubs. In the Block with Main Trees of short cycle, only Accessory shrubs were inserted. With respect to the drawing of figure 3.7 the plant density has been increased from 486 to 833 plants per hectare. In this case, the composition of the Blocks should follow the same criteria as shown in Figure 3.7 and described in the paragraph 6.3.

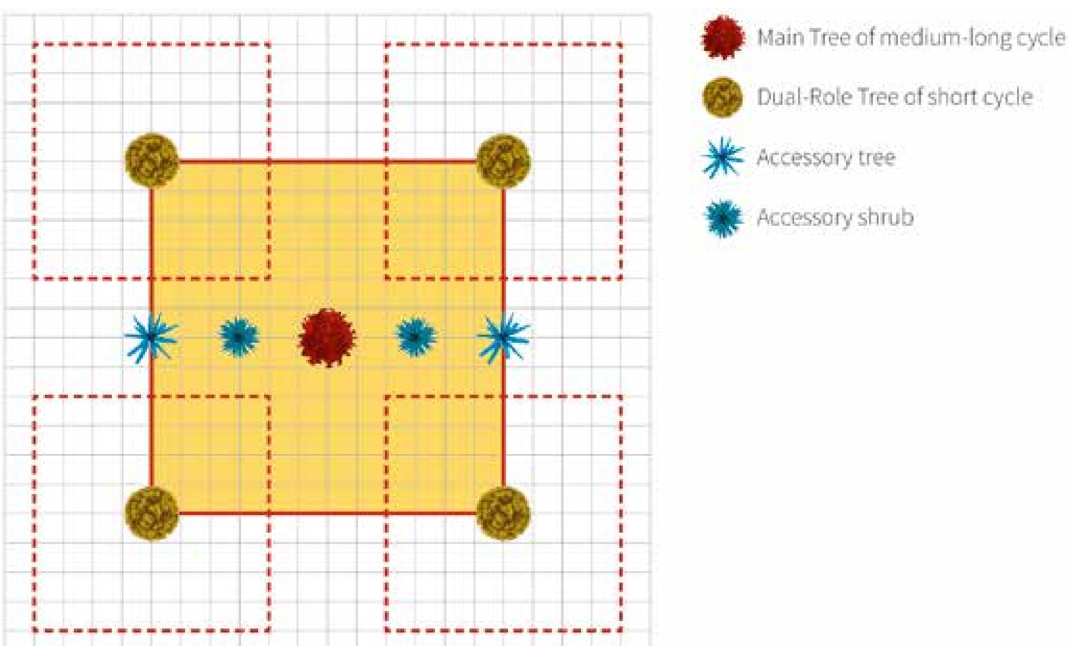


Figure 3.9 - Example of Polycyclic Block of Naturalistic type, composed of Main tees with medium-long cycle, Dual-Role Trees with short-cycle and Accessory Trees and shrubs.

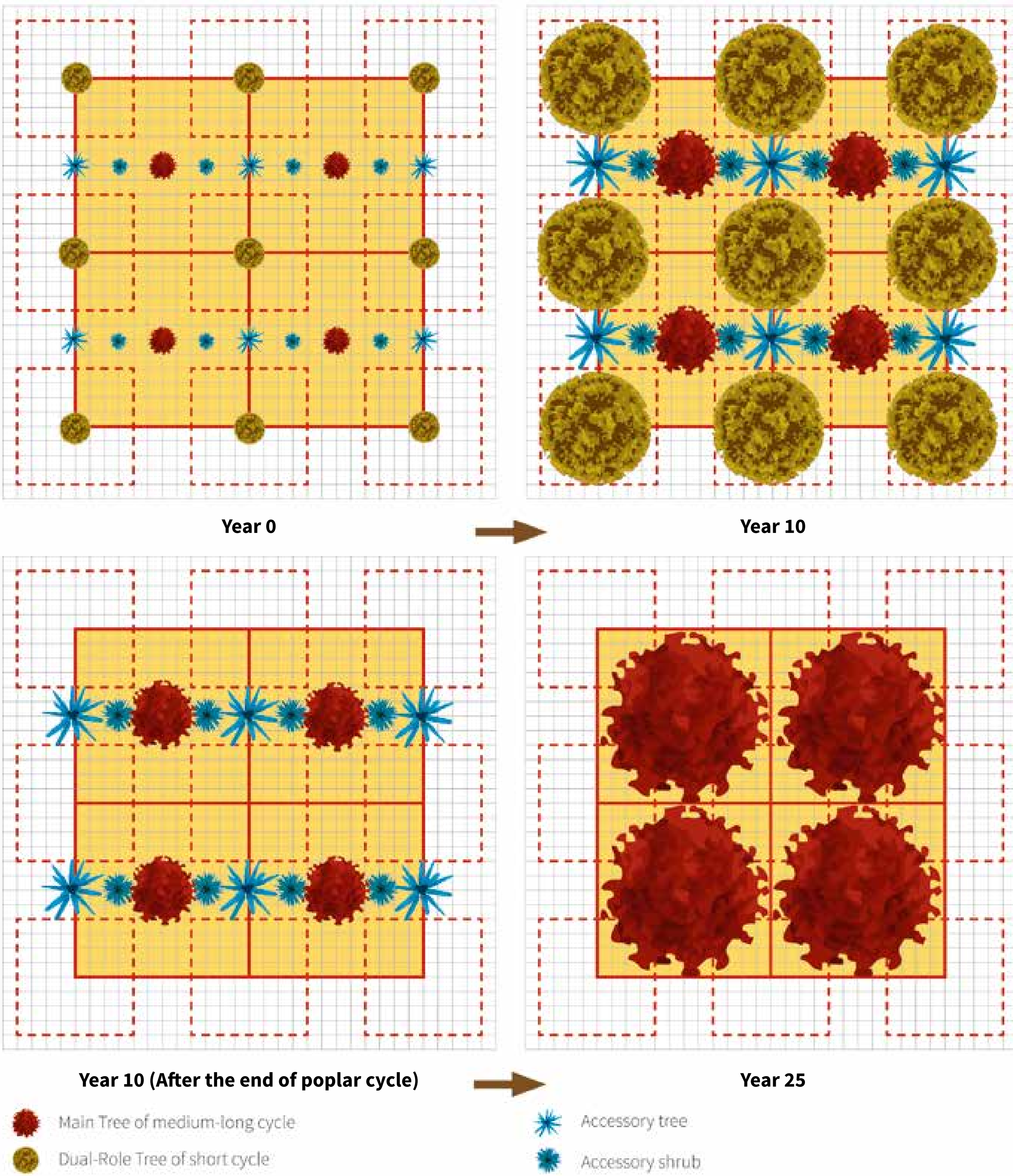


Figure 3.10 - Example of evolution over time of 4 adjacent Blocks with the same characteristics as the one shown in Figure 3.9. The 4 representations illustrate the expected situation:1) at the time of planting; 2) at year 10; 3) before and after harvesting the short cycle Dual-Role Trees; 4) at year 25, immediately before harvest medium-long cycle Main Trees.

3.10). After the harvest of Main Trees the tree farm is removed definitively. Therefore, in order to have a new production cycle, one must planted again the entire Tree farm;

- **Permanent Polycyclic Tree farms** (or 3P Tree farms), when they are composed of Main Trees with different cycle lengths. These Blocks can only have Main Trees and Accessory Plants or Main Trees, Dual-Role Trees and any Accessory Plants (Figure 3.11). The 3P Tree farms should never reach the condition of the development of a close canopy by the Main Tree crown, since the system must be designed, implemented and managed so as to differentiate the individual production cycle (Figures 3.12 and 3.13). For this reason, after the end of each cycle, while the Main Trees of the other production cycle continue to grow, it is virtually possible to introduce a new production cycle, same or different from the one just come to the end. In this way, a sequence of subsequent cycles can be triggered indefinitely, therefore the end of woody plantation can be decided by the tree farmer

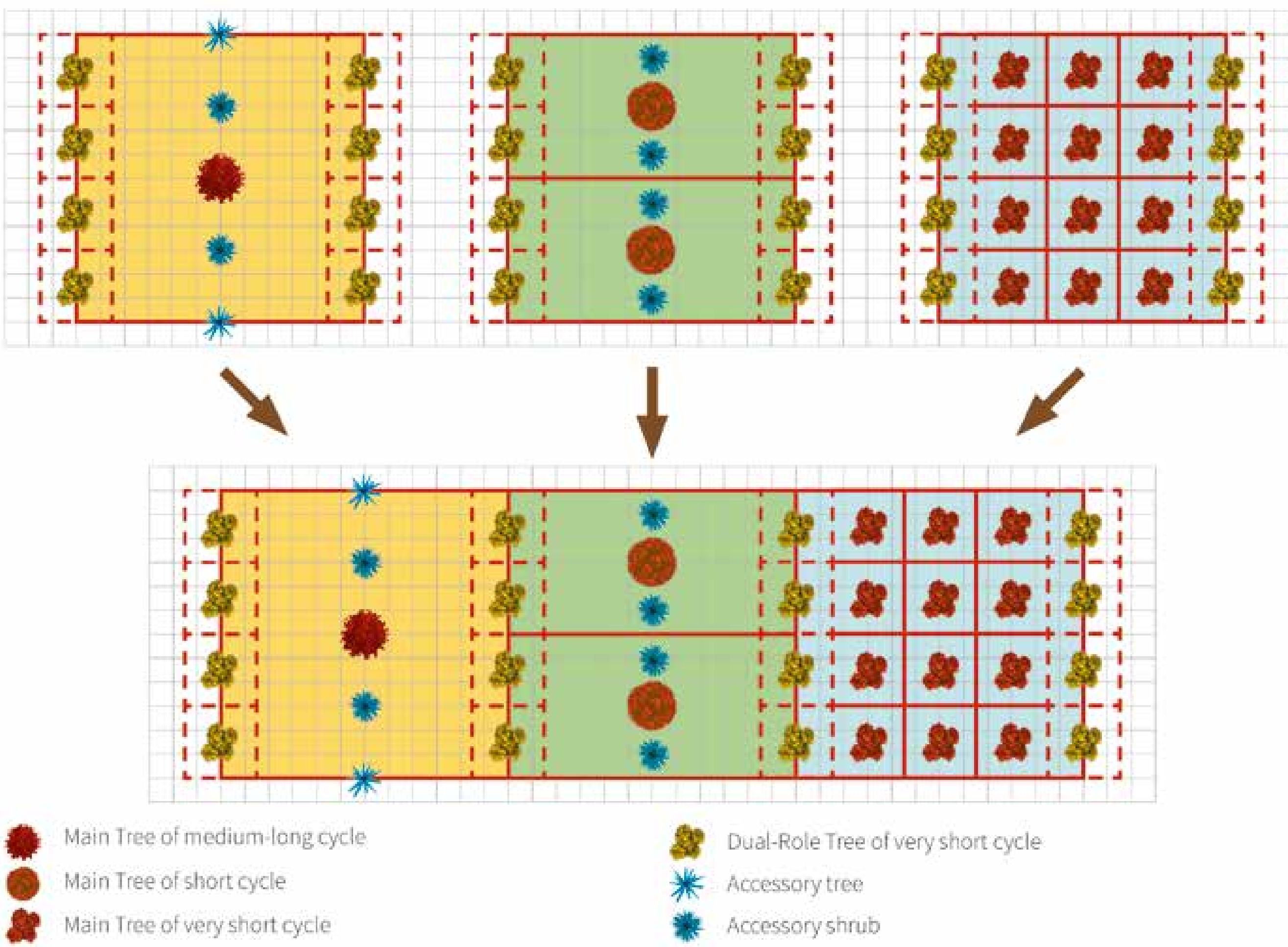


Figure 3.11 - Example of 2 polycyclic Blocks, naturalistic type (left and centre) and a monocyclic Block (right). The combination of which can bring into a 3P Tree farm scheme.

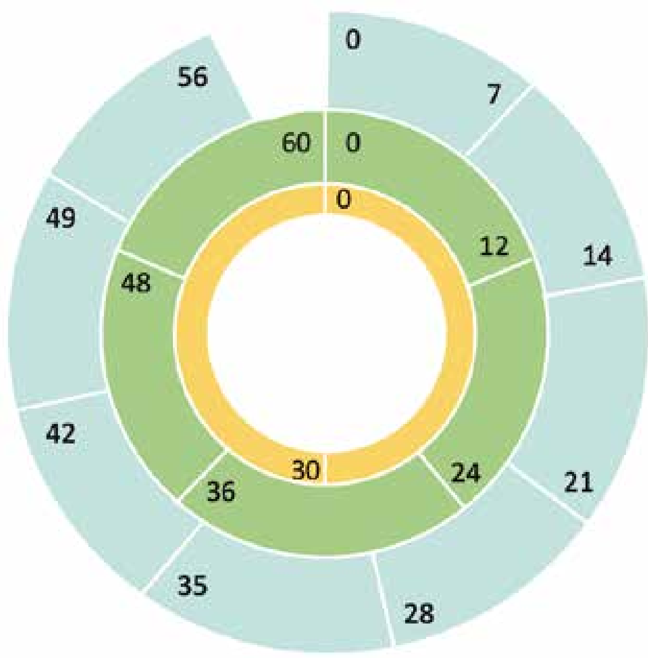


Figure 3.12 - Indicative production sequence of various woody assortments expected in planting scheme of figure 3.11, partially shown in Figure 3.13. The thickness of the rings indicates the different productive importance, in terms of mass, of the different cycles length, including that of Dual-Role Trees. Yelow shows the medium-long cycle production, green the short cycle production and blue the very short cycle production.

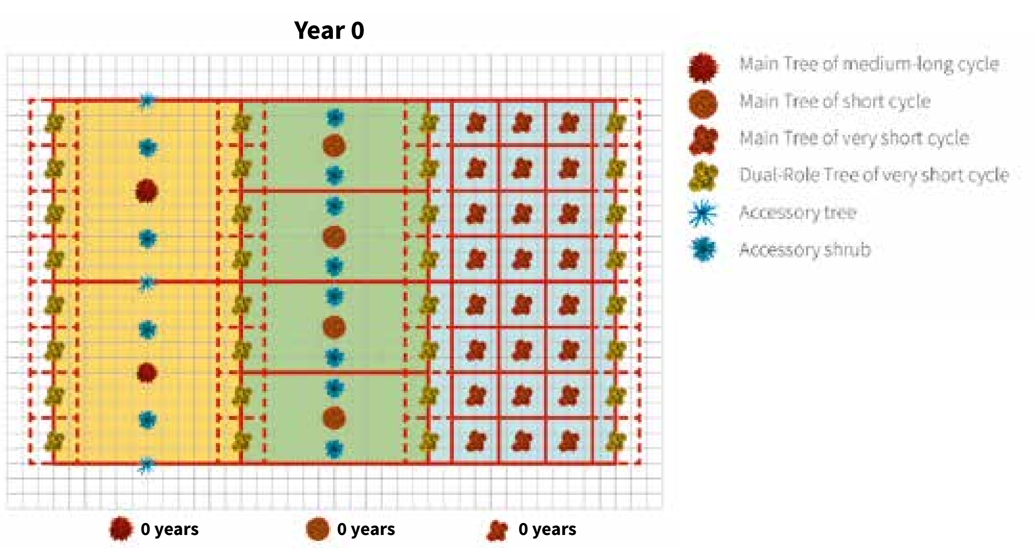
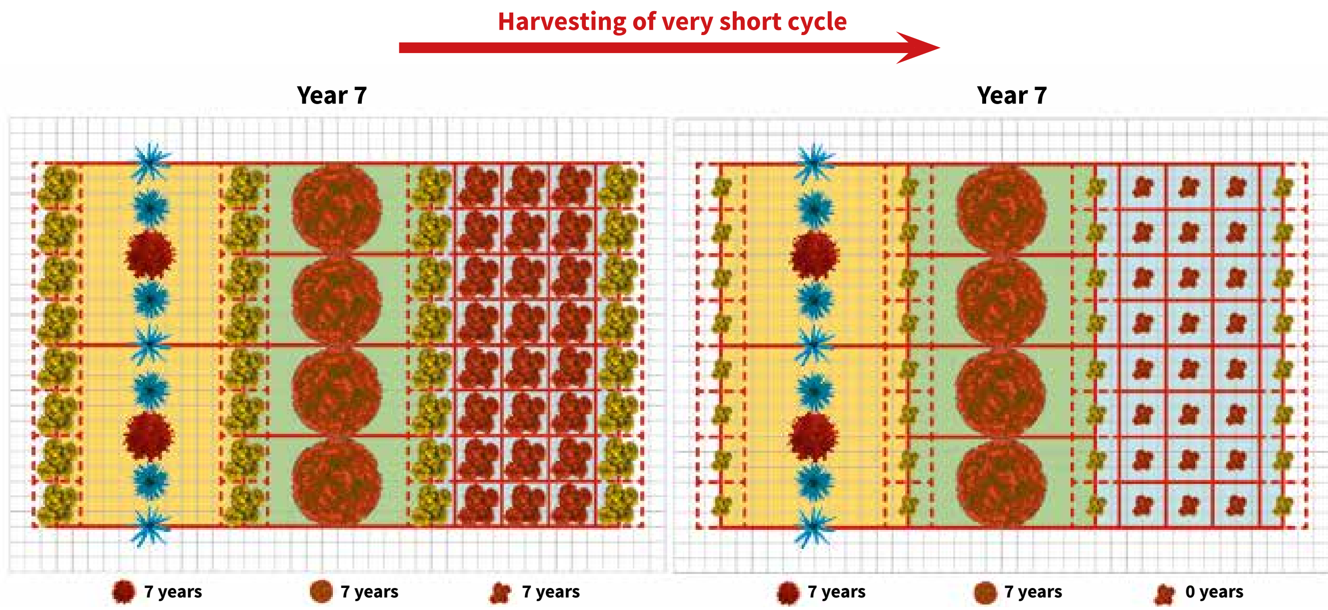
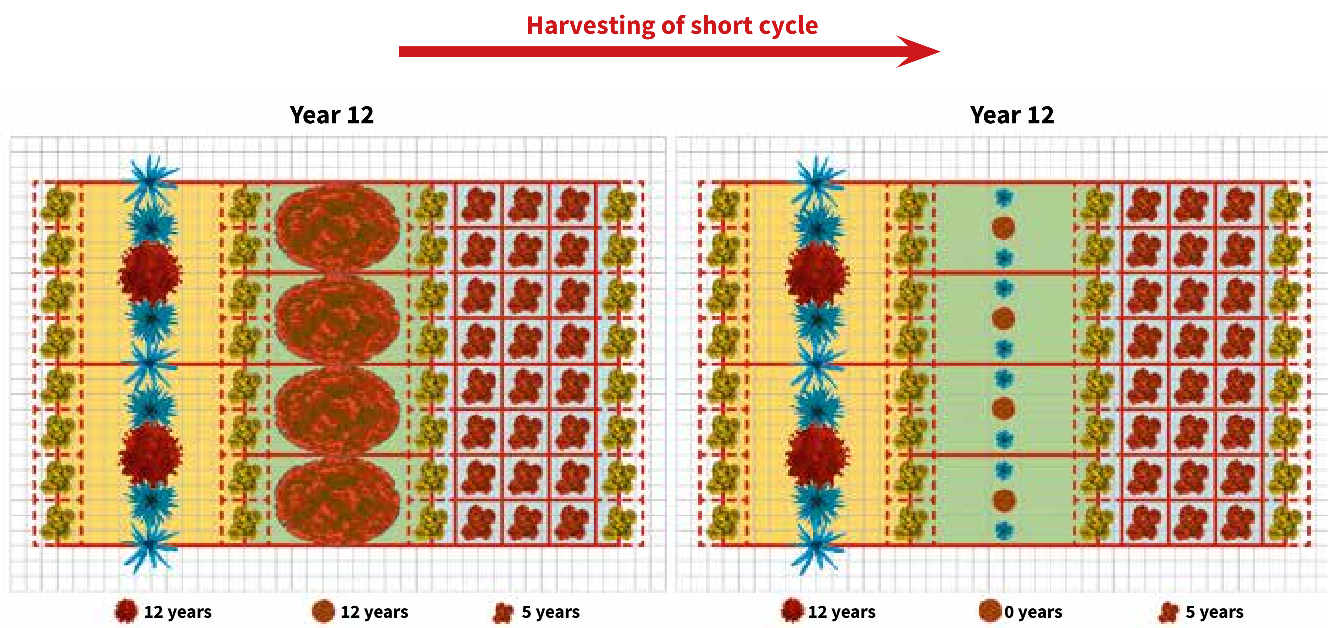
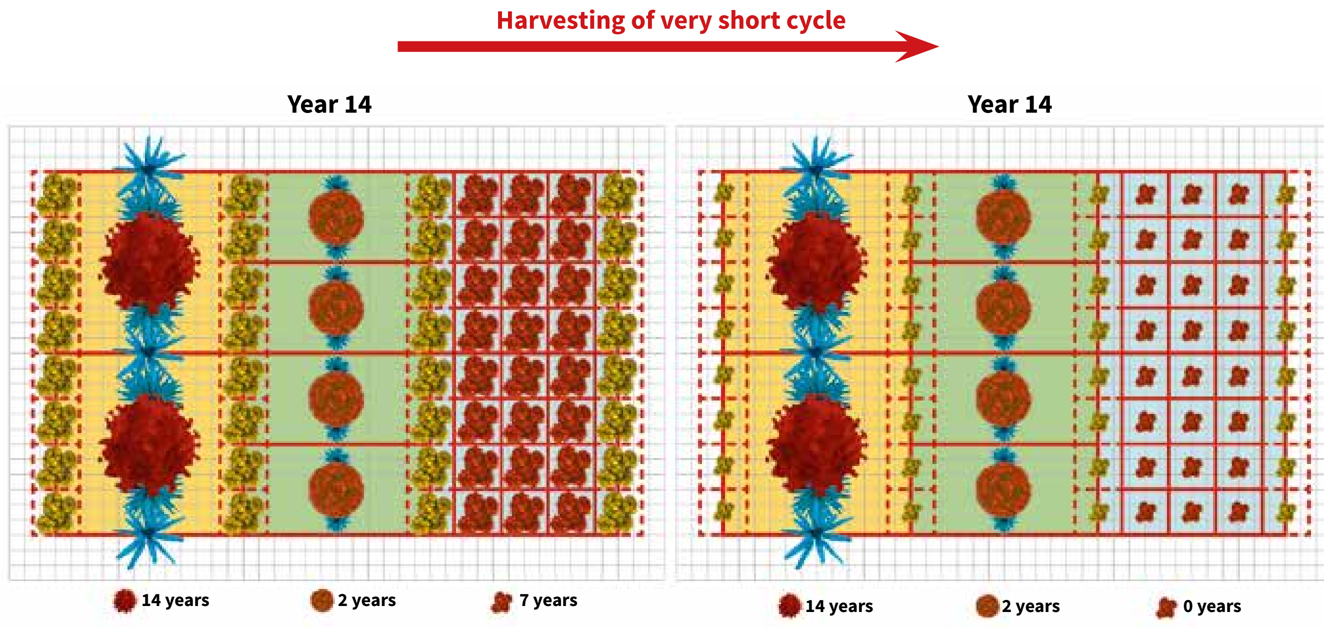
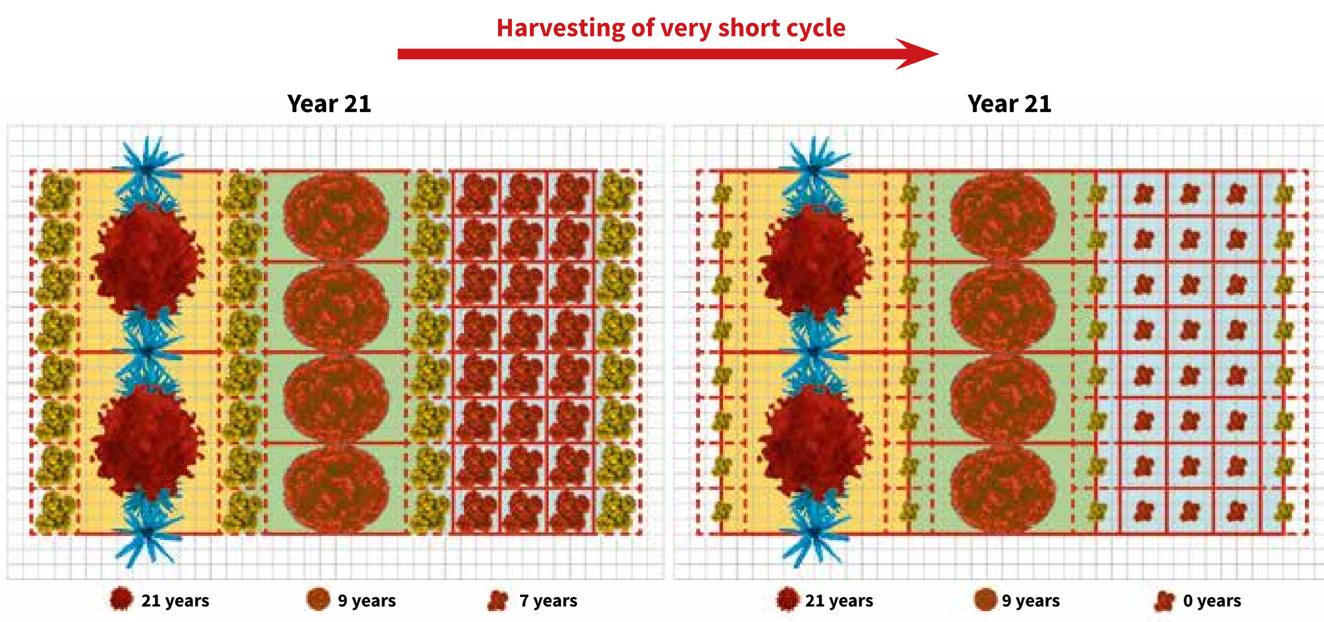


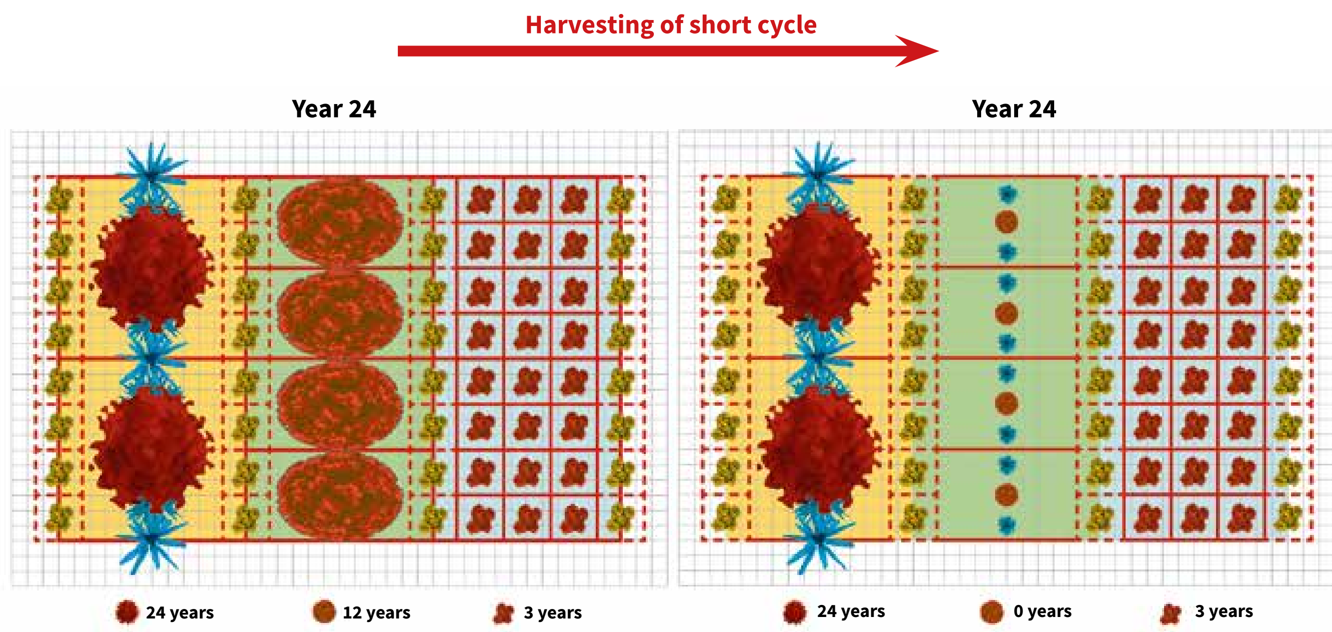
Figure 3.13 - Example of evolution over time of a portion of tree farm plot established by applying to the 3P farm scheme in figure 3.11 for a 3P Tree farm implementation. The simulation is limited to the first 30 years, although the plant may continue to develop potentially without a time limit. Figure 3.12, describes a similar situation but for a longer period of cyclical harvesting.

