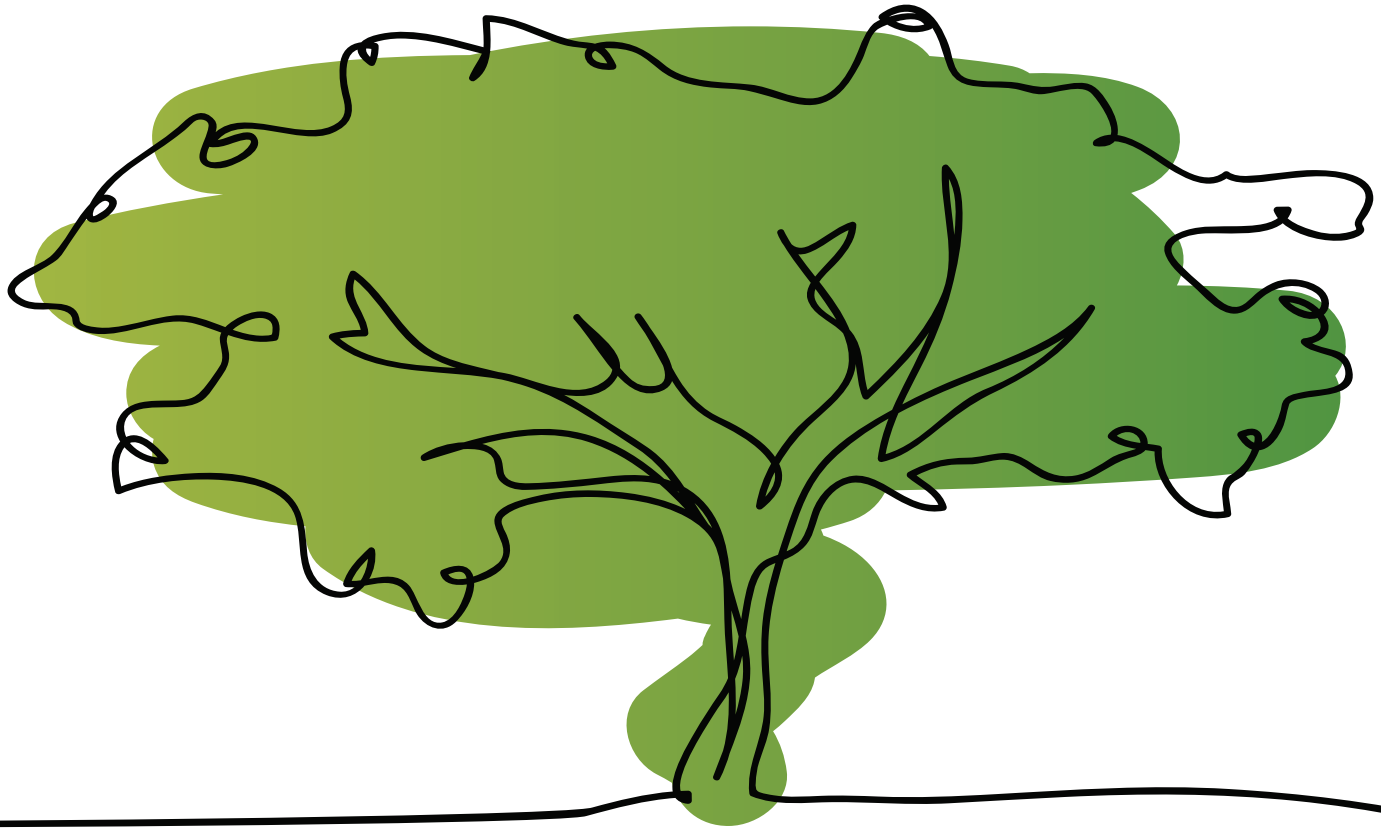
USAID
FROM THE AMERICAN PEOPLE

جمعية التشجير في لبنان
LEBANON REFORESTATION INITIATIVE

GUIDELINES

FOR IMPLEMENTING AGROFORESTRY IN LEBANON

OCTOBER 2022



This manual is made possible by the support of the American people through the United States Agency for International Development (USAID). The content of this manual is the sole responsibility of the Lebanon Reforestation Initiative (LRI) and doesn't necessarily reflect the views of USAID and the United States Government.

This manual is made possible by the support of the American people through the United States Agency of International Development (USAID). The content of this manual is the sole responsibility of the Lebanon Reforestation Initiative (LRI) and does not necessarily reflect the views of the United States Government.

Those Guidelines for implementing Agroforestry in Lebanon were developed by the Lebanon Reforestation Initiative (LRI) under the Livelihoods in Forestry Project funded by the United States Agency for International Development (USAID). It relates the expertise of agroforestry experts as well as LRI's practical experience in working on Agroforestry for the past four years.

Prepared by:
Sophie Mansour – Senior Sustainable Landscape Management Specialist
Sylvana Raydan – Agroforestry Program Coordinator
Authors:
Rana El Zein - Senior Expert in Forestry, Agroforestry and Terrestrial Ecology
Khaled Sleem – Senior Expert in Agroforestry, Agroecology and Native Nurseries Production
Maya Nehme – Senior Expert on Forest Entomology
Contributors:
Abdo Nassar – Senior Landscape Restoration and Rehabilitation Specialist
Mohamad Hajj - Agricultural Value Chains Specialist
Samara P. El Haddad – Wildlife Conservation Specialist
Reviewed by:
Maya Nehme –Director of the Lebanon Reforestation Initiative
Chadi Mohanna - Director of Rural Development and Natural Resources at the Ministry of Agriculture
This report should be cited as follows:
LRI. 2022. Guidelines for implementing Agroforestry in Lebanon. 140p.

TABLE OF CONTENTS

List of figures

List of tables

CHAPTER I. INTRODUCTION TO AGROFORESTRY

I.1. WHAT IS AGROFORESTRY?

Agroforestry (AF) is an age-old land use that has been practiced for thousands of years by farmers over the world and that has developed recently as a science that promises farmers and landowners to increase the productivity, profitability and sustainability of their land.

Accordingly, Agroforestry is defined as a sustainable land use management system that combines trees, agricultural crops/herbs, forest plants and/or animals simultaneously or sequentially to benefit from the resultant ecological and economic interactions, thus increasing the overall productivity of the land.

Agroforestry includes the presence of 3 complementary components: the **woody perennial**, the **herbs** and/or **animals**, each providing specific functions to the integrated system.

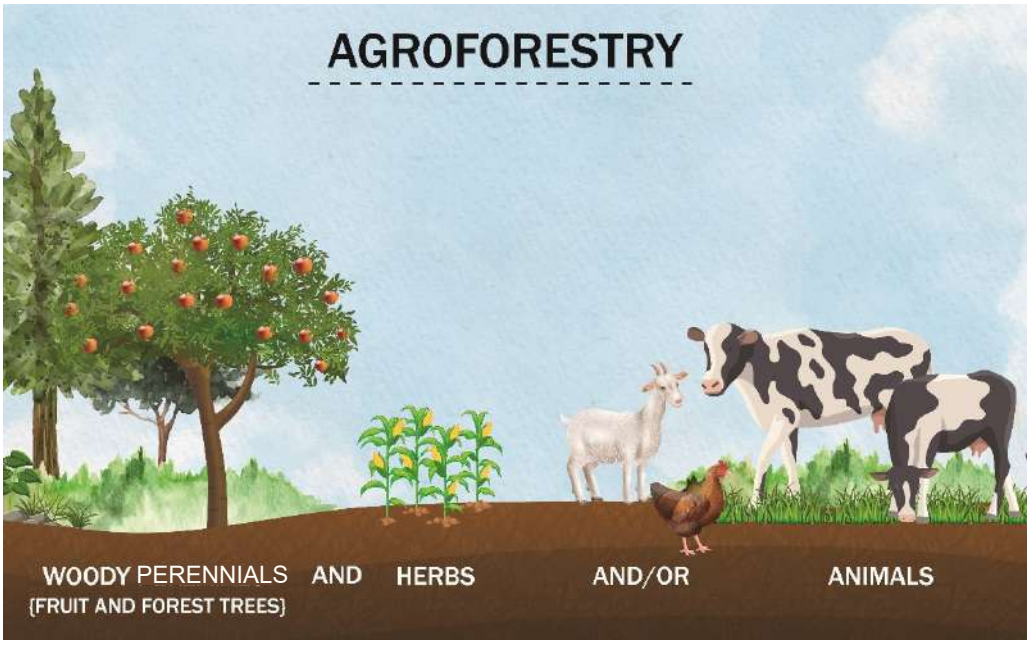


Figure 1 The three components of Agroforestry

I.2. THE DISTINCTIVE FEATURES OF AGROFORESTRY

When compared to traditional monoculture and farming, Agroforestry combines agricultural, forestry, horticultural and animal farming practices. By mixing different land use practices, agroforestry is a dynamic interface between agriculture and forestry that brings out multiple advantages. It creates a sustainable system with prolonged agricultural cycles over the years, more complex ecologically (in structure and function) and economically than a monoculture system (Table 1).

Table 1 Comparison between Monoculture and Agroforestry systems

MONOCULTURE	AGROFORESTRY
A traditional farming system adversely affecting and altering the ecosystem resulting in biodiversity losses.	A set of sustainable agricultural practices forming a sustainable farming system that enriches the ecosystem.
Depletion of land organic matter and impoverishment of soil leading to high application of fertilizers and increased production costs.	Enhanced soil quality, richness in organic material resulting in high nitrogen fixation rates, reduced usage of fertilizers and ensuring water optimum use.
Limited yields of crop species produced under monoculture practice.	Greater yields compared to monoculture, even greater than the addition of two separately planted yields (trees alone and crops alone).
Limited productivity.	Diverse productivity.
Extended period to benefit from an agricultural land leading to longer period prior to income generation.	Short-term and long-term income generation from the diverse components.
Increasing risk of diseases and outbreaks, leading to increased application of pesticides inducing pest resistance to chemicals.	High biodiversity and balanced ecosystem inducing natural and biological pest control.
High risks of yield losses due to environmental risks and lack of biodiversity affecting farmers' income.	Diverse yield all over the year safeguarding farmers' income.
Extensive usage of land resources, leading to soil destruction.	High efficiency of land usage leading to soil enrichment.
High soil degradation levels leading to reduced efficiencies in water retention and formation of algal blooms and anaerobic "dead zones" in nearby water bodies.	Tree–crop interactions exhibition, potentially contributing to nutrient-efficient agro-ecosystems.
Weak resilience to climate change provoked by farming uniformity.	Climate smart system enhanced by farming diversity.
Restricted human resources.	New employment opportunities.

Integrating trees with crops and/or animals aims at reducing the risks and increasing the total productivity of the land. Therefore, Agroforestry systems are more stable and sustainable compared to monocultures. The diversity of components in Agroforestry practices distributes the production over a long period of time, thus providing more regular income and increased cash flow stability to farmers. Additionally, integrating trees

into agricultural systems may result in a more efficient use of a land's resources such as light, moisture and mineral nutrients than is generally possible by monocropping or either agricultural or forestry crops alone.

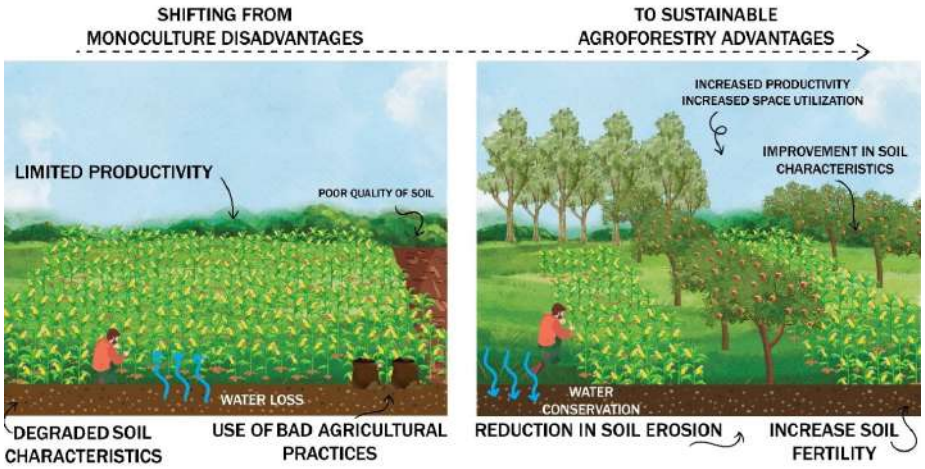


Figure 2 Shifting from monoculture system to sustainable Agroforestry systems

I.3. AGROFORESTRY COMPONENTS

I.3.1. THE WOODY PERENNIAL COMPONENT

The woody perennial is the central component of any agroforestry practice; it could be a tree or a shrub. Agroforestry requires both products and services from the woody perennial used. Products include wood products (fuel, small and large timber) and non-wood products (fodder leaves, fruits, nuts). Ecological services include soil and microclimate enhancement essentially. These services have a direct positive impact on the productivity of the herb and animal components increasing the overall system productivity as compared to monocultures and traditional livestock production.

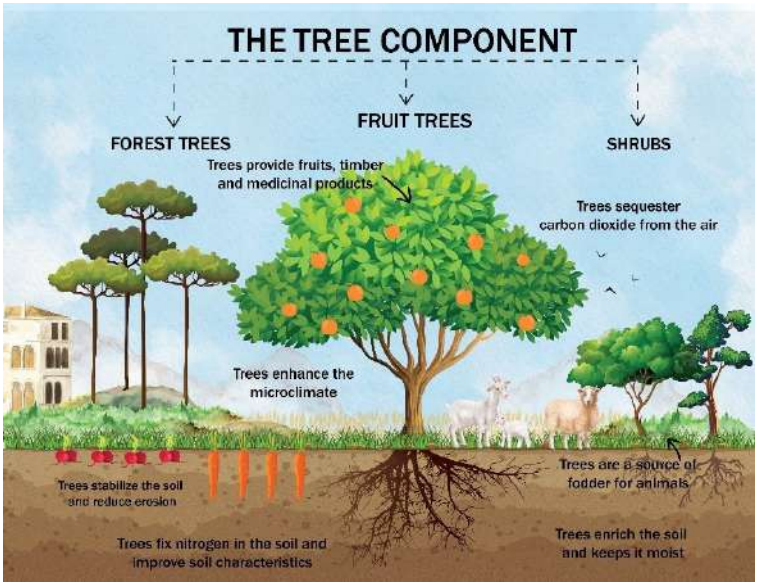


Figure 3 Benefits of the woody component (forest and fruit trees and/or shrubs)

I.3.2. THE HERB COMPONENT

The herb component could be a crop plant or a pasture plant. Crop plants could be seasonal productive food crops hence providing direct income, or cover crops protecting the soil from erosion and/or enriching it with Nitrogen (legume cover crops) during the rest or the dormancy season. Melliferous herbaceous species are grown when the agroforestry practice aims at raising bees. Some herbs could provide specific services function such as insect repellent properties in addition to their productive function. Pasture plants provide forage in agroforestry practices including animals ensuring an increased food availability and quality.

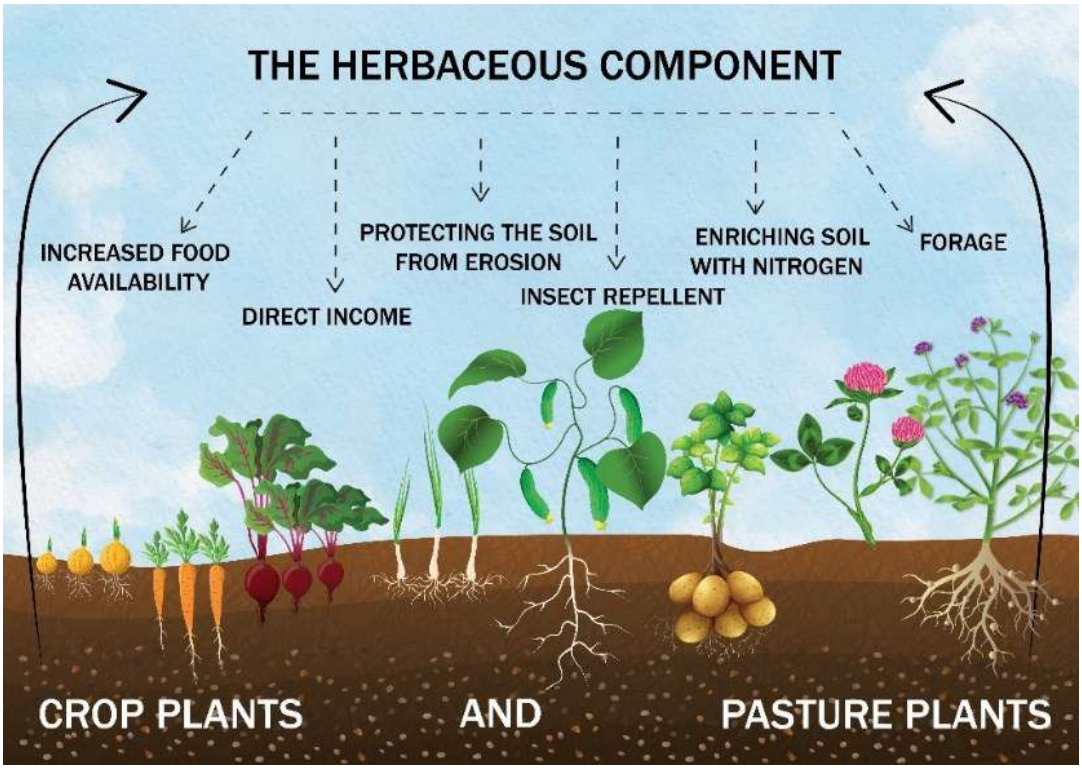


Figure 4 Benefits of the herbaceous component (crop or pasture plants)

I.3.3. THE ANIMAL COMPONENT

The animal component is found in agroforestry systems including woody perennial and crop or pasture plants. The choice of the animal species depends on the production aim of the farm as well as the farmers' preferences, needs and expertise. Animals used in agroforestry can be categorized according to their expected outcome when present on the agroforestry site:

- Production animals: animals integrated on AF lands for their products.
- Services animals: animals deliberately placed on AF lands for the services they provide to the agricultural cycles.
- Ecotouristic/agritouristic animals: animals included on AF lands to provide touristic services and additional income to the land.