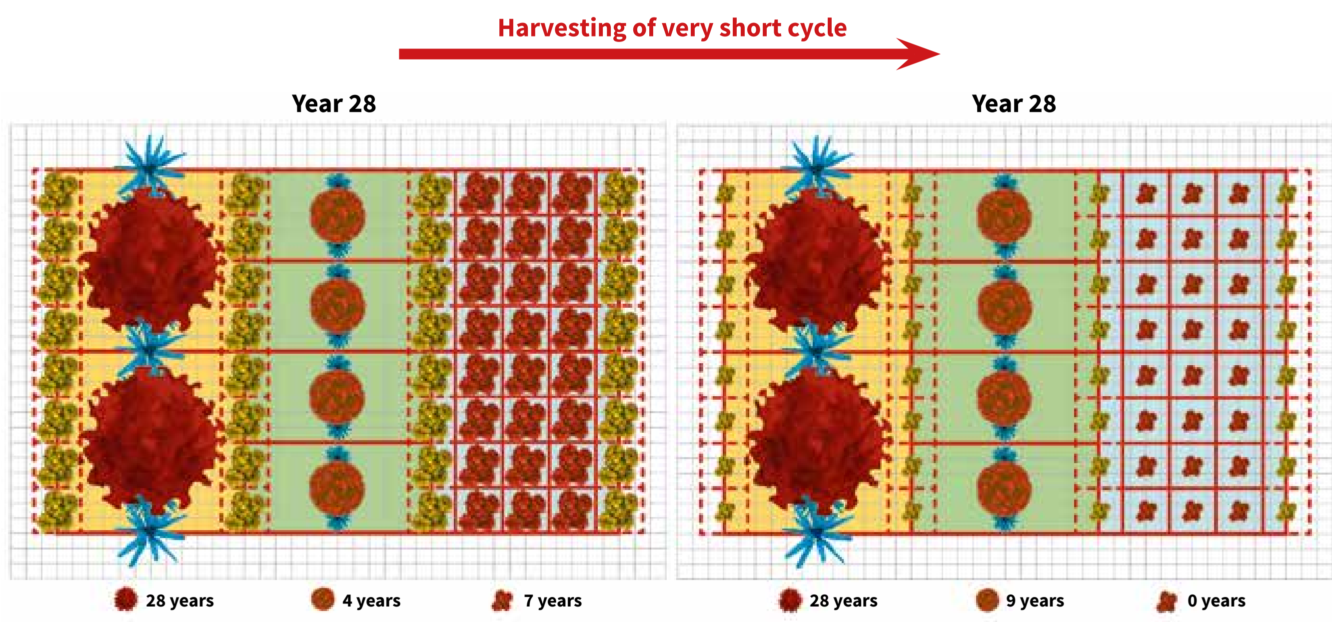

Harvesting of very short cycle
Year 7
Year 7
7 years
7 years
7 years
7 years
7 years
0 years

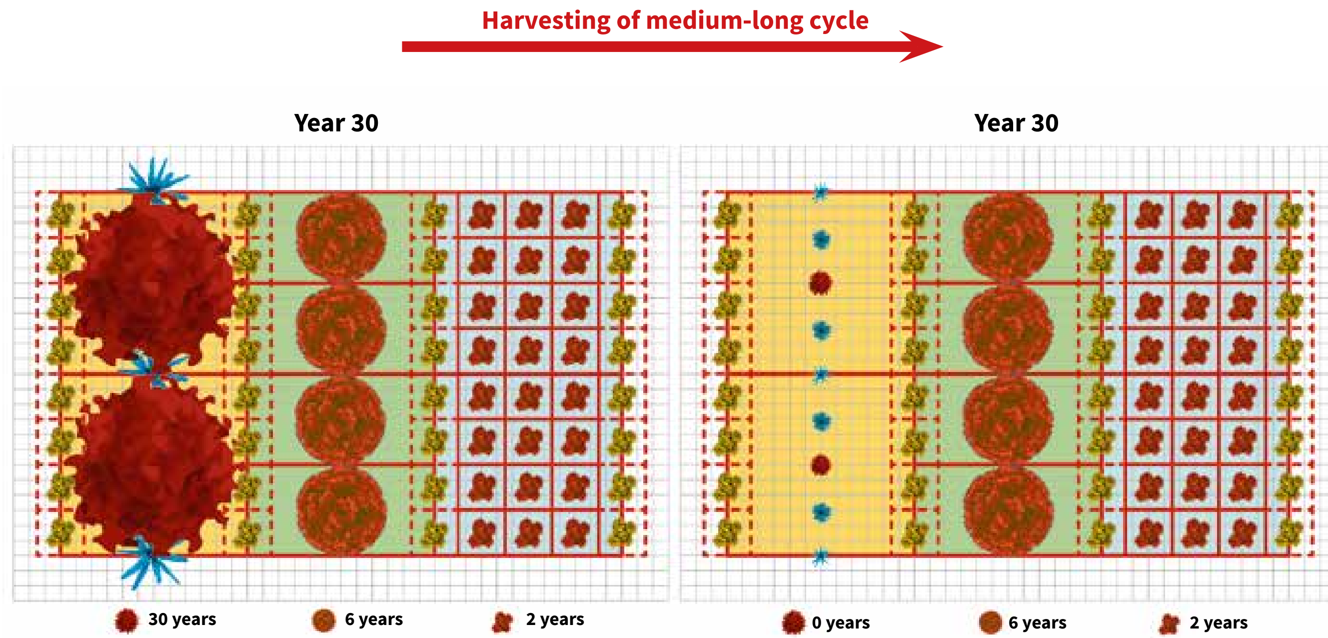

Harvesting of short cycle
Year 12
Year 12
12 years
12 years
5 years
12 years
0 years
5 years


Harvesting of very short cycle
Year 14
Year 14
14 years
2 years
7 years
14 years
2 years
0 years


Harvesting of very short cycle
Year 21
Year 21
21 years
9 years
7 years
21 years
9 years
0 years


Harvesting of short cycle
Year 24
Year 24
24 years
12 years
3 years
24 years
0 years
3 years


Harvesting of very short cycle
Year 28
Year 28
28 years
4 years
7 years
28 years
9 years
0 years



Picture 3.1 - Permanent Polycylic Tree farm (Picture: Paolo Mori).

Picture: Paolo Mori

4

HOW TO ASSIGN TO EACH MAIN TREE AND DUAL-ROLE TREE AREAS SUITABLE SURFACE OF PLOT

The Naturalistic Polycyclic Tree farm design strategy foresees that, once you have chosen a tree species suitable to both afford the climatic conditions of the plot and reach the tasks possible in the given environmental conditions, one defines:

- the surface area required at Main Trees of each species to achieve its specific production target.
- the surface area required at Dual-Role Trees to fulfil the production cycle before getting in competition with Main Trees;
- the surface required at Accessory Trees to carry out the target assigned to them, for as long time as necessary, without (or before) compete with Main Trees and Dual-Role Trees.

4.1 Production target and suitable area for each Main Tree and/or Dual-Role Tree

4.1.1 Medium-long cycle plants

Experimentation, carried out in Monocycle Tree farms and Polycyclic Tree farms, showed that a surface area between 81 and 144 m^2 is enough to obtain commercial assortments from Main Trees of species at medium-long cycle (e.g. walnut (*Juglans regia* L.), black walnut (*Juglans nigra* L,), pedunculate oak (*Quercus robur* L.), wild cherry (*Prunis Avium* L.), ash (*Fraxinus* spp.), maple (*Acer* spp.), *sorbus* (*Sorbus* spp.)). According to the production task, are indicatively required:

- 81 m^2 to get logs of about 35-40 cm in diameter (at 130 cm from the ground) in 20-25 years[8];

8) We show a range of values referred to the whole production cycle, in this case and in subsequent ones. The lower value may be considered indicative for optimal situations, while the upper one covers fairly good situations. For the same final diameter and provided that the production area would be adequate for canopy grown, factors affecting the production cycle length are: species (and its provenance) or clone; soil fertility; local climatic conditions and the tree farmer ability to properly manage the plantation. In exceptionally favourable situations or, conversely, very poor, the production cycle length could be respectively lower or higher than indicated here.

- 100 m^2 to get logs of about 40-45 cm in diameter (at 130 cm from the ground) in 20-30 years;
- 144 m^2 to get logs of about 45-50 cm in diameter (at 130 cm from the ground) in 25-35 years.

This suitable areas will be progressively made available to the Main Trees crown in order to:

1. benefit from favourable conditions induced by of Dual-Roles Trees and Accessory Plants presence;
2. get more constant as possible diameter increment, as strong as allowed by the species potential and by environmental conditions.

4.1.2 Short cycle plants

Experimentation, carried out in Monocycle Tree farms and in Polycyclic Tree farms, showed that for the Main or Dual-Role Trees with short cycle (mainly various poplar clones), depending on production goals, are generally required:

- 36 m^2 to get logs of about 30-32 cm in diameter (at 130 cm from the ground) in 9 -12 years;
- 72 m^2 to get logs of about 40-45 cm in diameter (at 130 cm from the ground) in 9 -12 years;
- 100 m^2 to get logs of about 45-50 cm in diameter (at 130 cm from the ground) in 11-13 years;
- 144 m^2 to get logs of about 55-60 cm in diameter (at 130 cm from the ground) in 12-15 years.

4.1.3 Very short cycle plants

Experimentation, carried out in Monocycle Tree farms and in Polycyclic Tree farms, showed that for the Main or Dual-Role Trees with very short cycle (e.g. oaks, elms, ashes, locus tree, plane tree, limes, hornbeam, willows, eucalyptus), depending on production target, are generally required:

- 9 m^2 to get logs of about 10 cm in diameter (at 130 cm from the ground) in 5 -6 years;
- 15 m^2 to get logs of about 15 cm in diameter (at 130 cm from the ground) in 6 -7 years.

Picture: Claudio Bidini

5

BEST USE OF THE PRODUCTION AREA AND SYNERGY BETWEEN TREES OF DIFFERENT CYCLES

5.1 What is a Block

In a Polycyclic Tree farm the Block is the unit surface in which the entire surface of plot can be divided. It is like an elementary tile (the Block), with a specific dimension, which we use to build a floor (the Tree farm plot). The Block size will be determined by the largest individual surface needed among Main Trees, of chosen species, to reach their final diameter with fast and constant growth.

Generally to define the Block surface we proceed as follows.

- In the case of a 3P Tree farm with Main Trees with short and very short cycles, it will be the surface needed to reach the final diameter fixed for short-cycle plants to define the Block size. For example, if you want to get poplars with a diameter of 45-50 cm, at 130 cm from the ground, the Block will have an area of about 100 m^2. The spaces dedicated to Main Trees for biomass production will be a fraction of 100 m^2. (see Figure 3.7) Similarly, if the final diameter would be 40-54 cm, at 130 cm from the ground, the Block surface will be 72 m^2, and so on.
- In the case of 3P Tree farms with medium-long and short-cycle the Block size will be determined by the planned final diameter of Main Trees in medium-long cycle, as well as in the case where there are Main Trees (and therefore Blocks) of 3 different cycles length.

Conventionally a Block is featured by 3 basic elements:

- the surface area needed by the Main Trees with the longest production cycle, to reach the target diameter[9];
- the trees and shrubs species which at different times and/or at different spaces will use part of the surface of the Block to develop;
- the plant's distribution in the Block and their mutual distances, depending on the productive surfaces available to each plant to play their role, synergy and positive competition and production target.

9) During experimental experiences of CREA-SEL - AALSEA - Compagnia delle Foreste with Polycyclic Plantations the most frequently Blocks surfaces was between 100 and 144 m^2.

The elements that characterize the single Block in **linear plantation** are similar to those of the Blocks in open field. In particular:

- the surface of a linear Block, based on the one required by Main Trees in the longest production cycle, as for Blocks in open field. In linear plantation the plants are completely free to expand their crown perpendicularly to the row. To give suitable surface to the Main Trees, the Block length is equal to the square root of the productive surface necessary to achieve the target diameter (e.g. if one needs 144 m^2 surface to produce logs with a diameter greater than 50 cm, the Block length will be 12 m);
- the trees and shrubs species which at different times will use a portion of linear Block to grow;
- the plant's arrangement in linear Blocks and their mutual distances. They depend on the productive surfaces available to each plant to play its role, the reciprocal synergy and competition as well as the achievable production target.

5.2 Minimum distances between Main Trees, Dual-Role Trees and between Main Trees and Accessory Plants

The minimum distances between trees of different rotation cycles are prudential parameters allowing to assign to all plants, trees and shrubs of each role, a **suitable area to get the expected products** (in case of Main Trees or Dual-Role Trees) or services (in case of Accessory Plants and Dual-Role Trees) (Picture 5.1).

The suitable production surface depend on species role assigned, speed of growth and target diameter to achieve. All this lead to different production surfaces and consequently different distances between trees.

5.2.1 Minimum distances between Main trees of medium-long cycle and Dual-Role Trees of short cycle

In Italy, poplars are the plants able to produce quality materials with a rotation cycle that can be considered short (8-12 (15) years). The minimum distance between poplar with Dual-Role and Main

Picture 5.1 - Minimum distance, 4 m, between Main Trees with short cycle and Accessory Trees (Picture: Paolo Mori).

Trees of medium-long cycle, depends on the expected final diameter of poplar logs. To obtain poplar logs of 30-32 cm in diameter the minimum distance from the Main Trees of medium-long cycle must be 6 m (Figure 5.1a). To get logs of 35-40 cm in diameter the minimum distance must be 7 m (Figure 5.1 b) and for logs with a diameter greater than 45 cm the minimum distance must be equal to or greater than 8 m (Figure 5.1c). Short-cycle plants with Dual-Role, to avoid high competition with Main Trees of medium-long cycle, will be harvest when the target diameter, considering specified minimum distance, will be reach (Picture 5.2).

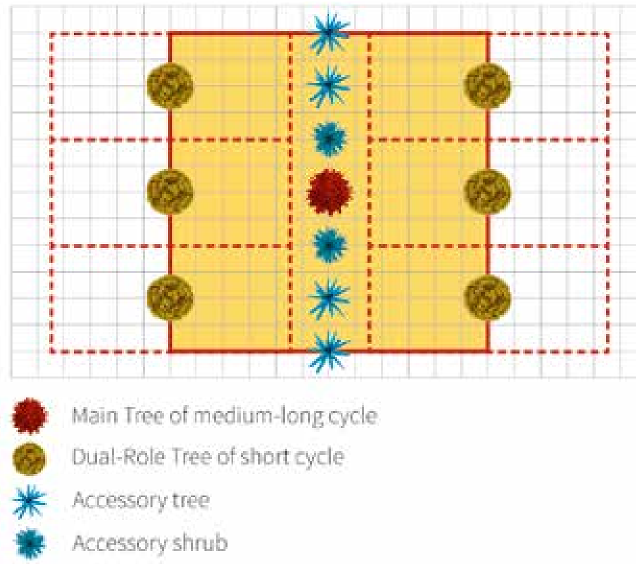


Figure 5.1a - Example of Block,144 m², fulfilling the minimum-distance criterion of 6 m between Main Tree of medium-long cycle and Dual-Role Trees aiming at producing logs of 30-32 cm in diameter in 8-10 years.

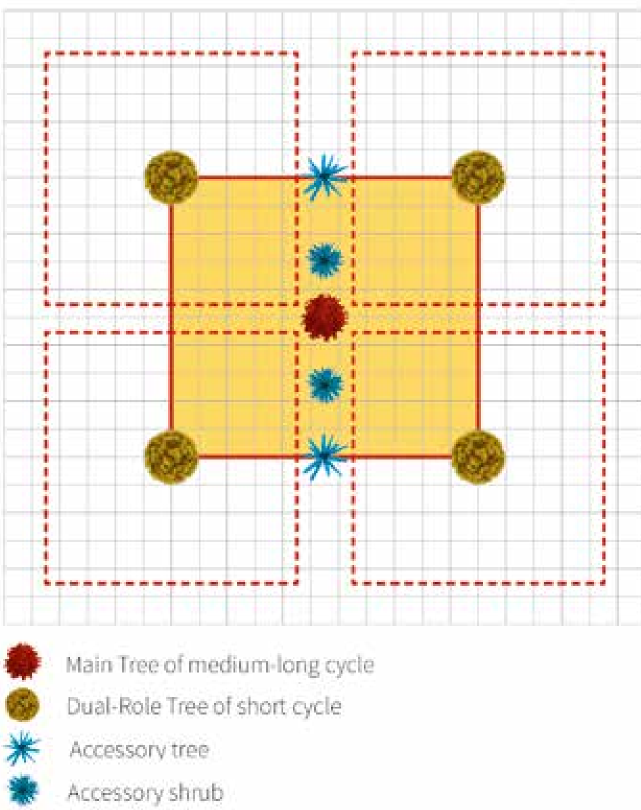


Figure 5.1b - Example of Block,110 m², with minimum distance of 7 m, between Main Trees of medium-long cycle and Dual-Role Trees of short cycle with a productive surface of 81 m², enough to produce logs of 40 cm in diameter in 9-11 years.

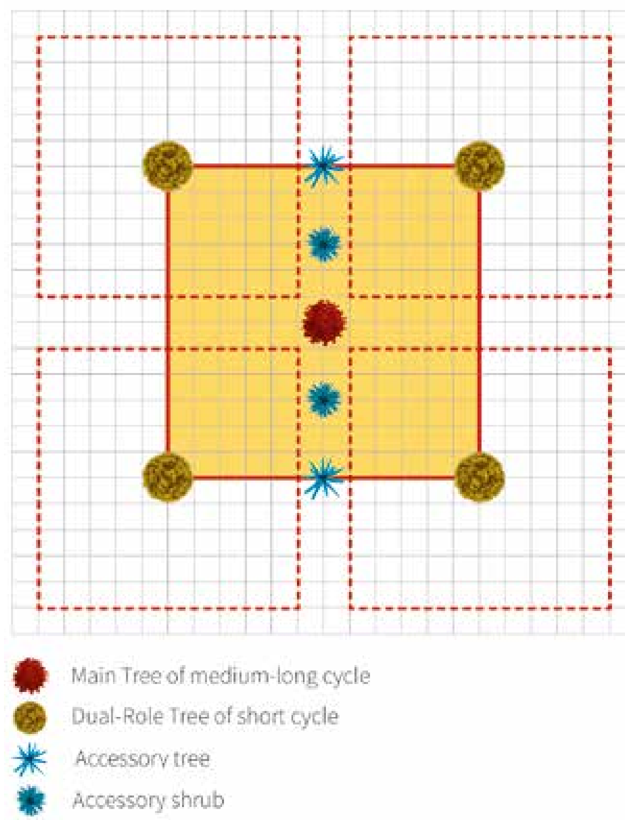


Figure 5.1c - Example of Block ,144 m², with minimum distance of 8 m between Main Trees of medium-long cycle and Dual-Role Trees aimed at producing logs with diameter greater than 45 cm in 11-12 years.

5.2.2 Minimum distances between Main Trees of medium-long cycle and Dual-Role Trees of very short cycle

The design of a tree farm with Main Trees medium-long cycle and Dual-Role Trees with very-short cycle is generally aimed at producing wood biomass with fast-growing broadleaves. The minimum distance between all Dual-Role Trees with very short cycle (except poplar) and Main Trees in medium-long cycle should be approximately 4 m (Figures 5.2). A longer distance has to be adopted for species with fast growth, could develop a too strong competition with Main Trees of medium-long cycle.

5.2.3 Minimum distances between Main Trees of short cycle and Dual-Role Trees of very short cycle

Among the Main Trees with short cycle for valuable timber production and the Dual-Role Trees with very short cycle for wood biomass production it is necessary to keep a minimum distance of 4 m (Figure 5.3).

5.2.4 Minimum distances between Main Trees or Dual-Role Trees and Accessory trees and shrub

In Blocks with Main Trees of medium-long cycle the distance between Main Trees or Dual-Role Trees and Accessory trees depends on:

- the effect to be raised on Main Trees or on Dual-Role Trees;
- the different degree of competition of the species used.

In the case of Accessory **Trees** the minimum distance from the Main Trees or from Dual-Role Trees must be of 4 m (Figure 5.4). This distance must be increased according to the different competition between species adopted: a greater competitiveness must match a higher distance.

In the case of Accessory **Shrub** the minimum distance from the Main Trees or from Dual-Role Trees must be of 1.5 m.

Picture 5.2 - Poplar tree cut down, in a TP Tree farm, create new spaces for Main Trees with medium-long cycle (Picture: Paolo Mori).

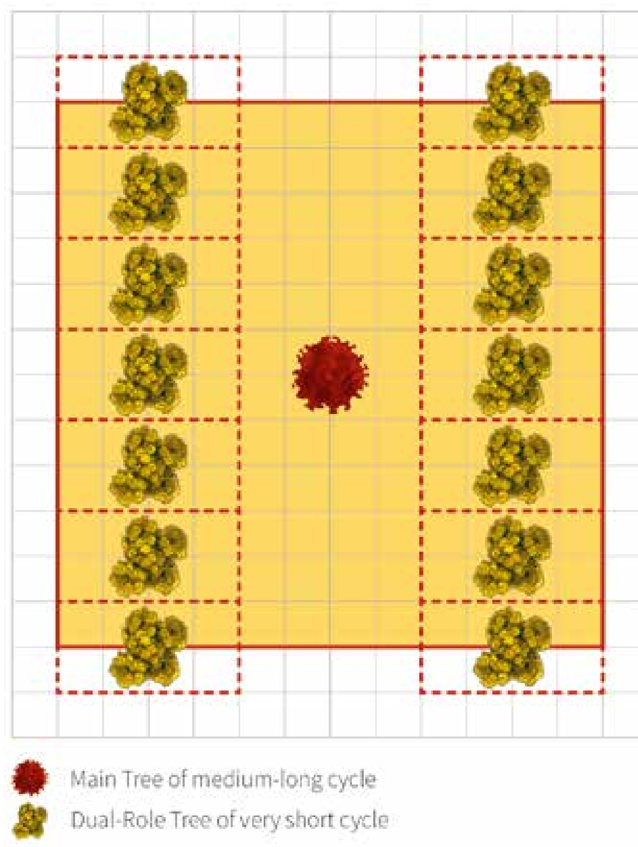


Figure 5.2 - Example of Block, 144 m^2, with minimum distance of 4 m between Main Trees of medium-long cycle and Dual-Role of very short cycle aimed at producing logs of about 10 cm in diameter in 5-6 years.

5.2.5 Minimum distances in linear plantations

In **linear plantation** or open fields with **Main Trees arranged in rows** well spaced from each other (e.g. agroforestry), the distance between Main Trees, Dual-Role Trees and Accessory trees in the same row can be reduced by approximately 0.5-1 m than reported earlier.

In Accessory shrub case the minimum distance stays at 1.5 m.

5.3 Defining a hierarchy within the Block on the basis of role

Within each Block has to be applied a hierarchy from the Main Trees to Dual-Roles Trees and then Accessory Trees and Shrubs (if presents). This is important to take decision about how to manage harvest/thinning of some plants for the benefit of others to reach each technical and financial target. In practice, the hierarchy, shown above, allows to operating while respecting those who are productive objectives previously designed. Such operation is very simple: when the crowns of two plants come in contact, the one hierarchically lower should be removed. This will allow:

- Main Trees, to have crowns always well lit without negative competition of Dual-Roles Trees and Accessory plants;
- Dual-Roles Trees, to have crowns always well lit without negative competition of Accessory plants;
- Accessory plants, to produce the expected services without exerting a negative competition towards plants intended to produce timber assortments.

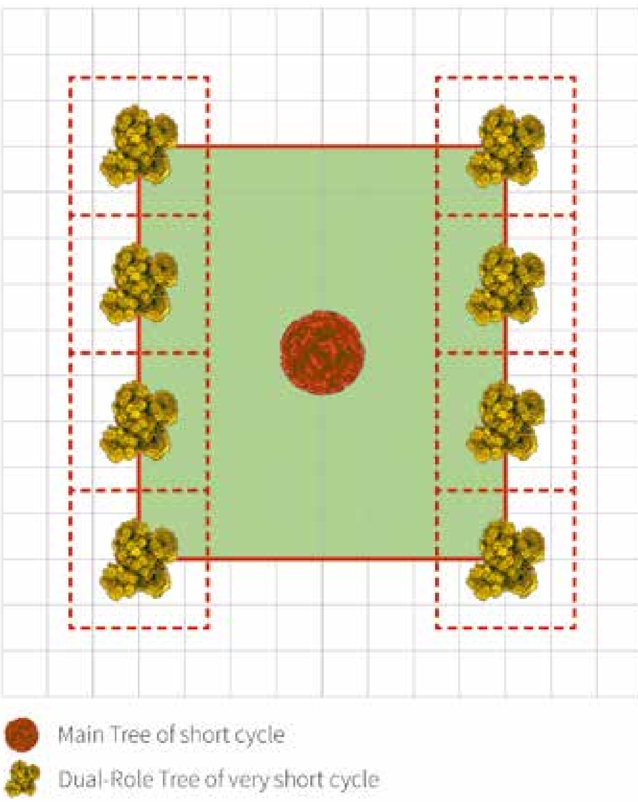


Figure 5.3 - Example of Block, 72 m², with minimum distance of 4 m between Main Trees of short cycle and Dual-Role of very short cycle.

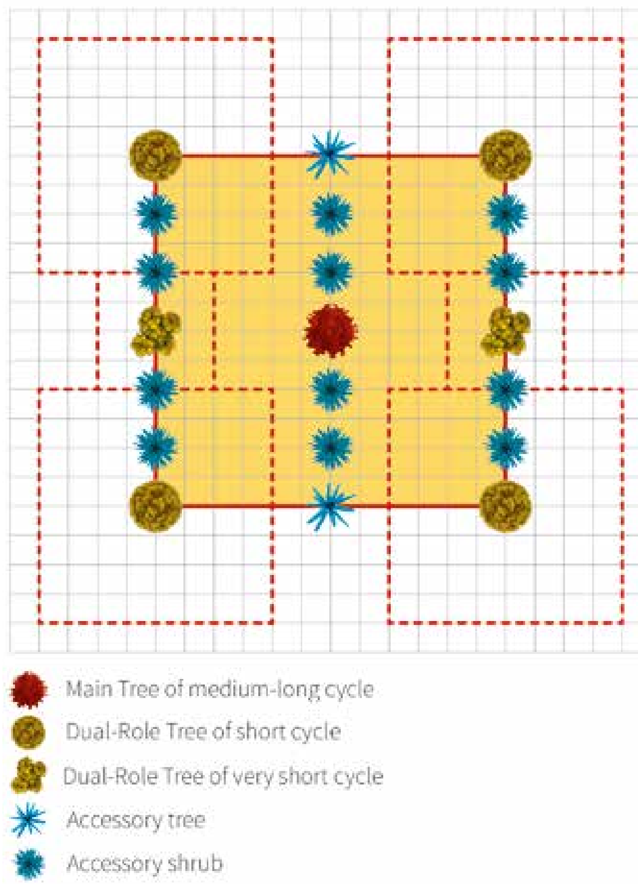
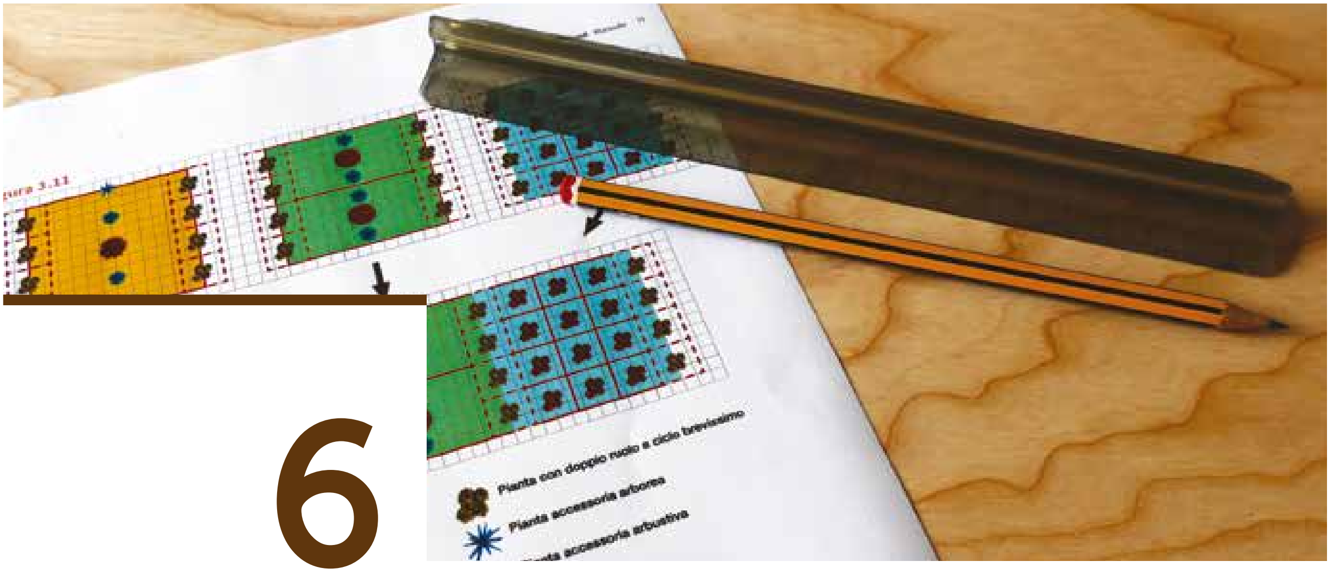


Figure 5.4 - Example of Block, 144 m², with respect of minimum distance between Main Trees and Accessory Trees and Shrubs, as well as between Dual-Role Trees and Accessory Trees and Shrubs.

Picture 5.3 - Demonstration open field Tree farm of LIFE+ InBioWood project (Picture: Massimo Bidini).

Picture 5.4 - Linear demonstration Tree farm of LIFE+ InBioWood project (Picture: Massimo Bidini).



Picture: Luigi Torreggiani

6

DESIGN OF PLANTING SCHEME FOR POLYCYCLIC TREE FARM

6.1 General criteria design in Tree farming

In Tree farming, a detailed design consists of textual description and graphics to describe the planting and crop management. The project have to includes also technical and estimation papers like price list and quantities.

6.1.1 Design technician's role

The role of the designer is to take into account all the factors that can affect the success of a specific Tree farm (plantation for wood production) and summarise in a project the suitable choices at getting the production target, in agreement with the tree farmer. (Box 6.1).

6.1.2 The entrepreneur role

The Tree farmer will provide information to the designer:

- on the pedo-climatic characteristics of the plot, on the previous tillage and crops;
- on individual and farm experience in Tree farming;
- on availability of manpower in farm, in terms of quantity, professional skills and periodicity;
- on availability of agricultural machinery and tools for planting and management of Tree farming;
- on business trends and tree farmer expectations.

In addition, the contractor, with the technician, defines the **production target**. At this stage the Tree farmer must take into account any constraints highlighted by the designer/technician, in order to avoid unattainable targets and wasting public and personal resources.

6.1.3 The elements to be considered for drafting the project

Before define a production project, in detail, it is important that the designer/technician should consider the main factors that can affect the Tree farm success (Figures 6.1 and 6.2).

BOX 6.1 TRACK FOR THE INTERVIEW WITH TREE FARMER

TREE FARMER CHARACTERISTICS
- Have you already experienced successful with tree farms? [yes] [no]
- If yes, which type? ……………………………………………….
- Do you know the specific characteristics of:
  veneer logs [yes] [no]
  veneer logs [yes] [no]
  sawn logs [yes] [no]
  industrial wood-logs [yes] [no]
  energy wood logs [yes] [no]
- Do you know how to manage a Tree farm with species among those suitable for your property land plot? [yes] [no]
- Please detail? …………………………………………………….
- ÈAre you available tofollowing a training course, or towards your employees, to improve your managing ability in Tree farming? [yes] [no]
- How many years do you expect to follow the farm and the Tree farm since its establishment? ....……….
  …………………………………………...........................…......

FARM CHARACTERISTICS
Farm management
[ ] Direct management of the tree farmer
[ ] With internal workers
[ ] With contractors

Workers competence in establishment and management of the Tree farm
- Have you already managed Tree farms with one or more species potentially suitable for your land plot? [yes] [no]
- If yes, which species? …………………………………………….
- Are you able to conduct all the farm machines? [yes] [no]
- If not all, which ones? ……………………………………………….
- Do you know the pruning techniques for timber production? [yes] [no]
- Are you able to choose the technique and the intensity of pruning for Main Trees and Dual-Role Trees? [yes] [no]
- If yes, which ones? ……………………………………………….
- Are you able to choose the best time for Accessory plants thinning? [yes] [no]
- Are you able to choose the best time for Dual-Role Trees harvesting? [yes] [no]

What kind of Technical assistance needed during management
[ ] Private freelance technician for the Tree farming
[ ] Technician of a trade association
[ ] Any external support

Availability of machines for crop planning realization
Tree farm establishment
[ ] Are there any tractors in the farm? [yes] [no]
- If yes, how many? ……………………………………………….
- If yes, of which power? …………………………………………..
- Are there any ripper? Subsoiler? Ordinary or chisel plough? [yes] [no]

Management of tree farm
- Are there any harrow? Disk harrow? Rototiller? [yes] [no]
- Are there any shears, loppers, telescopic tree pruner, folding saws or other pruning tools? [yes] [no]
- If yes, which ones? ……………………………...……………….
- Are there any chainsaws, timber winch or forestry trailer for thinning and felling? [yes] [no]
- Are there any portable sawmills to enhance the material from thinning and felling? [yes] [no]
- Are there contractors, in the area, with a portable sawmill? [yes] [no]
- Is it possible to use semi-finished and round timber materials from thinning and/or harvesting? [yes] [no]
- If yes, which one and how much? …………………………….....
- The conduction of the Tree farm will be included into farm planning in equal footing? [yes] [no]
- If not, which are the overlapping periods ? …………………..
  ……………………...……….

Site characteristics that cannot be detected directly
[ ] Early or late frosts presence
[ ] Dominant wind
[ ] Problems of water stagnation
[ ] Problems of soil tillage
[ ] The presence of wildlife able to damage plants
[ ] If yes to previous question, which ones? ……………..

Tree farmer general targets at farm level
[ ] Diversify production
[ ] Enhance the heritage
[ ] Use the Tree farming in marginal areas for agriculture
[ ] Eligibility for public funding

Tree farmer general targets at Tree farm level
[ ] Logs for sliced and rotary-cut veneer
[ ] Logs for use in fine carpentry
[ ] Industrial timber
[ ] Energy wood

Specific production targets
- Very short term (5-7 years)
  Energy biomass (percent) ....………………………………
- Short term (8-15 years)
  Valuable timber (percent) ....………………………………
- Medium-long term (20-40 years)
  Valuable timber (percent) ....………………………………

Specific requests from the Tree farmer
- Preferred species among those suitable to the plot
  ………………………………………….................…………………

……………………………………………………………………………
• Unwanted species among those suitable to the plot
……………………………………………………………………………
……………………………………………………………………………
• Favourite type of tree farm
[ ] monocyclic
[ ] design and management of agronomic type
[ ] pure
[ ] mixed
[ ] design and management of naturalistic type
[ ] pure with Accessory plants
[ ] mixed with Accessory plants

[ ] polycyclic
[ ] design and management of agronomic type (only Main Trees and only 3P Tree farm)
[ ] design and management of Naturalistic type (Main Trees, Dual-Role and/or Accessory plants)
[ ] TP Tree farmT
[ ] 3P Tree farm

• Possible additional benefits
[ ] Fruits
[ ] Honey
[ ] Truffles
[ ] Landscape
[ ] Fauna
Other……………………………………………………………………………

How the Tree farm will be financed
[ ] Tree farmer's capital (%) ……………………
[ ] Public funding (%) ………………………

Among these it is essential to consider (Figures 6.1 and 6.2):

- **Plot characteristics:**
  - late frost;
  - soil characteristics;
  - soil depth;
  - water table depth;
  - slope;
  - orientation;
  - indicator species;
  - presence of wildlife;
  - presence of pest and disease for some tree species;
  - wind dominance and intensity.
- **Farm characteristics:**
  - manpower availability;
  - presence of equipment for soil tillage and tending operations;

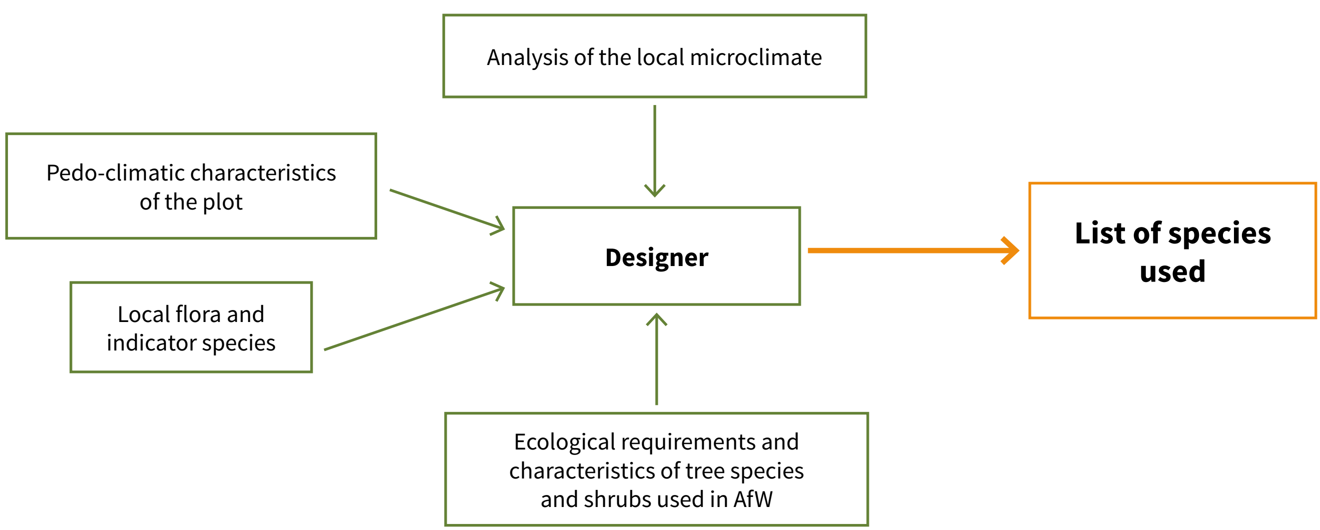


Figure 6.1 - Knowledge needed to make the species list of trees and shrubs potentially planted in the given agricultural plot.

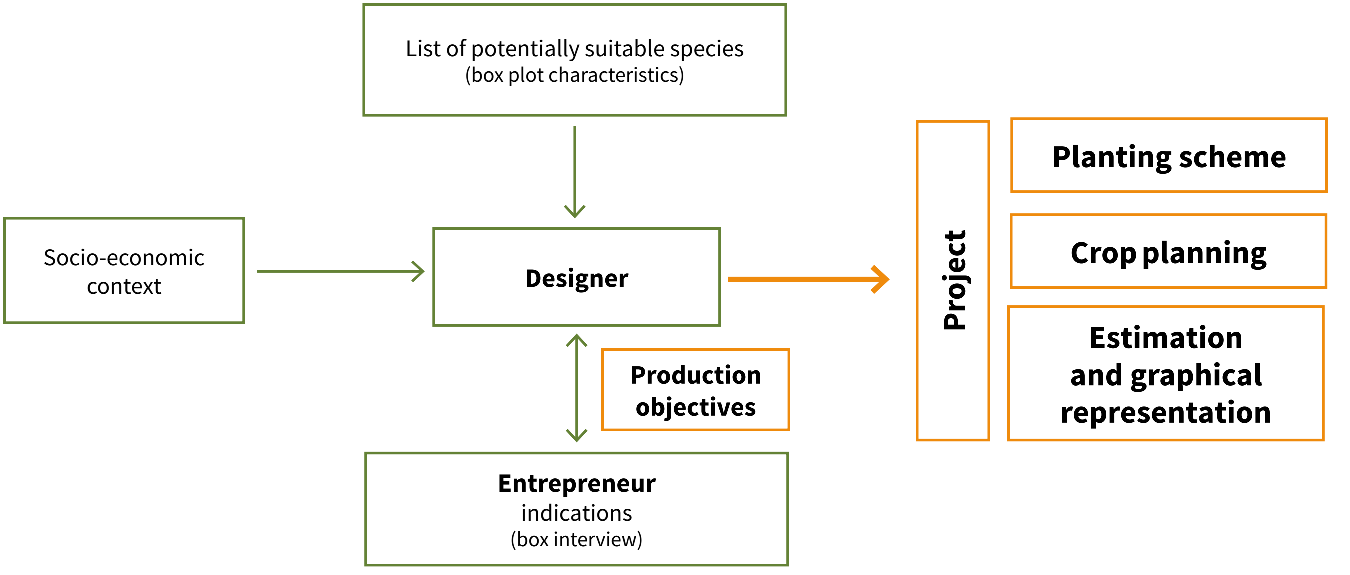


Figure 6.2 - Role of the designer and essential elements of the project.

- staff expertise about Tree farming and tending operations;
- compatibility between business planning and Tree farming.

- **Characteristics of the socio-economic context:**
  - possibility to obtain funding for tree farm and management in early years;
  - possibility to have qualified technical assistance;
  - marketable assortments from Main Trees;
  - interest in using part of the wood assortments produced within the farm;
- **species list of trees and shrubs that can be used in this Tree farm (Tables 6.1 and 6.2);**
- **production target** defined in agreement with the tree farmer in terms of:
  - Tree farm lifetime and proportion between the Blocks of the different production cycles;
  - type of wood assortments produced (e.g. round timber for veneers, for sawn, for energy biomass);
  - diameters and lengths of each round timber to produce;

Once all these elements are clear, the technician - using his own knowledge, information from the tree farmer's interview and from visiting the agricultural plot is ready to define one or more ideas, all aimed to achieving the production objectives. After considering and evaluating all those proposals, the tree farmer will take his decision.

6.1.4 The project

The project of Tree farm consists of three parts:

1. Planting scheme;
2. Crop planning;
3. Estimation data and graphical representation

Planting scheme

It is a graphical representation that shows:

- the shape (planting design) and the size of the Block;
- one or more sample Blocks for each of the selected production cycles. In each type of Block should be represented positions with mutual distances of:
  - Main Trees;
  - Dual-Role Trees (if any);
  - Accessory Trees (if any);
  - Accessory Shrubs (if any).

Overturning or shifting the planting scheme (Figure 6.3) it must be possible to represent the whole Tree farm. The scheme is therefore as the combination of 1, 2 or more tiles (in this case Blocks) of a floor that defines a repetitive geometric pattern. For this, as shown in the example (Figure 6.4), both in the Block that in the schema, can be present either whole plants that portions of them.

Crop planning

The crop planning defines the tasks to be implemented in Tree farm

for the planting and the tending operations that must be carried out for Main Trees.
Whereas in Tree farming, except poplar plantation, plants are being grown with high genetic variability, we cannot define tending operations in calendar. For this in crop planning must include the aspects to be observed in order to understand the tending operation to be made at various stages of development (e.g. soil tillage, pruning, thinning, partial harvesting).

Table 6.1 - List and characteristics of the main trees and shrubs species that can be used in Tree farming.

	SITE FACTORS								PRODUCTION										
	Phytogeographical districts		Soil pH			Soil texture			Wood Products				Non-wood products						
	Allovial plain	Collinare/Montano	Acid pH < 6	Neutral pH 6/8	Alkaline pH > 8	Clayey	Medium-textured	Sandy	Veneer	Sawn timber	Industrial biomass	Energy biomass	Wild fauna	Nectar production class	Pollen	Honeydew	Fruits	Herbal medicine	N fixation
hedge maple (*Acer campestris*)										1	1	2		2	*	*			
sycamore maple (*Acer pseudoplatanus*)									3	3	1	2		2	*	*			
hawthorn (*Crataegus monogyna*)											1		*	2	*			*	
hornbeam (*Carpinus betulus*)										1	2	2	*		*				
hop-hornbeam (*Ostrya carpinifolia*)											2	2	*		*				
chestnut (*Castanea sativa*)									3	3	2	2	*	6	*	*	*	*	
cedar (*Cedrus spp.*)										2	2	1							
wild service tree (*Sorbus torminalis*)									3	3	1	1	*	2	*			*	
sweet cherry (*Prunus avium*)									3	3	1	1	*	2	*		*		
Elaeagnus spp.											1		*	2			*	*	*
pedunculate oak (*Quercus robur*)									2	3	2	2	*		*	*		*	
glossy buckthorn (*Frangula alnus*)													*					*	
common ash (*Fraxinus excelsior*)									2	3	2	2			*			*	
narrow-leaved ash (*Fraxinus angustifolia*)										2	2	2			*			*	
mulberry (*Morus spp.*)										2		2	*				*		
Ligustrum spp.													*	3	*			*	
wilde apple (*Malus sylvestris*)									3	3		1	*	1	*		*		
myrobalan plum (*Prunus cerasifera*)											1	1	*				*		
hazel (*Corylus avellana*)											1	2	*		*		*	*	

(next page)

	SITE FACTORS								PRODUCTION										
	Phytogeographical districts		Soil pH			Soil texture			Wood Products				Non-wood products						
	Allovial plain	Collinare/Montano	Acid pH < 6	Neutral pH 6/8	Alkaline pH > 8	Clayey	Medium-textured	Sandy	Veneer	Sawn timber	Industrial biomass	Energy biomass	Wild fauna	Nectar production class	Pollen	Honeydew	Fruits	Herbal medicine	N fixation
walnut (*Juglans regia*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Severely limiting	Favourable	Favourable	3	3		1	*		*		*	*	
black walnut (*Juglans nigra*)	Favourable	Favourable	Partially limiting	Favourable	Partially limiting	Severely limiting	Favourable	Favourable	3	3		1	*		*	*		*	
elm (*Ulmus minor*)	Favourable	Partially limiting	Partially limiting	Favourable	Favourable	Favourable	Favourable	Partially limiting	1	2	2	3			*				
siberian elm (*Ulmus pumila*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Favourable		1	3	3							
italian alder (*Alnus cordata*)	Favourable	Favourable	Favourable	Partially limiting	Partially limiting	Partially limiting	Favourable	Favourable		2	2	2			*				*
black alder (*Alnus glutinosa*)	Favourable	Favourable	Partially limiting	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	2	2	2	2			*				*
princess tree (*Paulownia tomentosa*)	Favourable	Favourable	Favourable	Favourable	Favourable	Severely limiting	Favourable	Favourable	2	2	2	1		3	*			*	
european wild pear (*Pyrus pyraster*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Favourable	Favourable	Partially limiting	3	3	1	1	*	1	*		*		
white poplar (*Popolus alba*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Favourable	1	2	2	1			*				
poplar "clone"	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Favourable	3	2	3	1				*		*	
plane (*Platanus spp.*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Partially limiting	1	2	3	3						*	
sloe (*Prunus spinosa*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Favourable	Favourable	Favourable					*	1	*			*	
black locust (*Robinia pseudoacacia*)	Favourable	Favourable	Favourable	Favourable	Partially limiting	Partially limiting	Favourable	Favourable		1	3	3		6				*	*
sessile oak (*Quercus petrea*)	Partially limiting	Favourable	Favourable	Favourable	Partially limiting	Severely limiting	Favourable	Favourable	2	3	2	2	*		*			*	
pubescent oak (*Quercus pubescens*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Partially limiting			2	2	*		*	*			
willow (*Salix viminalis/alba*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Favourable	Favourable	Partially limiting		1	3	1	*	4	*	*		*	
elderberry (*Sambucus nigra*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Favourable			1		*	2	*	*	*	*	
service tree (*Sorbus domestica*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Severely limiting	Favourable	Partially limiting	2	3	1	1	*	2	*	*	*	*	
lime (*Tilia spp.*)	Favourable	Favourable	Partially limiting	Favourable	Favourable	Partially limiting	Favourable	Favourable	2	2	1	1		4/6	*			*	

KEY

Site factors

- Favourable
- Partially limiting
- Severely limiting

Wood products

- 1 Mediocre
- 2 Good
- 3 Excellent
- Cannot be obtained or not required

Non-wood products

- * Possible production

Nectar production class

1 up to 25 kg/ha
2 up to 50 kg/ha
3 up to 100 kg/ha
4 up to 200 kg/ha
5 up to 500 kg/ha
6 up to 500 kg/ha

Tabella 6.2 - Main characteristics of poplar clones selected in Italy, included temporarily in the National Register of Forestry Clones (*), some poplar clones grown in Italy and are included on the Register of Forest Clones in at least one European country (AA.VV., 2006).

CLONE		CROWN	FLOWERS		RESISTANCE											STEM						WOOD	
Denomination	Genetic origin	Shape	Sex	Production of "cotton"	Active limestone	Hydromorhpy	Aridity	Wind	Spring defoliation	Leaf rust	Leaf bronzing	Necrosis	Brown spots	Mosaic virus	Woolly aphid	Rooting ability	Regularity of sections	Straightness	Pruning suitability	Rapidity of growth	Stability growth	Suitability for rotary-cut veneer	Basal density (g/cm^3)
Harvard	d	fully developed	M		?	?	?	1	2	1	2	2	2	1	1	0	1	1	1	2	1	1	?
Onda	d	fully developed	M		?	?	1	1	2	1	2	2	2	1	1	0	1	1	1	2	1	1	0,31
Lux	d	fully developed	F	1	2	1	1	1	2	1	2	2	2	1	2	0	1	0	1	2	1	1	0,37
Dvina	d	partially developed	M		0	1	1	0	2	1	2	2	2	1	1	0	1	2	2	2	2	1	0,33
Lena	d	partially developed	M		1	1	0	1	2	1	2	2	2	0	1	0	0	0	0	2	1	1	0,33
Carolina di Santena	e	fully developed	F	0	?	?	1	0	2	1	1	2	2	1	0	0	0	0	1	0	1	1	0,41
San Martino	ex?	fully developed	F	2	2	0	1	0	2	1	1	1	2	2	1	0	1	1	1	2	1	1	0,31
Triplo	dxe	fully developed	M		2	2	0	0	2	0	1	0	0	0	1	0	1	1	0	0	1	0	0,32
I-45/51	ex?	fully developed	M		1	1	?	1	2	1	1	1	1	2	1	2	0	2	0	1	1	1	0,31
I-154	exn	fully developed	M		?	?	?	?	2	1	1	1	1	2	1	2	1	1	1	0	?	1	0,32
I-214	e	partially developed	F	1	1	0	0	1	2	0	1	0	1	2	1	2	0	0	1	1	2	2	0,29
I-262	e	partially developed	M		?	?	?	?	2	0	2	1	0	2	1	2	1	0	1	0	?	?	0,30
I-455	e	harvesting	F	1	?	?	?	?	2	1	2	1	0	2	1	2	1	2	1	0	?	1	0,28
BL Costanzo	e	partially developed	F	1	1	1	0	1	0	1	1	1	0	1	1	2	1	2	1	2	1	1	0,31
Cappa Bigliona	e	partially developed	F	1	1	1	0	1	0	1	1	1	0	1	1	2	1	2	1	2	1	1	0,30
Pan	e	partially developed	F	1	1	1	0	1	0	1	1	1	0	1	1	2	1	2	1	2	1	1	0,31
Boccalari	e	partially developed	F	1	1	0	0	1	1	1	0	1	0	1	1	1	0	1	1	0	0	2	0,33
Branagesi	e	partially developed	F	2	1	0	0	1	2	0	0	0	0	1	1	1	0	0	1	0	0	2	0,36
Gattoni	e	partially developed	F	1	1	0	0	1	1	1	0	0	0	1	1	1	0	1	1	0	0	2	0,35
302 San Giacomo	e	partially developed	F	2	1	0	0	1	2	1	0	1	0	1	1	1	0	0	1	0	0	1	0,33
Adige	e	partially developed	F	1	0	?	0	0	1	1	0	1	0	1	2	1	0	1	1	0	0	2	0,36
Stella Ostigliese	e	partially developed	F	1	0	?	0	0	1	1	0	1	0	1	1	1	0	1	1	0	0	2	0,36
Bellini	dx?	partially developed	M		2	?	1	0	2	1	0	2	2	2	1	2	1	2	0	1	?	1	0,35
Carpaccio	dxn	partially developed	F	0	?	?	?	0	1	1	0	1	1	2	1	2	1	1	1	1	?	1	0,31
Cima	dx?	harvesting	F	0	0	1	1	1	0	0	1	1	1	2	0	2	1	2	1	2	2	1	0,33
Guardi	dxn	harvesting	F	0	0	?	?	1	2	1	0	2	2	2	1	2	1	2	1	1	?	1	0,33
Luisa Avanzo	dx?	harvesting	F	0	0	1	1	2	0	1	1	1	1	2	0	2	1	2	1	2	2	1	0,34
Neva	dxn	harvesting	F	0	1	1	0	1	2	2	0	0	0	2	1	2	2	2	2	2	1	2	0,33
Jean Pourtet	n	harvesting	M		0	?	0	1	2	1	2	2	2	2	0	2	0	0	1	0	?	?	0,35
Eridano	dxm	fully developed	M		2	1	2	1	2	2	2	2	2	2	2	0	1	0	1	1	1	1	0,31
Villafranca	axa	fully developed	F	1	1	1	1	1	2	2	2	2	2	2	2	0	0	0	1	1	1	1	0,33

(next page)

CLONE		CROWN	FLOWERS		RESISTANCE											STEM						WOOD	
Denomination	Genetic origin	Shape	Sex	Production of "cotton"	Active limestone	Hydromorhpy	Aridity	Wind	Spring defoliation	Leaf rust	Leaf bronzing	Necrosis	Brown spots	Mosaic virus	Woolly aphid	Rooting ability	Regularity of sections	Straightness	Suitability for pruning	Rapidity of growth	Stability growth	Suitability for rotary-cut veneer	Basal density (g/cm³)
Brenta(*)	dxn	fully developed	F	?	?	?	1	?	2	0	2	0	1	1	2	2	1	2	1	2	1	1	0,36
Lambro(*)	dxn	fully developed	M		?	?	1	1	2	0	2	2	1	1	2	1	0	2	1	2	2	0	0,36
Mella(*)	dxn	fully developed	F	?	1	?	1	1	2	0	2	0	1	1	1	2	1	2	1	2	1	1	0,33
Soligo(*)	dx?	partially developed	M		?	1	1	1	2	2	2	2	2	1	1	1	1	2	1	2	2	0	0,35
Taro(*)	exi	partially developed	M		?	?	0	?	2	1	2	2	2	1	2	1	1	2	0	1	1	0	0,37
Timavo(*)	dxe	fully developed	M		2	?	1	?	1	0	2	0	1	?	1	1	1	2	0	1	1	1	0,35
Patrizia Invernizzi(*)	e	fully developed	F	?	?	?	0	?	1	0	1	0	1	1	?	2	1	1	1	1	1	2	0,33
Ballottino(*)	e	fully developed	F	?	?	?	0	?	1	0	0	?	?	?	1	2	1	2	1	0	1	1	?
A4A(*)	dxn	fully developed	F	?	?	?	1	?	2	0	1	?	?	1	1	2	1	0	0	2	2	1	0,30
Ghoy	dxn	partially developed	F	0	?	?	?	1	2	1	1	2	2	1	1	2	1	1	1	1	1	1	0,36
Beauprè	txd	partially developed	F	1	?	?	?	1	2	1	1	2	2	1	2	2	2	2	1	2	2	2	0,36
Koster	dxn	fully developed	M		?	?	?	1	?	?	?	?	?	?	?	2	2	2	2	1	1	1	?

- The ratings are updated to 2002 and, when not otherwise specified, are based on an arbitrary scale of 5 levels) encoded by the numbers:
  2: very scarce; 1: scarce; 0: sufficient; 1: high; 2: very high
  For the purposes of this classification the behaviour toward non- guest clone parasites was assimilated to that of the most resistant clones.
- Parent species are symbolically identified by the letters:
  "a": *Populus alba*; "d": *P. deltoides*; "e": *P. x canadensis*; "I": *P. x generosa*; "n": *P. nigra*; "t": *P. trichocarpa;*

(*) DM March 30, 2001 (G.U. 118 of May 23, 2001)

? Unknown

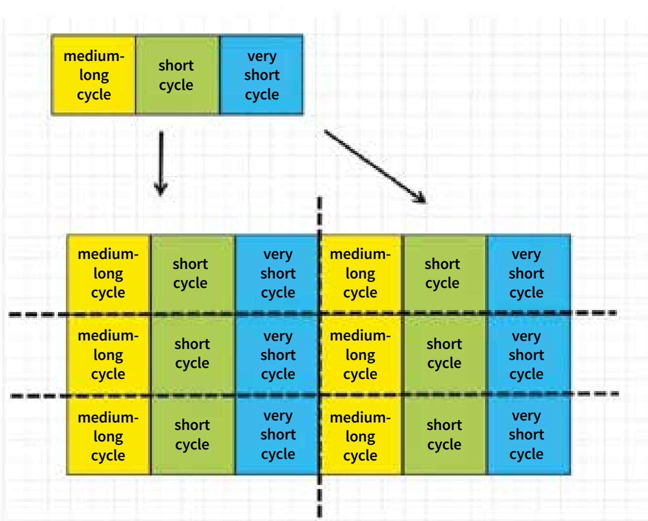


Figure 6.3 - Example of shifting of scheme design composite of 3 Blocks with Main Trees of 3 different duration cycles.

In more complex tree farms, such as some 3P Tree farms, are part of the crop planning a series of schemes that indicate the estimated development for the entire Tree farm with the sequence of various production cycles.

Estimation and graphical representation

Between the Estimation and graphical representation, in addition to those required by Public Administration to provide some funding, taking into account the planting scheme and the size of the plot, have to provide the exact number of seedlings, for each species, that will be required to purchase, the quantity and characteristics of any tree planting supplies considered necessary for Tree farm success (e.g. tutor pole, shelter, weed mats).

6.2 Scheme objectives

Both for TP Tree farms than for 3P Tree farms the planting scheme must make possible to achieve the following results:

1. production objectives set for Main Trees of every species;
2. allow easy wood extraction during each harvesting;
3. make the most of the production area according to the principles mentioned in Criterion 2 (paragraph 1.4).

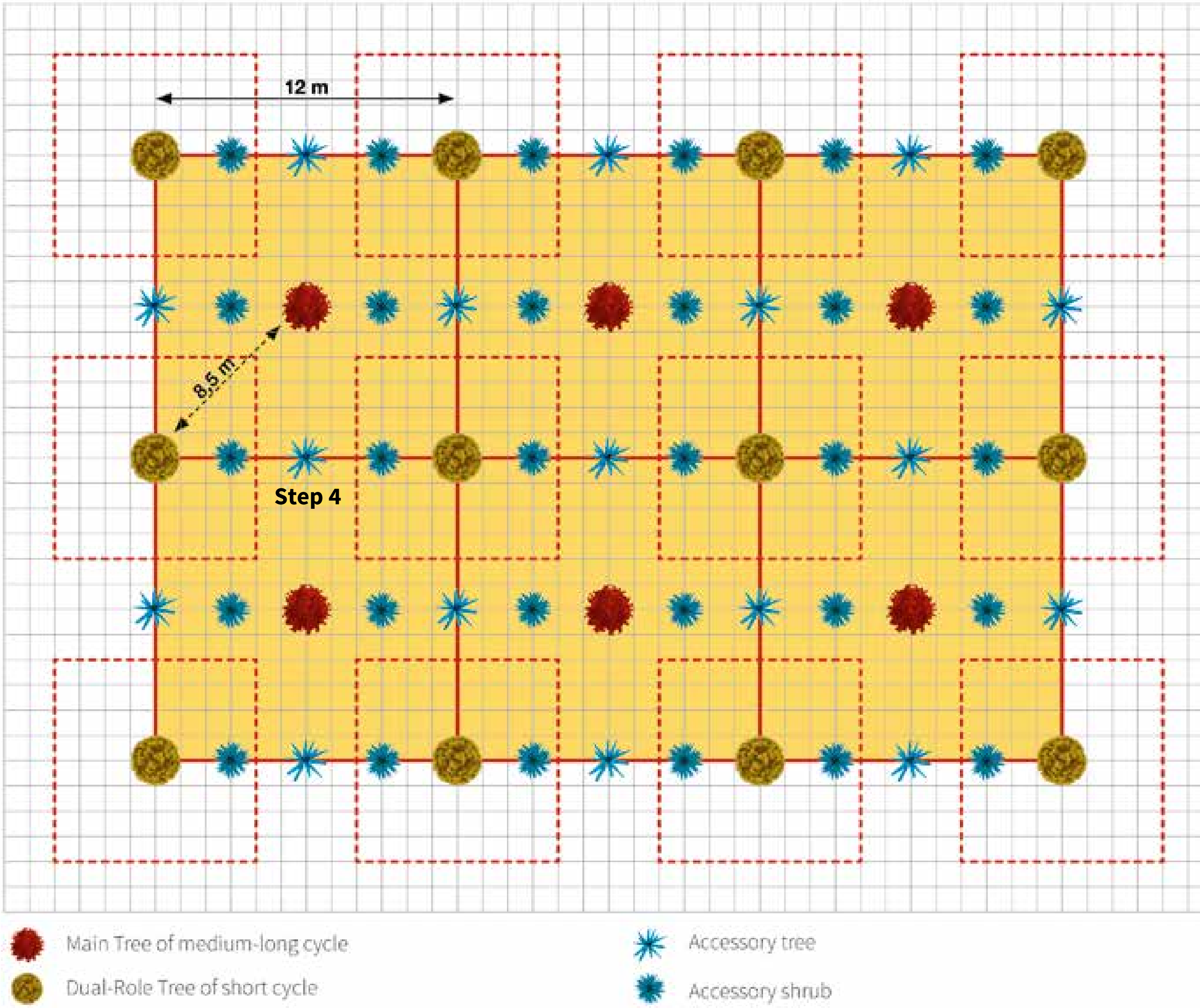


Figure 6.4 - Example of PT Tree farm where the blocks are shifted to represent all the plantation. Some dual-role trees and Accessory trees are partially represented in 2 or 4 neighboring blocks.

In general for the 3P Tree farms is also require that the schema considered Main Trees or Dual-Role Trees replanting after each harvesting. The reason for this requirement is to give each new Main Trees or Dual-Role Trees the space needed to reach the target diameter taking into account the actual growth conditions of Main or Dual-Role Trees already present in the Tree Farm.

6.3 The scheme design

Designing a planting scheme starts from the definition of area and Block size required at Main Trees with longer cycle to produce objective diameter.

For example, if you want to produce oak stems of 45-50 cm in diameter, that requires surface area of about 144 m^2, and poplar logs of 40 cm in diameter, that require approximately 72 m^2 of surface area, you will need Blocks of about 144 m^2.

If instead, if you want to produce poplar logs of 40 cm in diameter, that require approximately 72 m^2 surface area, and small log of firewood 10-12 cm in diameter which requires about 9 m^2, you will need Blocks of approximately 72 m^2.

The planting scheme of a Polycyclic Tree farm (both Temporary that Potentially Permanent) consists of a set of Blocks that, for simplicity, must have all the same surface.

In the composition Blocks of a Polycyclic Tree farm, both Temporary that Potentially Permanent (3P), it is important to take into account the minimum distances between plants of different species (see Chapter 5) and the role attributed (see Chapter 3).

6.3.1 The plants arrangement within the Block on TP Tree farms

Once the surface area of the Block wherewith we can split the entire Tree farm, the design activities to be carried out are:

Step 1: place the Main Trees so that at the end of the production cycle their crown will occupy all the Block surface;

Step 2: choose any Dual-Role Trees following the criterion 2 described in Paragraph 1.4. These must be placed respecting the minimum distances from Main Trees, so to complete production cycle before it becomes a negative competition (e.g. crown contact or crown above the tip of Main Trees);

Step 3: place the Accessory Trees respecting the minimum distances from Main Trees and Dual-Role Trees;

Step 4: place the Accessory Shrubs respecting the minimum distances from Main Trees, Dual-Role Trees and Accessory Trees.

The step operations described above is exemplified in Figure 6.5.