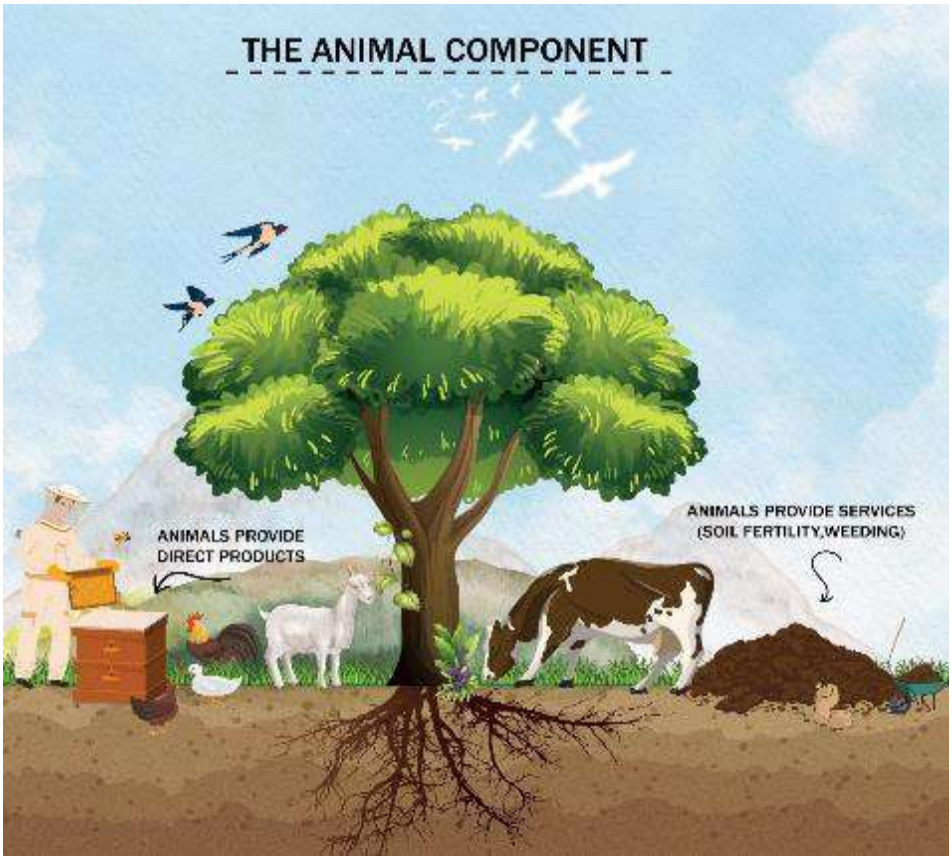


Figure 5 Benefits of the animal component (products and/or services)

I.4. WHAT ARE THE BENEFITS OF AGROFORESTRY?

Agroforestry systems rely on positive interactions between the components (tree, herb and/or animal) to increase sustainably the overall production of the lands and provide many environmental and socio-economic advantages.

P.S.: The following advantages are a generalization that might not apply to all sites and tree/crop/animal combinations. This list is a set of results in an ideal system rather than what can be expected at every site, in comparison to mono-cropping practices.

I.4.1. ENVIRONMENTAL BENEFITS

Increased space utilization: the presence of different plant components (trees, shrubs and herbs) results in an increased utilization of the above (light) and below-ground (soil, water, mineral elements) environment that should lead to an increase in total biomass production.

Improvement of soil characteristics: the presence of trees, i.e., deep rooted plants, enhances nutrient cycling and pumping within the soil. Tree roots extend into deep layers of the soil profile that may not be accessible to annual crop root systems, where they extract nutrients that will be translocated to surface horizons (root biomass) and above

ground plant biomass. Nutrients released from the decomposition of tree litter, roots fall and pruning increase the input of nutrients within the soil, particularly when nitrogen-fixing species are included in the mixture.

Increased productivity: aggregate production from agroforestry mixtures is often perceived to be greater than that of monocultures. The potential productivity of trees and annual crops in agroforestry systems is high with low power and chemical energy input requirements.

Reduction in soil erosion: the presence of a multistoried canopy (trees, ground cover of annual crops, pasture grasses and shrubs and a surface litter layer) in agroforestry reduces erosion risks caused by rainfall and wind. Stems and surface roots reduce the velocity and therefore erosion risk of surface runoff.

Reduction in microclimate extremes: under tree canopies, temperature and moisture extremes are modified. In fact, tree crowns shield the soil surface from solar radiation during daylight hours and reduce heat losses at night.

Reduced risk of complete crop failure: plant diversity can reduce the risk of total crop failure for many reasons: i) risk of losses from pest infestation and climatic stress is distributed among many species; ii) enhancement of microclimate and reduction of temperature extremes by trees, reduce the risk of crop failure, iii) some plants facilitate the growth of others by enhancing soil conditions or by repelling insects, iv) plant diversity reduces pest infestation compared to a monoculture system.

Physical support for herbaceous climbers: trees can provide support for climbers, which can be of significant economic value since tree stems substitute expensive poles that need to be replaced periodically.

Positive use of shade: some crops benefit from the provision of tree shade particularly when temperatures are extreme. Also, animals, when present, highly benefit from the shade of the trees, to improve their productivity, welfare and safety.

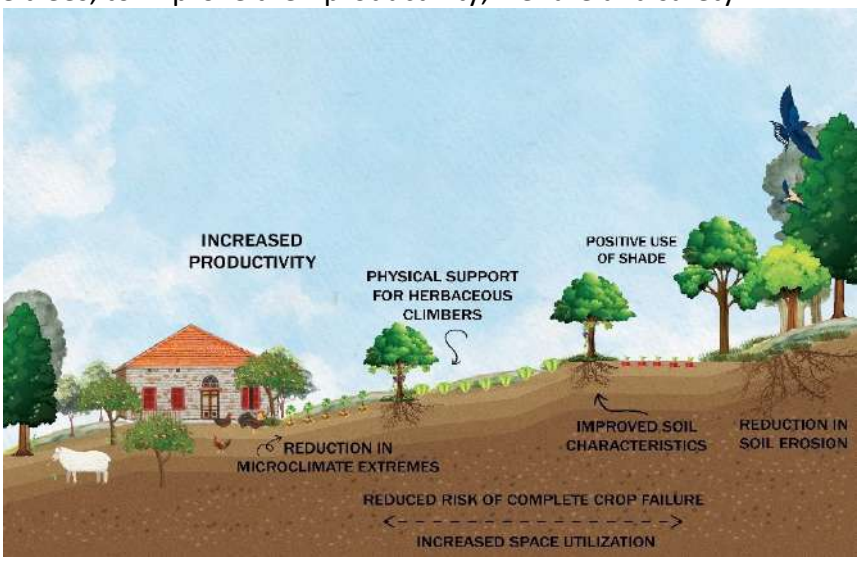


Figure 6 Environmental benefits of Agroforestry

I.4.2. ECONOMIC AND SOCIAL BENEFITS

Economic and social considerations are often more easily understood and appreciated by farmers who may only vaguely understand the biological benefits or drawbacks of agroforestry compared to other systems.

Increased income opportunities: agroforestry practices provide opportunities for earning greater income per surface unit per year, through the diversity of components integrated in Agroforestry lands. It also ensures a year-round distribution of employment and income compared to a highly seasonal income from annual mono-cropping.

Variety of products and/or services: a variety of products can be produced in the same land, including food, firewood, craft wood, poles, fodder, fertilizer, medicinal products, as well as a diversity of services such as shade for shade tolerant plants and for human and animal comfort, windbreak, ornament…

Improved human nutrition: the wide diversity of crops in agroforestry systems can provide a wide range of edible plants. Tree and shrub species could provide important sources of vitamins, protein, fruits and vegetable products, as well as other nutrients during periods of seasonal shortages, especially in rural and/or poor areas, to enhance food security.

Crop diversity and reduced risk: crop diversity helps to reduce the economic impact of price fluctuations of any single crop and may also reduce the risk of total crop loss.

Reduced establishment costs: the cost of establishing long-term crops can be reduced when trees and other crops are established together. Tree-crop-animal agroforestry systems may reduce also maintenance costs such as weeding, pruning…

Improved distribution of labor: labor requirements may be evenly distributed over a longer period of time since they occur at different times of the year for the various components. Rural poverty is in part caused by highly seasonal economic activities associated with annual crops and the lack of productive employment during substantial portions of the year. The perennial components in agroforestry could provide gainful employment during the lean months. Year-round farm activities ensure continuity rather than seasonality of incomes and benefits to the household families.

Reduced weeding requirements: the presence of a tree overstorey can reduce light levels at ground level and reducing the growth of light-demanding weeds.

Figure 7 Economic and social benefits of Agroforestry

CHAPTER II. AGROFORESTRY SYSTEMS AND PRACTICES

II.1. CLASSIFICATION OF AGROFORESTRY SYSTEMS AND PRACTICES

A key element to the success of agroforestry is designing the appropriate "type" of agroforestry that suits the land and responds to the landowner needs.

In agroforestry land use-systems, there are three basic sets of elements or components that are integrated:

- The tree or the shrub i.e., the woody perennial.
- The herb (agricultural crops and pasture species).
- The animal.

For a land-use system to be designated or defined as an agroforestry system, it should always have the first component: the woody perennial.

According to the choice of combination between agroforestry components, an **Agroforestry system** is identified, which refers to a type of land use specific to a site:

- Agrisilvicultural systems: combine trees and crops, including vegetables, shrubs, vines, mushroom, medicinal plants, decorative plants, etc.
- Silvopastoral systems: combine trees and grazing animals on the same farming land with pasture and/or fodder sources.
- Agrosilvopastoral systems: combine trees, crops, and animals with pasture and/or fodder sources on the same farming land.

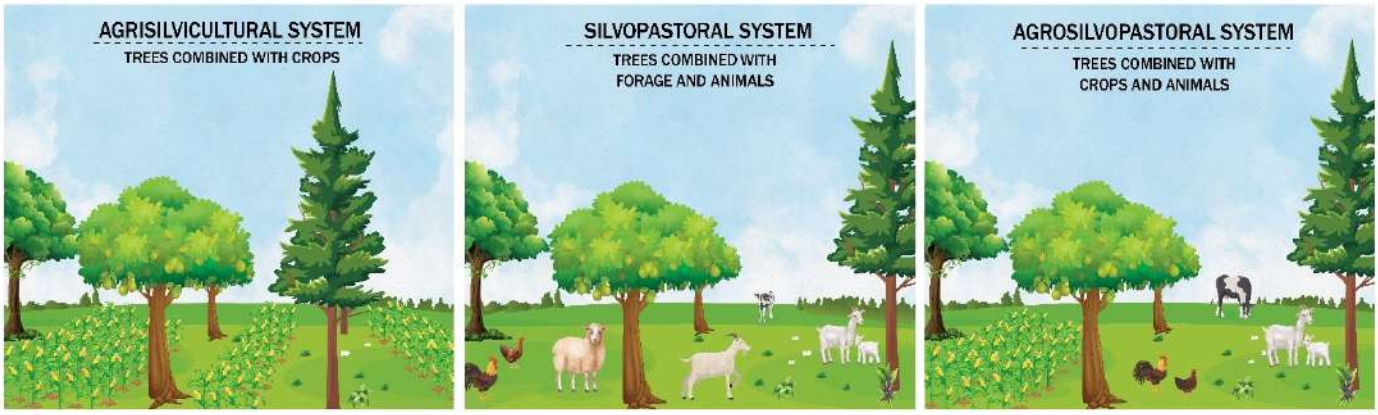


Figure 8 The three different Agroforestry systems

The arrangement of agroforestry components in space and time vis-à-vis the major function of the tree component results in various **Agroforestry practices**. Practices are the key to most of the benefits and limitations of agroforestry as a land-use system. Agroforestry practices can be classified according to many criteria:

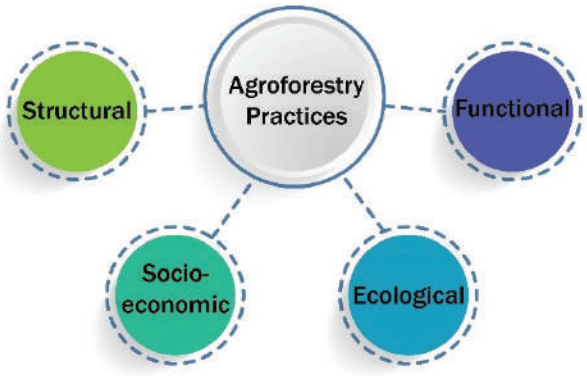


Figure 9 General classification of Agroforestry practices

- ***Structural basis*** refers to the composition of components including:
  a. Nature of components integrated: with the tree as a central component in all agroforestry practices, the integration of the agricultural crops and/or pasture and/or animals define the essential structural elements of Agroforestry practices (Agrisilvicultural, Silvopastoral, Agrisilvopastoral).
  b. Spatial arrangement of the woody component: varying from mixed dense stands (i.e., home gardens) to mixed sparse stands (i.e., silvopasture systems). These arrangements can be in zones or strips of varying widths (i.e., intercropping, boundaries or windbreaks).
  c. Temporal arrangement of all different components: corresponding to the introduction timing of each Agroforestry component, such as coincident, concomitant, overlapping, separate, interpolated, etc.

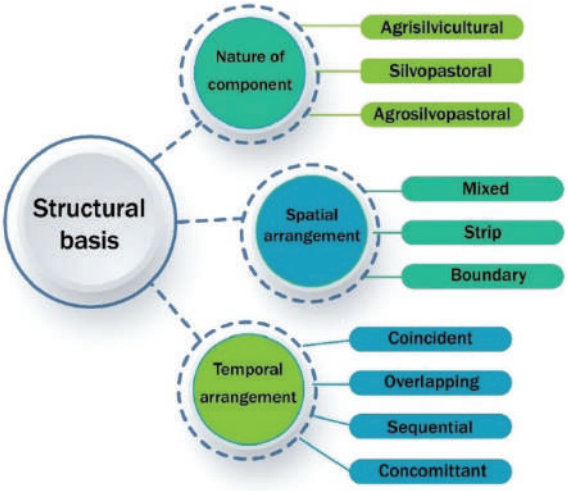


Figure 10 Structural basis classification of Agroforestry practices

- ***Functional basis*** refers to the major function of the system, classified as productive functions when products are expected from the combination of components (i.e., production of wood, non-timber forest products, fodder…) or protective functions, when the services are essentially expected from the combination of components (i.e., windbreak, soil conservation, shelter, etc.). The woody component of the agroforestry system is the main factor contributing to either of the 2 functions. All agroforestry systems have both productive and protective roles, though in varying degrees.

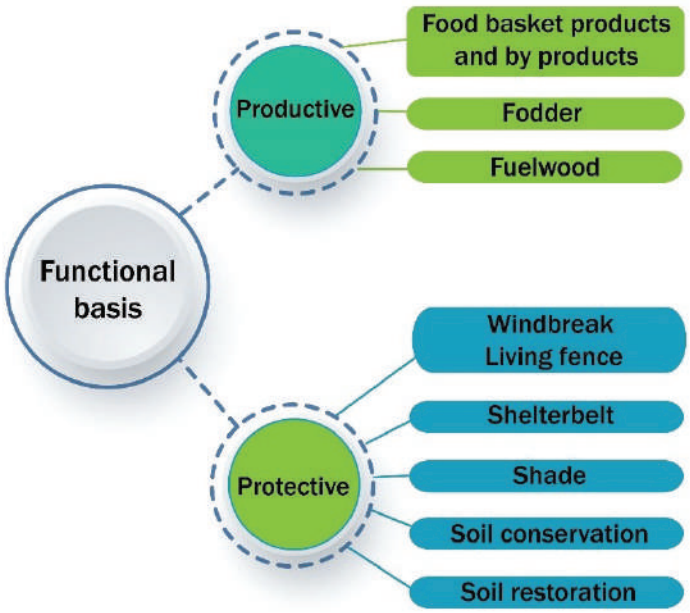


Figure 11 Functional basis classification of Agroforestry practices

- ***Socioeconomic basis*** refers to the level of management input (low, medium, high) required by the farmer, and commercial goals (subsistence, intermediate, commercial) eventually foreseen.
- ***Ecological basis*** refers to the ecological suitability of the system (e.g., for arid and semiarid lands, for tropical highlands…). Agroecological characteristics are to be used as a basis for designing agroforestry systems more than a classification criterion, especially when in the choice of plant species.

The structural and functional classification of agroforestry land uses are adopted in these guidelines. Below figures 9 and 10 show the detailed classification falling under each category.

Under each system, a set of Agroforestry practices, adequate for Lebanon and the Mediterranean context, are listed and detailed in the following section.

II.2. AGRISILVICULTURAL SYSTEMS (TREES WITH CROPS)

Trees with annual or perennial crops or Agrisilvicultural systems, is the most widely and easily recognized set of agroforestry practices, frequently encountered in the Lebanese landscapes, through the unintentional historical adoption of Agroforestry by farmers.

II.2.1. MULTIPURPOSE TREES ON CROPLAND

Trees are intentionally planted or allowed to persist from natural regeneration in crop fields in random or systematic spacing. Trees provide a diversity of wood and non-wood products and many ecological services such as microclimate enhancement, nitrogen fixation within the soil (when the tree is a legume species) which increases crop production and prolongs the production season.