6.3.2 The plants position within the Block on 3P Tree farms

In 3P Tree farms the Dual-Roles Trees are hierarchically higher to Main Trees with the same production cycle length, in the surrounding Blocks. In practice this means that in a Block With a Main Tree in medium-long cycle if you choose to insert a short-cycle Dual-Role Trees, these will be positioned first and the Main Trees with short-cycle in the surrounding Block will be positioned second, taking into account the minimum distances (and so production surfaces) required to achieve the target diameter.
Once defined the Blocks surface, with the same criteria of paragraph 6.2, the designing of 3P Tree farms is based on the following steps:

Step 1: place the Main Tree with medium-long cycle so that at the end of the production cycle their crown will occupy all the Block surface area;

Step 2: place any Dual-Role Trees with short cycle within the Block in which are placed the Main Tree with medium-long cycle in step 1.

Step 3: place the Main Trees with short-cycle within their Block taking into account, if present within the close Block, of the placing, step 2, of Dual-Role Trees with short-cycle.

Step 4: place any Dual-Role Trees with very short-cycle within the medium-long and/or short cycle Blocks.

Step 6: place any Accessory Trees respecting the minimum distances from Main Trees and Dual-Roles Trees within all Blocks in which is necessary.

Step 7: place any Accessory Shrub respecting the minimum distances from the Main Trees, Dual-Roles Trees with and Accessory Trees in all Blocks in which is necessary.

The sequence of steps, above, concerns of 3P Tree farms where there are Main Trees in 3 production cycles: medium-long, short e very short. However, so that we can name 3P Tree farms it's enough to have Main Trees by at least 2 different cycles. In this case, the operations steps remains the same by eliminating the steps in which are planned operations for plants with roles that are not necessary for the productive objectives.

6.4 Criteria for naturalistic Polycyclic Tree farms design

In order a plantation for wood production could be considered "naturalistic" (NPTF) it is necessary:

1. the presence of Blocks of at least 2 production cycles of different duration (3P Tree farms) or, if duration is same (TP Tree farms), the presence of Dual-Role Trees and/or Accessory plants for at least 600 plants per hectare (including Main Trees).
2. that, in 3P Tree farms, the Blocks with production cycle less represented involve at least 20% of the production area;
3. that, in 3P Tree farms, the most represented production cycle is spatially alternated with that/those less represented. Sequences 1+2, 1+3 or 1+4 are allowed, that is, up to a maximum of 1 Block with Main Trees with production cycle less represented and 4 Blocks with Main Trees with production cycle most represented (in a maximum ratio of 20% to 80%). Such composition obviously does not concern the TP Tree farms with Blocks polycyclic synchronic (e.g. all the Main Trees with medium-long cycle having assigned the same target diameter);
4. a minimum of 10% over the total number of N-fixing trees per hectare (except in areas subjected to the nitrate restriction).

The composition of the different types of Blocks within a planting scheme, as mentioned in paragraph 3 of this section, allows to adapt the production of timber assortments to tree farmer's production requirements. In other words if the expectation was to devote 50% of production area to medium-long cycle and 50%

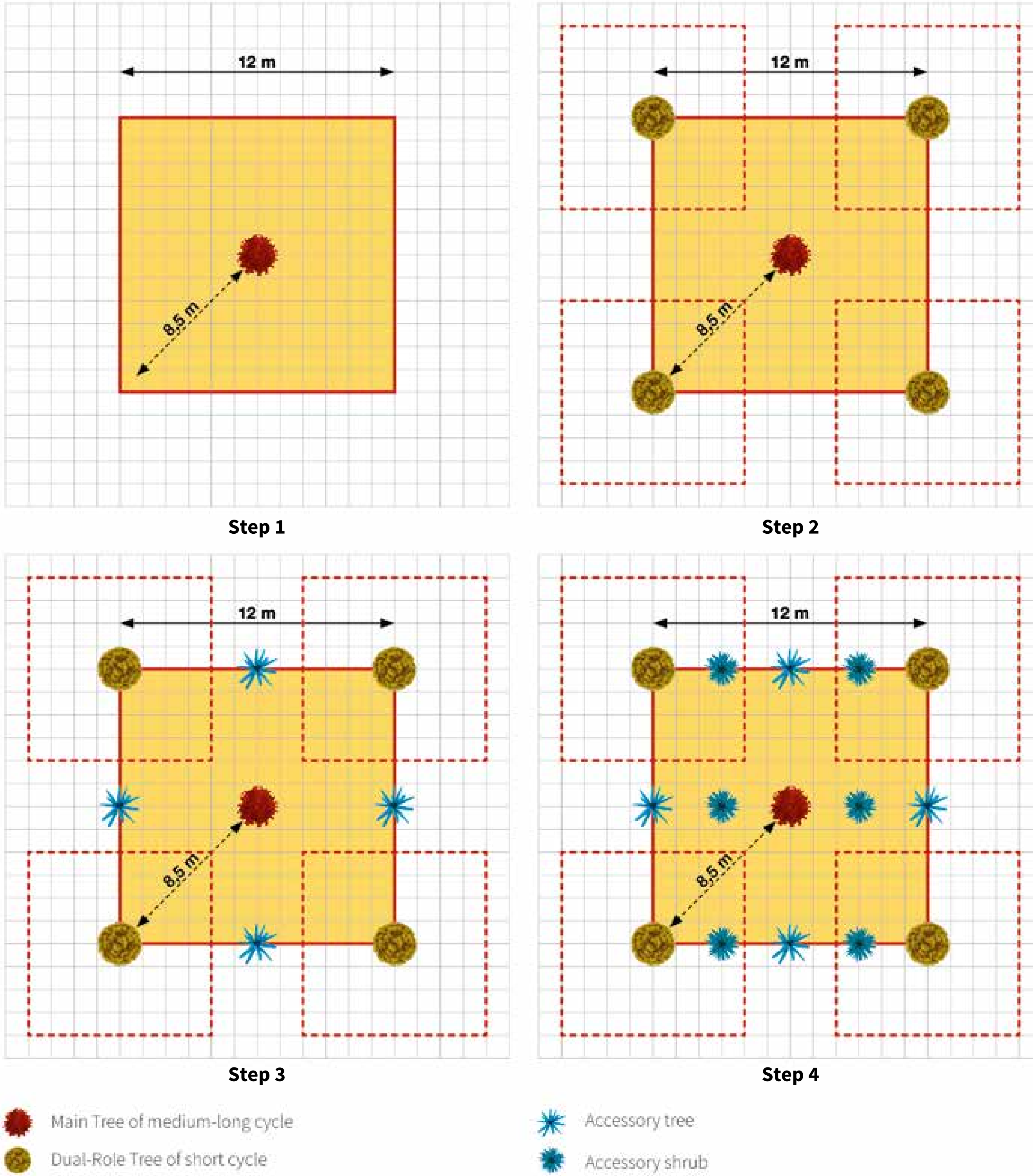


Figure 6.5 - Example of sequence of distribution of trees within the block (case of PT Block with Accessory trees and shrubs).

to short-cycle, we will choose a combination 1 + 1. If instead we want to devote 33% to medium-long cycle and 66% to short cycle plants, respectively, we will choose a combination 1 + 2, and so on up to a maximum of 1 + 4.

6.4.1 Information to be included within a project

General objectives of the tree farmer

Specific requirements of the tree farmer (e.g. species that can be used liked or disliked, need for benefits or non-wood products)

Choices adopted to make the Tree farm scheme:

- specific production target;
- additional benefits (if any);
- choice of species to which attribute role of Main or Dual Role Trees
- choice of species to which attribute role of Accessory Plants;
- Tree farm scheme drawing highlighting individual Blocks;
- estimate of the various production cycles duration;
- any others schemes describing the evolution consequent to harvesting actions;

Crop planning

- Planting:
  - techniques of soil preparation;
  - characteristics of seedlings;
  - planting help (if any);
  - planting techniques.
- Tending operations:
  - soil tillage;
  - pruning;
  - irrigation (if any);
  - phytosanitary treatments (if any);
- Monitoring of Main Trees.
- Thinning:
  - criteria for selecting a plants in a couple with medium-long cycle (if any);
  - criteria for the possible thinning of Accessory plants.
- Harvesting:
  - criteria for felling and logging of various production cycles.
- Tree farm management after harvesting:
  - criteria for the definition of any new production targets (new interview to the owner);
  - criteria for planting new Main Trees and/or Dual Role Trees;
  - criteria for managing stumps of Main Trees and/or Dual Role Trees in asexual regeneration;
  - criteria for planting, eventually, new Accessory plants.

Picture: Massimo Bidini

7

IMPLEMENTATION OF A TREE FARM

The implementation of a Tree farm (plantation for wood production) aims at achieving in the field the designed plantation scheme, by following indications from the technician related to the preparation of the plot, the selection and planting, in specific locations, the seedlings and the installation of any planting help (if any). The implementation of the Tree farm must follow a certain sequence of actions: each one of them, if badly performed, can compromise the success of the Tree farm. Below we will describe briefly all the steps in a sequence, while for the details, please refer to a specific publication (Buresti and Mori 2003).

7.1 Step's sequence

To implement each Tree farm, a precise sequence of actions must be followed. Some are indispensable for each Tree farm, while others are optional, according to the technician's criteria. The steps sequence includes:

1. order by time the seedlings at the nursery;
2. perform deep tillage;
3. prepare deep drainage arrangement (optional);
4. basal topdressing (optional);
5. perform shallow tillage;
6. perform surface drainage system;
7. mark rows on the prepared soil;
8. install the plastic mulch film (if any);
9. check the seedlings (planting stock) quality before buy them;
10. transport and stock seedlings before planting;
11. planting of seedlings;
12. install individual tree-shelter (if necessary).

7.1.1 Timely order of seedlings

It is appropriate to order seedlings quite in advance to the nursery farm, specifying their species and possibly geographical origin, in order to give the nursery enough time to get the right seed and produce a planting stock of suitable quality. In general, between 18 and 24 months have to be considered the period needed for seed collection and supplying of planting stock. The ordered number of seedlings relating to medium-long cycle species, with the role of Main Trees, has to be twice of the expected number at the end of production cycle because is useful planting them in couples (see par. 3.1).

7.1.2 Perform deep tillage

Contrary to what is often thought, even the "forest plants" are taking advantage of a well prepared soil for their root system. When the Tree farms are located on previously cropped land, a very severe compacted plough layer can occur. This, so called, "plough pan" is the effect of protracted use, during many years of farm equipment on land, like the classic rototiller or the plough, working always to the same depth. Thus, these operations compact the soil further, creating a layer not allowing water and roots penetration. Also the compacted layer prevents the right gas exchange with the lower soil layers. This circumstance can favour the occurrence of putrefactive processes. The compacted layer must then be broken prior to the planting, through a deep tillage (70-120 cm) which can consist of plowing or ripping. In addition, this type of work, promotes the exploration of the soil by plant roots and increases gas and water exchange in the soil. Both factors affect biological and chemical processes and thus affect the soil fertility. Further, deep tillage improves both superficial and deep water runoff.

7.1.3 Install deep drainage system (if needed)

Few trees and shrubs species tolerate asphyxia conditions, mainly if such situation occurs during the growing season or over a long time. For this reason it is always necessary that the technician, in case of asphyxia risk also for short periods, chooses species that can withstand these conditions without problems. If the tree farmer persists in using species poorly adapted to that conditions, a deep drainage system is needed (e.g. with installation of drainage pipes).

7.1.4 Basal topdressing (if needed)

To date there are no studies and consolidated experience on real nutritional requirements of species commonly used in Tree farming. Experiences better consolidated on relations between fertilization and trees growth have been developed for poplar's agronomic plantations, where the fertilizations have produced positive results (AA.VV. 1987). Generally an agricultural soil devoted to Naturalistic Tree farm rarely needs a fertilization. Every decision on fertilization should be based on soil analysis and evaluation of possible nutrient deficit. In Naturalistic Polycyclic tree farms, in order to reduce or eliminate use of nitrogen fertilizers during the production cycle, N-fixing plants are inserted at least 10% (in number). These plants can substantially affect the amount of nitrogen in the soil, as evidenced by Tani *et al* (2007). Tree farms set on soil rich in nitrogen due to previous agricultural actions, are excluded from this practice.

7.1.5 Perform superficial tillage

The superficial tillage involves the first 20-30 cm of soil depth and has mainly two objectives:

- prepare the soil layer where, in first growing season, the plants roots will develop;
- eliminate weeds through their burying or uprooting.

Immediately before row-tracking and planting the field surface has to be smoothed. This action, reducing the size of the soil aggregates, facilitates the planting of seedling and favours a better contact between soil and roots (Picture 7.1).

7.1.6 Prepare a surface drainage system

In **lowlands**, to drain off rainwater quickly, you must prepare secondary drainage ditches network, seasonal type (first time just after the superficial tillage). The secondary drainage ditches must be connected to a outlet channel. The goal is to avoid stagnation.

In **hilly areas**, in order to prevent surface erosion, the Tree farm need the same drainage system that is commonly designated for agricultural crops. Upstream of the field is necessary to make a diversion ditch that collects all the water of the upstream slope and drain in hydraulic network exists. Within the field will need to be create a seasonal ditches network with herringbone pattern of drain with respect to watershed lines.

In **both cases** the secondary drainage ditches must be maintained or restored after each work of soil, until the suspension due to the crown layer closure by trees and/or shrubs.

7.1.7 Mark rows on the prepared soil

For "mark row" establishment perpendicular lines are required and identify in the soil where the plants will be planted in such a way as to ensure the respect of distances (and surface production available for each role) and correct alignment. This is very important in order to perform the soil mechanical work of soil without risk of damaging or destroying plants.

7.1.8 Install the plastic mulch film (if planned)

Immediately after smoothing out the field surface a setting up of mulching can be made. It is important to remember that if you decide to install non-biodegradable mulch, it should be removed and properly disposed of as soon as you no longer need to control weeds (Picture 7.2).

7.1.9 Check the seedling's (planting stock) quality before buying them

Once you know that the plants proposed by the nurseryman are of the suitable species and origin (if required), it is important to assess seedlings quality.

In particular, it will be important to verify:

- vigour of the epigean part;
- stem straight;
- stem and last sprout well lignified;
- terminal bud intact;
- maximum age 2-3 years;
- absence of mechanical damage;
- plants balanced (ratio of height to diameter between 50 and 80);
- height between 30 and 60 cm;
- soft topsoil (in the case of delivery of seedlings in pot);
- adequate proportion between hypogean and epigean part
- pearly roots;
- root system properly developed, healthy and rich in root hairs.

As for the poplars it is necessary to obtain 1-2 years poplar planting stock, possibly in the same diametrical class, 5-7 m high for poplar hybrids and 3-5 m for white poplar (Villafranca clone), lignified and healthy (AA.VV. 1987, AA.VV. 1995)

7.1.10 Transport and store seedlings before planting

The nursery is definitely the most suitable place for plants conservation. The transition from nursery to planting area is a risky step for bare-root plants. Therefore it is advised to carry them at the place of use as late as possible and in any case not earlier than 15 days before planting. The transport must be carried out with the means to protect the plants from wind and low temperatures. Bare-root plants must be sealed in bags or wrapped in plastic sheeting.

Once you arrive at the plantation area must be detected a shaded where storing the seedlings pot or place the bare-root plants in a bin and/or in a trench[10].

7.1.11 Planting of seedlings

For the planting should be provided a sufficiently large and deep pit, the root system must be well stretched into the pit. For bare-root seedlings, immediately prior to planting, the root system can be immersed in a mixture of 1/3 of water, 1/3 of terrain and 1/3 of manure, with the aim to reduce drying and foster the establishment (Mezzalira 1995).

When working with bare-root plants, the operator carries, in addition to spade, also some seedlings placed in a plastic bag. To make things easier it tends to match every operator with a single species, so the operator should have only the exact location of that plants species in the Tree farm scheme not likely to cause confusion as they proceed along the rows.

Planting of seedlings in pot is preceded by the distribution these by tractor with trailer. Who distribute the plants must have in mind the Tree farm scheme. Who is planting find seedlings already deployed and will put in place what it finds from time to time.

__10)__ The trench, dug with shovels, within which are located the plants and whose depth is equal to that of plant roots length. After the placed of bare-root plants the trench must be filled with loose and damp soil or sand.

Picture 7.1 - Soil tillage before planting trees.

Picture 7.2 - Plastic mulch film installed in a Tree farm (Picture: Stefano De Pietri).

7.1.12 Set up individual tree-protectors (if necessary)

Seedlings protectors that are most commonly used in Tree farming are tree shelters (Picture 7.3). These are polypropylene tubes, closed (Brunori and Mori 1995) or metal mesh (Borchi 1995) or plastics, and with meshes of different sizes (Brunori and Mori 1996b). The tree shelters are installed around the single Main Trees to protect them by the action of deer, hares and/or porcupines (Sestini 1995, Brunori and Mori 1996a). The shelters should be used only in cases where they are absolutely necessary, when the presence of wild is in an amount sufficient to damage an high percentage of Main Trees and/or Dual Role Trees. The shelter must be locked in an upright position by a wood or bamboo picket.

The picket, firmly driven into the ground, must not exceed the height of the shelter to prevent that the stem of the seedling, in case of repeated swings, could be damaged by the end of the picket. In the case of tree shelter tube and heavy clay soils, it is important to avoid sinking the shelter base into the ground, because the tree protector could obstruct the smooth flow of water, causing phenomena of stagnation within it. For the purposes of environmental sustainability is crucial the removal and correct disposal of shelters as soon as the need for their protection against fauna will stop.

Picture 7.3 - Walnut (*Juglans regia* L.) trees in pairs with two shelters up to 60 cm high (Picture: Paolo Mori).

Picture: Enrico Buresti Lattes

8

TENDING OPERATIONS

8.1 Steps of the production cycle

Dealing with Naturalistic Polycyclic tree farms, it is essential to understand at any time the development conditions of Main Trees, Dual-Roles Trees and the relationship between these latter and Accessory plants in order to establish the appropriate tending operations to be carried out.

8.1.1 Three stages for valuable timber production

The development stages, during the Tree farm management to produce valuable timber, can be divided into three steps: establishment, qualification and sizing. For each stage you can define priority objectives to be attained and the tending operations best suited for them.

1st Stage => establishment
Priority objective: let the root system expands.
Basic operations: control weed through soil tillage, and, if necessary, supplementary irrigation.

2nd Stage => qualification
Priority objective: get from Main Trees and Dual-Role Trees a straight stem and free from branches on a sufficient portion (minimum 250-300 cm for valuable broadleaves and 500-600 cm for poplar clones).
Basic operation: pruning.

3rd Stage => sizing
Priority objective: get a stem that has a diameter greater than 30-40 cm characterized by annual diametric increments as strong and regular as possible in connection to the species and the plot fertility.
Basic operations: monitoring Main Trees and Dual-Role Trees and thinning Accessory plants or timely harvesting Dual-Role Trees.

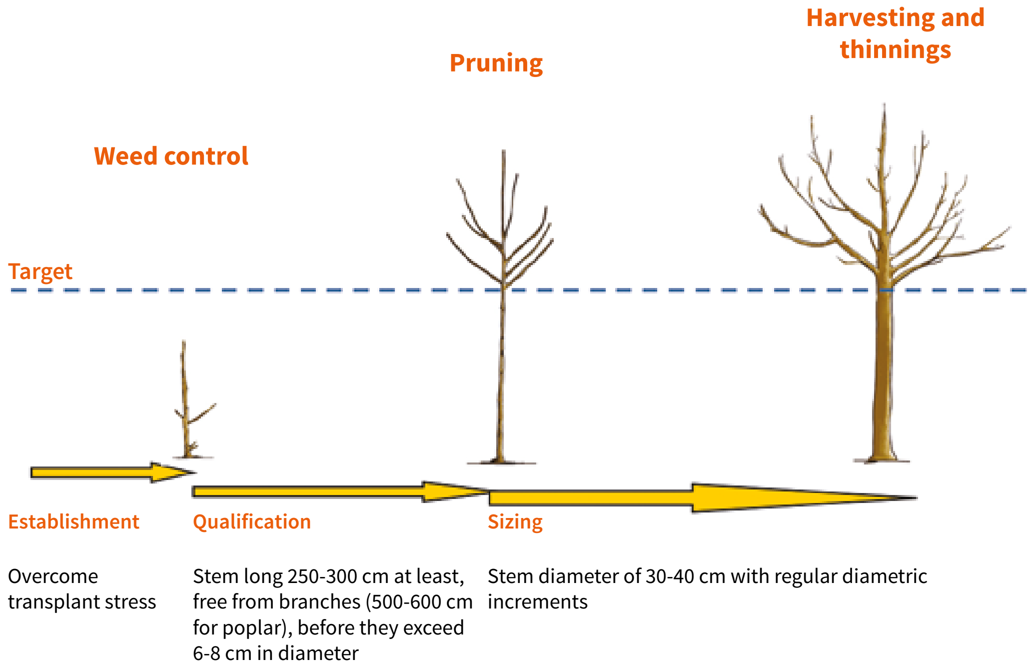


Figure 8.1 - Stages of the production cycle for Main Trees and Dual-Role Trees of medium-long and short cycle, highlighting the most important management activities to be carried out at each stage. In the case of poplar clones in short cycle, in all the development stages it is important to monitor the possible emergence of biotic attacks to be faced with phytosanitary treatments.

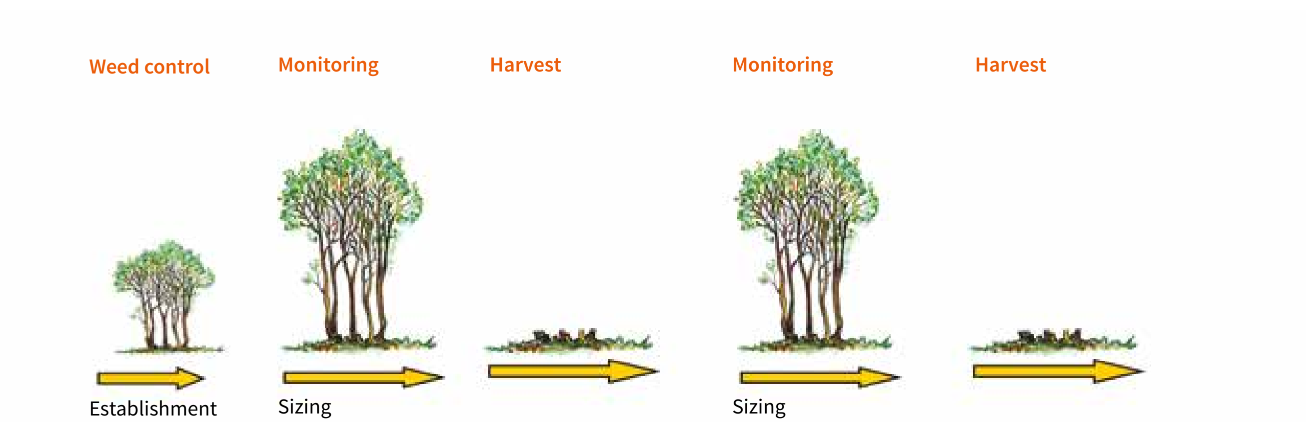


Figure 8.2 - Stages of the production cycle for Main Trees and Dual-Role Trees of very short cycle and the most important management activities to be carried out at each stage.

In the case of Main Trees for woody biomass production the stages of the production cycle are only 2: establishment and sizing. During establishment stage the priority objective and basic operations are the same as above. Obviously target diameters are different. Specific operations are not requested only the final harvest at the end of sizing stage.

8.2 Establishment stage

At this stage the primary objective is the formation of a strong and extended root system. The techniques and tending operations most suitable for the rapid formation of a good root system are:

- the correct soil preparation;
- the use of seedlings with good cultivation characteristics;
- the proper planting technique;

Picture 8.1 - Soil tillage for weeds control during the first years after planting.

- the regular weeds control;
- the timely fight against unpredictable adversity (e.g. face summer drought relief with supplementary irrigation).

Until you are sure that the rooting phase has ended, it is important not to carry out pruning in planting material. The pruning could represent a further source of stress in addition to transplant.
The duration of this stage is not easily to define, but a reference value lies between 1 and 3 years. Generally, from the second year onwards, sprout over 50 cm show that the plant has a well developed and installed root system and that the establishment stage has ended. For containerized seedlings the first year sprout doesn't deserve too much confidence, since it may be affected by nursery tending. Due to the Naturalistic Polycyclic Tree farms (PPN) characteristics the weeds control, especially during the establishment stage, should be made preferably by tractors (Picture 8.1).
If the Blocks have been well designed in terms of mixture of species with different growth speed and density, soil tillage should not last more than 3-5 years from planting.

8.3 Qualification stage

When establishment stage ends the qualification stage begins. The primary objective in this stage is to get a straight stem, at least 250-300 cm high and without branches before it reaches 6-8 cm in diameter. Sometimes you can point to produce longer logs, but only with poplar clones (target set between 500 and 600 cm long) or broadleaves Main Trees with valuable timber and very vigorous and located in plots suitable for these species.
The most important tending operation to be carried out in qualification stage is **pruning**. This must be appropriate to the species and the vigour of each plant, both in technique and in intensity, and must be done in the appropriate moments of the year.
The qualification stage ends when you get, from each Main Tree, a clear log (called "real log") long enough, that is at least greater than the minimum value.

8.3.1 When pruning (season)

The "wood pruning" generally can be done either "in winter", when the plant is not in vegetation, or "in green".
Winter pruning is practiced in the late winter and early spring (March-April approximately). The best time is between the end of the period in which frost can occur and the issuance of the first sprouts.
Green pruning is practiced between mid-June and mid-July.

8.3.2 How to cut (where cut)

When you remove an entire branch the cut must be practiced near the stem, but respecting the branch collar. It's important not to leave branch stumps because these, in future semi-finished products, will become non adherent knots with a consequent timber depreciation (Figure 8.3).

8.3.3 Which pruning (size branches)

A "wood pruning" done at the right time prevents development of unwanted branches with diameter greater than 3-4 cm. This means that pruning should be carried out prior those branches exceed this size.

8.3.4 Formative pruning

The **formative pruning** aims to get for each Main Trees the following characteristics for the log:

1. at least 250 cm long (500 cm for Main Trees with a short cycle);
2. straight;
3. cylindrical and without sudden variations in diameter ("bottleneck").

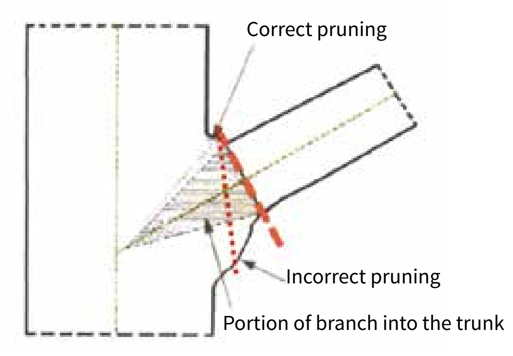


Figure 8.3 - Productive pruning on poplar ('I-214').

Depending on the technique used, formative pruning can eliminate unwanted branches already produced by the plant or get it to produce, the following year, many small branches easy to eliminate with the production pruning. In the first case we talk about pruning a *posteriori* (the operator cuts branches after the plant has produce them), in the second case we speak instead of pruning a *priori*, that is to say you delete some very specific branches in order to induce the plant to produce, the next year, branches with the desired characteristics.

Without entering into the merit of individual techniques, the "**progressive pruning**" is considered a *posteriori* formative pruning and the "**flagpole pruning**" and "**reiterative pruning**" are both a *priori* formative pruning type.

For formative pruning single branches are selected that have to be strictly eliminated or controlled (Picture 8.2). It is therefore impossible to control the pruning intensity, if not marginally, trough the control pruning (see par. 8.3.6) .

8.3.5 Productive pruning

The productive pruning aims to contain in a **central cylinder** as small as possible the knots and the resulting wound occlusion, resulting from the elimination of the branches. The central cylinder of a sawn timber is nothing else that the young tree stem before it's completed pruning. This operation shall be carried out with common sense, because on the one hand an intensive pruning contains defects in a small central cylinder, on the other hand the cutting of too many branches produces tree stress and loss of photosynthetic surface. Production pruning allows the operator to **adjust the intensity of the intervention, raising the canopy in**

Picture 8.2 - Formative pruning, a new extremity will be create after apical sprout damage (Picture: Luigi Torreggiani).

proportion to the vigour of plant and the more suitable pruning technique (Picture 8.3). For details, please refer to specific articles to understand the proper technique and intensity of productive pruning (Buresti Lattes and Mori 2004a, Buresti Lattes *et al*. 2001, Buresti Lattes and Mori 2003b).

8.3.6 Control pruning (pruning back, pinching, breaking)

The **control pruning** is used to contain the development of branches too vigorous in plants where it is not appropriate to remove the entire branch (Buresti Lattes and Mori 2004). Even control pruning can be practiced both with winter and green pruning with 3 techniques:

- **pruning back** (winter or green pruning), to practice in the surrounding of buds turned downwards;
- **pinching** (green pruning), also in this case, to practice in the surrounding of buds turned downwards;
- ***Cassage***, green pruning practiced. This is a partial breaking of the fibres that hinders the branch development, but it does not deprive the plant of leaves photosynthetic activity carried by the same branch.

Picture 8.3 - Productive pruning on poplar ('I-214') (Picture: Alessandro Pasini).

8.4 Sizing stage

In the sizing stage the primary objective is to let the Main Trees to obtain diametrical increments strong and regular at least up to the minimum commercial diameter (Pictures 8.4, 8.5, 8.6 e 8.7). In the case of valuable timber for veneer production (with rotary-cut and sliced) the minimum diameter is 30-40 cm (this range depends on species, transformation type, market conditions and the needs of each buyer).

Picture 8.4 - Walnut (*Juglans regia* L.) tree of 20 years and 40 cm in diameter at 130 cm (DBH) (Picture: Luigi Torreggiani).

Picture 8.5 - Poplar clone 'Neva' of 10 years and 45 cm in diameter at 130 cm (DBH) (Picture: Luigi Torreggiani).

Strong and constant diameter increment, if the pedoclimatic conditions are suitable to the species used, are achieved by allowing Main Trees to explore with the roots system and crown, progressively increased spaces. At this stage the most important activity is to monitor the Main Trees growth to determine if is needed the **early harvesting** of Dual Role Trees. The objective of this procedure is to prevent the competition at canopy and roots level or both systems that could lead to reductions, important and repeated, in diameter growth of Main Trees. This would have a consequence doubly negative:

- reduction of the market value, since logs with irregular increases are not suitable for the production of valuable sawn wood and veneer;
- longer production cycle and **exponential growth of financial burden of costs** in implementing and managing Tree farm.

The sizing phase ends once it reach the target production parameters.

Picture 8.6 - Poplar clone 'deltoide 83.120.036' (not on the market) of 10 years and 50 cm in diameter at 130 cm (DBH) (Picture: Luigi Torreggiani).

Picture 8.7 - Clone 'Villafranca' (white poplar) of 10 years and 36 cm in diameter at 130 cm (DBH) (Picture: Luigi Torreggiani).

Picture: Paolo Mori

9

HARVESTING AT THE END OF EACH PRODUCTION CYCLE AND RESTORING OF THE TREE FARM

In Naturalistic Polycyclic Tree farms harvesting have different effects on environment and tree farmer cash flow, depending on either TP Tree farms or 3P Tree farms.