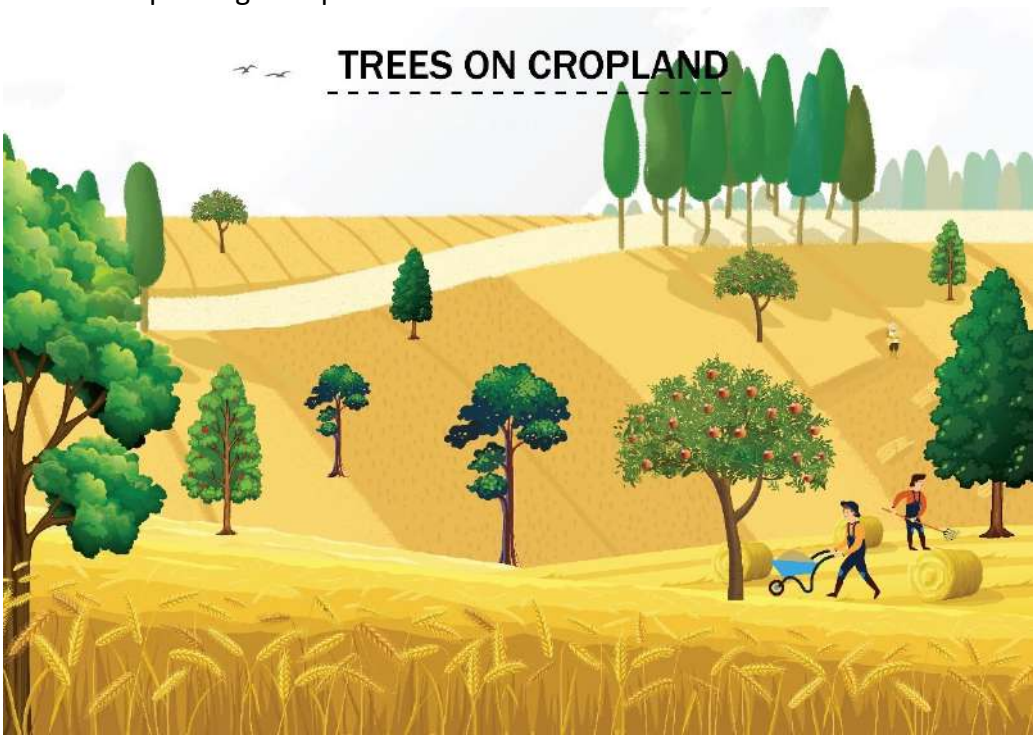


Figure 12 Trees on cropland practice

II.2.2. HOME GARDENS

Home gardens consist of multi-species and multi-storied associations of trees with shade tolerant herbaceous crops particularly in humid and sunny locations. This highly diversified multilayered practice is associated with subsistence objectives where the combination of trees, shrubs and agricultural crops provide a wide range of products, while mutually benefiting each other. The trees that provide a diversity of products (fruit, fodder, timber, flowers) may as well perform supportive functions for the crops: canopy shades from the sun, slow down the wind, fertilizing the soil, trunks serving as support to climber plants, etc.

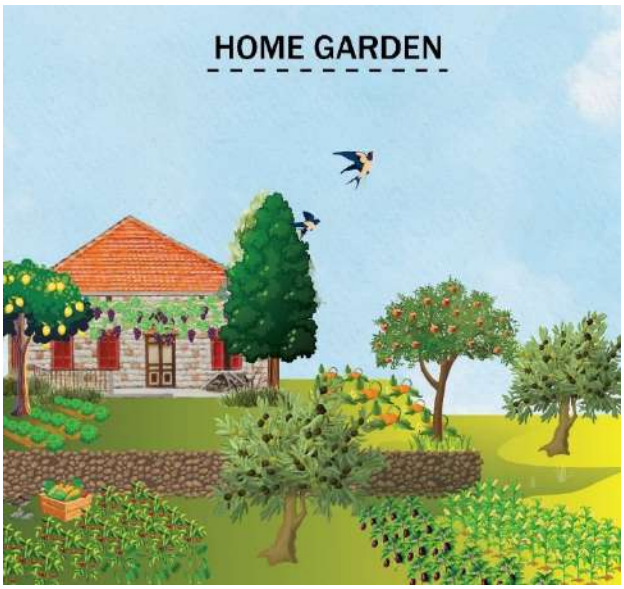


Figure 13 Home garden practice

II.2.3. IMPROVED FALLOWS

This is the replacement or enhancement of natural fallow vegetation by the introduction of trees and shrubs for the purpose of fallow improvement. When the farmer decides to leave his land fallow for a rest period, it is highly effective to apply agroforestry to prevent invasion of this land with wild weeds, to enhance soil fertility, and to protect it from erosion. The farmer can choose fast growing crops, that compete with the non-desirable weeds, and can be easily harvested and removed from the land when the rest period concludes. Not only does this practice provide services to the land and the soil, but it also offers direct products/income from fast growing trees that provide forage, wood or other products.

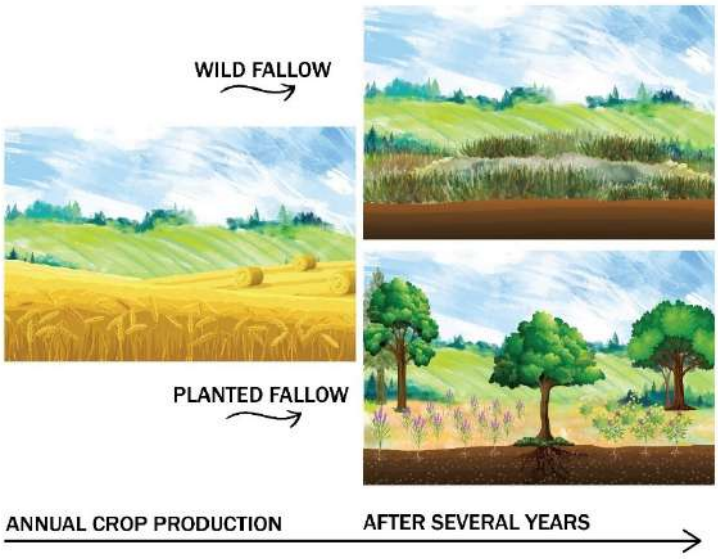


Figure 14 Improved fallows practice

II.2.4. ALLEY CROPPING

It is the most common practice in agroforestry, also called intercropping, which consists of arable crops (herbs/forage/crops) that are planted between hedgerows of planted trees and/or shrubs, and which are pruned to prevent shading the companion crops. One of the main advantages of alley cropping is the direct income generated from the annual harvest of crops, while waiting for the trees to mature and start producing. Alleys or rows of trees are well designed, where inter and intra spaces are calculated according to the tree canopy diameter, and growth rate, to optimize the use of sun, water and soil resources and avoid competition between the trees and the crops.

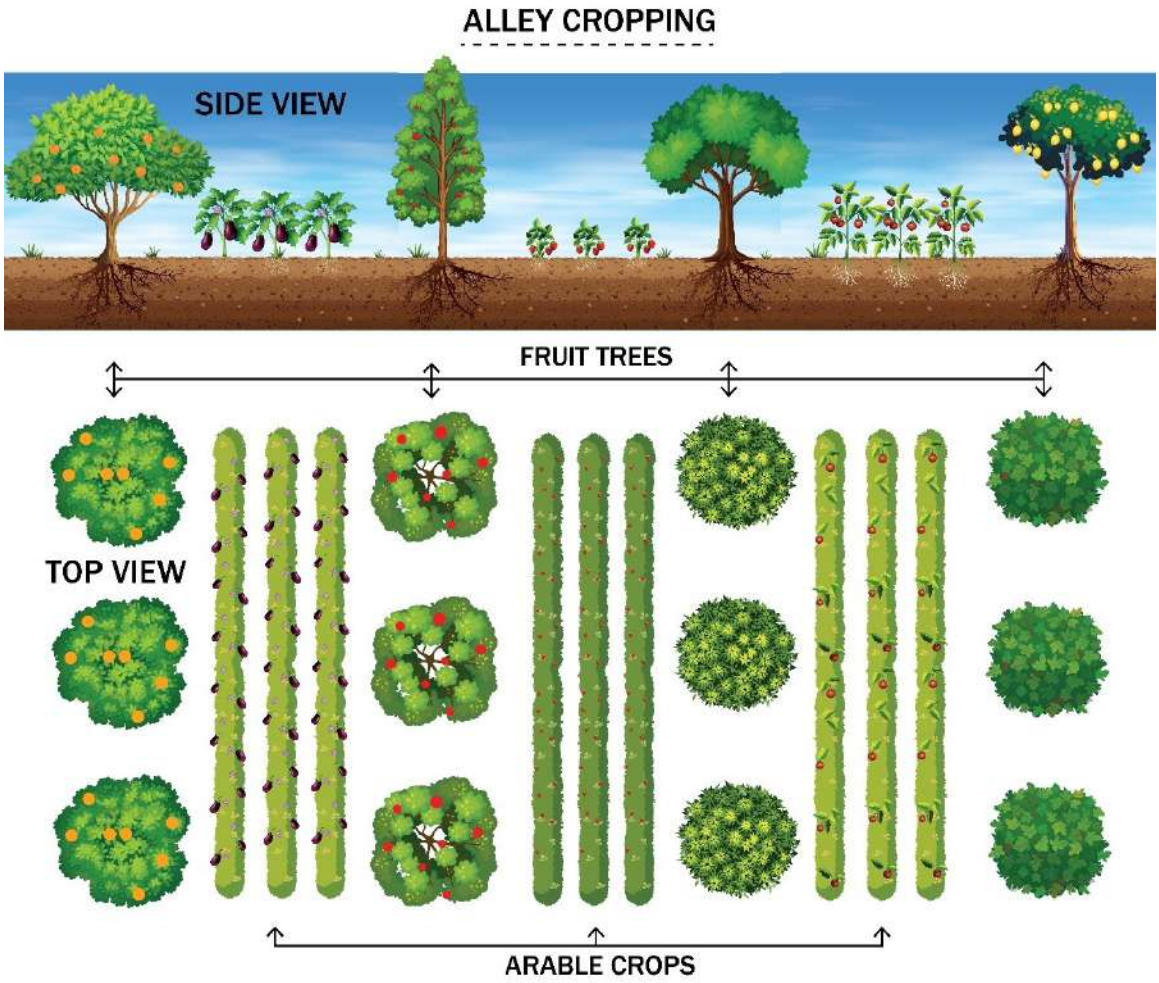


Figure 15 Alley cropping practice

II.2.5. WINDBREAKS AND SHELTERBELTS

Strips of trees and/or shrubs are maintained at the farm's boundaries or edges, to provide protection and shelter from wind, sun or snow to the crops, animals and/or farm's buildings on the land. Very commonly adopted, windbreaks help create a controlled environment within the farm, and mitigate environmental impacts on the crops and the livestock. Windbreaks/shelterbelts can improve crop yields by minimizing losses due to

environmental factors (wind, frost) while providing valuable wood and non-wood products. They are planted in a single or multiple rows to prevent soil erosion and nutrients leaching, as they interrupt pest infestations from one field crop to another.

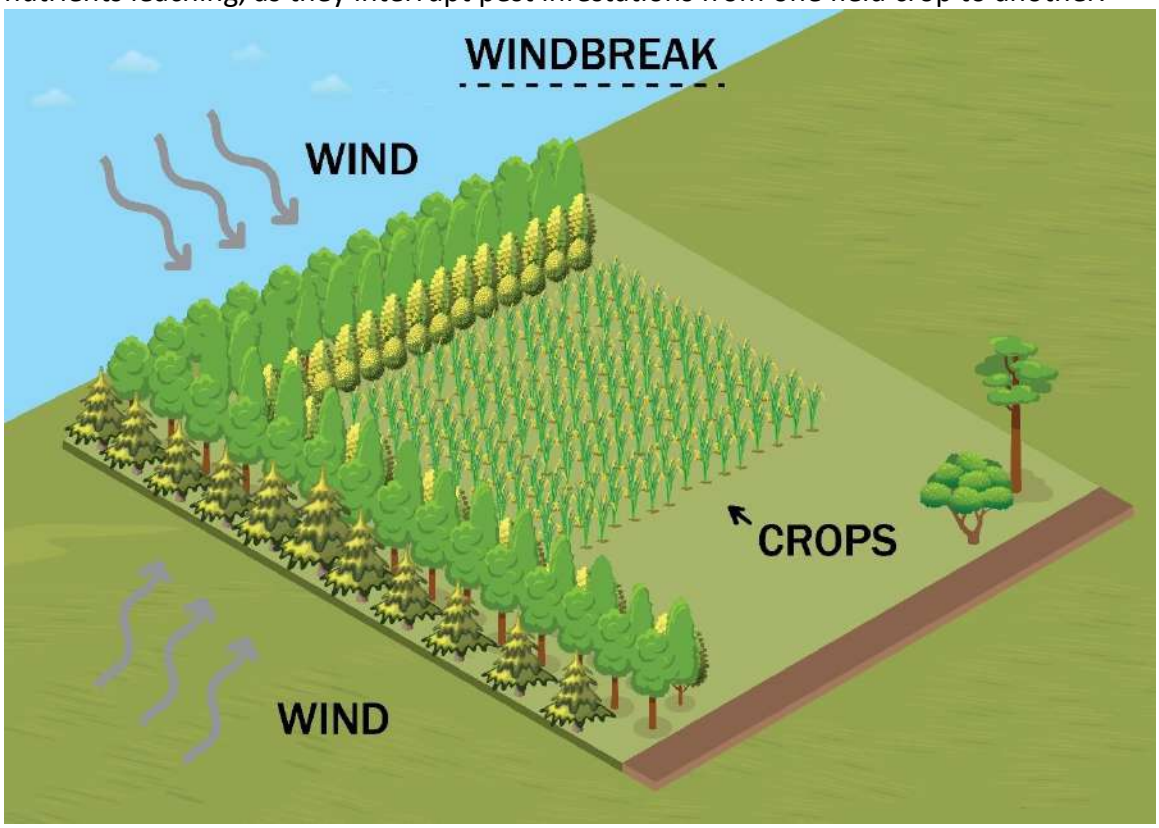


Figure 16 Windbreak practice

II.2.6. FOREST FARMING

Forest farming is the intentional cultivation of high value edible, medicinal or decorative native crops under forest or woodland tree canopy. It is a well-designed management plan that enhances forest productivity through a multilayered vertical usage of spaces combined with existing trees management plans as well. These introduced crops are called: non-timber forest products, that can vary from shade tolerant species to sun tolerant species, mushrooms, seeds, bulbs or any other native crop naturally adapted to the local ecosystem of the forest location. This intensive management practice will provide:

- Short-term income (seasonal and annual sources) with minimal capital investment.
- Diversification of products by growing high value crops.
- Enhanced rural development through cash for work seasonal or annual activities, leasing contracts, etc.
- A powerful tool for fire prevention through continuous clearing and pruning practices.
- An ecologically responsible plan to protect endangered species.

- Better agricultural practices where local farmers can benefit from forest mulch reducing thus usage of chemical fertilizers.
- Conservation of forest ecosystems against deforestation.

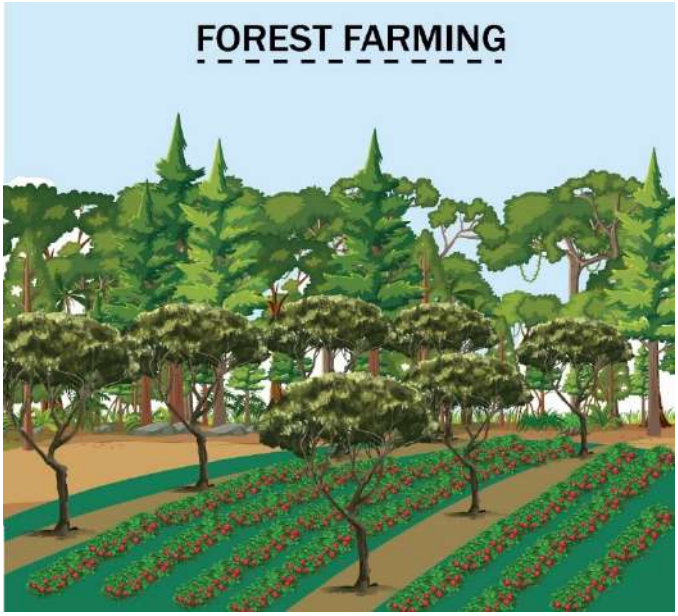


Figure 17 Forest farming practice

II.3. SILVOPASTORAL SYSTEMS (TREES WITH PASTURE AND LIVESTOCK)

The combination of trees (forest, fruit or forage trees) with pasture or forage grasses on the same piece of land to grow animal livestock and increase the productivity of the land.

II.3.1. TREES ON RANGELAND OR PASTURES

Trees planted on rangelands and pasturelands provide shade and produce fodder from leaves or pods that are browsed. This practice is especially needed when green pasture is absent in the cold or drought seasons. Planted trees are integrated on rangelands and pasturelands to supplement feed for livestock during low seasons. Livestock is either allowed to roam freely among trees and directly graze from the fodder trees, or trees are pruned by the farmers who feed the prunes to the livestock in the barn (cut and carry). The choice of tree species should be adequate to the greening season, reversibly correlated with the unavailability of green pasture grasses on the land. Tree species belonging to the legume family are used as protein banks to provide high-protein and mineral fodder in rangelands, while simultaneously fertilizing the soil with Nitrogen.

Figure 18 Trees on rangeland practice

II.3.2. PLANTATION COMBINED WITH PASTURES AND ANIMALS

Tree or shrub plantation comes with grazing by livestock as a secondary benefit. This is when introducing livestock and pasture (shade tolerant species) component to well established orchards, initially planted with productive trees. The land is now used to raise animal and benefit from environmental interactions between different components. It allows maximum utilization of the land, where the grazing animals help with site maintenance: removing weeds, fertilizing the soil, and suppressing pests. Farmers gain especially from the economic benefits of this practice, as they generate income from the animal production component, while waiting for harvest from the trees.

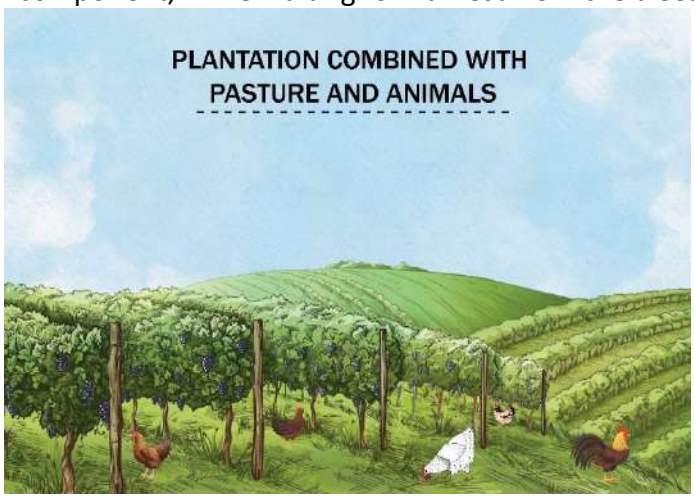


Figure 19 Plantation combined with pasture and crops practice

II.3.3. LIVING FENCES

Fences composed of living trees or shrub species that surround pasturelands and provide fencing for livestock, protection, privacy and can serve as windbreaks that produce wood and foliage products. Living fences are usually made of thorny and/or legume species or other multipurpose species and can be formed by a single or multiple rows of tree and shrub species that make the pastureland appear safe and separated from the exterior. Living fences are also used to protect farms (crops and/or animals) from wildlife animals that could damage the yield by accessing the farm. The thorny species of the living fences can be a great alternative to other fencing material, and they usually last longer.