In the **case of TP tree farms**, one or more partial-cycle harvesting of Dual-Role Trees can occur. After each harvest, the surface for the remaining plants is freed up, particularly for Main Trees that, at the end of their production cycle, will cover with their crowns the entire field surface (Pictures 9.1 and 9.2). When Main Trees will reach the expected diameter, a final harvest will be done that, as with traditional monocyclic Tree farms, will eliminate 100% of tree cover, bringing the production area to the bare soil condition. Despite this abrupt change caused by the removal of the whole Tree farm, with TP Tree farms almost all the tangible and intangible benefits typical from Naturalistic Polycyclic Tree farm for wood production can be obtained, as described in Chapters 11 and 12.

In the **case of 3P tree farms**, harvesting may cover the Dual-Role Trees, if any, and part of Main Trees, namely those at the end of their production cycle. However, since the 3P Tree farms must consist of Blocks with Main Trees with at least 2 different cycle length that should never overlap temporally. The soil uncoverage will not be never the 100% of the surface (80% is the maximum allowed). For example, if the 3P Tree farm had 3 different production cycles that had been given the same weight percentage of production area, the soil uncover could rise at max up to 33%.

After Main Tress harvest of a given production cycle (except for Blocks entirely dedicated to the woody biomass production with broadleaves, potentially coppice) it is necessary to proceed with a new Tree farm in uncovered areas. This can be done by restoring identical Blocks to those just used or design new Blocks with different composition of species, length of the production cycle and production goods and services. This makes the

3P tree farms flexible and then able to adapt over time to novel requirements from tree farmer, market and society, both locally and globally.

Also thanks to this feature the 3P Tree farms allow to obtain all environmental and socio-economic benefits described in Chapters 11 to 13.

Picture 9.1 - Walnut 13 year old 3 year after the poplar harvesting (Picture: Paolo Mori).

Picture 9.2 - Oak (*Quercus petraea* Liebl.) 13 year old 3 year after the poplar harvesting (Picture: Paolo Mori).

Picture: Paolo Mori

10

EXAMPLES OF PLANTING SCHEMES CARRIED OUT WITH THE LIFE+ INBIOWOOD PROJECT

The possible combinations between the various Blocks with very precise production targets and achievable in a given plot are very numerous and may also depend on the planned quantities to be obtained for each assortment.

The following describes an example of project for each of the 4 possible combinations of production cycles, with different length, is given:

1. medium-long cycle, short cycle and very short cycle
2. medium-long cycle and short cycle
3. medium-long cycle and very short cycle
4. short cycle and very short cycle

10.1 Case 1: medium-long cycle, short cycle and very short cycle (Picture 10.1)

General objectives of the tree farmer

Produce round timber for veneer, sawlog and woody biomass (firewood). Round timber for veneer and sawlog must be produced both with medium-long cycle than short cycle. The field surfaces dedicated to Main Trees (Blocks) for the production of medium-long, short and very short cycle must be equal.

Specific requirements of the tree farmer

(e.g. species that are liked or dislikes, need for benefits or non-wood products).

- Additional production of woody biomass by Dual-Role Trees.
- For the production of woody biomass (firewood) are not acceptable planting potentially invasive species, in particular *Robinia pseudoacacia* L.

Choices for the planting scheme definition

Specific objectives for production:

- Main Trees diameter with medium-long cycle = 45-50 cm
- Main Trees diameter with short cycle = 40-45 cm
- Main Trees diameter with very short cycle = 8-12 cm
- Dual-Role Trees diameter with very short cycle = 8-12 cm

Additional benefits (requested from tree farmer)

- Additional biomass production obtained through dual-role trees with very short cycle. These, in case they cause a negative competition with Main Trees (e.g. crown contact) must be harvest before the target diameter is reached.
- Avoided nitrogen fertilization, during the production cycle, thanks to the presence of N-fixing specie.

Picture 10.1 - Example of 3P Tree farm with short cycle and medium-long cycle Main Trees and very short Dual-role Trees (Picture: Paolo Mori).

Choice of species to which attribute role of Main or Dual Role Trees

Main Trees

- medium-long cycle => walnut (*Juglans regia* L.)
- short cycle => poplar clone 'I-214'
- very short cycle => oriental plane (*Platanus orientalis* L.)

Dual-Role Trees

- very short cycle => oriental plane (*Platanus orientalis* L.)

Choice of species to which attribute role of Accessory Plants

Accessory trees

- Black alder (*Alnus glutinosa* (L.) Gaert.)

Accessory shrubs

- Autumn olive (*Elaeagnus umbellata* L.)

Planting scheme representation with single Blocks highlighting

Estimating the duration of production cycles

- medium-long cycle => walnut (*Juglans regia* L.) => 25-30 years
- short cycle => poplar clone 'I-214' => 10-12 years
- very short cycle => oriental plane (*Platanus orientalis* L.) => 5-7 years

The Figure 10.2 shows indicatively the sequence with which each wood assortment will be produced. The years in which they will be actually delivered will depend on the time at which the commercial size will be achieved.

Crop planning

Implementation of the Tree farm.

Pre-planting soil management.

- Fracture the plough pan with subsoiler or chisel plough, ordinary ploughing up to 30-40 cm depth, soil harrowing by tilling/disk harrowing and surface drainage system (if necessary).

Nursery material characteristic.

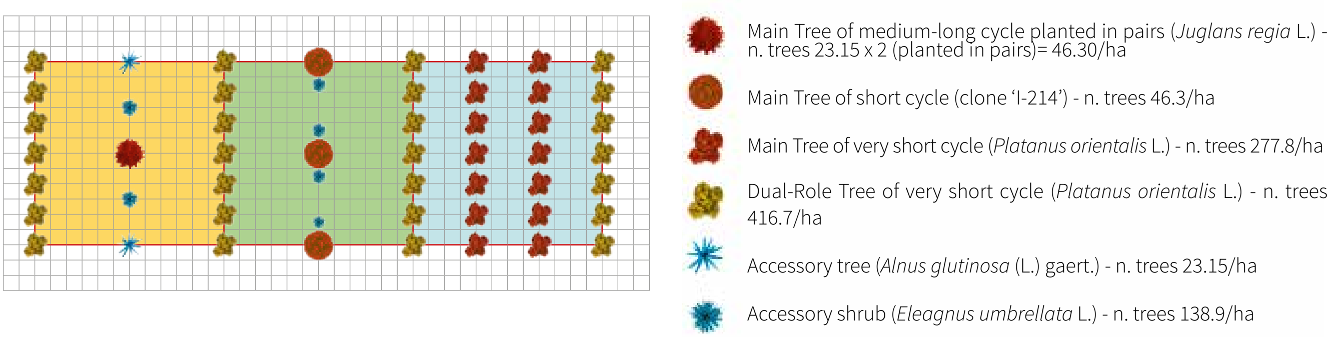


Figure 10.1 - Example of planting scheme and symbols caption for a 3P tree Tarm composed of Blocks with 3 different production cycles length.

- Main Trees with medium-long cycle (walnut), use 1 year seedlings which origin is considered more likely (indicated by the technician's design).
- Main Trees with short cycle (poplar clone 'I-214') use 2 years old cut back rooted cuttings (called barbatelles).
- Main Trees with very short cycle (oriental plane) use 1 year bare-root seedlings.
- Accessory Trees and Shrubs (black alder and autumn olive) 1 or 2 years bare-root or containerized seedlings.

Planting techniques.

- Main Trees of walnut, should be prepared holes of about 25-30 cm side and depth
- Main Trees of poplar clone 'I-214', cylindrical holes must be carried out by at least 20 cm in diameter and 80-120 cm deep.
- Main Trees and Dual Role Trees of oriental plane and Accessory plants should be placed in the ground by plant-transplanter (if in container) or by opening a hole with spade or hoe.

Support for the management (optional).

- Installation of 1,945 m of mulch film along rows, including those with 'I-214' and N-fixing Accessory plants. In case of non-biodegradable film, it must be properly removed and correctly disposed by the fifth cultivation year.

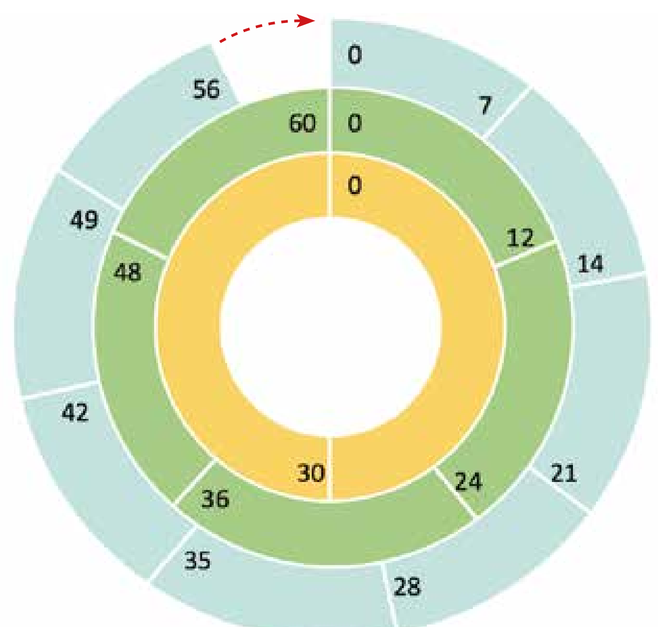


Figure 10.2 - Expected production sequence, indicative, of various woody assortments. Thickness of rings indicates the different productive power (in volume) of each cycle, including that of Dual-Role trees. In yellow the medium-long production, in green the short production cycle and in light blue the very short production cycle are shown, respectively.

- Installation of shelter tubes (741 per hectare in polypropylene) 60 cm height to defend walnut with medium-long cycle and oriental plane with very short cycle, due to the presence of hares that could damage the planting stock in the first 2-3 years. All shelters should be removed and correctly disposed by the fifth year.

Tending operations:

Soil tillage.

- Mechanical tillage (rot tilling, harrowing or disk harrowing) 2-3 times a year for the first 2-3 years. 1-2 tilling between fourth and fifth year as needed.

Pruning.

- pruning on walnut trees has not to be practiced in establishment stage and in any case not during the first vegetation year. The stem part free of branches after pruning (real log) should have approximately a length between 250 and 400 cm, since the walnut total height typically doesn't exceed 10 -12 m.
- pruning on poplar trees, will start the first year and will continue until of 550-600 cm real log has been reached.
- oriental plane, black alder and autumn olive should NOT be pruned, because branch cutting would reduce their ability to contain the growth of weeds.

Irrigation (if needed).

- Help irrigation can be made during the first and second year to facilitate the establishment in periods of water stress. In this case all the planted trees will be irrigated.

Phytosanitary treatments (if needed).

- Preventive treatment against poplar and willow borer (*Cryptorhynchus lapathi*) only for clone ' I-214 is forwarded during the first and second year. Also, during the first year, immediately after planting, a hares repellent must be applied at the stem's base of ' I-214 ' up to a height of approximately 60-80 cm.

Monitoring Main Trees

Monitoring is used to check:

- Main Trees development stage and, consequently, tending operations to be carried out;
- Main Trees growth rate and the estimation of production cycle real duration;
- achieving of the productive objective.

The development stage should be evaluated for each species that has the role of Main Tree or Dual-Role Tree, following the diagram in Figure 10.3.

To assess whether the growth rate reach the target diameter, in the fixed time, it will need to measure 30 Main Trees for each species. The 30 plants must be choices in a representative area of average condition of the Tree farm.

Data processing and comparison with that of previous years, will help to determine if the development is adequate and when will be possible harvest the Main Trees or Dual-Role Trees of different production cycles duration.

Thinnings
Selection criteria within plants in pairs with medium-long cycle (if any).

- Potentially Main Trees planted in pairs should be thinned within the first 3-5 years. The choice, provided that stem shape is useful to obtain the expected assortment, will have to fall back on a more vigorous plant. The deadline for the choice of the best plant of the couple is the last year of pruning.

Criteria for a possible thinning of Accessory plants.

- Accessory Trees will be thinned, promptly, the year before their crowns is expected to conflict with that of Main Trees or Dual-Role Trees. An approximate distance of 50 cm can be considered among the crowns as a limit beyond which the Accessory Trees will be felled.

Harvest

- The Main Trees of each production cycle will be cut down and extracted along the lines indicated in Figure 10.4.

Management of the Tree farm after each harvest
Management criteria of Main Trees with very short cycle.

- After harvest, the stumps will be left to produce new stems for wood biomass production. Their damage has to be then carefully avoided during felling and logging operations.

Management criteria for Dual-Role Trees with very-short cycle.

- Deadline for their harvest is defined by the achievement of a pre-determined diameter. However, if Dual-Role Trees, during the subsequent production cycles, should get into a negative competition with Main Trees of short and or medium-long cycle, they will be harvested promptly. Even the stumps of Dual Role Trees must remain so they can continue to produce wood biomass.

Management criteria for Main Trees with short cycle.

- After harvesting Main Trees with short cycle other plants should be planted (Picture 10.2), in the position indicated in the diagram in Figure 10.5.

Management criteria for Main Trees with medium-long cycle.

- After the harvest of walnuts in medium-long cycle, new Main Trees should be planted in the same place of the first cycle. For this the felled plants stumps should be removed and soil must

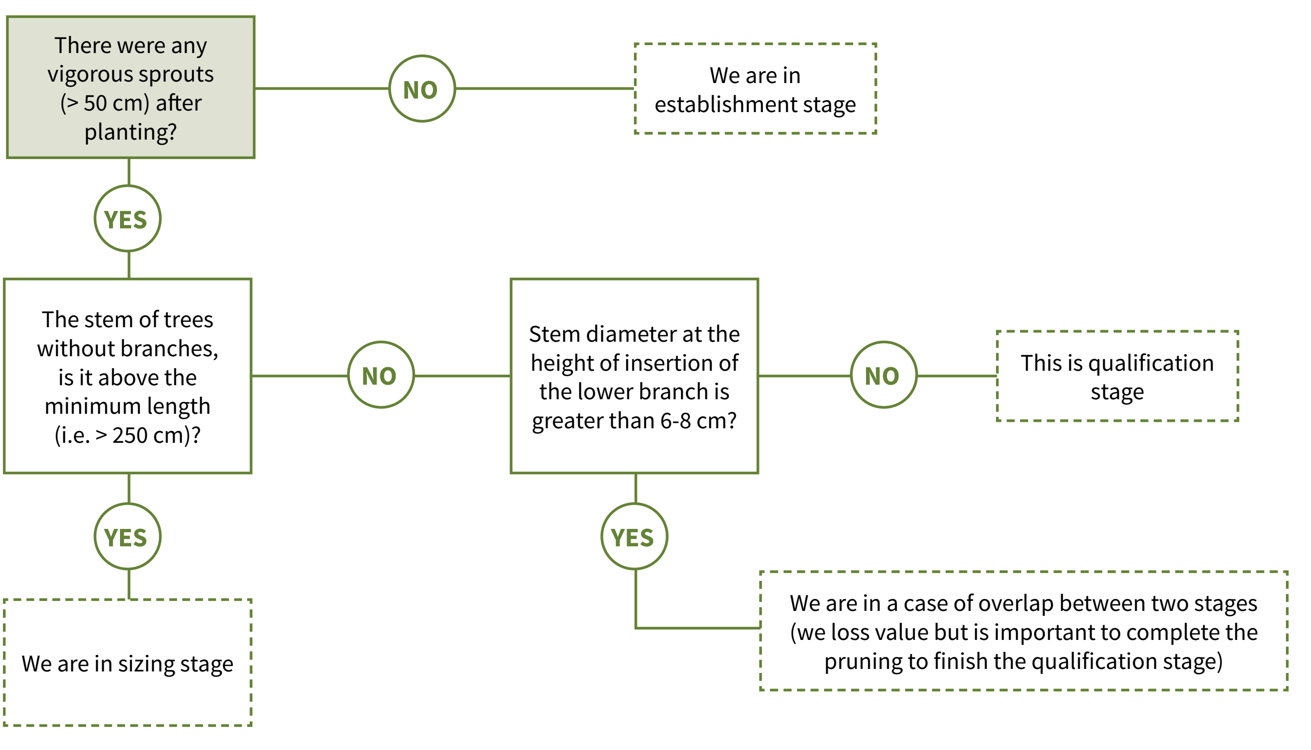


Figure 10.3 - Scheme for the evaluation of the Main Trees development stage.

be locally tilled in order to make it suitable for new plants. This new plants could be walnuts again or other medium-long cycle species considered most interesting.

Management criteria for Accessory plants.

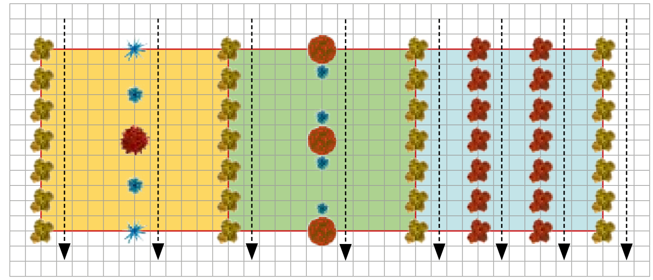
- Both the black alder than autumn olive plants should be felled in connection with the poplar 'I-214 ' or walnut plants harvest. Their stumps shall not be damaged so they can produce shoots easily and play again their accessory role without replanting costs. In the case that black alder plants came into negative competition with walnut Main Trees, the first plants must be promptly felled following the same criteria for oriental plane Dual-Role plants.

Possible variations to the previous scheme

After each Main Trees harvest it should be decide whether to start a new production cycle same as before or not. The Box 10.1 shows the possible variations that this planting scheme might suffer during the first 25-30 years (estimated production cycle length of walnut). It is important to note that any variation compared to the initial scheme involves additional costs respect to the provisions in the design phase.

The solution of the Case 1 can also be achieved **through linear plantation**. These can be made along waterways and moat drains, but also into agroforestry systems. Designing and manag-

Picture 10.2 - Polycyclic Tree farm, it was planted a second cycle of poplar (evident to the white repellent against hares) (Picture: Paolo Mori).



Main Tree of medium-long cycle planted in pairs (*Juglans regia* L.) - n. trees 23.15 x 2 (planted in pairs)= 46.30/ha

Main Tree of short cycle (clone 'I-214') - n. trees 46.3/ha

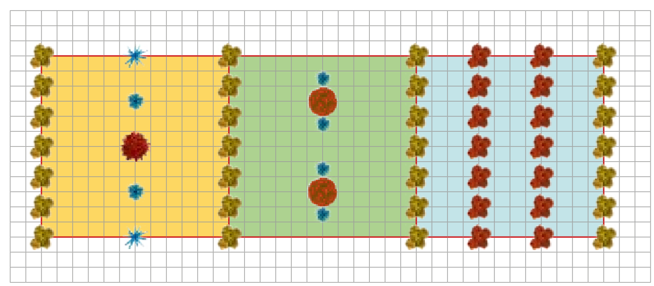
Main Tree of very short cycle (*Platanus orientalis* L.) - n. trees 277.8/ha

Dual-Role Tree of very short cycle (*Platanus orientalis* L.) - n. trees 416.7/ha

Accessory tree (*Alnus glutinosa* (L.) gaert.) - n. trees 23.15/ha

Accessory shrub (*Eleagnus umbrellata* L.) - n. trees 138.9/ha

Figure 10.4 - Extraction lines for various production cycles.



Main Tree of medium-long cycle planted in pairs (*Juglans regia* L.) - n. trees 23.15 x 2 (planted in pairs)= 46.30/ha

Main Tree of short cycle (clone 'I-214') - n. trees 46.3/ha

Main Tree of very short cycle (*Platanus orientalis* L.) - n. trees 277.8/ha

Dual-Role Tree of very short cycle (*Platanus orientalis* L.) - n. trees 416.7/ha

Accessory tree (*Alnus glutinosa* (L.) gaert.) - n. trees 23.15/ha

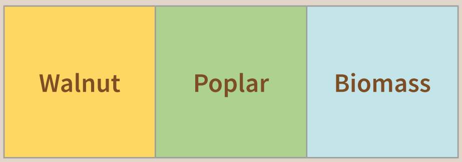
Accessory shrub (*Eleagnus umbrellata* L.) - n. trees 138.9/ha

Figure 10.5 - Planting scheme of the figure 10.4 after the first harvest of Main Trees with short-cycle rotation.

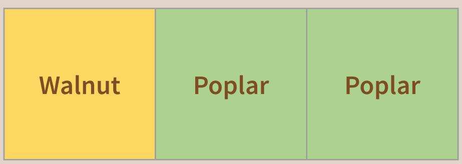
ing linear plantation follow the same criteria for open-field Tree farms, except for minimum distances between Main Trees and between them and Dual-Role Trees which can be reduced by 0.5 -1 m (see par. 5.2.5).

As open-field tree farms the linear Blocks combinations can lead to a very large number of patterns to suit the needs of the Tree farmer. Below has shown an example of one of many linear plantation schemes of 3P plantations that can meet the needs of the Case 1.

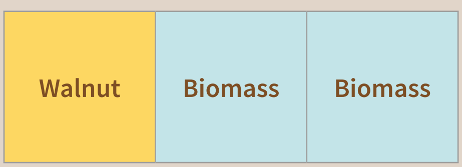
BOX 10.1 DIFFERENT POSSIBLE CHANGES OF PLANTATION SCHEME INTRODUCED IN FIGURE 10.1



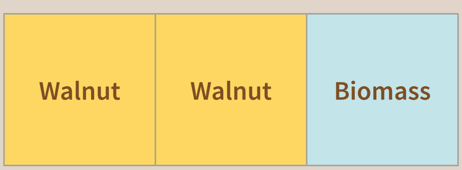
Initial scheme.



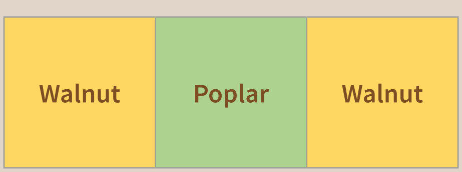
Scheme after the first wood biomass harvest in case there was greater interest in poplar.



Scheme after the first poplar harvest in case there was greater interest in wood biomass.



Scheme after the first poplar harvest in case there was greater interest in walnut or other medium-long cycle species.



Scheme after the first wood biomass harvest in case there was greater interest in walnut or other medium-long cycle specie.

10.2 Case 2: medium-long and short cycle

(Figures 10.6 and Picture 10.3)

General objectives of the Tree farmer

Produce valuable timber in medium-long cycle and a short cycle. The surface of plot for Main Trees (Blocks) with short-cycle production must be maximized while remaining within the framework of the principles set out by the 3P tree farms. Ratio between number of Main Trees Blocks with medium-long cycle and short-cycle ones cannot exceed 1/4.

Specific requirements of the Tree farmer (e.g. species that can be like or dislike, need for benefits or non-wood products).

- Additional production of woody biomass through Dual-Role Trees.
- For the production of woody biomass (firewood) is not acceptable use of potentially invasive species, in particular *Robinia pseudoacacia* L.

Choices for the planting schema definition:

Specific objectives for production:

- Main Trees diameter with medium-long cycle = 45-50 cm
- Main Trees diameter with short cycle = 40-45 cm
- Dual Role Trees diameter with very short cycle = 8-12 cm

Additional benefits (if any)

- Additional biomass production obtained through Dual Role Trees with very short cycle. These, after the first cycle, in case

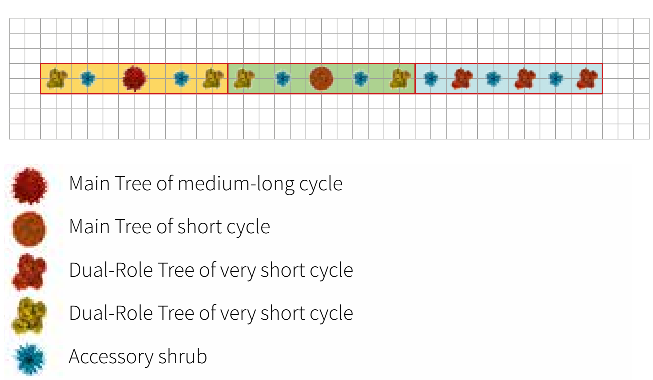


Figure 10.5bis - Example of linear plantation that can solve the Case 1.

they cause a negative competition to Main Trees (e.g. crown contact) must be harvest before the objective diameter is reached.
- Prevented nitrogen fertilization thanks to the presence of N-fixing species.

Estimate of the various production cycles lengths

- medium-long cycle => walnut (*Juglans regia* L.) => 25-30 years
- short cycle => poplar clone 'I-214' => 10-12 years
- very short cycle => oriental plane (*Platanus orientalis* L.) => 5-7 years

Figure 10.7 shows approximately the sequence in which it is assumed, with reasonable certainty, will produce the various wood assortments required. The years in which the target will be obtained will be established in relation to the commercial size achievement.

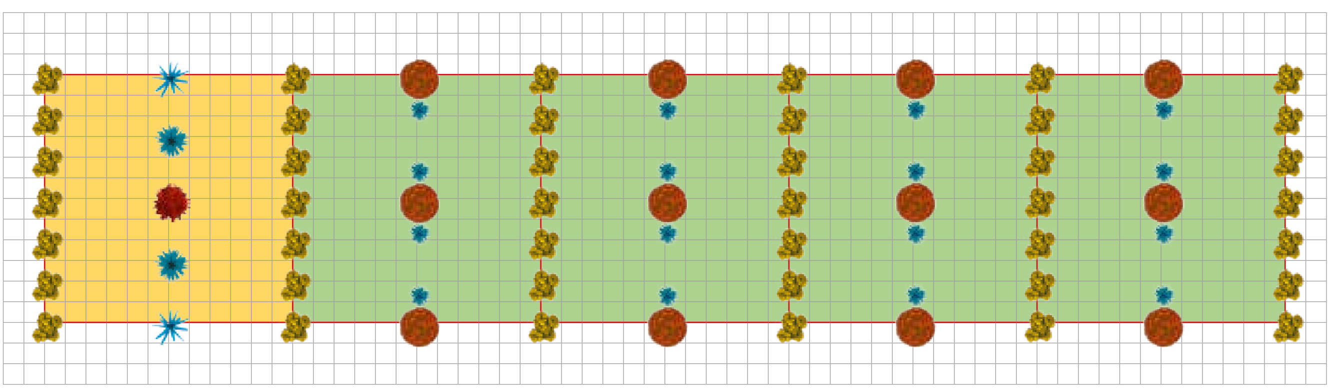
For all other tree farm and crop suggestions please refer to those already described in **Case 1**. Basically, changes are restricted to the planting scheme that, while holding production targets and species used, changes only in number and type of Blocks adapting to the different goals of tree farmer.

Same considerations as for **Case 1** can apply to the Tree farm evolution in **Case 2** after harvesting of Main Trees of short-cycle.

After each harvest of Main Trees the owner will be free to reconsider the type and combination of wanted products and, therefore, either repeat the same pattern of planting or adopt a scheme with a different combination of same type of Blocks or with different Blocks (see Box 10.1).

The solution of the Case 2 can also be obtained **through linear plantation**. In Figure 10.7bis we can see an example of one of many linear plantation schemes that can meet the needs of **Case 2.**

Picture 10.3 - Example of PT Tree farm with medium-long cycle Main Trees, short cycle Dual-Role Trees and Accessory trees and shrubs. (Picture: Paolo Mori).



Main Tree of medium-long cycle planted in pairs (*Juglans regia* L.) = n. trees 13.19 x 2 (planted in pairs)= 27.8/ha

Dual-Role Tree of very short cycle (*Platanus orientalis* L.) - n. trees 416.7/ha

Accessory shrub (*Eleagnus umbrellata* L.) n. trees 250/ha

Main Tree of short cycle (clone 'I-214') - n. trees 111.1/ha

Accessory tree (*Alnus glutinosa* (L.) gaert.) n. trees 13.9/ha

Total number of plants per hectare in planting phase = 847,1

Figure 10.6 - Example of planting scheme and symbol caption for a 3P tree farm composed of 1 Block of medium-long cycle and 4 Blocks of short cycles that satisfies the requirements defined for the Case 2.

10.3 Case 3: medium-long and very short cycle (Figure 10.8)

General objectives of the tree farmer

Produce valuable timber in medium-long cycle and wood biomass in a very short cycle. The surface for Main Trees (Blocks) with very short cycle production must be maximized, while remaining within the framework of the principles set out by the 3P tree farms. Ratio between number of Blocks with medium-long cycle and very-short-cycle ones cannot exceed 1/4.

Specific requirements of the entrepreneur (e.g. species that can be like or dislike, need for benefits or non-wood products).

- Additional production of woody biomass through Dual Role Trees.
- For the production of woody biomass (firewood) is not acceptable use of potentially invasive species, in particular *Robinia pseudoacacia* L.

Choices for the planting schema definition:

Specific objectives for production:

- Main Trees diameter with medium-long cycle = 45-50 cm
- Dual Role Trees diameter with very short cycle = 8-12 cm

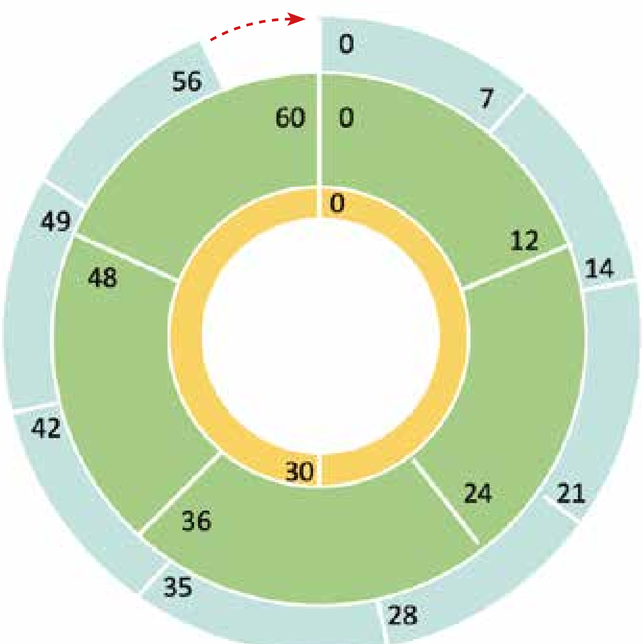


Figure 10.7 - Expected production sequence, indicative, of various woody assortments. Thickness of rings indicates the different productive power (in volume) of each cycle , including that of Dual-Role trees. In yellow the medium-long production, in green the short production cycle and in light blue the very short production cycle are shown, respectively.

Additional benefits (if any)

- Additional biomass production obtained through Dual Role Trees with very short cycle. These, in case they cause a negative competition to Main Trees (e.g. crown contact) must be harvest before the objective diameter is reached.
- Prevented nitrogen fertilization thanks to the presence of N-fixing species.

Estimate of the various production cycles length

- medium-long cycle => walnut (*Juglans regia* L.) => 25-30 years
- very short cycle => oriental plane (*Platanus orientalis* L.) => 5-7 years

Figure 10.9 shows approximately the sequence in which it is assumed, with reasonable certainty, will produce the various wood assortments required. The years in which they will be produced shall be established in relation to the commercial size achievement.

For all other tree farm and crop suggestions please refer to those already described in **Case 1**. Basically, changes are restricted to the planting scheme that, while holding production targets and species used, changes only in number and type of Blocks adapting to the different goals of tree farmer.