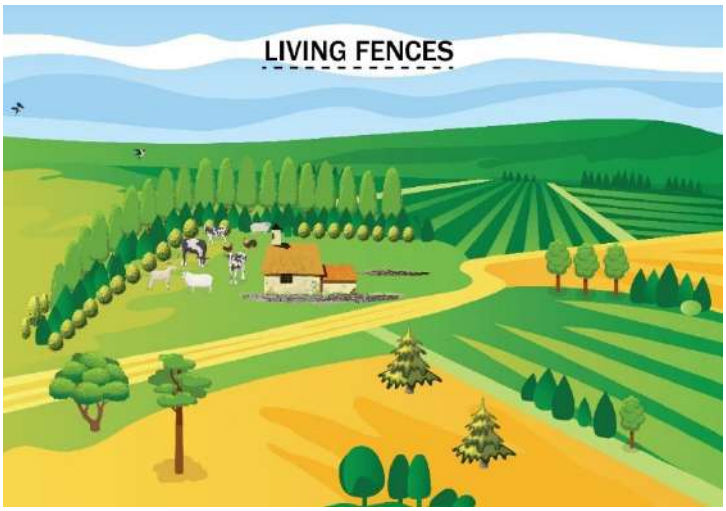


Figure 20 Living fences practice

II.4. AGROSILVICULTURAL SYSTEMS (TREES, CROPS AND ANIMALS)

The integration of the 3 components: trees, crops and animals on the same piece of land is the set of practices that requires the most planning and management, yet the most rewarding socio-economically as they contribute to increasing the value of the lands.

II.4.1. HOME GARDENS INVOLVING ANIMALS

This practice is a home garden association of multi-storied associations of trees with shade tolerant herbaceous crops, with the addition of livestock on the same home garden land. The combination of highly diverse multilayered plants integrated with animals on small to medium scale farms are classified as subsistence farms as they provide a wide range of products for the farmer, including protein nutrients from animal products, fruits, vegetables, beans, medicinal plants, etc. It is a practice commonly adopted to increase food security at small scales.

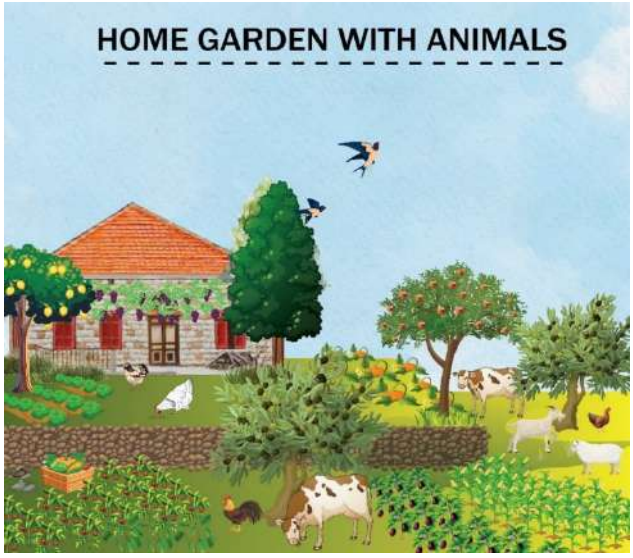


Figure 21 Home garden with animals practice

II.4.2. MULTIPURPOSE WOODY HEDGEROWS

Incorporating woody component (fast growing trees and/or leguminous trees, or shrubs) with protective and/or productive role into production farms. Trees can be grown in a sparse and scattered manner within agricultural lands or in regular rows around field borders. When adopted to define farms' boundaries to confine the livestock, woody hedgerows play windbreak roles to protect the crops planted in the farm, they provide habitat for insects and pollinators, and control the agricultural production. The woody component can be trees (forest or fruit), shrubs, bushes, etc. with multipurpose uses (browse, mulch, green manure, fruit, etc.).

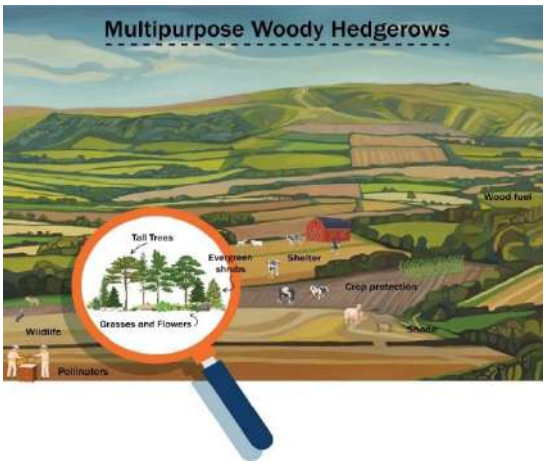


Figure 22 Multipurpose woody hedgerows practice

II.4.3. APICULTURE WITH TREES

Trees and melliferous plants cultivated for the main purpose of honey production and beekeeping is a practice easily implemented in agroforestry. Beehives can be located in a controlled zone of the farm, or along tree lines, which leaves plenty of space for agricultural production and/or other livestock. In addition to the honey products that apiculture provides, and the standard production generated by the trees and crops, beehives on agroforestry sites offer the essential pollination services to produce large and healthy quality of fruits and seeds.

Figure 23 Apiculture practice

CHAPTER III. AGROFORESTRY DESIGN

III.1. CRITERIA FOR A GOOD AGROFORESTRY DESIGN

There is no substitute for a good design. Minimally, a well-designed agroforestry system should rely on three basic criteria: Productivity, sustainability and adoptability.

Productivity:

Well-designed agroforestry systems can contribute to the improvement of rural welfare through a variety of products as well as through a wide range of indirect services. In designing productivity improvements for a given land-use system, what is needed is a careful assessment of the actual needs and production potential of local land users.

Productivity improvements can be achieved not only by raising or diversifying yields of useful products, but also by reducing the cost of production inputs for example by using green manure from nitrogen fixing plant/tree species instead of costly industrial nitrogen fertilizers.

Sustainability

The adoption of conservation-oriented agroforestry practices to increase the long-term productivity of the system could conflict with the farmer's own interest. In fact, most farmers have short term horizons when it comes to the planning of conservation measures, particularly if they do not have a secure tenure over the plots they cultivate. Incentives (i.e., subsidies) are often required to encourage the adoption of conservation farming practices. Nevertheless, there are ample agroforestry approaches that combine long-term sustainability benefits with medium and short productivity gains in cleverly designed systems. For example, contour hedgerows of multipurpose trees provide erosion control along with yields of valued products.

Adoptability

To avoid the non-adoption of technical innovations by the farmer then blame his conservatism for this failure, a more constructive approach consists of involving the intended users directly in the technology development process from the beginning as active participants in the design, trial, evaluation and redesign of the agroforestry innovations.

Agroforestry is not the answer to every land use problem, but the range of agroforestry options is very broad, and every agroforestry farmer has his or her favorite technologies. What is needed is a systematic way of matching agroforestry technologies to the actual needs and potential of existing land use systems.

III.2. PHASES FOR PLANNING AND DESIGNING AGROFORESTRY

A unique land management approach, agroforestry generates opportunities to blend profitability and productivity with careful and responsible environmental management to support sustainable agricultural systems, economies, and communities. It is a tool and technique that can overcome or at least alleviate farmers' agricultural, economic and social challenges.

To reach the most suitable Agroforestry design for their lands, Agroforestry designers (farmers, practitioners, landowners, agriculture engineers, etc.) need to consider a sequence of phases that will enable the development a useful, practical, and adoptable design on the designated land. The following section provides practical tools to guide the designers in the development of the most appropriate Agroforestry design for their lands.

Figure 24 Phases of Agroforestry design

PHASE 1: LEARN AGROFORESTRY

Shifting from a traditional historically adopted farming system to another requires a deep understanding of the new system's usages, best practices, and benefits. To achieve this goal, farmers, practitioners, landowners and communities should have access to the needed information allowing them to properly understand the new concept. Information on Agroforestry farming systems and practices can be found in manuals, online, and in workshops or seminars. Agroforestry designers should be encouraged to seek information allowing them to design, adopt and implement the agroforestry practices tailored to their objectives.

PHASE 2: SET OBJECTIVES AND PRIORITIES

The first practical step toward designing an agroforestry land is to set management objectives and priorities specific to the conditions and circumstances of the land. Management objectives may range from productive, to protective, conservative, and financial. The below Table 2 lists some of the main management objectives to inspire Agroforestry designers and assist them in identifying management priorities for their lands.

Table 2 Defining Agroforestry objectives and priorities

Objectives	Low	Medium	High	Top 3
New source of income from low to unproductive land				
Increase short term income while waiting for the long-term income from the tree component				
Develop new sources of long-term income on lands producing short term income				
Reduce cost of agricultural operations on the land (fertilizers, pest control, etc.)				
Protect or improve environmental conditions (soil erosion, microclimate, etc.)				

Increase forage/fodder production for livestock				
Adopt good agriculture practices for a long-term sustainable system				
Others				

PHASE 3: ASSESS THE LAND

Prior to designing an agroforestry system on a land or site, some questions should be addressed, and information collected. This diagnosis aims at a focused connection between the objectives of the agroforestry system to be developed and the potential and challenges of the existing land. Below Table 3 lists the essential information to be collected through assessment and evaluation prior to designing.

Table 3 Land assessment technical sheet

Assessed data	**Purpose**
General site description	
Area: - *Location* - *Map* - *Size*	Locating the land and defining the local conditions to simulate suitable Agroforestry designs according to the intrinsic land characteristics.
Topography: - *Elevation* - *Slope* - *Orientation*	
Description of current land conditions: *Bare land, planted, fallow, forest, other*	
Existing plants: - *Trees (forest/fruit)* - *Vegetation/cover types*	Identifying the existing planted trees and vegetation cover types allows the designer to determine the number and species of needed trees/crops and take decisions on keeping or removing existing plants.
Land History: - *Species and crops* - *Number of seasons* - *Shade/sun tolerant* - *Irrigation type etc.…*	Identifying the crop calendar historically used by the farmer to determine traditional species suitability, land performance, current land conditions, nutritional assessment, etc.
Recreational and aesthetic values	Designing an AF model that conserves and adds value to the existing.
Site Climatic/Agricultural conditions	
Wind: - *Direction*	

- *Speed* - *Frost wind*	Assessing the site climatic conditions allows the farmers to understand the local climatic conditions and challenges and hence adopt an agroforestry model including that take into consideration the local conditions (selection of suitable species for local climatic conditions) and alleviate climatic challenges (finding solutions for extreme weather conditions, i.e., building windbreaks).
Average and extreme temperatures: - *Winter average and extreme* - *Summer average and extreme*	
Weather Conditions: - *Precipitation level* - *Frost/snow persistence* - *Floods* - *Extreme conditions*	
Soil: - *Type (calcareous, sandy, other)* - *Soil rockiness (% of rocks)* - *Fertility (Soil testing)* - *pH*	Determining the soil and organic material profile dictates the soil fertility program that the landowner must adopt and the suitable species to select in compatibility with the soil edaphic conditions. Landowners can choose between directly applying organic matter or planting green cover crops.
Ecosystem: - *Existing wildlife and their impact* - *Threatened and endangered species* - *Environmental threats (disease, pests, etc.)*	Designing AF practices that conserves the ecosystem, enhances presence of natural enemies, sustainably resolve diseases challenges and limit usage of pesticides and adopting the proper AF practices that protect and do not disrupt the balance in the existing ecosystem.
History of usage of pesticide or chemicals	Defining soil amendments requirements needed prior implementation taking into consideration the spraying intensity measures and the level of chemical soil residues.
Agricultural practices adopted: - *Rotation* - *enhancing soil fertility,* - *plowing or not,* - *mulching, etc….)*	Defining the level of management and skills needed for a successful implementation and monitoring techniques and indicators of the AF system.
Other	

PHASE 4: ASSESS RESOURCES

Land assessment is a key factor to be considered prior to designing any agroforestry system. It must be completed by conducting a complete resources assessment: economic, human and logistic, to perfectly plan the Agroforestry startup/management. Below Table 4 shows main questions that need to be addressed to complete the assessment.

Table 4 Resources and site logistics assessment technical sheet

Assessed resources/ site logistics		**Purpose**
Economic resources	Annual crops income, livestock revenues, by products produced, wood or fuel wood, etc.	Calculating the total income of each component separately to identify the income/expenditures per component to develop a feasibility study and identify if any intervention is needed.
Human resources	Farmer skills	Planning for the needed skills: capacity building trainings, sessions, etc.
	Available labor (annual or seasonal)	Designing manageable agroforestry system within available resources and defining needed resources.
	Labor skills	Differentiating between skilled and unskilled workers, distributing tasks based on labor force existing, identifying the needed skills and providing needed trainings to improve labor skills.
Site Logistics and Assets	Water resources	Assessing farmers water assets (the available water quantity) and defining the irrigation techniques, costs, type of crops to be planted based on water resources on site.
	Equipment/Machines (list, age, condition)	Creating an inventory of tools of equipment and identifying the needed items. Identifying the technology level and the productivity and capacity of existing machines to plan the implementation phase. Calculating machines value, running and depreciation costs.
	Organic compost resources (animal manure, organic mulch, etc.)	Developing a fertilization and land preparation program through existing sources and defining needed soil amendments.
	Animal resources: livestock, bees, poultry, etc.	Defining suitable AF practice for the animal component and management plans.
	Existing roads and access	Defining practical feasibility of the project and needed logistics needed for the implementation.

	Utilities (electricity, cable, phone)	
	Zoning restrictions	Identifying the exact boundaries of the private property and resolving any conflicts (in case) before the project startup.

PHASE 5: PRE-DESIGN brainstorming

After completion of the assessment phase, Agroforestry designers need to start linking and analyzing all the information collected, assimilating the challenges and needs of the local context of the land to the potential benefits and services that Agroforestry designs can present. Below Table 5 includes core questions guiding the designers through this phase and orienting their choices for the design phase.

Table 5 Pre-design brainstorming technical sheet

Question	**Example**
What is/are the main environmental problem(s) that agroforestry needs to solve for you?	Frost, wind, flood, soil erosion, dust, soil fertility, limited revenues, etc.
What function of the agroforestry system are you seeking?	Production, protection, both.
What agroforestry system and practices will you adopt? The most suitable for your land?	Silvopasture, Agrisilviculture, Agrosilvopastoral, Windbreak, trees on cropland, living fence, home garden, alley cropping, improved fallows, trees on rangeland, forest farming, apiculture
What is the arrangement of components to be adopted?	Spatial Temporal
What are your commercial goals and management input?	Self-sufficiency, communal, commercial Large, medium, small scale

PHASE 6: SPECIES SELECTION

Following the brainstorming phase, Agroforestry designers need to prepare an inventory of the desired suitable species (woody component, herbs component and animal component) that will be integrated on the land under design. The tree component (woody perennial) is the most essential element in Agroforestry, and it is highly recommended that the choice of trees follows the concept of the multipurpose tree described below.

THE CONCEPT OF MULTIPURPOSE TREE:

A multipurpose tree species provides more than one service or product. Multipurpose tree species provide a variety of wood and non-wood products as well as many services i.e., soil conservation, soil fertilization, shade, insecticidal properties, etc.

All trees provide at least shade and protection from soil erosion services. The use of multipurpose trees or shrubs in agroforestry is economically and ecologically motivating as well.

The most common multipurpose tree species belong to the legume family, since they offer a wide variety of products and services, such as:

- A variety of wood products (timber, poles, fuel…).
- Non-wood products such as fruits and pods, leaf fodder, edible flowers for some species, ornamental shoots…
- The have fertilizing properties as a result of mutualistic (symbiotic or not) roots association with nitrogen fixing bacteria and could be used as a green manure. Their use in an agroforestry system increases significantly crop yields, pasture production and animal production in Silvopastoral systems.
- Many species are spiny or thorny and can be used as living fences in addition to the functions cited above.

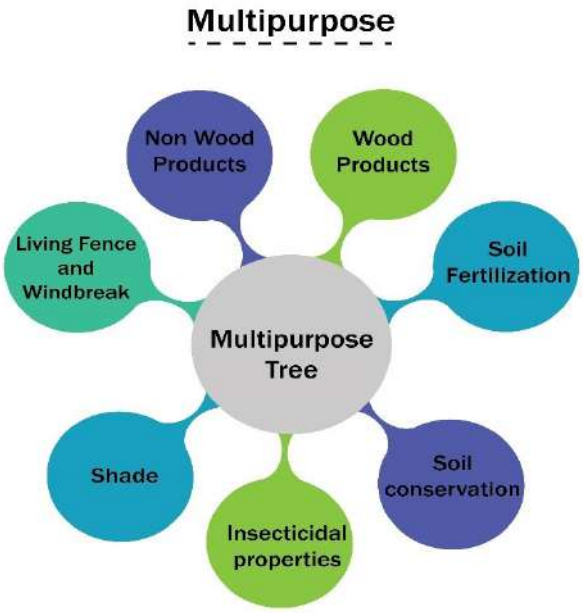


Figure 25 Benefits of the multipurpose tree

The following table lists the most elementary tree attributes influencing tree performance in agroforestry systems and multipurpose tree characteristics. These attributes should be assessed by the Agroforestry designer prior to species selection. For the choice of species (forest, fruit, forage, service trees) refer to the full list of species in Chapter IV.

Table 6 Selection of tree species: tree attributes and relationship to performance in Agroforestry systems

Tree attributes		Relationship to performance in Agroforestry systems
Bioclimatic zone of the land		Define the vegetation zone to determine the species to be planted.
Service or product		Determine the desired outcome (service/role/product) from trees species and introduce multipurpose tree concept
Tree morphology	**Size & life span**	Ensures ease of harvesting leaf, fruit seed and branch wood, shading or wind effects.
	Rate of growth	Overcome sites limitation where wind is a limiting factor for crop growth and yield. (Fast growing trees are favored)
	Deciduous or evergreen foliage	Implies the desired outcome from the planted trees
	Mono or dioecious species	Important for fruit, seed production, and essential for pollen flow and the beekeeping component
	Stem form / multi-stem habit	Defines the purpose of the trees planted or the type of production (timber, posts, poles and fuelwood; shading or wind effects)
	Crown size, shape and density	Determine the effects of leaf quantity, mulch and fruit production, shading or wind: direct effect on the microclimate, light interception by the understory and on tree-herb interactions.
	Rooting pattern (deep or shallow, spreading or geotrophic)	Determine the level of competitiveness with other components, particularly resource sharing with crops, suitability for soil conservation
	Physical and chemical composition of leaves and pods	Identify fodder, litter and mulch quality determining soil nutritional aspects.
	Thorniness	Suitability for living fences and barriers
	Wood quality	Determine the heat capacity from various wood products
	Phenology (leaf flush, flowering and fruiting, and cycle (seasonality)	Determine the time and labor needed for fruit, fodder and seed harvest, season of fodder availability, barrier function and windbreak effects
	Pest and disease resistance	Reduce the risk of diseases and problems regardless of the tree function
	Vigor	Biomass productivity early establishment and overall yield

	Response to pruning and cutting management practices	Use in alley cropping, row planting in silvopastures
	Possibility of Nitrogen fixation	Determine the growth level on poor soils, soil enhancement and fertilization needed, site rehabilitation and improved herb (crop and pasture yields)
Farmer skills and knowledge on agriculture practices for each species		Assess farmers skills to provide the needed capacity building program needed (Pruning techniques, maintenance of the orchard, etc.).
Plantation season		Determine labor required and set management plans
Sun/shade tolerances		Determine the suitability of species
Animal component		Decide on: Type of livestock (goat, sheep, cow, pigs, etc.), poultry (chicken, ducks…). - Herd size and breed to define a clear grazing management plans and identify pasture areas required.
Economic considerations		Cost vs revenues: Calculating the operational costs and identifying the prices at which yield will be sold Market supply and demand: identifying the local dietary requirements and market demand, potential markets and availability on the market of species to be used.

PHASE 7: DESIGNING AND MAPPING

In this last phase, Agroforestry designers are expected to compile all the information collected and developed in the previous phases, into a visual design of their land. It is recommended to draw a sketch map of the land under design to display the Agroforestry model developed and visualize the overall integration and arrangement of the different components of Agroforestry. The following table lists the main elements that can be incorporated into the map design of the land. Design maps can be developed either as free-hand sketches or computer simulated: simple simulation or detailed designs that specify exact planting distances and quantities of plants needed (AutoCAD software or similar).

Table 7 Essential elements for mapping an Agroforestry design

Map elements	Examples
Existing land uses	Farm, pasture, crop land, etc.
Water resources	Tank, irrigation network, pond, steam, etc.
Topographic data	Terraces, big rocks, roads, North orientation, etc.
Wind direction	South-West, North, etc.
Agroforestry practices planned	Alley cropping, silvopasture, trees on cropland, etc.
Spatial arrangement of components and tree density	Divide the land as parcels as per AF practices and tree species to be included. Define inter and intra row spaces for each tree (refer to Chapter IV below for more details and data)
Species distribution	
Orientation	North south alleys (for Alley cropping practice). Windbreak trees facing wind direction, etc.

MAPPING THE SPATIAL ARRANGEMENT OF TREES:

Well designed and planned spatial arrangement of the woody component is crucial to:

1. Reduce competition between different components (mainly trees and herbs).
2. Achieve an overall positive gain of the system.

In this last mapping phase, Agroforestry designers need to define the pattern that the trees will be displayed on the designated land, according to the desired AF system, practices and services expected from the trees on the land. Spatial arrangement for trees most suitably adopted for the common Agroforestry practices are:

- **Individual or clumps of scattered trees:** suitable for trees on croplands, trees on rangelands and pasturelands, apiculture with trees, improved fallows practices.
- **Mixed dense stands of trees:** suitable for home gardens, forest farming, apiculture with trees practices.
- **Blocks with straight edges:** suitable for windbreaks, shelterbelts and living fences practices.
- **Clumps with round edges:** suitable for any Silvopastoral practices to limit grazing zones.
- **Field border (single or multiple rows):** suitable for windbreaks, shelterbelts, living fences and appropriate for defining the borders of the lands.
- **Middle field strips (single or multiple rows):** suitable for alley cropping, trees on croplands, plantation combined with pasture and animals' practices.

This list of suggested spatial arrangements per agroforestry practice is only a set of recommendations to guide the designers toward the most appropriate patterns suitable for their designs. Trees arrangements can have any desired shapes and patterns in Agroforestry as long as they're meeting the desired objectives while mitigating any possible competitions between the different Agroforestry components.

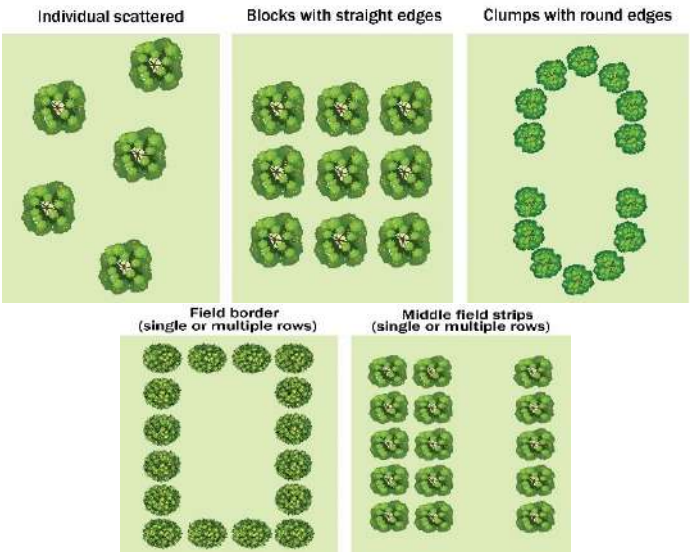


Figure 26 Illustrated tree arrangements

At the end of this phase, the landowner must have a clear vision on applied agroforestry practices, land uses and spatial arrangements of trees and species. A sketch of the adopted design needs to show a visual map of the tree arrangements, integration of elements (trees, crops, animals), system(s) and practice(s) adopted. The advancement of this map can be gradually conducted as practitioners enter the implementation phase and investigate further about each desired component of his land. More information on the implementation of Agroforestry components follows in Chapters IV, V and VI.

Examples of designing and mapping Agroforestry systems

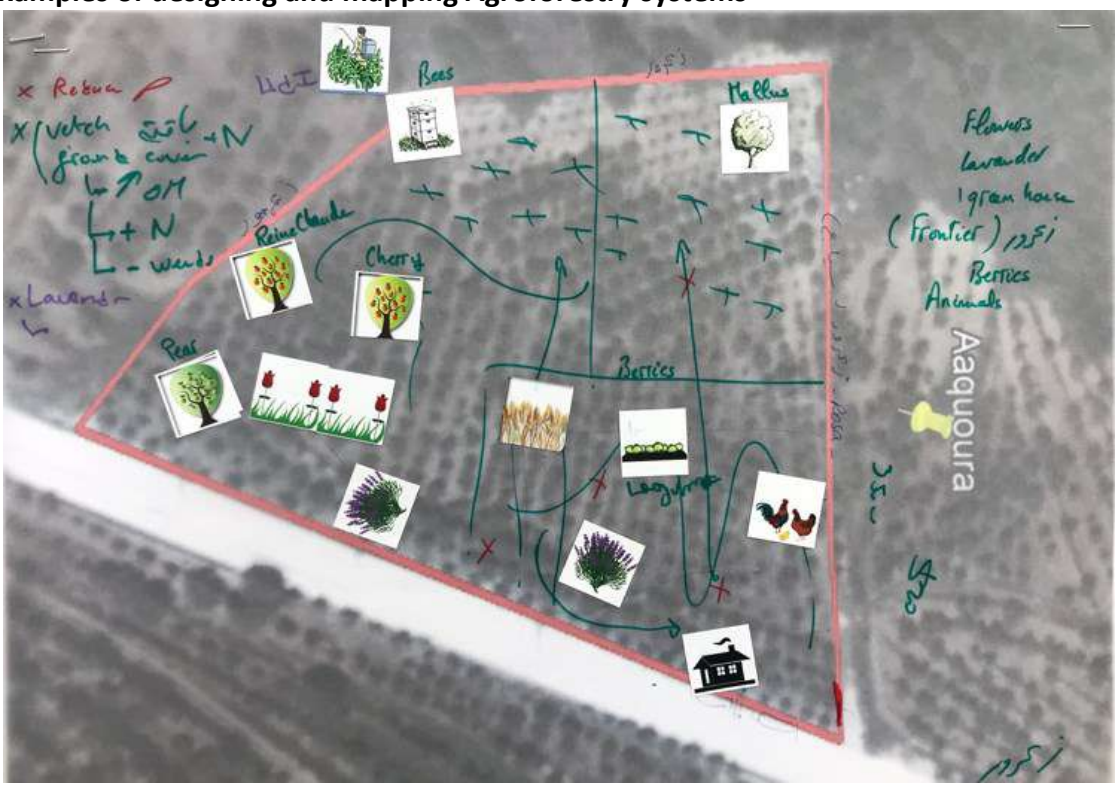


Figure 27 Free-hand design and map

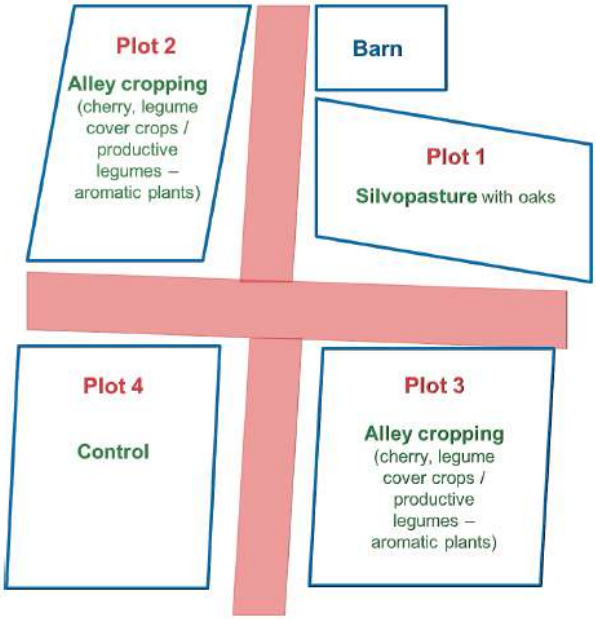


Figure 28 Computer simulated design and map

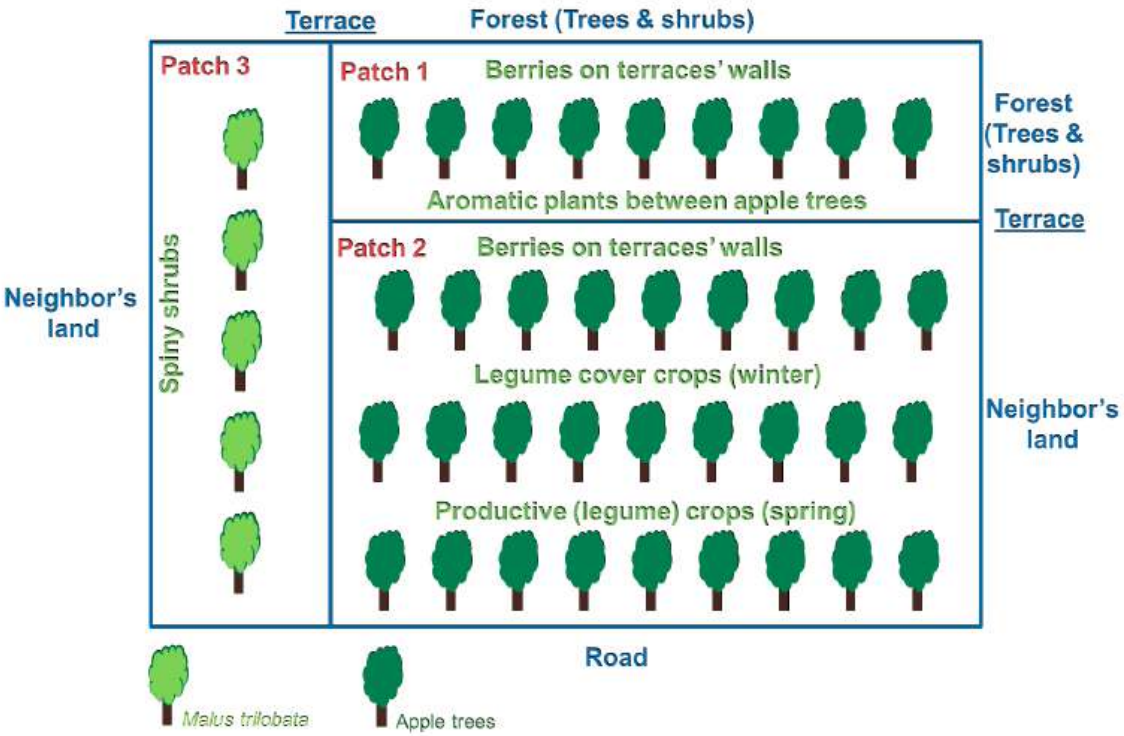


Figure 29 Detailed computer simulated design and map

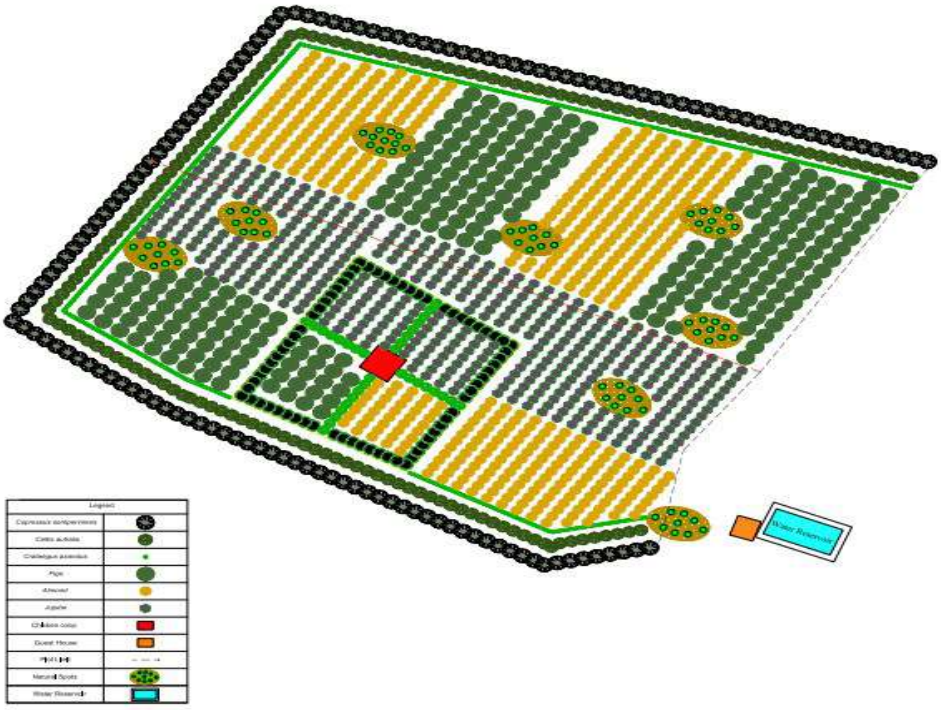


Figure 30 AutoCAD simulation of Agroforestry map and design

CHAPTER IV. AGROFORESTRY IMPLEMENTATION: ESTABLISHING THE TREE COMPONENT

Agroforestry practices are implemented classically on existing croplands, rangelands, and forests. Agroforestry can be also established in fruit orchards and on fallows or abandoned lands. Agroforestry practices can be applied as a restorative approach for degraded lands suffering from erosion or desertification.

Every land could be a candidate for agroforestry practices. However, each land-type requires specific site preparation operations prior to the establishment of the agroforestry system.

On croplands, pasture lands and fallow lands, trees are planted in homogenous rows or random distribution. Meticulous attention is brought to the spacing between the trees, between the rows and between the trees and the herbs (crops) to favor positive interactions and optimal growth patterns for the tree and the herb component as well.

On forest sites or tree plantations, trees are pruned, and their density is managed to create spaces and light gaps in order to introduce the herb component.

The establishment of an agroforestry system proceeds progressively as follows:

- Preparing the land.
- Establishing or managing an existing Tree component.
- Incorporating or managing an existing Herbaceous layer.
- Integrating the Grazing animal (in Silvopastoral and Agrosilvopastoral systems).

In this chapter, the land preparation for hosting the central Tree component in Agroforestry are discussed, whereas the implementation of the herbaceous and animal components is detailed in Chapters V and VI.

IV.1. LAND PREPARATION

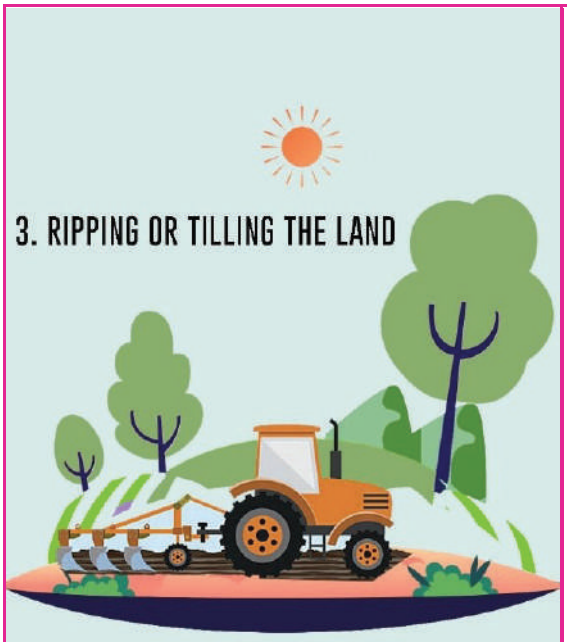
In almost all practices of Agroforestry, land preparation is the initial step, considered as the founding stone for implementing any designed Agroforestry system. Ideal lands for establishing Agroforestry need to:

- Have the most suitable topography for the design.
- Have a sandy loam textured soil deeper than 50 cm.
- Have a rich organic content.
- Not form surface seals or crusts or contain an inappropriate proportion of rocks and stones.
- Not have restrictive layers in the top 50 cm.