After each harvest of Main Trees the owner will be free to reconsider the type and combination of wanted products and, therefore, either repeat the same pattern of planting or adopt a scheme with a different combination of same type of Blocks or with different Blocks (see Box 10.1).

The solution of the **Case 3** can also be obtained through linear plantation. In Figure 10.9 bis is shown an example of one of many linear plantation schemes that can meet the needs of **Case 3**.

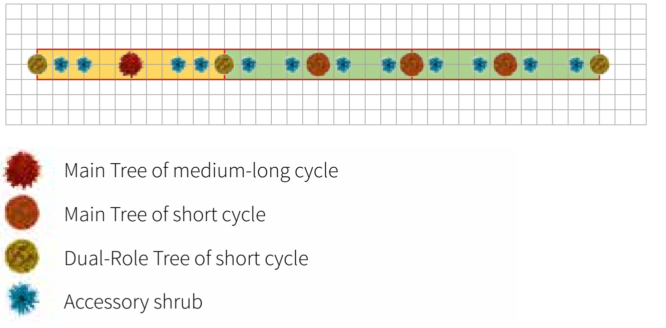


Figure 10.7bis - Example of linear plantation scheme that can solve the Case 2.

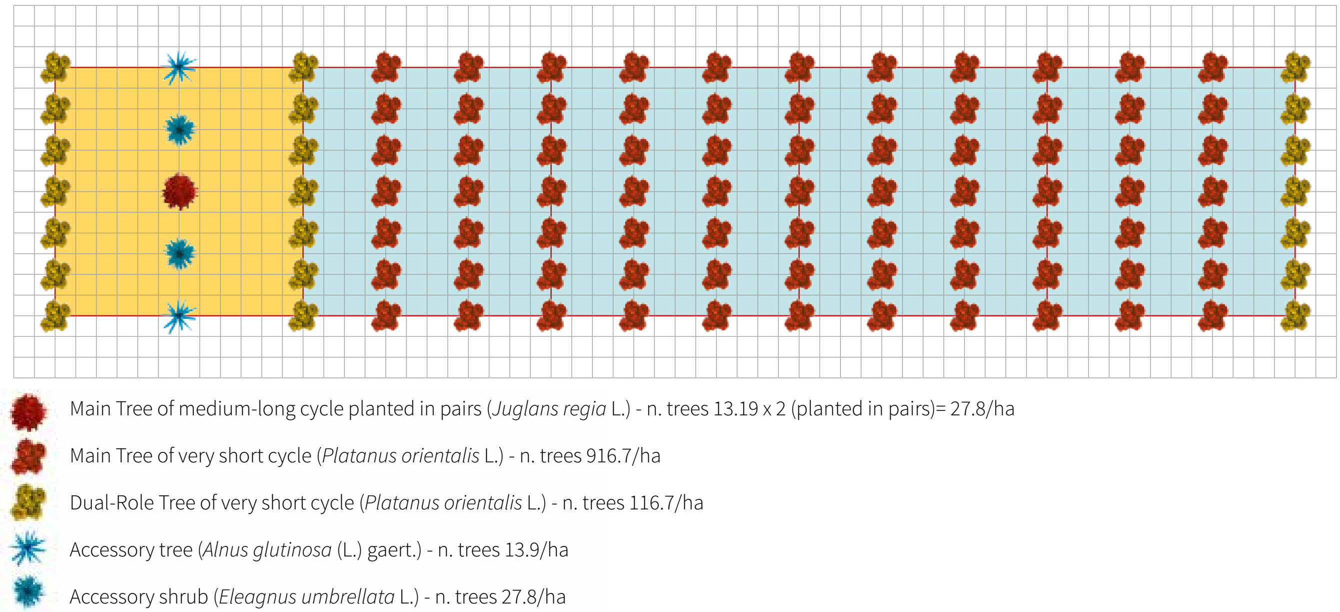


Figure 10.8 - Example of planting scheme and symbol caption for a 3P tree farm composed of 1 Block of medium-long cycle and 4 Blocks of very short cycles that satisfies the requirements defined for the Case 3.

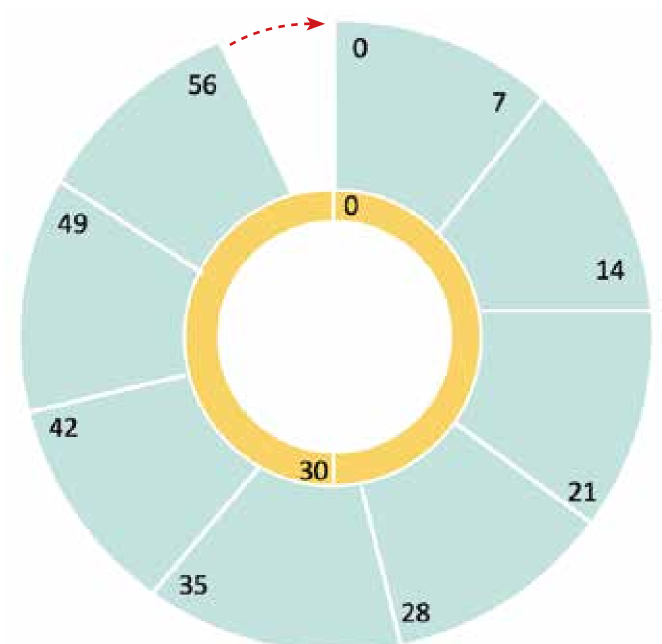


Figure 10.9 - Expected production sequence, indicative, of various woody assortments. Thickness of rings indicates the different productive power (in volume) of each cycle, including that of Dual Role trees. In yellow the medium-long production, in green the short production cycle and in light blue the very short production cycle are shown, respectively.

10.4 Case 4: short and very short cycle (Figure 10.10 and Picture 10.3)

General objectives of the tree farmer

Produce valuable timber in a short cycle and wood biomass in a very short cycle. The field surface for Main Trees (Blocks) with very short cycle production must be equal to the field surface dedicated to short cycle. Ratio between number of main trees Blocks with medium-long cycle and very-short-cycle ones must be 1/1.

Specific requirements of the tree farmer (e.g. species that can be like or dislike, need for benefits or non-wood products).

- Additional production of woody biomass through Dual Role Trees.
- For the production of woody biomass (firewood) is not acceptable use of potentially invasive species, in particular *Robinia pseudoacacia* L.

Choices for the planting schema definition:

Specific objectives for production:

- Main Trees diameter with short cycle = 40-45 cm
- Dual Role Trees diameter with very short cycle = 8-12 cm

Additional benefits (if any)

- Additional biomass production obtained through Dual Role Trees with very short cycle. These, in case they cause a negative competition to Main Trees (e.g. crown contact) must be harvest before the objective diameter is reached.

- Prevented nitrogen fertilization, in favour of Main Tress, thanks to the presence of N-fixing species.

Estimate of the various production cycles duration

- short cycle => poplar ('I-214') => 10-12 years
- very short cycle => oriental plane (*Platanus orientalis* L.) => 5-7 years

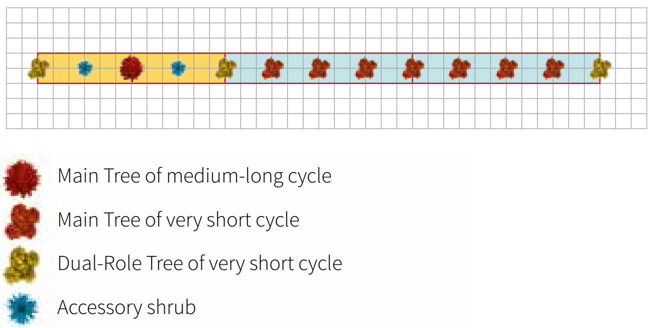


Figure 10.9bis - Example of linear plantation scheme that can solve the Case 3.

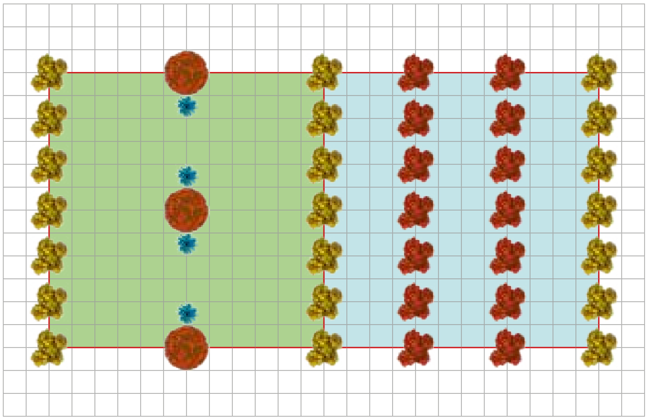
Picture 10.3 - Example of TP Tree farm with Main Trees of short cycle and with Dual-Role Trees of very short cycle (Picture: Francesco Pelleri).

Figure 10.11 shows approximately the sequence in which it is assumed, with reasonable certainty, will produce the various wood assortments required. The years in which they will be produced shall be established in relation to the commercial size achievement.

For all other tree farm and crop suggestions please refer to those already described in **Case 1**. Basically, changes are restricted to the planting scheme that, while holding production targets and species used, changes only in number and type of Blocks, adapting to the different goals of tree farmer.

After each harvest of Main Trees the owner will be free to reconsider the type and combination of wanted products and, therefore, either repeat the same pattern of planting or adopt a scheme with a different combination of same type of Blocks or with different Blocks (See Box 10.1).

The solution of the **Case 4** can also be obtained through linear plantation. Below has shown an example of one of many linear plantation schemes that can meet the needs of **Case 4**.



Main Tree of short cycle (clone ‘I-214’) - n. trees 69.4/ha

Main Tree of very short cycle (*Platanus orientalis* L.) - n. trees 416.7/ha

Dual-Role Tree of very short cycle (*Platanus orientalis* L.) - n. trees 416.7/ha

Accessory shrub (*Eleagnus umbrellata* L.) - n. trees 138.9/ha

Figure 10.10 - Example of planting scheme and symbol caption for a 3P tree farm composed of 1 Block of short cycle and 1 Blocks of very short cycles that satisfies the requirements defined for the Case 4.

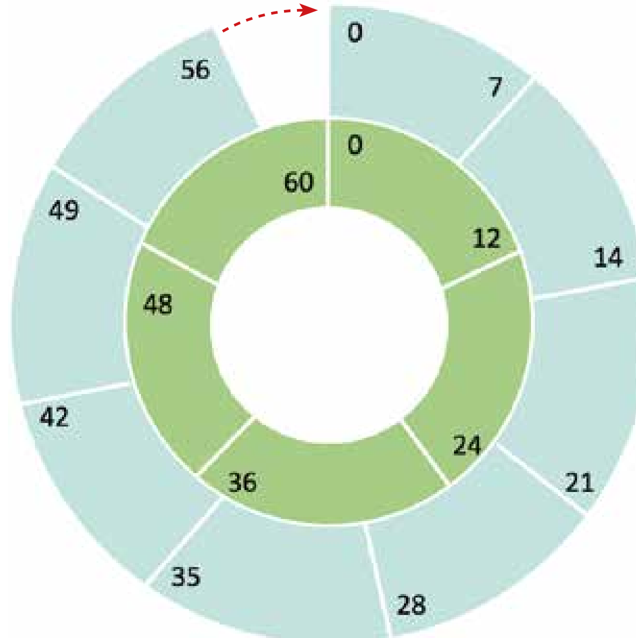
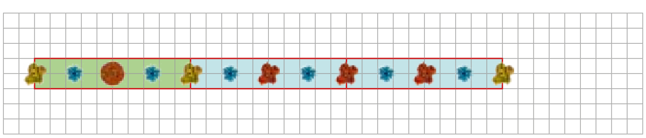


Figure 10.11 - Expected production sequence, indicative, of various woody assortments. Thickness of rings indicates the different productive power (in volume) of each cycle length, including that of Dual Role trees. In green the short production cycle and in light blue the very short production cycle are shown, respectively.



Main Tree of medium-long cycle

Main Tree of very short cycle

Dual-Role Tree of very short cycle

Accessory shrub

Figure 10.11bis - Example of linear plantation schema that can solve the Case 4.

Picture: Paolo Mori

11

POLYCYCLIC NATURALISTIC TREE FARMS AND THE ENVIRONMENT

The PPN allow to produce wood and get environmental benefits both in a local and global scale. The following describes the major effects that a PPN can produce.

11.1 Soil tillage

The PPN, both Temporary that Potentially Permanent, must have a density as to contain the weeds growth with trees and shrubs crowns, in the first 4-5 years. Then, soil is progressively covered by trees and shrubs leaves. This, associated with crown closure, causes the gradual disappearance of weeds. This means that starting from 3rd-5th year, depending on tree farm type and soil fertility, the tillage can be gradually reduced and finally interrupted as not necessary. In agronomic tree farm soil tillage are carried out for almost the entire production cycle.

The numerical reduction and subsequent interruption of soil tillage allow to:

- contain the production costs in terms of
  - wear of agricultural machine necessary for tillage;
  - amount of fossil fuel used;
  - work days;
- reduce the carbon footprint;
- gain time to devote to other activities.

11.2 Irrigation

The PPN, both Temporary that Potentially Permanent, must have a specific composition and densities such (minimum 600 plants per hectare) to allow a water cycle control, better than in traditional systems. The rapid-grown crown coverage and stratification in many layers by the inclusion, in the same Block or in contiguous Blocks, of trees and shrubs species with fast and medium growth, would allow, by stomatal control, a reduction of 20-40% evapotranspiration compared to a body of water (Piussi 2015). Also the density and their stratification reduce the wind effect in favour of inside tree farm humidity conditions that in turn reduces the leaves evapotranspiration. This means that, in the absence of exceptional events, on Naturalistic Polycyclic Tree farms for wood production[11], irrigation are generally limited to those supplementary in establishment stage.

The limited use of irrigation, for poplar logs production, allows the tree farmer to:

- reduce production costs in terms of;
  - wear of machine necessary for irrigation (engines and pumps);
  - amount of fossil fuel to be used for machines and water pumping;
  - work days;
- reduce the carbon footprint of wood production;
- gain some time to devote to other activities.

11.3 Phytosanitary treatments

In the PPN, both Temporary that Potentially Permanent, the mix of species inside the Block and between Blocks seems to obstacles spread of certain pathogens. Phytosanitary treatment should not be made at fixed dates, but should only take place as a consequence of sanitary emergencies and only targeted on the affected species.

This requires a periodic inspection of Main and Dual-Roles Trees. Due to the specie's mix a certain degree of competence is required from the tree farmer in order to identify promptly any pathogen's spread to be faced. However, until now, the Polycyclic Tree farms that have come to the conclusion of poplar production cycle are not treated with pesticides, except one case where 3 preventive treatments were made, of which 2 the first and 1 the second tree farm year. Subsequently there haven't faced pathogen's spread so serious to require treatments.

The limited use of pesticides, including the case of poplar logs production, allows the tree farmer to:

- reduce production costs in terms of
  - wear of machine necessary to spraying;
  - amount of fossil fuel to be used for machines and water pumping;
  - consumption of active substances against pathogens;
  - work days;
- reduce the carbon footprint of wood production;
- reduce water pollution;
- reduce air pollution;
- gain time to devote to other activities

In case of active substances to face the emergence of specific poplar pathogens would be needed, refer to those indicated in the Technical standards PEFC (AA.VV 2006).

11) Realized to date in medium and excellent plain areas.

11.4 Fertilizer application

In Polycyclic Tree farms for wood production, fertilizations are not given during tree farm development. It should also be considered that part of the nutrients necessary for the annual growth go back into the soil with leaves and, within a few years, becomes available again to the root systems.

When designing the scheme of the PPN is however recommended to insert Accessory plants, for a minimum of 10% in number, N-fixing species so as to provide, naturally, additional nitrogen. This recommendation can be disregarded for tree farms areas particularly rich in nitrogen from agricultural sources.

Not undertaking fertilization during all the production cycles, including the case of poplar logs production, allows tree farmer to:

- reduce production costs in terms of;
  - wear of machine necessary to fertilize;
  - amount of fossil fuel to be used for machines;
  - consumption of fertilizing products;
  - work days;
- reduce the carbon footprint of wood production;
- reduce water pollution, in particular with regard to nitrogen in waterways that can lead to eutrophication;
- gain time to devote to other activity.

However, it is possible that, during Blocks planting or replanting (in 3P Tree farms), it is deemed useful to undertake a basal fertilization adopting a supplement application for nitrogen, phosphorus, potassium or trace elements deficient. In this case, even for the PPN, if you do not wish to or cannot make use of organic fertilizers, you can refer to the types of facilities products indicated in Technical Standards PEFC (AA.VV. 2006).

11.5 Soil carbon storage

Atmospheric CO_2 storage in wood and in soil organic compounds is an important environmental service that is conducted both by TP Naturalistic Tree farms that 3P Naturalistic Tree farms. However there is a significant difference between the two types of Polycyclic Plantations for wood production. This difference is not strictly related to assortments type produced, but to the conservation of carbon stored in the soil, linked in turn to the cover permanence of any tree and shrubby.

On the other hand we know that in traditional plantations of Tree farming, the final harvest which removing 100% of plants, the carbon stored in the soil, which can reach values close to those of a forest soil, is release again into the atmosphere within a few months after harvest (Boni and Petrella 2013). Despite lack of specific studies, it is likely to think that the same occurs after TP Naturalistic Tree farms harvest, since even in their case the end use involves the removal of 100% of the plants. Instead, this should not be the case with the 3P Naturalistic Tree farms, where the harvesting is always partial, with at least, 20% of higher crown coverage, twice the threshold beyond which the FAO define a forest (land spanning more than 5,000 m^2 with tree higher than 5 m and a canopy cover of more than 10%).

In order PPN may be regarded as 3P Naturalistic Tree farms, at least 300 plants/stumps per hectare have to be left after each harvesting, while at least 600 plants/stumps per hectare are expected again after 1 or 2 years.

11.6 Maintenance part of habitats
(maintenance of plant density)

The implementation and management of a Tree farm that remains in a given plot of land for 10, 20 or more years, results in the gradual formation of habitats for insects, fungi, micro mammals and birds (Picture 11.1). In tree farms with Main Trees of the same production cycle length, they are agronomic pure, mixed or Naturalistic Temporary Polycyclic, at the time of the end harvest, with a return to the status of bare agricultural field, all the habitats created are abruptly lost. This occurs only partially instead in the 3P Naturalistic tree farms, as the harvest involve only a part of the surface, due to the fact that at least 20% of canopy cover and half of the plants/stumps, remain in the tree farm. This means that many life forms, like certain birds, insects or micro mammals can move a few meters to find suitable habitat conditions.

Life forms, associated with specialized relations to Main Trees species, will be lost with harvesting, unless there is a care at distributing the time of the production cycles end for the same species.

11.7 Landscape

The 3P tree farm concept takes also in account to reduce the perturbation of the landscape feeling of the resident population. Partial harvesting can produce limited change in landscape perceived that in a few years are completely recovered. With the total harvest and return to the bare agricultural field, typical of agronomic tree plantations and of Main Trees harvested in a TP Tree farm of Agronomic and Naturalistic type, the landscape changes in terms of masses, horizons and colours is abrupt and traumatic for those who perceived the wood plantation like a stable component of the landscape 10, 20 or more years along.

Choosing to insert 3 or more Blocks with Main Trees of different species or same species, but with different cycles length or staggered over time, reduces the changes in the landscape perceived. Even in this case, the greater is the different Blocks number in the 3P Naturalistic Tree farm the lower is the impact on the landscape caused by each harvest.

Picture 11.1 - Fungi within a Polycyclic Naturalistic Tree farm (Picture: Paolo Mori).

11.8 Increase of bird population: a study for LIFE+ InBioWood

Within the framework of InBioWood LIFE+ a particular study has been carried out by D.R.E.AM. Italia, in order to compare the bird fauna present in Naturalistic TP tree farms and the one from traditional poplar plantations. Such a study is aimed at testing the hypothesis that polycyclic systems are better for birds than traditional poplar plantations (Londi *et al*. 2016).

During the study were detected in total 30 species, among which 25 in polycyclic tree farms, 24 in poplar plantations. 19 common species were found; the remaining 11 species, each group found only in one kind of plantation, appeared with very low frequency. They are related to marginal environments (such as herons, mallard, collared dove, Eurasian kingfish, moorhen) respect to the main plantation context or they were barely migratory species (like Bonelli's warbler or *Locustella naevia*) with the exception of turtle doves and magpie (only observed in the polycyclic tree farms) and green woodpecker and spotted flycatcher (only observed in the traditional poplar plantations).

The analyses show that among traditional poplar plantations and Polycyclic Tree farms there is no difference in richness or diversity, which depend largely on the proximity to the margins (Table 11.1). Substantially the two areas host the same nesting birds and the context is similar to that outlined in other studies of poplar plantations in Padana Valley (Bogliani 1988).

As regards to the activity levels, however, the difference is significant and very consistent in favour of polycyclic systems where vocalizations are on average 40% more (Table 11.1, Figure 11.1); also on 14 species that it was possible to analyze individually, for 7 the activity was significantly greater in Polycyclic Tree farms, and only one in poplar plantations (Table 11.2).

Higher activity levels recorded in Polycyclic Tree farms indicate, compared with traditional poplar plantations, a largest "carrying capacity", that is basically an increase of resources available to birds. Despite the sample studied is very reduced (approximately 50 ha of Polycyclic Tree farms, in an area mainly characterize by intensive farming and intensive poplar plantations) and birds population in the two types of plantation was very similar, the differences revealed in terms of activities are very sharp. Compared to conventional plantations, where the birds density are generally very low (Riffell *et al*. 2011), the more "carrying capacity" of the polycyclic tree farms translates into greater ability to "substitute" natural or semi-natural forests (Martín-García *et al.* 2013). And where forests, as in the plains of the Mediterranean region, were strongly reduced or cleared, Polycyclic Tree farms can assume particular importance by replacing part of the intensive farming or intensive poplar cultivation whose effectiveness in terms of support for biodiversity is rather low (Martín-García *et al.* 2016).

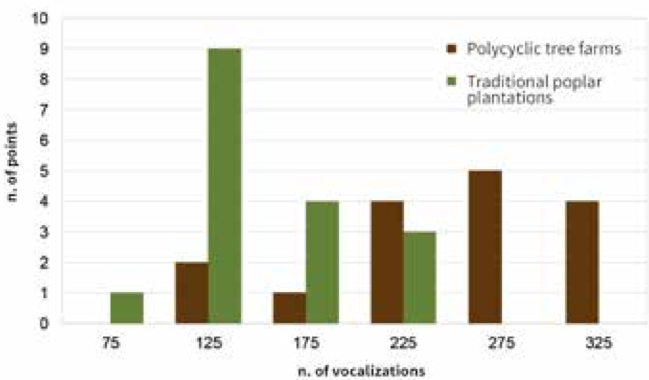


Figure 11.1 - Distribution of the total number of vocalizations vs. the number of points in the two types of plantation. It is clear that points with increased activity are in Polycyclic Tree farms (fonte: Londi *et al*. 2016).

	Polycyclic Tree Farms		Traditional Poplar Plantations		Effect of Polycyclic tree farms	Effect of the other variabiles	
	Mode	IC (95%)	Mode	IC (95%)		Distance	Time
Richness per point	10,00	(9,50-10,50)	9,65	(8,84-10,45)	n.s.	-(**)	n.s.
Diversity (Shannon Index)	1,758	(1,701-1,815)	1,776	(1,660-1,892)	n.s.	-(***)	n.s.
Total vocalizations	250,3	(229,4-271,2)	152,4	(137,7-167,1)	+(***)	-(*)	-(**)

Table 11.1 - Results for the total population. Data collected, the sign and significance of variables are shown. The "+" sign indicates, respectively for the three tested effects, that the values are significantly greater in polycyclic tree farms compared with poplar plantations, with distance increase and time progresses. The sign "-" indicates the opposite effect. Levels of significance are (*) $p < 0.05$; (**) $p < 0.01$; (* * *) $p < 0.001$; n.s. indicates no significant effect (fonte: Londi *et al*. 2016).

Picture 11.2 - Naturalistic Polycyclic Tree farm where the canopy shade of trees and shrubs removed weeds and increase the organic compounds of soil (Picture: Paolo Mori).

Picture 11.3 - Walnut tree where it's visible a bird's nest (Picture: Paolo Mori).

Species		**n. of vocalizations/10'**		**Effect of Polycyclic tree farms**	**Effect of the other variables**	
		Polycyclic tree farms	**Traditional poplar plantations**		**Distance**	**Time**
Hooded crow	*Corvus cornix*	49.4	26.6	$+^{(*)}$	n.s.	n.s.
Nightingales	*Luscinia megarhynchos*	40.6	12.2	$+^{(*)}$	n.s.	n.s.
Golden oriole	*Oriolus oriolus*	27.1	21.2	n.s.	n.s.	n.s.
Chaffinch	*Fringilla coelebs*	7.0	35.8	$-^{(**)}$	$+^{(*)}$	n.s.
Great tit	*Parus major*	30.3	8.5	$+^{(*)}$	$-^{(*)}$	n.s.
Blackcap	*Sylvia atricapilla*	24.6	11.4	$+^{(*)}$	$-^{(*)}$	n.s.
Great spotted woodpecker	*Dendrocopos major*	17.4	8.5	$+^{(*)}$	n.s.	n.s.
Ring-necked pheasant	*Phasianus colchicus*	15.3	9.9	n.s.	n.s.	$-^{(***)}$
Blackbird	*Turdus merula*	18.9	1.1	$+^{(*)}$	n.s.	$-^{(***)}$
European starling	*Sturnus vulgaris*	3.7	8.9	n.s.	n.s.	n.s.
Common cuckoos	*Cuculus canorus*	4.6	2.0	n.s.	n.s.	$-^{(**)}$
Wood pigeons	*Columba palumbus*	4.3	0.4	$+^{(*)}$	$-^{(*)}$	$-^{(*)}$
Long-tailed tit	*Aegithalos caudatus*	3.4	0.5	n.s.	n.s.	n.s.
Blue tit	*Cyanistes caeruleus*	0.6	2.6	n.s.	$-^{(*)}$	$+^{(**)}$
Eurasian jay	*Garrulus glandarius*	0.2	0.7	-	-	-
Spotted flycatcher	*Muscicapa striata*	-	0.8	-	-	-
Collared dove	*Streptopelia decaocto*	0.9	-	-	-	-
Grey heron	*Ardea cinerea*	0.6	0.1	-	-	-
Magpie	*Pica pica*	0.7	-	-	-	-
Moorhen	*Gallinula chloropus*	0.2	0.3	-	-	-
Eurasian kestrel	*Falco tinnunculus*	0.3	0.2	-	-	-
Black-crowned night heron	*Nycticorax nycticorax*	0.3	0.1	-	-	-
Green woodpecker	*Picus viridis*	-	0.4	-	-	-
Whitethroat	*Sylvia communis*	-	0.2	-	-	-
Bonelli's warbler	*Phylloscopus bonelli*	-	0.1	-	-	-
Eurasian kingfish	*Alcedo atthis*	-	0.1	-	-	-
Grasshopper warbler	*Locustella naevia*	0.1	-	-	-	-
Mallard	*Anas platyrhynchos*	0.1	-	-	-	-
Common swift	*Apus apus*	-	0.1	-	-	-
Turtle doves	*Streptopelia turtur*	0.1	-	-	-	-

Table 11.2 - Results for individual species. Data collected, the sign and significance of variables are shown. The "+" sign indicates, respectively for the three tested effects, that the values are significantly greater in polycyclic tree farms compared with poplar plantations, with distance increase and time progresses. The sign "-" indicates the opposite effect. Levels of significance are (*) $p < 0.05$; (**) $p < 0.01$; (* * *) $p < 0.001$; n.s. indicates no significant effect (fonte: Londi *et al.* 2016).

Picture: Paolo Mori

12

POLYCYCLIC NAURALISTIC TREE FARMS AND QUALITY OF LIFE

12.1 Less amount of work

As noted in Chapter 11, naturalistic Polycyclic Tree farms for wood production can reduce the amount of work required in valuable timber production. This is possible because, both in the TP Tree farms than in the Naturalistic 3P Tree farms, the tree farmers make use of some natural mechanisms of synergy and/or positive competition between plants that facilitate the Tree farm management and/or reduce the intensity/number of interventions.
This allows the tree farmer to use each day saved from soil tillage, irrigation, fertilization and phytosanitary treatments not performed. The bigger is the Tree farm plot and the greater is the number of working days saved.

12.2 Lower emissions of climate-altering gases

Climate-altering gases emissions caused by the wood production outside the forest are essentially related to the use of fossil fuels for the machinery and equipment operations. In Chapter 11 is highlighted how there can be a significant fuel saving thanks to the possibility of using less machinery and equipment for soil tillage, irrigation, phytosanitary and fertilizer treatments. Such a feature of the PPN has an impact on a global scale on the containment of climate change, since it decreases strongly the emission of new CO_2 and climate-altering gases in general.

12.3 Minor releases of chemicals into air and water

The mixture of tree species and sometimes even shrubs that can be found in the Naturalistic Polycyclic Tree farms from wood production, hinders the development of some diseases of Main Trees and Dual Role Trees. This results in a reduced use of the pesticides and then a reduced release of chemicals into air and water. Such a feature also increases physical wellbeing for both the tree farmer that the residents of the areas nearby tree farms.

12.4 Reduced delay between investments and revenues

Conventional plantations, pure or mixed, are generally characterized by long periods in which, before getting the revenue determined by wood sale, the tree farmer has to afford production costs and related interest for the Main Trees implementation and management. With Polycyclic Tree farms for wood production instead, thanks to the simultaneous occurrence of several production cycles, the revenues flow comes, from a single land plot, in a very short period of time (see Chapter 13), especially if compared with Tree farming of medium-long cycle.

Discounting of cash flows due to short cycles and/or very short cycles compared to medium-long production cycle, can help to mitigate significantly the burden of costs in financial statement. The consequence is a chance to get better financial results by that business activity.

12.5 Lower trade risks

The timber market evolves in times much shorter than the production times of the various wood assortments. The risk with usual plantations is to plant when the market requires a specific assortment while at the end of the production cycle requests are changed. In order to respond, at least partially, to the changing market demands and reduce commercial risks, the Polycyclic Tree farms can produce, starting from the same land plot, valuable timber in medium- long cycle of more species, valuable timber in short cycle and woody biomass in very short cycle. In practice, if the land plot has no special restrictions and if environmental conditions are favourable, with Polycyclic Tree farms you can cover each category of wood products required by the market (Picture 12.1; 12.2; 12.3 e 12.4).

Picture 12.1 - Example of poplar rotary-cut veneer (Picture: Paolo Mori).

Picture 12.2 - Example of non-edged boards of walnut obtained by sawing (Picture: Paolo Mori).

Picture 12.3 - Example of firewood for stove (Picture: Paolo Mori).

Picture 12.4 - Example of woodchips from scraps of poplar and branches (Picture: Paolo Mori).