To achieve that, some land preparation operations are required, which include the manual or mechanical adjustment of land structure and topography, as well as the improvement of soil characteristics and fertility. Some best practices of agroforestry land preparation are described in the table below. It is highly recommended to limit the use of machinery for land preparation to the minimal requirements in order to avoid soil compaction and deterioration of soil characteristics.

Table 8 Steps for preparing Agroforestry lands

	Preparing the land for Agroforestry plants (trees and herbs) includes the following steps: 1. Remove any undesired wildly grown weeds and herbs that could interfere and compete with the desired plantations: - Weeds can carry crop pathogens and host damaging insects and pests. - Weeds can affect the yields' quantity and quality, being aggressive competitors for nutrients and water. 2. Remove undesired weeds can be manual or by using hand tools: - Weeds need to be completely removed from the soil, including roots, and totally extracted from the land to avoid any potential of regeneration through the seeds or the roots. - Weeding residues can be added to a composting pile or provided as forage for animal. - Prescribed fire for cleaning and clearing is highly undesirable as it can destroy the organic matter content of the soil, kill beneficial soil organisms and results in soil erosion.
	Removing rocks and stones from agricultural fields: 1. Rocks and stones in agricultural fields aren't likely to have a negative impact on the Agroforestry plants: - Their presence in an acceptable percentage is considered a `good soil characteristic as it helps in water infiltration into the soil. However, high rockiness in a land has the potential to block the growth of the roots and hence affect the survival of the plants. 2. Removal of big to medium sized rocks and stones from the topsoil through manual picking or using a tiller or a wheelbarrow. 3. Usage of collected stones for building structures on the land such as terraces or swales.

<table>
<tr>
<td> 
</td>
<td>Adopting Agroforestry based Conservation Tillage (AFCT) to:

- Minimize mechanical operations and soil disturbances and hence reduce the risk of soil erosion and surface compaction.
- Conserve water and avoid evaporation.
- Decrease fuel expenditures and costs of production.
AFCT consists of minimal tillage interventions, where tillage is only recommended in specific cases, such as:

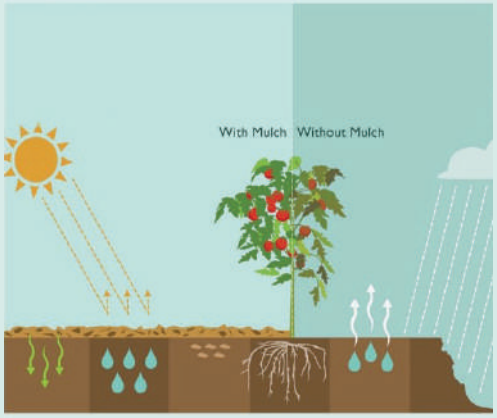
- The first tillage, plowing the land prior to any plantations, to remove stones, rocks and remaining weeds.
- Strip tillage, where tillage is specifically localized in rows where plantation will occur.
- Ridge tillage, where ridges or raised beds are built to provide a better drainage in wet soils.
Small hand tools and equipment are recommended for tilling Agroforestry lands as mechanical tillage is preferably to be avoided as possible.</td>
</tr>
<tr>
<td> 
</td>
<td>Soil leveling and terracing is an essential step while implementing agroforestry designs, having many beneficial outcomes:

1. Increases farmability and land productivity of sloped fields.
2. Contributes to water conservation: slows down and reduces water runoffs, improves rainwater harvesting.
3. Prevents soil erosion by decreasing rill formations.
4. Boosts soil conservation.
5. Reduces sedimentation and water pollution.

Terraces, ridges or swales can be built using the local resources available on land or nearby locations (rocks and stones) with machinery interventions avoided as possible.</td>
</tr>
</table>

<table>
<tr>
<td> 
</td>
<td>Compost is the best and fastest recommendation a partitionist can give to improve the organic matter content in the soil. In turn, the soil takes care of the plants, offering a smorgasbord of nutrients, pest, and disease resistance, and more. But those nutrients are slow release, feeding plants over time. The benefits of a single compost application can stretch over multiple seasons. While establishing the land, compost is preferable to cover the whole surface of the land and tilled with the soil as a first application, while more compost applications are recommended at the exact locations of tree plantations.
The amount of compost spread per year should not exceed the following limits:

1. 17g/m^2 total nitrogen
2. 6g/m^2 phosphate
3. 12g/m^2 potassium oxide

Compost of grade A is preferable. For the Lebanese soils, compost application must be at least between 10-15% of the volume of soil where compost will be applied at a depth of 50 cm.</td>
</tr>
<tr>
<td> 
</td>
<td>Applying mulch at the soil surface to cover the soil with insulating organic material (tree leaves, straw, sawdust, etc.) before or after plantation, is essential to the survival of the plants, as mulching:

1. Conserves the soil moisture, enhances the nutrients status of soil, controls the erosion losses, suppresses the weeds in crop plants, and removes the residual effects of pesticides, fertilizers, and heavy metals.
2. Improves the aesthetic value of landscapes and economic value of crops.</td>
</tr>
</table>

Fertilizing the soil with green manures is a very effective tool to cover bare soils and enrich them with nutrients and organic matter. Seeds of green manure plants (cover crop seeds) are sown and grown, to be incorporated into the soil while still green. The essential role of green manures is to add organic matter to the soil. Several species of green manure seeds are available. It is recommended to use legume crops to add nitrogen to the soil and increase fertility. They also help in reducing soil erosion and improve soil structure.

How to calculate the amount of compost needed for the land?

- Minimum application rate: 10%
- Maximum application rate: 50%

Depending on the soil fertility tests.

Soil volume (m^3) = Area (m^2) x depth (0.5 m – 1 m)

Quantity of compost (m^3) = Soil volume (m^3) x application rate (%)

IV.2. IMPLEMENTING THE TREE COMPONENT

The woody perennial component is the most essential element in any Agroforestry system, and it is a defining element of the intended Agroforestry practice. Besides the spatial arrangement of trees i.e., how trees occupy the land, the spacing between the trees and between the trees and the herb components (crop, pasture) is crucial to foster positive interactions between the components and avoid competition for resources.
A good tree arrangement (and spacing) should ensure light transmission to the understory and microclimate modification for an optimal herb production, avoiding any competition between the trees and the herbs that might lead to a decline in productivity.

IV.2.1. TREES IN ALLEY CROPPING/INTERCROPPING

Alley cropping or intercropping, is the practice of planting rows (single sets or multiple) of trees and shrubs at wide spacing, creating alleys, within which diversified species of crops can be planted (agricultural, horticultural, or forage crops). To implement an alley cropping pattern, the following steps are recommended.

DETERMINE ORIENTATION

To maximize the light uptake by the trees and avoid sun competition between the alleys of trees and herbs, the orientation of the alleys is recommended to follow a North-South direction. As the sun rises from the East, alleys receive sunlight from their eastern side, at noon sun is directed toward the top of the trees canopy, and the western side of the canopy is covered by sunlight during the afternoon as the sun sets in the West.

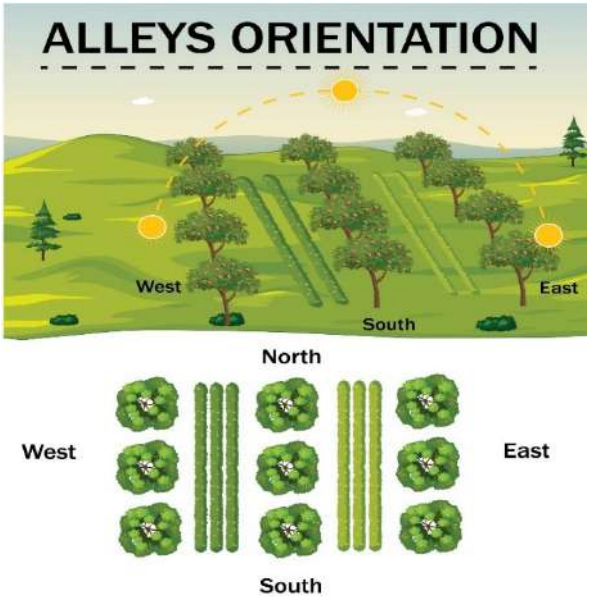


Figure 31 North – South orientation of tree/crop alleys

To determine the North-South orientation, implementers can:

- Use compass.
- Follow his shadow direction, at midday (usually at noon, depending on the season and the month).

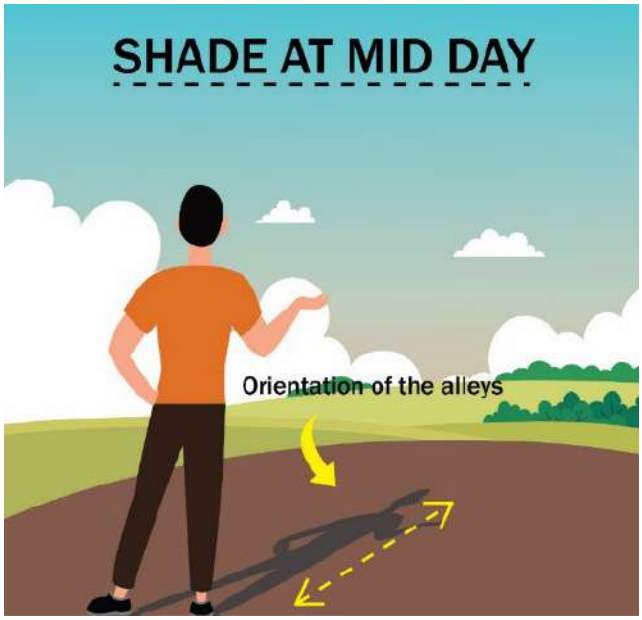


Figure 32 Defining orientation of the alleys by following the shadow at mid-day

MEASURE INTER AND INTRA-ROW SPACES

Alley cropping/intercropping practice does not require planting under trees all the time, but it promotes the plantation of herbs and crops between the rows of trees. Shade tolerant species can be planted under the tree canopies and sun tolerant species are planted within rows of trees.

- Inter-row spaces:

Defining the distance between an alley of trees and another (the inter-row spaces) is an essential step to mitigate any competition for sunlight and water between trees and crops. Inter-row spaces must allow corridors between one row and another for intercropping the herbs between the trees. To define the distance needed, several factors need to be accounted for:

  - Canopy at maturity of the selected species: spaces between an alley and another should remain clear for sun penetration even when the trees reach their optimal canopy growth. The canopy or crown of mature trees (the maximum diameter that tree branches can reach) should not shadow the alleys of crops. Canopies depend on the tree species, and inter-row distance must account for the optimal size of the canopy at maturity. Distances between a row and another must always account for the canopy diameter of trees at maturity.
  - Tree versus crop production: increasing the intra-row spaces might affect the number of trees placed on the land and hence the land productivity from the trees, while minimizing the intra-row spaces can affect the productivity from the crops as less crops will be planted in between rows. Landowners and farmers need to balance the inter-row spaces based on the desired productivity from their lands.

Inter-row spaces can vary from a section of the land to another, based on the different species planted in each alley and according to the desired crops productivity.

- Intra-row spaces:

Intra-row spaces are the distance between a tree and another within the same alley of trees. It is usually an equal distance between trees of the same row, and it directly depends on the tree species planted within the row. Calculating the intra-row spaces must take into consideration the size of the tree canopy/crown at maturity. Intra-rows distances are always smaller than inter-rows distances. Management practices must maintain this difference by pruning trees regularly to maintain an open canopy for inter-rows crops to grow, while trees canopies are encouraged to grow toward the intra-row spaces.

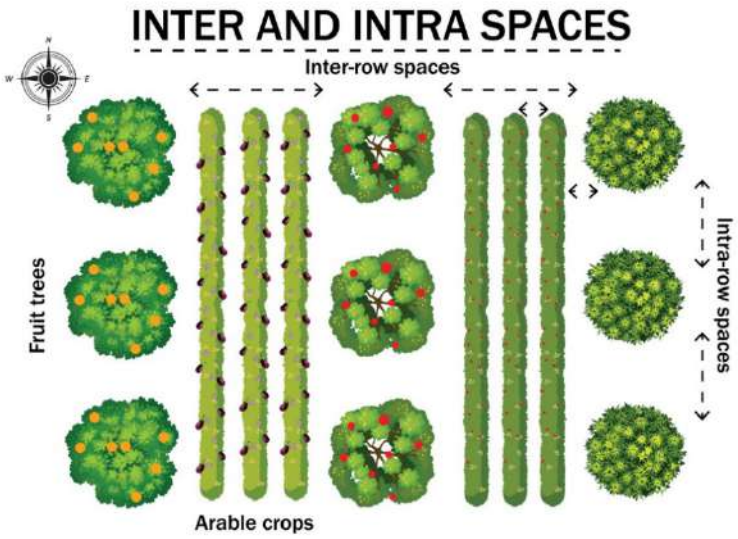


Figure 33 Inter and intra-rows spaces in alley cropping

IV.2.2. TREES IN WINDBREAKS AND SHELTERBELTS

Windbreaks and shelterbelts are fundamental structures in Agroforestry, commonly adopted for the benefits and services they provide in agricultural lands, by protecting crops and yields from climatic factors (wind, frost, snow, dust). Each windbreak design is unique depending on the objectives of the landowner, local site conditions and desired functions of the windbreaks. Implementing a functional and efficient windbreak structure must take into consideration windbreak structural components: orientation, height, continuity, density, length, width and species composition.

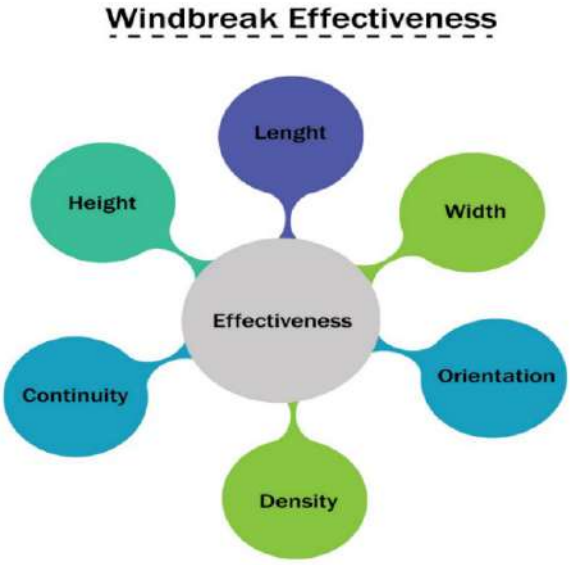


Figure 34 Windbreak structural components affecting its effectiveness

FUNCTIONS OF WINDBREAKS/SHELTERBELTS

Windbreaks/shelterbelts are single or multiple rows of trees and shrubs that reduce the force of the wind as an essential function, while reducing soil erosion due to wind, increasing crop yields and protecting animals from heat and cold. When present on agricultural fields, windbreaks reduce wind speed, modify the climate and have a direct effect on:

- Moderating soil and air temperature.
- Balancing the relative humidity.
- Reducing evaporation and increasing soil moisture.
- Improving snow distribution.
- Reducing soil erosion.

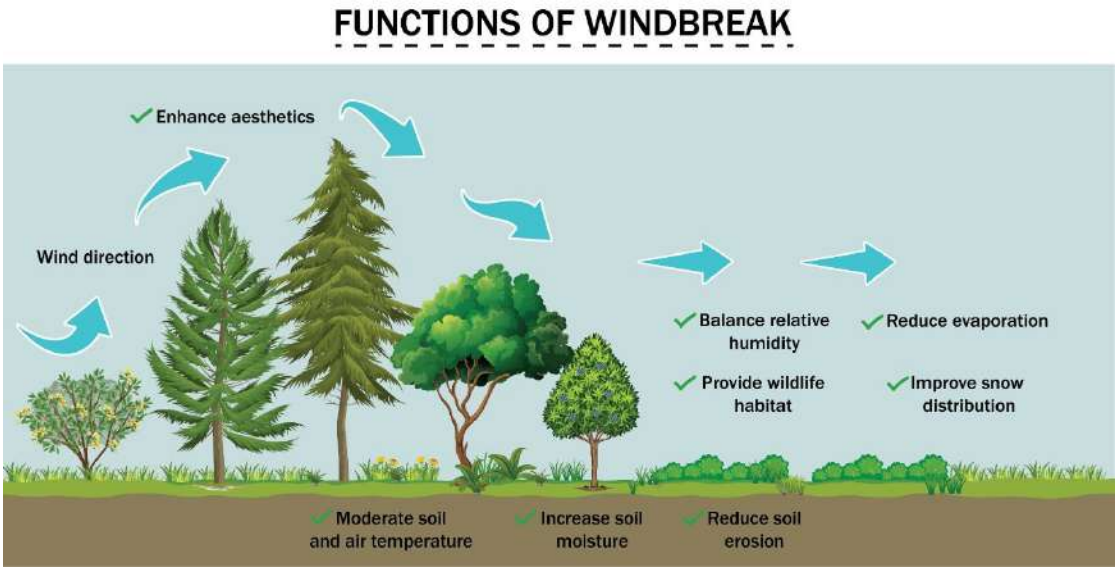


Figure 35 Functions provided by the presence of the windbreaks/shelterbelts

Foremostly, windbreaks are established on Agroforestry fields to improve crop quality and yield as their presence provides lower temperatures in the day and warmer temperatures in the night, increases relative humidity and help retain moisture in the soil, leading to less irrigation requirements, in addition to reducing physical damage caused by high wind speed and frost. Yields are estimated to increase by 25% when protected by windbreaks and shelterbelts. The presence of windbreaks does not only help improve yield quality and quantity, it also provides several protective and productive functions to sustain the land's productivity and conserve its natural resources.

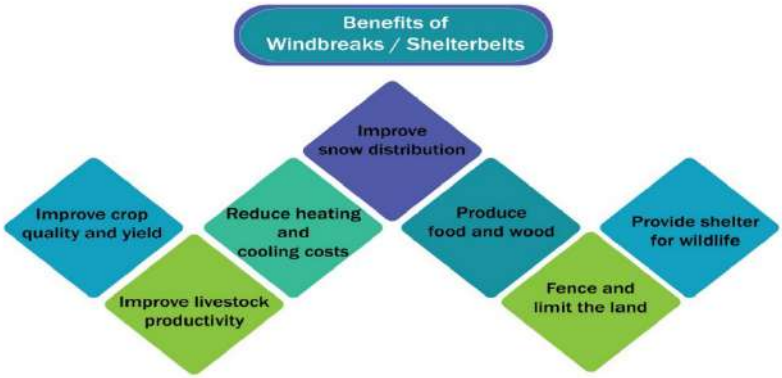


Figure 36 Benefits of windbreaks/shelterbelts

ORIENTATION AND HEIGHT

Windbreaks are most effective when oriented at right angles to prevailing winds, when the essential desired function of the windbreak/shelterbelt is protection against prevailing winds. Cold winds, blowing snows, dust control can be also considered in windbreaks planning, and orienting the windbreaks perpendicular to the problem direction provides the most useful protection.

Windbreak height (H) is the most important factor that determines the downwind area protected by the windbreak. In multiple row windbreaks, the height of the tallest tree determines the value of H. Windbreaks provide protection on both windward and leeward sides:

- Windward side of the windbreak: wind speed reductions are measured up to 2 to 5 times the height of the tallest tree (2-5H).
- Leeward side of the windbreak: wind speed reductions occur up to 10 times the height of the tallest tree (10 H).

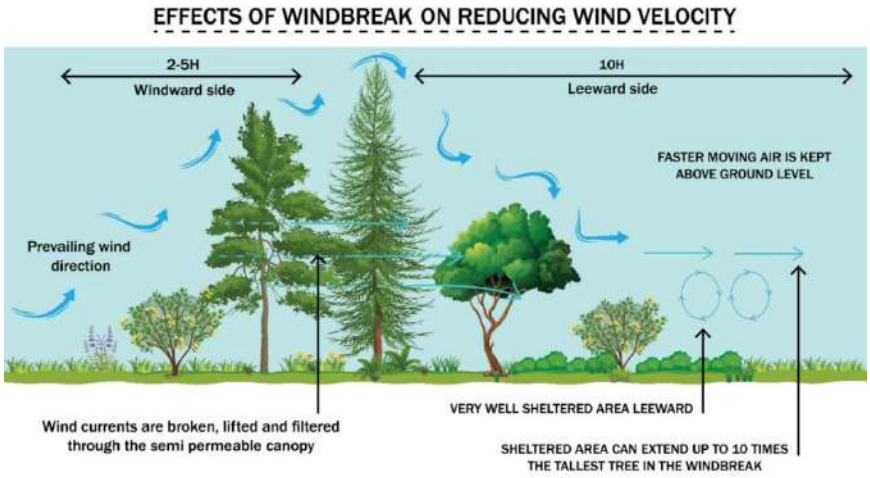


Figure 37 Effects of orientation and height on reducing wind velocity

Example if the tallest tree of 10 m, the protected area will be 20 to 50 m windward and up to 100 m leeward, depending on severity of wind and frost conditions of the land. In large scale lands, Agroforestry practitioners are encouraged to establish several inland windbreaks to ensure the protection of the total land from weather hard conditions.

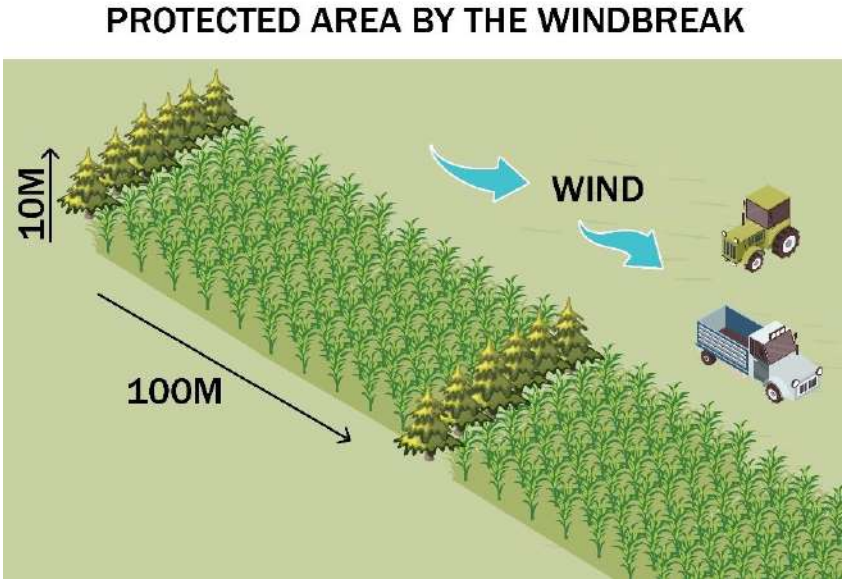


Figure 38 Protected area by the windbreak

LENGTH AND CONTINUITY

While the height of the tallest tree of the windbreak defines the extent of the protected area downwind, the length of the windbreak determines to total area receiving protection. Extending the windbreak length beyond the desired area for protection is essential to ensure maximum protection of the total planted area. Winds at the extremity of the windbreaks can alter the border crops if not protected by a windbreak extension.

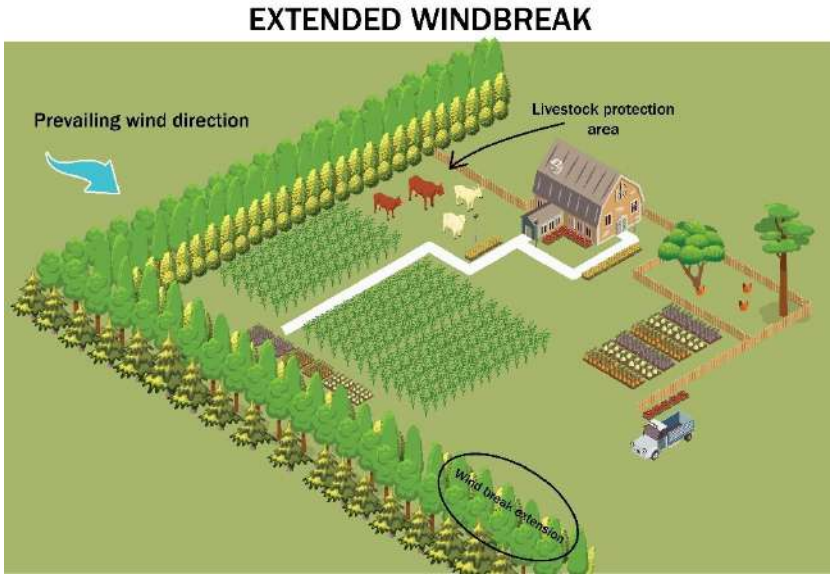


Figure 39 Windbreak extensions

Similarly, the continuity of windbreaks has also an influence on its efficiency. Gaps within a windbreak become funnels for undesired concentrates of wind flows and create access lanes for wind, which diminishes the effectiveness of the windbreak and results in losses in yields.

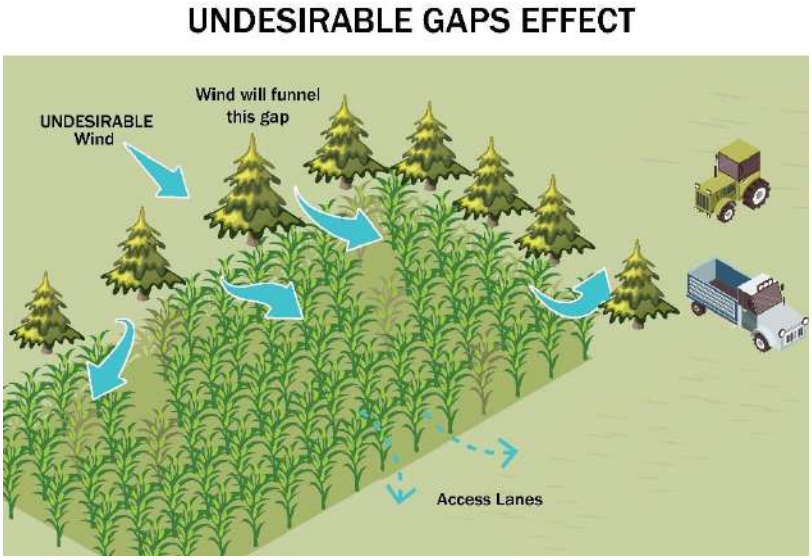


Figure 40 Undesirable gap effect of windbreaks

DENSITY

Windbreak density is the ratio of the solid portion of the barrier to the total area of the barrier. The more solid a windbreak, the less wind passes through, and decreasing the density of the windbreak results in increasing the amount of air passing through. However, less dense windbreaks allow for protection of a greater distance. Optimal densities for windbreaks are directly related to the expected functions of the windbreaks:

- A density of **60-80% (dense)** provides maximum wind reduction but short wind shadow (protection distance). This density is most suitable in fields where wind speed is extremely damaging.
- A density of **40-60% (moderately dense)** provides less wind reduction but longer protection distance. It is the most suitable density for Lebanese agricultural lands, where wind speed is moderate.
- A density less than **40% (lightly dense)** is most suitable for providing an even snow distribution across the field. This density is most recommended for snow control.
- A density **less than 20%** does not provide useful wind reduction, and **higher than 80%** generates wind turbulence and may reduce wind effectiveness.

Adjusting the density to the objectives is correlated to the choice of species (evergreen versus deciduous), the spacing and arrangement of trees, and the number of windbreak rows. Evergreen species (ex. Coniferous species), shorter spacing between trees and multiple rows increase the density of the windbreaks, while deciduous species, larger distances between trees and single rows decrease the density of the windbreak and allow

for air infiltration. The figure below provides an estimation of wind reduction based on species, density and number of rows.

	Deciduous 25-35% Density Open Wind Speed 10m.sec^{-1}				
H distance from windbreak	5H	10H	15H	20H	30H
m.sec^{-1}	5	6.5	8	8.5	10
% of open wind speed	50%	65%	80%	85%	100%
	Conifer 40-60% Density Open Wind Speed 10m sec				
H distance from windbreak	5H	10H	15H	20H	30H
m.sec^{-1}	3	5	6	7.5	9.5
% of open wind speed	30%	50%	60%	75%	95%
	Multi-Row 60-80% Density Open Wind Speed 10m sec				
H distance from windbreak	5H	10H	15H	20H	30H
m.sec^{-1}	2.5	3.5	6.5	8.5	9.5
% of open wind speed	25%	35%	65%	85%	95%
	Solid Fence 100% Density Open Wind Speed 10m sec				
H distance from windbreak	5H	10H	15H	20H	30H
m.sec^{-1}	2.5	7	9	9.5	10
% of open wind speed	25%	70%	90%	95%	100%

Figure 41 Effect of density, deciduous and evergreen trees on wind speed reduction Adapted from: University of Missouri Center for Agroforestry, 2021

WIDTH

The width of the windbreak is primarily defined by the number of rows adopted as a means to manipulate the density desired. Multi-row windbreaks are not only essential for ensuring the density required, but they also generate multiple benefits when a diversity of trees and shrubs are integrated to increase biodiversity on the land, increase productivity of wood and non-wood forest products when trees of the windbreaks are productive, they help in reducing diseases as they attract wildlife and enhance the biological pest control.

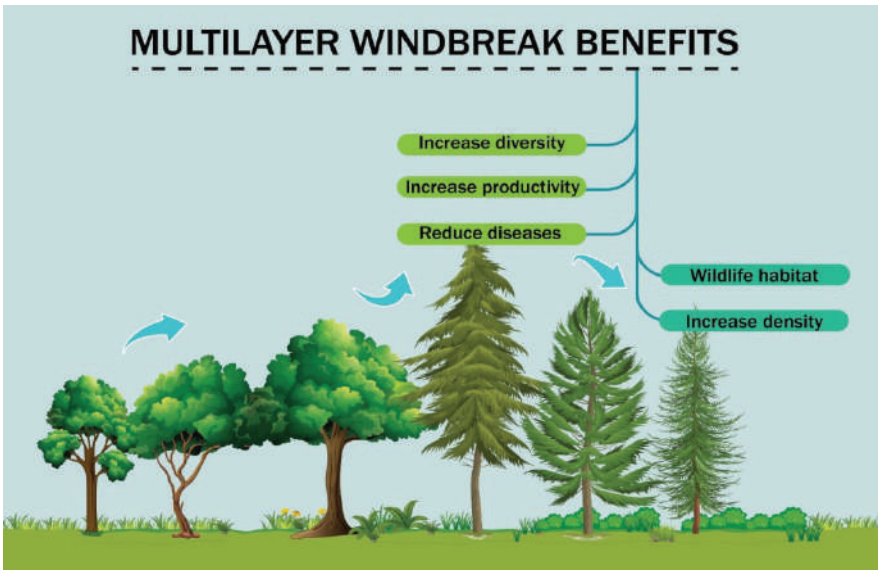


Figure 42 Benefits of multilayer windbreak

Patterns of windbreak designs (single, double, and multiple rows), arrangement, composition, establishment and management steps are all detailed in the following table and displayed in the illustration to guide Agroforestry practitioners in the implementation of windbreaks.

Table 9 Windbreak types

Type	Suitability for land spaces	Composition	Establishment and management requirements
Single-row windbreak	Small to medium scale lands. Low to moderate wind speed.	One evergreen trees row or densely branched deciduous tree row.	Densely planted for maximum effect. Continuous monitoring and replacement in case of dead trees. Avoid gaps.
Twin-row windbreak		Two evergreen rows, or one evergreen row and one deciduous.	Parallel row planting when trees of the same rows are densely planted. Alternate row planting when trees of the same row are spaced.
Triple and multiple-row windbreak	Medium to large scale lands. High wind speed.	One row of low, dense shrubs, followed by a row of medium-tall evergreens that retain foliage on their lower branches throughout their life, and a row of tall evergreen trees.	Short trees/shrubs to be placed on the outer layer of the windbreak. Gradual degradation in height of trees from a row to another. At least one row of dense evergreens (the tallest tree), other row(s) consisting of deciduous trees, shrubs, or pines. An inner row of shrubs can be used after the tall evergreen increase windbreak density.

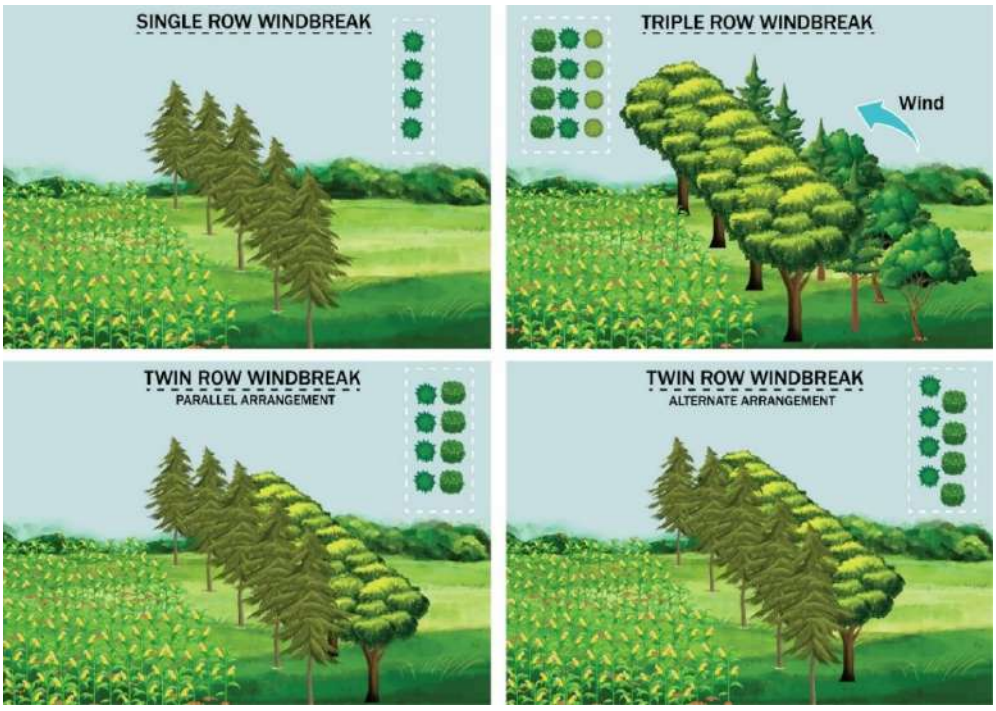


Figure 43 Windbreak patterns: rows and arrangement

SPECIES COMPOSITION

Windbreak tree species play a major role in contributing to its efficiency as they define key windbreak characteristics such as density, wind permeability, and leeward area of protection. To choose tree species for windbreaks, a set of criteria must be followed:

- Evergreen versus deciduous: evergreen trees (trees that keep their foliage all year long) are most suitable for windbreaks as they ensure protection against wind all year long especially during the winter season when winds and frost are most damaging, as they ensure an average density of 60%. Deciduous trees (trees that shed their foliage in the winter season) are less preferable except when they are densely branched and closely arranged, as they ensure an average of 40% density.
- Fast growing: when established, windbreaks are expected to grow and mature into a fully functional windbreak the fastest possible. Choosing fast growing species, especially for the tallest tree of the windbreak is a key criterion for designing and implementing a windbreak.
- Production: to increase the overall productivity of the Agroforestry land, incorporating productive trees within the windbreak, especially in the multiple-row type of windbreaks, is highly beneficial to produce wood and non-wood products. Productive windbreak trees can be forest and fruit trees, melliferous trees, fodder trees, ornamental trees, etc.
- Diversity: multi-species windbreaks are highly appreciated in Agroforestry, as they promote wildlife attraction, increase the biodiversity and help in controlling diseases. Ensuring the degradation in trees heights (shrub, medium-sized tree, tall tree) from one row to another is essential when choosing diverse species to

enable a gradual degradation of wind speed hitting the windbreak. It is essential to plant one tree species per layer/row of windbreak, and to diversify in species from one layer/row to another, to maintain the windbreak continuity and homogeneity.