Picture: Luigi Torreggiani

13

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FINANCIAL ANALYSIS OF NATURALISTIC POLYCYCLIC TREE FARMS (PPN)

This chapter presents the main results of a work - carried out within the Life+ InBioWood project (Increase Biodiversity Through Wood Production - LIFE12 ENV/IT/000153) - where the financial returns of different plantations for wood production models in Northern Italy are analyzed and compared: poplar, walnut and Potentially Permanent Polycyclic Tree farms (3P Tree farms). Comparison with the main agricultural crops profitability and effects on the profitability of land use cost and subsidies are a substantial part of the analysis.

To assess the financial returns of different wood plantations, suitable models were used following ordinary procedures defined by specific studies (Cubbage *et al* 2010; 2014). Specifically, three types of plantations were considered:

1. conventional poplar plantation schemes, the most widespread and consolidated typology of Tree farming in Italy;
2. specialized walnut Tree farms as an example of tree farming with valuable broadleaved tree species that achieved a significant widespread the last 20-30 years, mainly due to the support measures EEC Reg. 2080/92 (Colletti 2001);
3. 3P Naturalistic Tree farms, those Tree farms where there are simultaneously Main Trees of different production cycle lengths (Buresti Lattes e Mori 2009).

The results obtained with plantations for wood production were later compared with major alternative investments in agriculture.

The methodology develops in four main stages:

- definition of management models;
- analysis of costs and incomes;
- calculation of profitability index;
- sensitivity analysis.

13.1 Definition of management models

Management strategies of different types of wood plantations achievable in North Italy have been defined:

model 1 - traditional poplar short rotation system (square design and distance of 6 m);

model 2 - medium-long rotation cycle of walnut (square design and distance of 10 m);

model 3 - 3P tree farm with 20% of Blocks with Main Trees of medium-long cycle, 80% of Blocks with Main Trees of short cycle and Dual Roles Trees of very short cycle (Figure 13.1);

model 4 - 3P Tree farm with surface equally distributed between Main Trees with 3 different rotation cycles and plants with Dual Roles Trees of very short cycle (Figure 13.2);

model 5 - 3P Tree farm with surface equally distributed between Main Trees with medium-long cycle and Main Trees with short cycle (Figure 13.3).

Table 13.1 reports in comprehensive way the five management models defined for the analysis. Each management model was tested in four conditions: two in relation to management costs (low and high), and two referred to site fertility conditions[12] (medium and high fertility). In order to compare models with different rotations times, we simulated two rotations with productive cycles of different length. We have then identified the two most frequent agricultural alternatives to tree farming: maize silage, maize grain and soy productions (Trestini and Bolzonella 2015). These alternatives have been in turn evaluated in conditions of both high and low cost as well as within soils of high and low productivity. In total, 26 models have been compared (20 of them for tree farming, 6 for arable land).

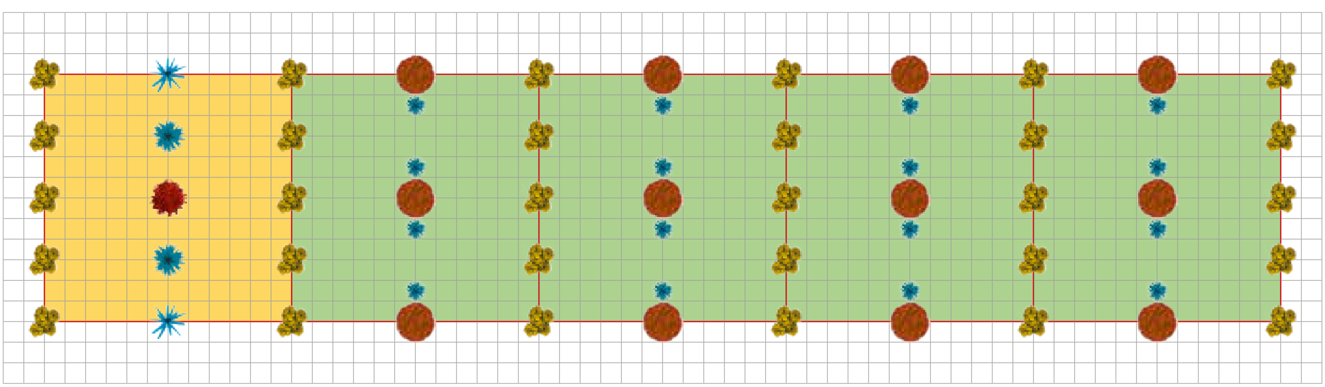
12) In a good fertility condition we suppose a production cycle of 6 years for the plane-tree, 10 years for the poplar and 20 years for the walnut tree. In case of medium fertility we suppose longer production cycles : 7 years for the plane-tree, 12 years for the poplar and 27 years for the walnut tree.

13.2 Analysis of costs and revenues

In the second phase, costs of establishment, management and selling prices were collect.

Collective managing costs were calculated per hectare while the costs for individual manage were calculated per plant. The taxation was not included in the model and even harvesting costs (trees are sold as standing trees "stump price").

Growth values were referred to a case study in the province of Mantua, whose data have been published in Castro *et al*. (2013) and Buresti Lattes *et al.* (2007). Costs for planting and management of poplar and walnut models were obtained from Buresti Lattes *et al.* (2008, 2014) and Mori (2009). For polycyclic Tree farms models, data were collected during the 2014 and 2015 in the case study of the InBioWood Life + project in Legnago (VR) by the Consorzio Bonifica Veronese. The data was subsequently integrated through direct interviews to tree farmers in the provinces of Mantova and Cremona. As for the prices, for the poplar stump price were used prices tracked by the Borsa Merci of Camera di Commercio of the CCIAA of Mantova during the 2015 (results in line with those collected from other agencies). For the other prices was referred to those detected by Borsa del Legno of the Tecnico & Pratiko magazine (numbers 114, 116, 117 and 119) and market analysis carried out within the InBioWood Life + project and published by Pasini and Pividori (2014 and 2015). Finally, costs and prices relating to agricul-



Main tree with medium-long cycle - n. trees 13.9 x 2 = n. trees initial 27.8; n. trees final 19.9/ha

Dual role trees with very short cycle (firewood) - n. trees 277.8/ha

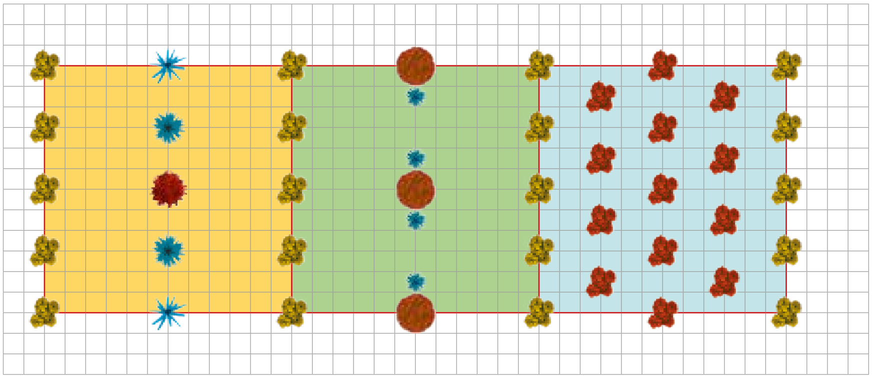
Accessory shrub - n. trees initial 250/ha

Main tree with short cycle (poplar) - n. trees initial and final 111.1/ha

Accessory tree - n. trees initial 13.9/ha

Total number of plants per hectare in planting phase =680.6

Figure 13.1 - The Tree farm layout of **model 3** (3P Tree farm). Red continuous vertical lines indicate points of separation between the Blocks with Main Trees with the same production cycle length, whereas background with different colour mark the Blocks with Main Trees of medium-long cycle than those with main trees of short cycle. Any square represents 1 m^2.



Main tree with medium-long cycle - n. trees 23.9 x 2= n. trees initial 46.3; n. trees final 23.15/ha

Main tree with short cycle (poplar) - n. trees initial and final 46.3/ha

Main trees with very short cycle (firewood) - n. trees 277.7/ha

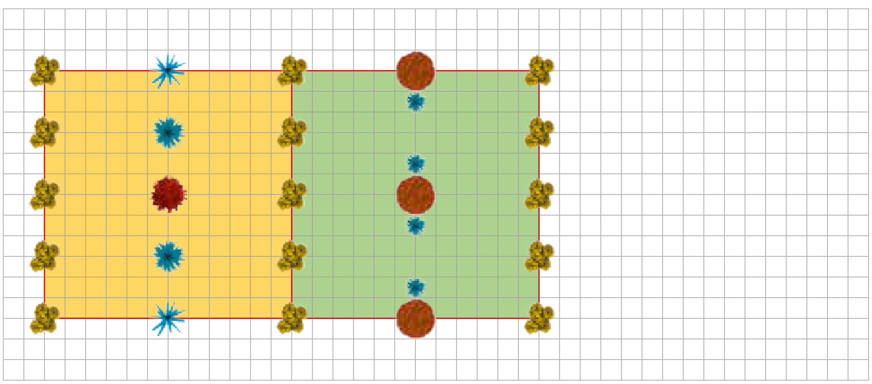
Dual role trees with very short cycle (firewood) - n. trees 277.7/ha

Accessory tree - n. trees initial 23.15/ha

Accessory shrub - n. trees initial 139/ha

Total number of plants per hectare in planting phase = 810,15

Figure 13.2 - The tree farm layout of **model 4** (3P tree farm). Background with different colour mark the Blocks with Main Trees of different production cycle. Any square represents 1 m^2.



Main tree with medium-long cycle - n. trees 34.7 x 2= n. trees initial 69.4; n. trees final 34.7/ha

Main tree with short cycle (poplar) - n. trees initial and final 69.4/ha

Dual role trees with very short cycle (wood biomass) - n. trees 277/ha

Accessory tree - n. trees initial 34.7/ha

Accessory shrub - n. trees initial 208.3/ha

Total number of plants per hectare in planting phase = 659,7

Figure 13.3 - The tree farm layout of model 5 (3P Tree farm). Background with different color mark the Blocks with Main Trees of different production cycle. Any square represents 1 m^2.

Model	Species	Number of trees (piante/ha)		Rotation (years)		Number of rotation cycle in the model
		At rotation start	At rotation end	High fertility	Medium fertility	
Poplar (**Model 1**)	*Populus x canadensis* clone I-214	278	278	10	12	1
Walnut (**Model 2**)	*Juglans regia*	100	100	20	27	1
Polycyclic tree farms with prevalence of wood biomass production (**Model 4**)	*Platanus x acerifolia*	463	463	6	7	3
	Populus x canadensis clone I-214	46	46	10	12	2
	Juglans regia	46	23	20	27	1
	Accessory plants (trees and shrubs)	162	0	10	12	1
	Total	718	532	-	-	-
Polycyclic tree farms with prevalence of rotary-cut veneer production (**Model 3**)	*Platanus x acerifolia*	278	278	6	7	3
	Populus x canadensis clone I-214	111	111	10	12	2
	Juglans regia	28	14	20	27	1
	Accessory plants (trees and shrubs)	264	0	10	12	1
	Total	681	403	-	-	-
Polycyclic tree farms with prevalence of valuable timber (**Model 5**)	*Platanus x acerifolia*	278	278	6	7	3
	Populus x canadensis clone I-214	69	69	10	12	2
	Juglans regia	69	35	20	27	1
	Accessory plants (trees and shrubs)	243	0	10	12	1
	Total	659	382	-	-	-

Table 13.1 - Cultural model for tree farming.

Model	Variable	Product	Unit of measurement	Value
Agriculture	Prices	maize silage	€/q	4
		maize grain		16,3
		soy		35
Plantations	Walnut price	sliced veneer	€/m³	300
	Poplar price	rotary-cut veneer	€/m³	55
		paper	€/t	25
	All the species	woodchip	€/t	10
	Plane tree price	firewood	€/t	35

Table 13.2 - Prices of agricultural and forest products.

tural crops, was referred to Trestini and Bolzonella (2015) and the data collected in the case study of the Bosco Limite, in the province of Padua, for the period 2005-2015 (De Carli 2015). Table 13.2 summarize the prices used for the analysis.

13.3 Calculation of profitability index

In the third phase, cash flow was simulated and two profitability indicators were calculated for all the 26 models: the Net Present Value (NPV) and Internal Rate of Return (IRR). Methods of calculation and benchmark of the two indicators are provided by specialized literature (Bernetti and Romano 2007, Pettenella and Toffanin 2008). As basic scenario a 3.5% of discount rate was used, as suggested by analyses specifically addressed to the Italian context (HM TREASURY 2003), excluding public support and land renting cost. It follows that the values of VAN per hectare provided do not provide the net income (which would include the cost of capital-land use) but the land income.

Sensitivity analysis

Finally, a sensitivity analysis was conducted to test the effect of different factors on the profitability of the models we have compared:

- first, different discount rates using the 2% (BOT ten-year) a 5% were compared, as suggested by the European Central Bank and finally the 8% was applied, as used in analyses of global reference on forest plantations (Cubbage *et al.* 2014);
- the effect of public support has been tested, taking into account the direct payments of the European Union Common Agriculture Policy (Bolzonella *et al.* 2014) and project based subsidies of the Rural Development Plan, considering the level of average contribution, the conservative scenario and the best scenario RDP 2014-2020 of Friuli Venezia-Giulia, Emilia-Romagna, Lombardia and Piemonte;
- the effect of the payment of a cost of land use has been tested, accounting for both renting (462 €/ha per year) and land purchasing(33,800 €/ha), on the basis of prices and land values for the lowland Northern Italy land in 2014 recorded by CREA (2015). Both these last two hypotheses were tested either in presence or absence of an average level of contribution.

13.4 Results

The Table 13.3 shows the costs of land plot preparation, planting, management and incomes for each of the twenty models of wood plantations. The cost of land plot-preparation/planting and management of a plantation varies between 2,469 €/ha for walnut and 9,898 €/ha for poplar and the average cost of land plot-preparation/planting is 5,293 €/ha. Soil preparation costs are homogenous, while higher variability is found in planting costs ranging from 487 €/ha for walnut to 2,591 €/ha for the model of biomass production prevalence of Polycyclic Tree farm with a standard deviation of 714 €/ha mainly due to the number of trees planted. Management costs also show great variability ranging between 1,563 €/ha of walnut and 7,584 €/ha of poplar. In Table 13.3 mean annual diametrical increments are also shown, resulting from the sum of commercial components of biomass for energy purposes and round timber for rotary-cut and sliced veneer for each model. The mean annual diametrical increments ranges from 1.4 m^3/ha/year of walnut up to 26.9 m^3/ha/year in poplar and 26.6 m^3/ha/year for Polycyclic Tree farms with high fertility.
Incomes over a twenty-year production cycle ranging from a minimum of 11,734 €/ha for walnut tree farms to a maximum of €/ha 24,998 for the 3P tree farms with poplar.

Profitability rank refers to scenario-based, NPV (expressed in terms of VAN/ha/year in order to allow a comparison on a consistent basis between investments of different length and extension) and IRR are shown for all 26 models in Table 13.4.
Although the model of maize silage (in conditions of high fertility and with minimum costs due to submergence irrigation) offers much higher income (1,429 €/ha/year), the same model in a situation of increased costs is at a level of profitability (728 €/ha/year) that is in line with that of the model aimed at greater rotary-cut veneer production in Polycyclic Tree farms with high fertility and minimal cost (669 €/ha/year).
If we take into account the average among models, divided by type (arable land, walnut, poplar, 3P tree farms), we see that arable crops have an average NPV of 457 €/ha/year but show great variability linked to site fertility and costs conditions. The 3P Tree farms models have an average NPV of 423 €/ha/year. The models of traditional poplar plantations have an average NPV of 213 €/ha/ year and offer good opportunities for income in situations to high fertility. The models of Tree farming with walnut[13] have a lower average NPV of 166 €/ha/year, mainly due to the low growth rates not fully compensated by the market price presently at its minimum.
As for the SRI, this varies from 4.9% for the walnut model in medium fertility sites with maximum costs to 16.4% for 3P tree farm

13) With regard to walnut and Polycyclic tree farms, other possible revenues not related to wood production (e.g: rental land for beekeeping, truffles production) were not taken into consideration.

Model			Rotation (years)	Mean annual increment (m^3/ha/year)	Costs (€/ha)				Income (€/ha)
					Site preparation	Planting	Management	Tot costs	
Walnut		High fertility and minimum costs	20	1,9	463	443	1.563	2.469	11.734
		High fertility and maximum costs	20	1,9	679	734	2.518	3.931	11.734
		Medium fertility and minimum costs	27	1,4	463	443	1.563	2.469	11.734
		Medium fertility and maximum costs	27	1,4	679	734	2.518	3.931	11.734
Poplar		High fertility and minimum costs	10	26,9	463	1.084	4.524	6.071	12.931
		High fertility and maximum costs	10	26,9	679	1.635	7.030	9.344	12.931
		Medium fertility and minimum costs	12	22,4	463	1.084	4.890	6.437	12.931
		Medium fertility and maximum costs	12	22,4	679	1.635	7.584	9.898	12.931
3P tree farms	Valuable timber	High fertility and minimum costs	20	20,5	463	1.517	1.992	3.972	18.302
		High fertility and maximum costs	20	20,5	679	2.527	2.900	6.106	18.302
		Medium fertility and minimum costs	27	15,2	463	1.517	1.992	3.972	20.360
		Medium fertility and maximum costs	27	15,2	679	2.527	2.900	6.106	20.360
	Rotary-cut veneer	High fertility and minimum costs	20	26,6	463	1.530	2.424	4.417	22.179
		High fertility and maximum costs	20	26,6	679	2.523	3.505	6.707	22.179
		Medium fertility and minimum costs	27	19,7	463	1.530	2.424	4.417	24.998
		Medium fertility and maximum costs	27	19,7	679	2.523	3.505	6.707	24.998
	Wood biomass	High fertility and minimum costs	20	23,0	463	1.530	1.625	3.618	15.903
		High fertility and maximum costs	20	23,0	679	2.591	2.380	5.650	15.903
		Medium fertility and minimum costs	27	17,0	463	1.530	1.625	3.618	17.910
		Medium fertility and maximum costs	27	17,0	679	2.591	2.380	5.650	17.910
Mean				17,5	571	1.623	3.099	5.293	16.898
Standard deviation				8,9	111	714	1.703	1.973	4.522

Table 13.3 - Costs and incomes for 20 different models of tree farming.

Rank(*)	Typology	Model	NPV (€/ha/year) r=3,5%	IRR
1	Maize silage	High fertility and minimum costs	1429	-
2	Maize silage	High fertility and maximum costs	728	-
3	Polycyclic - Rotary-cut veneer	High fertility and minimum costs	669	16,4%
4	Polycyclic - Rotary-cut veneer	Medium fertility and minimum costs	543	13,5%
5	Polycyclic - Rotary-cut veneer	High fertility and maximum costs	524	11,5%
6	Polycyclic - Valuable timber	High fertility and minimum costs	509	13,9%
7	Poplar	High fertility and minimum costs	454	12%
8	Polycyclic - Wood biomass	High fertility and minimum costs	440	13,7%
9	Policicliche - Sfogliati	Medium fertility and maximum costs	425	10%
10	Polycyclic - Valuable timber	Medium fertility and minimum costs	399	11%
11	Polycyclic - Valuable timber	High fertility and maximum costs	372	9,5%
12	Polycyclic - Wood biomass	Medium fertility and minimum costs	353	11%
13	Polycyclic - Wood biomass	High fertility and maximum costs	307	9%
14	Poplar	Medium fertility and minimum costs	303	9%
15	Maize silage	Medium fertility and maximum costs	300	-
16	Polycyclic - Valuable timber	Medium fertility and maximum costs	287	8%
17	Walnut	High fertility and minimum costs	266	10,0%
18	Polycyclic - Wood biomass	Medium fertility and maximum costs	244	8%
19	Walnut	High fertility and maximum costs	176	7,0%
20	Maize grain	High fertility and maximum costs	152	-
21	Walnut	Medium fertility and minimum costs	148	7%
22	Poplar	High fertility and maximum costs	106	5%
23	Walnut	Medium fertility and maximum costs	74	5%
24	Maize grain	Medium fertility and minimum costs	69	-
25	Soy	High fertility and minimum costs	64	-
26	Poplar	Medium fertility and maximum costs	-10	n.d.
1	Mean arable lands	457	-	-
2	Mean 3P tree farms	423	11,3%	-
3	Mean poplar	213	8,4%	-
4	Mean walnut	166	7,2%	-

Table 13.4 - Financial revenue in scenario-based of the 26 models of Tree farming and agricultural crops.
(*) The ranking is based on NPV per hectare per year. We remember that the NPV set out the land income does not include the cost of capital-land use.

model with main production of poplar rotary-cut veneer in high fertility sites with minimum cost. The average SRI fluctuates between 7.2% of walnut to a maximum of 11.3% of 3P tree farms[14].

Table 13.5 shows the results, aggregated by typology, of the sensitivity analysis conducted by testing on the scenario-based the effect of several factors on the profitability of the models considered. If the analysis uses the discount rate of 8% (international reference), profitability remains positive just for arable crops and 3P Tree farms. The competitiveness of Tree farms production in respect of arable crops is maximum if we take into consideration a discount rate of 2%.

The main element that emerges from the analysis is the fundamental role of public financial support of the contributions CAP and RDP for Tree farms referred to in programming period 2014-2020. In the presence of the contributions CAP and RDP tree farms systematically become competitive with arable crops.

Finally, if we assume the inclusion of a cost for the land (a rental or a land benefit tied to the purchase of the same), no investment, even into arable crops, is positive. Only in case of a rental land and only with the support of CAP and RDP the investment becomes positive.

Considerations on evaluation results LIFE+ InBioWood

This work presents a first systematization of cost data and profitability of Tree farms in Northern Italy.

Relevant are the contributions of the CAP and RDP regional, in the absence of which would be very difficult to support the costs of land use. Among the most lucrative plantations are the Polycyclic for the prevailing production of poplar rotary-cut veneer which combines the traditional culture of poplar with the production of biomass for energy and valuable timber. However it has to be taken into consideration that although the 3P Tree farms are the most promising financially, they remain an example still limited in terms of extension, then basically experimental tests.

In addition the 3P tree farms, being mixed plantations, require management techniques more demanding than for conventional plantations and must therefore be accompanied by appropriate training for technicians and operators. On the other hand 3P Tree farms have different market and production times: this will allow, in perspective, to better manage the risk components of investment than monospecific tree farms. Evidently, considering aspects of risk and therefore the waiting time for investors to have the costs covered by incomes (see payback period), the annual agricultural productions have a greater attractiveness.

Finally, this work, carried out under the LIFE+ InBioWood, highlights one of the most limiting factors for the development of investment in tree farms in Northern Italy: prices of lumber that, poplar excluded, are uncertain. This is due to the fact that the market is far from being well structured and consolidated. Under conditions of great instability in the prices of final products (condition that occurred for forestry productions and especially for those agricultural in recent years), annual investments allow to have more flexibility and ability to market adaptation.

__14)__ Please note that these values do not include the cost of land and thus represent the land income and not net income.

Hypothesis	Index	Average agriculture crops	Average 3P tree farms	Average walnut	Average poplar
r=8% (international reference)	NPV (€/ha/year)	470,50	163,00	-35,00	-67,90
r=2% (ten-year BOT reference)	NPV (€/ha/year)	453,12	514,19	248,30	315,73
r=5% (European Central Bank reference)	NPV (€/ha/year)	461,00	334,00	92,00	115,00
with average PAC and PSR medium	NPV (€/ha/year)	796,35	1.014,07	686,80	784,26
Base, with average CAP and RDP	NPV (€/ha/year)	796,35	1.659,97	1.310,43	857,12
Base, with minimum CAP and RDP	NPV (€/ha/year)	796,35	927,18	577,63	747,83
Base, with land rent	NPV (€/ha/year)	-37,46	-68,90	-325,64	-300,48
Base, with land rent or average CAP and RDP	NPV (€/ha/year)	301,84	522,45	195,18	270,58
Base, with land purchase	NPV (€/ha/year)	-1.921,16	-760,28	-1.017,02	-969,79
Base, with land purchase or average CAP and RDP	NPV (€/ha/year)	-1.581,85	-168,93	-496,20	-398,74

Table 13.5 - Results of sensitivity analysis.

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GLOSSARY
main terms used in Tree farming for wood production

Tree farming (Arboriculture for wood production) is a relatively young and rapidly evolving discipline that is placed between the agricultural and the forestry worlds. For this reason Tree farming involves technicians and researchers from both worlds. A mixed terminology grew, including both expressions from agriculture and forestry, as well as neologisms typical of only Tree farming, specifically addressed to the issues of the new discipline. It is frequently that different terms are used to describe the same situation or that, conversely, the same term is used with different meanings.
The purpose of this glossary is to standardize the multiple technical expressions related directly or indirectly to the Tree farming in one widely accepted terminology.
That's why the first version of the glossary (in Italian), released in 2005 in the context of the project "Ri.selv.Italia 2.1", has been submitted to critical reading of specialists of the academic and research world engaged in Tree farming. From their revision the glossary came out more rich both in accuracy of definitions and number of terms. Two upgrades have followed the first glossary in 2007-2008 and 2016, with new terms accounting for the Tree farming evolution.

A

Accessory plant - A plant is attributed the role of Accessory tree or shrub when it makes easier the plantation management by the tree farmer and/or to influence positively the development of Main Trees.

Additional product - Product or benefit obtained without specific devoted actions during the Tree farm design or management.

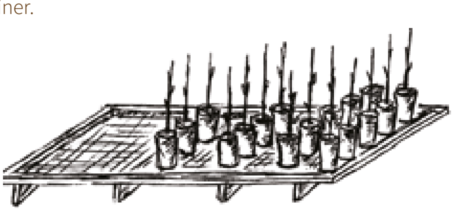
Adventitious bud - Bud that can found in any part of the stem, root or branch, lacking any connection with the pith.

Afforestation - Forest plantation in a land that has been without forest for almost 50 years, via plantation of seedlings, direct seeding and/or by supporting the natural regeneration.

Agroforestry - Growing trees in a land unit together with agriculture and/or animal farming.

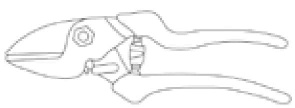
Agronomic Tree farming - Trees cultivation, in any land area, managed with high energy inputs.

Air pruning - Break of tissue growth of root apices when they reach the air. In a nursery, air pruning is deliberately made (setting containers on devoted drilled supports, allowing air to circulate without any obstruction) to prevent roots from deformation or spillage outside the container.



Allochthonous (if referred to the forestry context) - Indicates a forestry stand where propagation material is introduced from forest land other than that in exam.

Anvil blade - Cutting part formed by a blade sharpened from both sides and a flat anvil.



Apical shoot - Portion of stem produced in the last growing season (over one or more vegetation cycle).

Arboriculture - Trees cultivation addressed at obtaining products and/or benefits.

Architectural structure - Relationship between the above ground elements of the plant. These relations are the result of the genotype, environmental influences and possible human practices. In assessing the architectural structure, taking into account the plant age, we consider the relationship between the total height of the stem, the potential trunk, the real trunk, the crown depth, the crown width, the branches shape, their layout and their sizes.

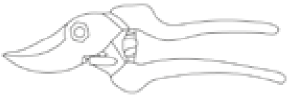
Assurgent branch - Branch that grow vertical. In some species, this type of branch, tends to develop a lot in length and diameter to the point that it can compete with the apex of the stem.

B

Bifurcation - Point at which a vegetative apex gives rise to two (or more) branches almost equivalent as for development, forming in general an acute angle between them.

Biomass - Commonly refers to the organic matter produced by photosynthetic processes.

Blade and counter-blade - Sharp body formed by an external cutting blade and a no cutting counter-blade. The two blades "passing by" each other to make the cut.



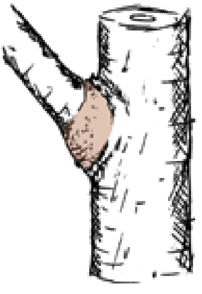
Block - The Block is the unit surface in which is ideally subdivided the entire land plot. A Block is conventionally featured by 3 basic elements:

- the surface area needed by the Main Trees with the longest production cycle to reach the target diameter;
- the trees and shrubs species which at different times and/or at different spaces (e.g. dominant layer certain trees and dominated layer certain shrub) will use part of the surface of the Block to develop;
- the plant's distribution in the Block and their mutual distances, from which depends the productive surfaces available to each plant to play its role, the synergy and positive competition among plants, as well as the production targets.

Bole (or trunk) - Stem portion that have reached a marketable size.

Bottleneck - Sudden narrowing in stem diameter caused by the presence of large branches.

Branch collar - Collar of cells, arranged at the point of insertion of the branches on the stem or on the branches of a higher order. The branch collar is capable of facilitating healing in the event that the branch be removed artificially (see Pruning) or by natural causes (see branch bark ridge of the branch collar).



Branch of Crown - Branch inserted in the stem near the start point of apical shoot of the last year.

Breaking (or *cassage*) - Practice aimed at limiting the development of branches that should be pruned, but not immediately. The breaking is performed by folding down and partially breaking of woody fibres.

Picture: Francesco Pelleri

Buffer strip - Buffer of vegetation with trees and shrub that separate a surface waters (e.g. trench, canal, river, lake) from a source of pollution, generally represented by an agricultural area.

Bush cutter - Denomination of the machine (portable) and/or of the tool (led and driven by the power take-off of the tractor) used to bush cutting.

Bush cutting - Mechanical removal of bushy vegetation (shrubs and/or grasses) through eradication, cutting or grinding.

C

Carbon sequestration - Process leading to increased carbon content of an ecosystem.

Carbon stock - The amount of carbon stored in an ecosystem or in un agro-ecosystem (e.g. forest, agricultural crops).

Chipping - Mechanical action which reduces the specific woody material in particles specifically sized in order to be used either in the paper or panels industry or for energy uses.

Chisel plough working - Deep tillage of soil (70-120 cm) to make it suitable for particular crops. Is achieved by means of special plows said, precisely, chisel plow (or chisel plough).

Chopping - Fragmentation of vegetal material with a mulching device attached to a tractor.

Clampdown - Cut of a small portion of the terminal part of a branch carried out during the growing season.

Clones - Vegetative offspring (ramet) from a single ancestor (ortet).

Compartmentalization - Dynamic process of defence implemented by plants around the wounds. Consists in the formation of barriers, structural and chemical, that hinder the pathogens spread.

Coppice shoot - The above ground part of a tree that originates from an adventitious or dormant bud, of the stump or roots, of a woody plant with coppicing ability; generally a broadleaved species that was cut.

Coppicing - Cutting near the ground level of trees and shrubs (essentially broadleaved trees), made to cause the shoots sprouting from stump and/or from root.

Coppicing ability - Aptitude of a plant species to reproduce the aboveground part from the stump after coppicing, from the stump or from surface roots.

Crop cycle (see vegetative cycle)

Crop planning - All the activity that are planned, from planting to final harvest, and which normally must be provided as an attachment to the final design of a Tree farming plantation.

Cutting of crown branches - In Tree farming is cutting whole or part of the branches of the crown, that is the branches born at the base of last apical shoot, and, by extension, to those who have the terminal bud placed above the insertion point of the apical shoot.

Cuttings - Pieces of the stem or branch, with buds, for plants vegetative propagation. Can also be used pieces of root (root cuttings).

D

Deep tillage - Soil tillage to a depth up to 50-70 cm

Defect - Trunk feature compromising, in whole or in part, a defined evolution, or an expected use.

Design with early decision - It defines, through a textual description and graphics, the production surface and the distance between the Main Trees, for each species and for each production target. The distance depends on the trunk diameter target we intend to achieve with strong increments: with the same species and growing conditions, the higher the target diameter, the higher the distance between plants (and surface for each tree). In the case of the production of valuable timber the diameter increment must be also constant. With early decision design is also consider the distance between main trees that will end their production cycles at different times (i.e. short cycle trees for valuable production and very short cycle trees for woody biomass). Some authors use the expression “plant in definitive scheme” to indicate plantations similar to those obtained with design with early decision .

Design with postponed decision - It does not define the tree final production surface and the distance between the Main Trees, for each species and for each production target. In this case the trees of medium-long cycle species are much more numerous than those who can get at the end of production cycle with strong and constant diameter increment, for species and site in which it was designed, and constants (see Potentially Main Trees). The identification of individual production surface and distance between Main Trees of each species is delayed in time and coincides with the last thinning. Some authors use the expression “plant in variable design” to indicate Tree farms similar to those obtained with design with postponed decision.

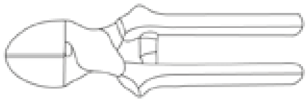
Designer - Person who balances into a planting scheme and crop planning the set of information on the land plot where the plantation will be established, on the ecological needs of species to be used, on socio-economic features (both local and general), on farm organization and production targets defined in agreement with the tree farmer. The designer takes precise responsibilities of technical and legal character in front of the tree farmer and any third party.

Direct seeding - Plantation made by distribution of seed in the land plot.

Director of works - The person in charge, from the technical and legal point of view, of the yard devoted to the realization of a project and/or of a specific cultivation action.

Dormant bud - Bud that is found in any part of the stem, root or branch, having connection with the pith.

Double blade - Sharp cutting tool formed by two equal and symmetric blades, which cut closing on the same axis.



Double function tree - Particular example of Multifunctional Tree farming, typically refer to walnut (*Juglans regia* L.), when the production objectives are both wood assortments and fruits.

Double tree - Trees planted in pair, Potentially Main Trees, one of which will be early (3-5 years) selected for the role of Main Tree.

Dual-Role Tree - Accessory tree that in addition to influence the architectural structure of Main trees and control weeds, also providing wood assortment The dual role can be attributed to relatively rapid growth trees species, that have a production cycle shorter than that of Main Trees on which they exert their influence. For example, poplar trees with dual role placed at suitable distance, can simultaneously produce logs for rotary-cut veneer and, like the Accessory trees, the slender structure in walnut tree, inducing a better pruning (Figure 3.9).

E

Ecotype (race) - Intra-specific entity that has particular biological characteristics deriving from the effect of selective pressures from a particular environment.

Equilateral triangle design - Arrangement of plants at the vertices of an equilateral triangle.

Establishment - Plant development after planting, which is showed with the full activity of absorption and transport by existing roots and/or by newly formed roots.

Establishment stage - Period of time between planting and complete establishment of a plant.

Exotic (if referred to the forestry context) - Species planted in an unusual geographical area, far away from its native geographic area (e.g. Douglas fir in Italian plantations).

External support - It is the set of subjects which while not carrying out activities aimed at a specific plantation, with their work can make a major contribution to the core of each plantation operating (i.e. research, public administration, machinery production, dissemination of best practices)

F

Fork (see Bifurcation)

Formative pruning - Selective elimination of branches aimed at the production of a trunk with desired characteristics (potential trunk) at least as long as the theoretical target.

Function of a plantation - General purpose that is assigned to each facility (i.e. produce timber, produce fruits, reduce pollution in waterways, lessen the intensity of the wind, improve landscape ...) not to be confused with the production goal (see production goal).

Fungicides - Pesticides used to control fungal diseases of plants.

G

General production target - General purpose for which a plantation is established (e.g. produce round timber for sliced veneer of walnut, produce round timber for saw of cherry, produce woody biomass of willow ...)

Geometric thinning (mechanical or systematic) - Thinning technique whereby trees are felled with a spatial criteria determined a priori.

Girdling - Removal of a narrow ring of bark and cambium along the whole stem circumference of a standing tree. In Tree farming the girdling, similar to a thinning, can be carried out to induce the gradual death of Accessory plants or Potentially Main Trees. The girdling can be practised to avoid adverse reactions when the Main Trees are suddenly isolated.

Picture: Francesco Pelleri

Green pruning - Cutting of unwanted branches made when the plant is in vegetation period.

Growing season - In boreal and temperate climate zones is the period between the first production of spring leaves and the beginning of winter dormant stage. In a growing season, particularly for broadleaved species, we can have more than one stage of growth (see vegetative cycle).

Guy line for trees - Tie rod for anchoring unstable plants.

H

Hacksaw - Cutting tool consisting of a metal foil of variable length, equipped with sharp teeth and ergonomic handle. Allows to cut up to heights of about 50 cm higher than the pruner on branches with a diameter greater than 3 cm.

Hedge - Linear vegetable formation composed of only shrubs or shrubs and trees.

Hybrid (interspecific) - Individuals deriving from the crossing of two different species.

I

Indicator species - Plant species in specific environmental contexts, used for defines ecological characteristics details of a land plot.

Indigenous (if referred to Forestry context) - Term qualifying an artificial tree stand created under the native distributional range of the species used (indigenous to a given area).

Individual target - Tree height up to which the trimmer decides to implement productive pruning. This height is referred to as “Individual target” because it can vary from plant to plant depending on its characteristics.

Individual tree protection - Mechanical or chemical protection of individual plants against certain pests, animals or other causes of damage (eg. installing tree shelter).

Isosceles triangle design - Arrangement of plants at the vertices of an isosceles triangle.

L

Lammas growth - Secondary shoot (see vegetative cycle) that many broadleaved tree species, in relation to the seasonal pattern, develop in the period between June and July.

Land plot - Portion of land devoted to a particular cultivation.

Land plot preparation - Set of operations including soil tillage, fertilizations (if any) and water facilities to be made before installing the planting stocks.

Land plot restoration - Series of operations that are done after the Tree farm final harvest to return arable land: stumps removal, chipping of tree residues, removal of superficial root system with successive grubber passages, tillage.

Lateral tree protection - Plant protection system against natural phenomena potentially trees damaging (e.g. wind)..

Lignocellulosic biomass - Biomass rich of lignin and/or cellulose, poor in oil and starch.

Linear plantation - A plantation along a prevalent axis whose ratio between width (max. 20 m) and length is equal to or less than 1/10.

Log - Trunk segment cut at a definite length suitable for the purpose of further processing.

Loppers - Pruning tool suitable for cutting large branches. The mechanics adopted more frequently on the loppers is a compound lever (the long arms are advantageous levers) useful to amplify the force exerted by the operator. The tool allows to cut branches with a diameter not exceeding 5 cm up to 60-80 cm height , higher than that of the pruner.

M

Main Tree - A plant is attributed the role of Main tree when provides at least one of the main products for which the Tree farm was designed.

Management with decision postponed - Management in which the individual tending operations are carried out in favour of all the Potentially

Main Trees. The Main Trees will be selected with the last thinning.

Management with early decision - Management in which the individual tending operations are made only in favour of Main Trees.

Minimum distance - The shortest distance between two plants needed to achieve the expected result.

Mixed plantation - Plantation whose Main Trees belong to two or more species.

Mixed plantation with Accessory plants - Plantation with Main Trees of two or more species and Accessory trees or shrubs, are inserted with the aim of favouring the plantation management and/or positively influence the Main Trees development .

Monoclonal plantation - Pure plantation with plants from a single clone.

Monocycle plantation - Plantation with Main Trees with the same production cycle length to be harvested at the same time.

Mono-objective Tree farming - Tree cultivation designed to obtain only one type of wood product. In this type of Tree farming you can also get, as a side production, other product assortments of lower value than the main plantation assortment.

Mulch - Soil coverage, made with products from different materials, with the aim of keeping down weeds and facilitate crop growing.

Multifunctional tree farming - Tree cultivation designed to satisfy multiple functions (e.g. timber production and reduction of pollutants into waterways, or, in the case of common walnut, timber and fruit, typically called dual purpose).

N

Native (if referred to the forestry context) - Naturally renovating plantation at the place where it originated or where it was introduced in ancient times (Etruscan or Roman age).

Native seed zone (or region of provenance) - Locate the territory or collection of territories subject to sufficiently uniform ecological conditions and on which there are stands or seed sources with similar phenotypic and genetic characteristics.

Naturalistic Tree farming - Tree cultivation, in any land area, designed to take advantage of natural dynamics (e. g. positive competition between trees, natural nitrogen fixation, weed control) able to condition the vigour and shape of Main Trees as well as cropping intensity.

Negative competition (or a negative effect) - Competition between plants that has negative effects for the achievement of one or more plantation objectives (e.g. reduction of diameter increments of Main Trees).

Nursery container - Container variable in shape, material and dimension, where stock from seed or transplant is planted and remains until the next transplant (in a different container or flowerbed in full field) or planting. Depending on its material, the container can be removed at the time of planting or buried with planting stock root system.

O

Open-field plantation - In Tree farming it refers to a plantation where the ratio between width and length is greater than 1/10. Not to be confused with the same agriculture expression indicating outdoor cultivation (out of greenhouse).

Operational team - Team directly or indirectly working, simultaneously or at different times, in a definite plantation (e.g, tree farmer, project designer, director of work, nurseryman, agricultural worker, contractor, customer).

Origin - Place where a native population originated and evolved. In the case of a non-indigenous population, is the place from which it was originally sampled and subsequently propagated in different context. Sometimes the origin may be unknown (in the case of to the times when the certification of origin/source was not required)

Overall tree protection - Mechanical protection of the whole plants present in a Tree farm against certain animals (e.g. fence).

Q

Qualification stage - Period of time between complete establishment of a plant and the achievement of the individual target (see Individual target).

P

3P Tree farms (or Potentially Permanent Polycyclic Tree farms) - For 3P means the Tree farms established with the characteristics and purposes of Potentially Permanent Polycyclic Tree farming (see definition).

"Parachute" Accessory plant - In addition to performing the normal functions of an Accessory plant, the "parachute" Accessory plant must also:

- perform a function of future insurance because it can replace a Main Tree if that will not be able to achieve the expected goal;
- be pruned as the Main Trees.

When it becomes necessary make thinning we must decide whether to cut it or give it the role of the Main Tree and cut one of the Main Trees that had been considered in the design phase.

Partial taproot cutting - Partial cutting of the taproot of bare root plants. It is performed ,both during the growing season that at the end of the growing season, through a blade to a depth between 5 and 20 cm (within tree nursery).

Pelletization - High pressure extrusion of shredded wood through the holes of special steel matrices. Friction develops high temperatures and lignin plasticizes slightly forming a natural binder of pellet and gives them a hard, smooth and glossy surface.

Pellets (Pellet fuel) - Small assemblies of cylindrical shape obtained by compression and agglutination of shredded material of wood (pelletization). They are characterized by low humidity and are used for fuel to power stoves and automatic boilers.

Permanent branch insertion - Point where the main branches of the crown are inserted.

Phytoremediation - Land recovering (remediation) through the use of living plants. Improving the land quality, can take place through processes of volatilization, absorption, removal, stabilization and degradation.

Plant examination - Method of plant investigation, mainly used in the establishment and qualification stages (see definitions below), which consists in the identification and study of the architectural structure and/or significant morphological details for tending operations.

Plant-transplanter - Tool used for quick planting of small seedlings containerized.

Plantation - Set of trees or set of tree and shrubs planted in a specific plot.

Planting design - Geometric arrangement of plants.

Planting distance - Distance between plants in a Tree farm.

Planting scheme - It is a graphical layout showing:
- shape and size of the block;
- one or more sample blocks for each of the selected production cycles. In each type of block positions with mutual distances should be represented for:
  - Main Trees;
  - Dual-Role Trees (if any);
  - Accessory trees (if any);
  - Accessory shrubs (if any).

  By overturning or shifting of the planting scheme it should be possible to represent the whole Tree farm. The scheme is therefore as the combination of 1, 2 or more tiles (in this case Blocks) of a floor that defines a repetitive geometric pattern (Figure 3.12). For this reason, as shown in the example (Figure 3.11), both in the block and in the scheme, either whole plants or portions of them should be visible.

Planting stock - Generic name of tree nursery product intended for Tree farm. The tree nursery with regard to planting stock obtained from seed distinguishes the seedlings and transplants, while in the case of seedlings obtained by vegetative propagation indicates the rooted cuttings, poles and grafted plants.

Plant's role - Function attributed to each plant in order to obtain the technical and/or financial results expected or to facilitate the plantation management. This function (role) has to be determined in the designing stage, if it had not occurred or if the conditions for the development of the plantation could required (e.g. Main Trees were not able to reach the productive target) we can assign or change the role of some tree during the plantation management.

Plants growth in container - Growing the planting stock in special containers or pots for the production of propagation material be marketed with roots-ball plants seedlings.

Plants growth in open field - Growing the planting stock, in nursery bed in open field, for the production of propagation material be marketed with bare roots.

Plants grown in tree wicking beds - Growing the planting stock, marketed bare roots, in special nursery bed called tree wicking beds (see tree wicking beds).

Plough pan - Soil layer more compact, located over the horizon the undersurface land plot, which originated after repeated processing (e.g. ploughing) to the same depth or in particular agricultural condition. It limits the deepening of the root system and water percolation.

Pole - Planting stock without branches (e.g. poplar pole of 1 or 2 year).

Pollard - Denomination of the architectural structure of a pollarding broadleaved tree.

Pollarding - Operation that consists in cutting the stem at specific height with the aim to control the growing and reach new shoots.

Poplar plantation - Tree farm specialized in wood production of poplar .

Poplar planting stock (or pioppella) - Poplar nursery planting stock of 1 or 2 years. At the time of planting the pioppella is reduced to "bare rod", severing all branches close to the trunk and shortening the roots or even eliminating them with a cut near the collar.

Polyclonal plantation - Pure plantation with plants of two or more clone.

Polycyclic plantation (see Polycyclic Tree Farming)

Polycyclic Tree farming - A plantation is defined Polycyclic Tree farm if it has, in the same plot of land, at least one of the following characteristics:
- blocks (see definition) with Main Trees of different productive duration cycle;
- blocks with Main Trees of equal rotation cycle length and Dual-role Trees of short cycle;
- blocks where Main Trees have equal rotation cycle length, but with harvest times delayed each other for at least 20% of the blocks after some time of at least 30% of the production cycle length (e.g.. plantations for only wood biomass or only poplar rotary-cut veneer production in which with a 10-years cycle you can harvest 50% of the plantation every 5 years).

Positive competition (or a positive effect) - Competition between plants that has positive effects for the achievement of one or more plantation objectives (e.g. acquisition of a slender architectural structure characterized by small diameter branches).

Potential trunk - Maximum potential length of the bole, with the desired characteristics, expected at the time of plant examination.

Potentially Main Tree - Tree that is pruned as if it were actually Main Tree but that is at a lower distance (and insufficient surface) than the minimum needed to achieve the production target with constant diameter increment (Figures A-B). After one or more thinning could be considered Main the trees which distance is equal or more than the minimum needed to achieve the expected diameter target with constant increments (Figure C).

Potentially Permanent Polycyclic Tree farming (3P Plantation) - A polycyclic plantation can be defined a Potentially Permanent Polycyclic Tree farm (or 3P plantation) if Main Trees of longer cycle, at harvesting time, don't cover with their crowns the entire plot of land, but occupy completely only a part of blocks of Tree farm (at maximum 80% in number). For this in the rest of blocks Main Trees of different duration cycles or with harvest times delayed will grow without problems. (Figure 3.11 and 3.12).

Potentially usable species - Species of trees and shrubs that can be inserted in a Tree farm taking into account the ecological characteristics of a land plot.

Premature branch - First-order branch which develops in the same year of the apical shoot where it is placed.

Productive cycle - The period between planting and the final cut of the Main Trees.

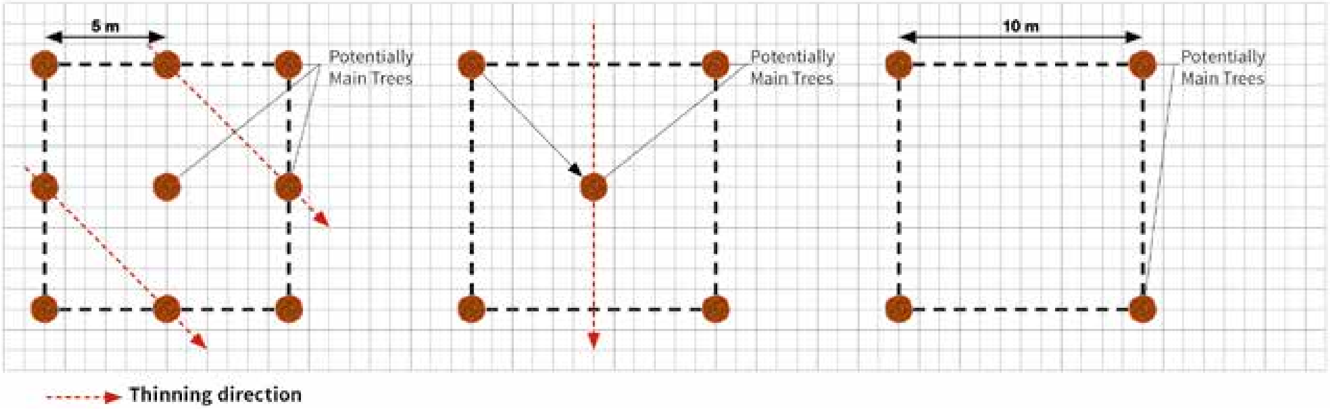


Figure A Figure B Figure C

Productive pruning (see limbing up) - Gradual cutting from below of stem branches. The operation is repeated until length of real trunk is equal to length of individual target. The productive pruning also aims to contain knots and defects in a central cylinder (the stem of the young plant) that has the smallest possible diameter, without cause excessive stress to the plant.

Project - Detailed work plan, consisting of textual description and graphics to represent the planting scheme and crop planning, aimed at achieving the production target through the establishment and management of a specific plantation. The project includes also technical and estimation papers like price list and bill of quantities.

Progressive pruning - A posteriori pruning technique whereby the operator lefts the plant to develop and then converts it into an architectural structure as close as possible to the one suitable at getting the planned production.

Provenance (of the reproductive material) - The place where are collected productive material in a specific populations. It can be an artificial or natural population and may coincide with the origin or not, as in the case of alien plant species .

Pruning - Combination of cutting interventions aimed at influencing the architectural structure of the plant.

Pruning a priori (approach to) - Approach that aims to remove branches in advance to induce the plant to produce, during the next growing season, the desired architectural structure.

Pruning a posteriori (approach to) - Approach that aims to remove unwanted branches that were produced by the plant during the previous growing season.

Pruning back - Cutting a piece of branch. In Tree farming this operation is carried out immediately above a bud or twig inserted at the bottom of the branch to prune.

Pruning saw (see hacksaw)

Pure plantation - Plantation having Main Trees from a single species.

Pure plantation with accessory plants - Plantation Main Trees of a single species and Accessory plants of two or more species, trees or shrubs, inserted with the purpose of favour the plantation management and/or positively influence the Main Trees development.

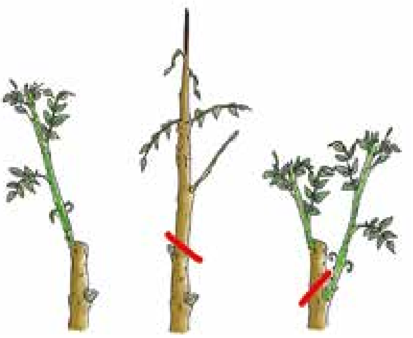
Q

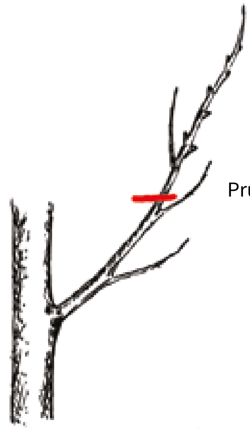
Quiescence - In botany arrest or slowdown of plant (or organ) activity.

R

Real trunk - Length of the free branch bole and that, at the end of the qualification stage, will coincide with the individual target.

Recovery apical dominance - Replacing a vegetative apex damaged by a bud or the best of the branches nearest below, to vigour and position.





Rectangular design - Arrangement of plants at the vertices of a rectangle.

Reforestation - Conversion, by plantation, direct seeding and/or by favouring natural regeneration, of a deforested area in the recent past. For the purposes of the Kyoto Protocol and subsequent efforts to contain climate change, reforestation activities relate to those carried out on areas that was not a forest on December 31, 1989.

Reiterative pruning - A priori pruning technique bringing the plant towards a precise architectural structure. It is repeated every year until the production target is obtained.

Ripping - Tillage, usually deep, without inverting the soil horizons. It is made with the purpose to break the possible “plough pans”, facilitate the deepening of the root system, facilitate the drainage and aeration and increase the “field capacity” of the soil. Sometimes known as “subsoiling”.

Rod pruning - Systematic elimination of buds issued along the stem except that apical until to obtain the theoretical target length of the real trunk (maximum 2-3 year) .

Root asphyxia - Condition of lack of oxygen in the environment surrounding the plant’s root system.

Rotary cutting - Industrial transformation whereby you can reduce in veneers (rotary cut veneer) a trunk with adequate characteristics.

Rotary cut veneer - Thin sheet of wood obtained by rotary cutting. The rotary cut veneer is also known, generically, as veneer.

Round timber for rotary cut-veneer - Trunk suitable to rotary cutting process for veneer production (rotary-cut veneer).

Round timber for saw - Trunk suitable to sawing process for sawn timber production.

Round timber for sliced veneer - Trunk suitable to slicing process for veneer production (sliced veneer).

S

Sawing - Industrial process producing sawn timber (e.g. boards, beams, laths, scantling) from round timber.

Sawn timber - Generic term for products obtained by sawing of logs.

Seedling growth inhibitors - Active chemical herbicide in the period between the stage of seeds germination and seedlings

Seedling - Plant that, in natural environment or in nursery, growing where the seed has germinated. This term is also referred to the planting stock from seed that has not been transplanted.

Seedling film bag - Plastic film package, used in plant nursery. To be removed just before planting the stock.

Secondary tillage - Soil tillage to a depth equal or lower than 30 cm.

Selective Thinning - In Tree farming is a thinning aimed to release Main trees (or Potentially Main Trees) from its direct competitors.

Set-aside - Temporary rest of a cultivated land or their use for non-food crops.

Shears - Tool, similar to scissors, used for pruning of branches up to 2.5-3 cm in diameter. The drive can be mechanical, hydraulic or pneumatic.

Shelter - Sleeve with a great variety of different shapes and sizes, used for individual protection of planting stock from the bite of animals in the early years of plantation.

Shoot - Portion of stem or branch grown in a vegetative cycle.

Short Rotation Forestry - The cultivation of fast-growing tree species on farmland, with high density (10-15,000 plants/ha), repeated coppicing in short rotation cycle (1-6 years) and with cultivation practices similar to those used for agricultural crops (see Arboriculture short cycle).

Site - Topographically defined area on which uniform ecological conditions suitable for a single natural vegetation.

Sizing stage - Period of time between complete establishment of a plant and achievement a stem diameter suitable at the economic target of the tree farmer.

Slenderness coefficient (or taper) - Relationship between total plant height and diameter at 130 cm from the ground. In the case of planting stock the diameter is measured at collar. It is mechanical stability index in the case of adult plants or it is quality index in the case of nursery seedlings stock.

Slicing - Industrial transformation whereby we can reduce in thin sheets of wood, called veneers (or sliced veneer), a log with suitable characteristics.

Sliced veneer - Thin sheet of wood obtained by slicing. The sliced veneer is also known, generically, as veneer.

Soil disinfectant - Pesticide used for elimination of animal or vegetable parasites present in the soil.

Species scheme - Geometrical arrangement of the plants of a species that has been given the same role.

Specific production target - Specific purpose for which a Tree farm is established (e.g. produce 100 logs of walnut (Juglans regia L.) per hectare of 40 cm in diameter to 130 cm above ground and equal or longer of 300 cm in length)

Sprout - Any regrowth from a dormant bud.

Square design - Arrangement of plants at the vertices of a square.

Square off a land plot - Find points on the soil where the plants will be planted, in order to ensure the respect of productive surfaces (and distances among all the different plants) and proper alignment.

Stem - Aboveground portion of a tree, which corresponds to its principal axis from the collar to the vegetative apex or, in some broadleaved trees, to the point where a bifurcation determines the crown structure (Figure 8 - 109).

Stem collar - Transition zone between aboveground and belowground portion of a plant.

Stool (in coppice) - Roots, basal part of stem and shoots in their entirety, exposed to coppicing.

Stump - The part of plant, especially a tree, remaining after cutting near the ground level. It is composed of root system and of basal portion of stem (or stems).

Stump grinder - Tool used to fragment tree stumps.

Stump harvester - Tractor’s tool used to extract stumps.

Substitution of dead plants - Operation consisting in planting or seeding again at the points where the first plantation, after a reasonable amount of time (maximum 3 years), has not passed the stage of establishment or where the first seeding did not give rise to sufficient germination.

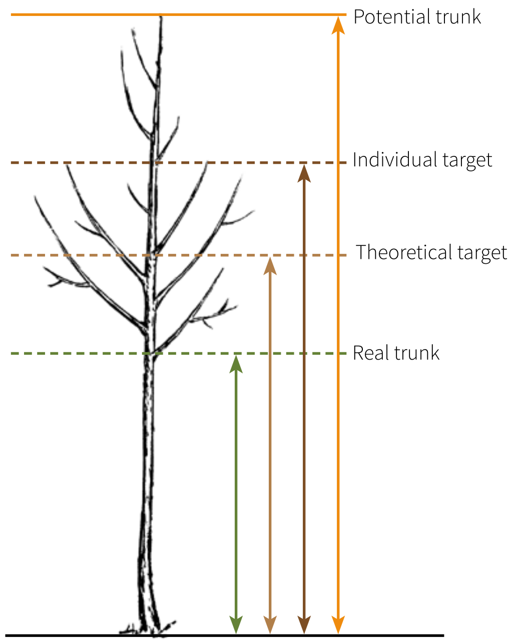
T

Taproot - Main root, growing straight downward from the stem, in young plants of certain species. It grows faster than secondary roots, with a cone-like shape.

Temporary Polycyclic Tree farming - Temporary Polycyclic Tree farm is defined as plantation where Main Trees of longer cycle, at the harvesting time, cover with their crowns the entire plot of land (Figures 3.9 and 3.10).

Tending operation - Agricultural and forestry practice or practices, in order to achieve the objective (or objectives) both in terms of quality and quantity, as well as to reduce the production cycle length.

Theoretical target - Real minimum trunk length (future sawn log) to which, during the design stage, we think should theoretically get all the main trees of a plantation.



Thinning - Operation of reduction the number of trees in a plantation. It is made to prevent or face negative effects of competition (negative competition) between trees for light, water and/or nutrients.

Timber eligibility - Degree of usability of a woody material for a specific use.

Timber value - Indicates synthetically in what market range can be placed a particular woody material (e.g. high, medium or low).

Topping - The practice of removing the top of a tree.

TP Tree farms (or Temporary Polycyclic Tree farms) - For TP means the Tree farms established with the characteristics and purposes of Temporary Polycyclic Tree farming (see definition).

Transplanting - Plant that, in the nursery, underwent one or, occasionally several times the transplant operation. This operation consists of extracting the seedlings from the flowerbed where they are germinated and replant them at regular distance in a different flowerbed or, more rarely, in container.

Tree architecture - Overall model of the individual development encoded by genotype.

Tree architecture model - Overall design of plant growing, shrubby or arboreal, encoded by its genotype.

Tree farmer - Person who assumes business risk in plantation establishment and management and determines the amount of the investment and the production targets.

Tree farming - Cultivation of trees addressed at obtaining exclusively wood products with defined characteristics.

Tree farming with medium-long rotation cycle - Trees cultivation with production cycle over 20 years (e.g. production of walnut sliced veneer).

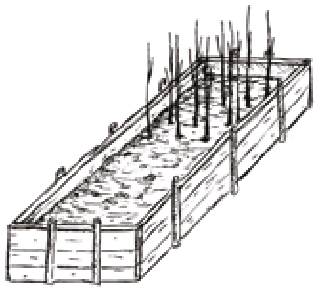
Tree farming with short rotation cycle - Cultivation of trees with production cycle between 8 and 20 years (e.g. production of poplar rotary-cut veneer).

Tree farming with very short rotation cycle - Trees cultivation with production cycle less than 8 years (e.g. production of woody biomass). The productions listed internationally as Short Rotation Forestry (SRF) are part of Tree farming in very short cycle.

Tree pruner - Tool with single or telescopic pole, which allows to prune branches over 2 m high from the ground. Generally allows to cut branches between 3 and 5 cm and up to 6 m high.

Tree stake (or tree pole) - The element that give a mechanical support to a plant.

Tree wicking beds - Nursery bed box-shaped, whose walls are made of wooden panels or other material, filled with various types of substrate properly fertilized and isolated from soil through inert material, artificial or natural, which could prevent the deepening of tap root system. It's used in forestry nursery to get planting stock with bare root larger than the ordinary production.



Trench - A ditch built near the plantation area where bare root plants were collocated and their root system covered to keep it in good condition before planting.

Trimming (see also clampdown) - Cut of a small portion of the terminal part of a branch carried out during the growing season.

V

Valuable broadleaves (or timber value) - Broadleaves of medium to large dimensions, from many woody species, joined by the technological advantage, from a preference of mesic environments and not to form, naturally, extended pure populations. In favourable areas pedunculate oak and sessile oak are exceptions to this last feature.

Valuable timber (see the advantage of timber)

Vegetative cycle - Period in which there is an intense growth activity followed by a period of dormancy.

Veneer - Thin semi-finished wood product under 7 mm that is achieved by slicing, shearing or, for some wood type, sawing.

W

Water stagnation - A condition of water excess in the soil that limit the choice of species to be used and/or require drainage interventions.

Weed control - Operation, mechanical or chemical, aimed at the elimination of weeds.

Windbreak - Vegetation barrier (or other kind of barriers), permeable or windproof, used to hinder the wind action.

Winter pruning - Cutting of unwanted branches made when the plant is in dormancy period. Term used for deciduous broadleaved species.

Wood assortment - Wood product of given size and quality, obtained from a tree (e.g. woody biomass) or part of it (e.g. round-wood for sliced veneer), making it suitable for specific processes and/or uses.

Wood biomass - Woody fraction of organic matter produced by trees or shrubs species .

Wood chips - Wood reduced in chips through chipping.

Wood pruning - Combination of cutting interventions aimed at achieve trunk with specific characteristics.

Wood quality - Briefly indicate to what extent (e.g. good quality, average q., low q.) material might meet the objectives of a specific transformation process or intended use.

Wrinkle of the branch collar - Swelling of the collar located at the top of the insertion point of branch on the stem.

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