Inter and intra-row distances (spaces between trees of the same row and distances between rows) are dependent on the species and its crown size at maturity. Refer to Annex 2, 3 and 4 for the selection of windbreak species based on trees and shrubs characteristics.

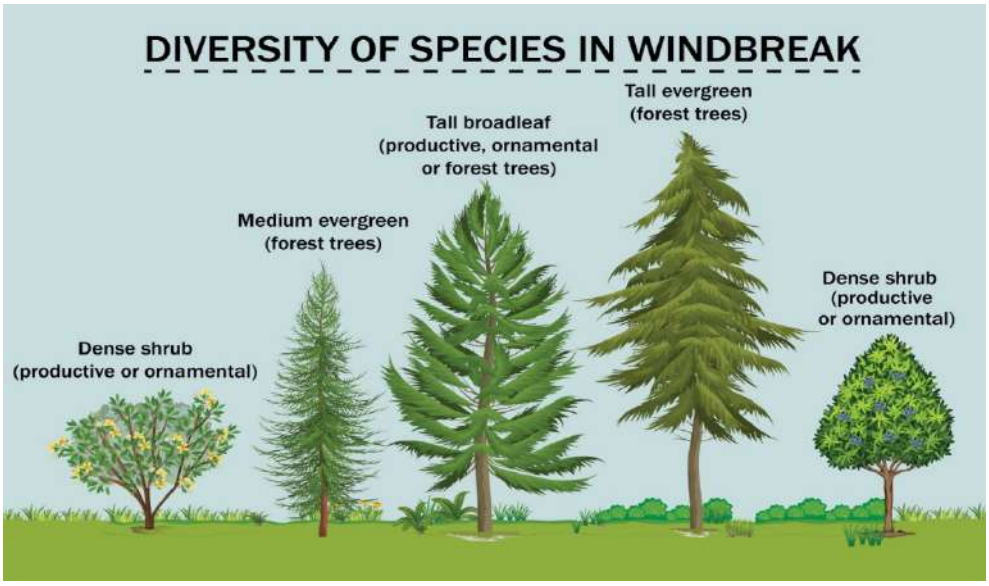


Figure 44 Diversity of windbreak species

IV.2.3. TREES IN FOREST FARMING

Forest farming is a practice that encourages the conservation of forest ecosystems and promotes the exploitation of forest stands with high-value crops and herbs under and within the forest canopy. It is a practice highly encouraged in Lebanon to prevent deforestation and conserve green cover.

It doesn't intensively require new plantation of trees, but rather the conservation of existing forest trees on the plot, along with the exploitation of the total canopy and the amount of light penetrating the forest. It is a practice that calls for the optimal utilization of available spots within the forest. Thinning, pruning and weeding are activities recommended to clear canopy spaces (spaces in between forest trees), alter/increase the amount of light reaching the forest ground and hence grow edible and sellable produces within the forest. The implementation steps in a forest farming practice are:

- **Canopy clearing activities:** weeding (removing understory undesired weeds and vegetation), pruning (cutting small to medium branches) and thinning (cutting trees) to open spaces, remove wild weeds and minimize forest canopy for more sun penetration are the first implementation activities to conduct in forest farming. Pruning residues make a valuable product to be used as fuelwood, compost, mulch.

- **Soil and topography improvement**: forests topography tends to be wild, rough and rocky. To prepare for forest farming, it is essential to prepare the land topography for the cultivation of crops and herbs. Removing rocks, levelling the soil, building dry stone terraces are all improvement activities to conduct based on the local forest site conditions. Adding compost to fertilize the soil is sometimes needed when organic matter content is low.
- **Introducing high-value crops**: forest farming practice promotes the exploitation of specialty crops usually considered as high-value crops, due to the limited spaces availability and high management requirements. Specialty crops can be very diverse, producing food: mushroom, nuts, herbs, bulbs, berries, fruits, honey, etc., decorative: flowers, ferns, etc.
- **Regular maintenance**: ensuring the regular pruning and weeding activities to maintain optimal light penetration and sustain site productivity.

When planting forest clearances and spaces, it is important to adopt multi-layered multi-species designs to maximally exploit the available spaces within the forest. In addition to the existing forest trees, several layers of trees, shrubs and herbs can be integrated:

- Tall tree layer: usually consist of the existing forest trees (oak, pine, cypress, cedar, etc.). In the case of shrubland and woodland types of forests, this layer of trees can be integrated to upgrade the horizontal layering of the forest. Lebanese forest trees can be exploited for their myriad wood and non-wood forest products they offer. Refer to Annex for the full list of wood and non-wood products offered by Lebanon's forest trees and shrubs.
- Low tree layer: might be fruit trees or forest trees, shade tolerant if directly planted in juxtaposition to the tall tree layer, or sun tolerant if planted in the forest clearances.
- Shrub layer: a shorter layer that fills the gaps of the low tree layer, which could be fruit, forest, or ornamental flowering species that provide direct products or serve as melliferous purposes for beekeeping.
- Herb layer: vegetables, herbs, flowers, forage, or any other herbaceous size plants.
- Root layer: exploiting the underground to grow bulbous and other plants that grow products at the roots layer.
- Vine layer: using tall tree layer as support to grow climbing vines to either produce additional products (berries) or enhance the aesthetics of the forest.
- Trunk layer: even broken or pruned trunks and woodlots can be exploited in forest farming to grow wild or commercial mushroom species. Mushroom production is especially suitable in forest ecosystems with a dense canopy that allows the optimal lighting and humidity for mushroom growth.

More research and trials are required for mushroom production on woodlots in Lebanese forests. Forest mushroom farming in bags has been successfully tried by the Lebanon Reforestation Initiative.

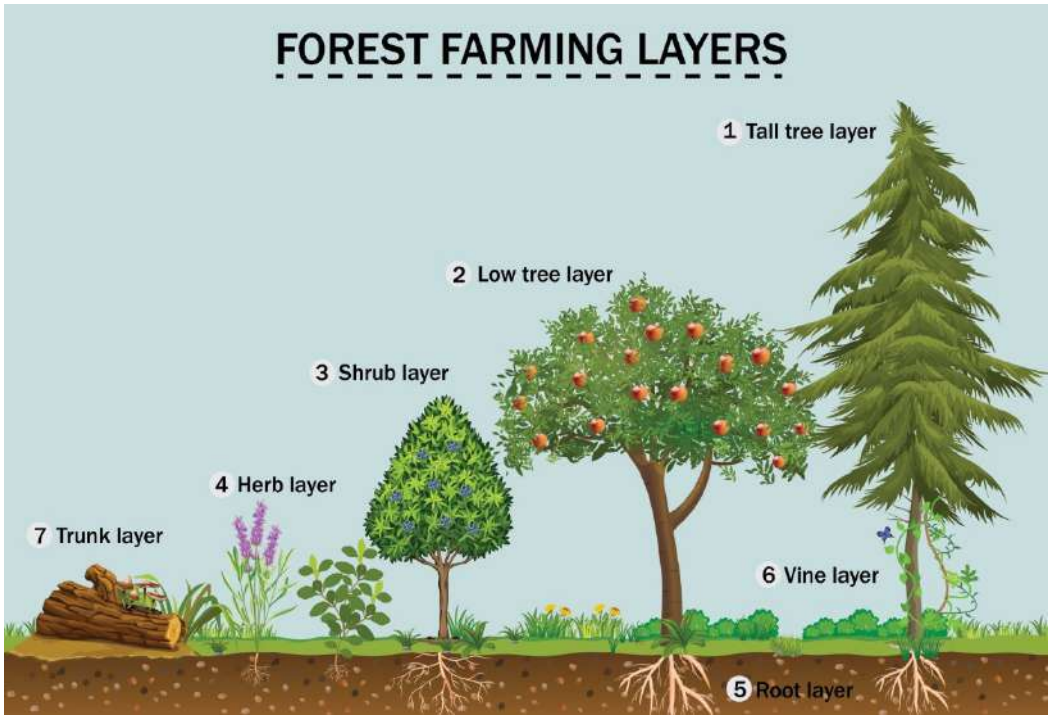


Figure 45 The 7 layers of forest farming

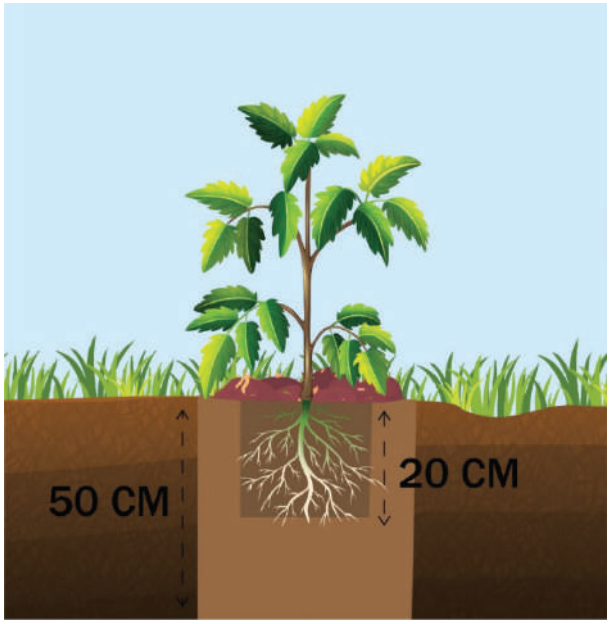
IV.2.4. BEST PRACTICES FOR PLANTING AGROFORESTRY TREES

In all Agroforestry practices, planting trees is an essential implementation activity to establish Agroforestry designs. Trees are the most vital component in Agroforestry, thus, need to be primarily established and rapidly grown to ensure harvesting the goods and services of mature trees the soonest. Preparing a rich and smooth soil where tree roots can grow deep into the search for underground water, with an abundance of nutrients, is the core objective of this phase. This section details some best practices for planting Agroforestry trees for fastest growth.

PLANTING INDIVIDUAL TREES

When adopting practices that require scattered or distant trees across the Agroforestry land, such as planting multipurpose trees in croplands, home gardens, trees on rangelands, apiculture with trees, and in the cases where composting the whole land is exhaustive and not feasible, the following table provides best practices for planting each tree separately for fastest growth, lower costs and minimal soil disturbances.

Table 10 Best practices for planting individual trees in Agroforestry

Pre-planting soil preparation (at least one day prior to planting)	Dig a deep hole of 0.5-1 m^3 (1 m width 0.5-1 m depth).	
	Mix the soil extracted from the hole with soil organic amendments such as compost. *In case the compost or organic matter was not previously added to the whole land and plowed within the soil.*	
	Refill the hole with the soil-compost mixture.	
Planting tree	Dig a hole of 50 cm depth (at least).	
	Loosen roots around the rootball of the tree.	
	Place tree roots at 30 cm, leaving 20 cm void below root system to enhance their optimal growth.	
	Plant the tree vertically and keeping on this posture when filling back soil onto the hole.	
	Tamp down the soil around tree trunk to eliminate air pockets.	

PLANTING IN "TRENCHES"

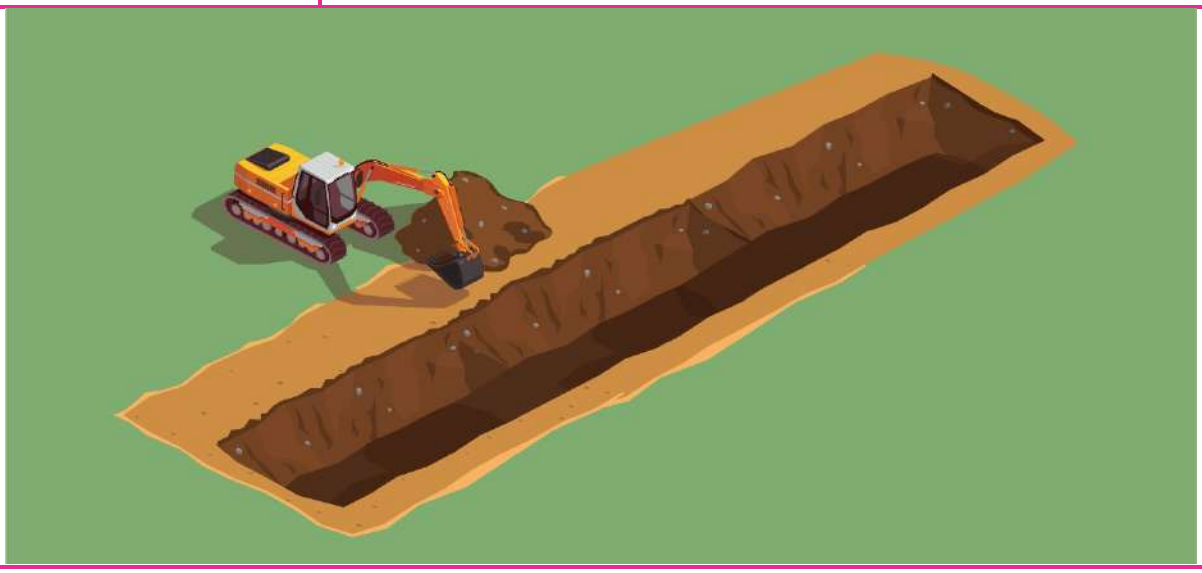
This planting practice is mostly recommended for windbreaks, shelterbelts and hedgerows to boost their growth rates the fastest possible. Windbreak trees need to reach maturity the earliest possible in an Agroforestry land to provide the services and products required. Planting in "trenches" is a practice that calls for loosening the soil as deep as possible for rapid roots extension, while providing the plants with a sufficient organic matter content to enhance the growth rate. Digging deep trenches along the whole line of windbreaks will allow the planted trees to send their roots far away into the deep soil layers and thus enabling fast tree growth. This planting practice is elaborated in the below table.

Table 11 Best practices for planting trees in "trenches" in Agroforestry

Digging deep trenches	Dig a "trench" of ٥٠ cm-1 m depth and 1 m large using a backhoe loader or any suitable machinery. Replicate this trench size or widen the trench in the case of multiple rows windbreaks.
Mixing soil with compost	Mix the soil extracted from the trenches with soil organic amendments such as compost.

Table 11 Best practices for planting trees in "trenches" in Agroforestry

Refilling the trenches	Refill the trench with the soil-compost mixture. Prepare the previous steps at least one day prior to planting.
Planting trees	Dig a hole in the soil-compost mixture of 50 cm depth (at least) in the exact locations where trees will be planted.
	Loosen roots around the rootball of the tree.
	Place tree roots at 30 cm, leaving 20 cm void below root system to enhance their optimal growth.
	Plant the tree vertically and keeping on this posture when filling back soil onto the hole.
	Tamp down the soil around tree trunk to eliminate air pockets.
	Repeat above steps for each tree of the windbreak, respecting the inter and intra-row distances.



II.2.5. TREES AND SHRUBS SPECIES

A balanced mix between forest and fruit tree species is recommended when implementing Agroforestry in Lebanon. While fruit trees provide a direct source of income through the forest products, forest trees help in balancing the ecosystem by providing myriad ecosystem services and products. The following section guides Agroforestry practitioners toward the selection of suitable forest and fruit tree species for their lands.

NATIVE VERSUS EXOTIC TREES

Native plant species (forest and fruit) are species that are naturally growing in a given geographic area in contrast to exotic or introduced species, that are introduced from foreign geographic regions accidently or on purpose to a new geographic area, where they do not naturally grow.

Beside valorizing the natural heritage of Lebanon, native plant species present valuable advantages over exotic or introduced species, which makes them an asset for agroforestry systems. On the other hand, the use of introduced and exotic species presents many risks and threats. The table below highlights the advantages of native trees in opposition to the risks of exotic trees.

Table 12 Native versus Exotic trees

Advantages of Native Trees	Risks of Exotic Trees
Naturally evolved in the local environment Optimal growth and yields with low maintenance requirements Refugee for Lebanese Wildlife: - Pollinators - Natural Predators considered as a tool for biological control in IPM for pests and diseases Resilient and have the ability of quick recovery due to extreme weather events and insects' outbreaks	High risk of introducing new pests and diseases that may cause severe outbreaks and can be harmful to native species Tendency of becoming invasive species in absence of natural enemies that control population growth and promotes species coexistence causing a disturbance in the ecosystem Reduced growth and productivity when environmental conditions are unmatched Lower ability to recover after extreme weather, climate variation and insect outbreaks.

LEBANON'S NATIVE FOREST TREE AND SHRUB SPECIES

The native forest tree species (or wild tree species) found in Lebanon are listed in the following table. Their potential use in agroforestry is discussed based on criteria such as their ecological suitability per geographic range and the products and services that they provide. Ecological and geographic distribution of Lebanon's forest native tree and shrub species is available in Annex 1 to guide Agroforestry practitioners toward the best choice of tree species for their lands.

Table 13 List of Lebanon's forest naive tree species

Latin name	Arabic name	English name	French name
Abies Cilicia	شوح كيليكيا	Cilician fir	Sapin de Cilicie
*Acer hyrcanum subsp. tauricolum (*synonym *Acer tauriculum*)	قيقب جبل طوروس	Taurus maple	Erable du Taurus
Acer monspessulanum subsp. microphyllum (synonym A. hermonum)	قيقب جبل حرمون	Hermon maple	Erable de l'hermon
*Acer obtusifolium (*synonym *Acer syriacum,)*	قيقب سوري	Syrian maple	Erable de syrie
Alnus orientalis	نغث	Oriental alder	Aulne oriental
Arbutus andrachne	قطلب	Oriental strawberry tree	Arbousier d'orient

Table 13 List of Lebanon's forest naive tree species

Arbutus unedo	طعمة حمراء	Strawberry tree	Arbre aux fraises
Cedrus libani	الارز اللبناني	Cedar of Lebanon	Cèdre du Liban
Celtis australis	الميس	European nettle tree	Micocoluier austral
Ceratonia siliqua	الخروب	Carob tree, Carob-St John's bread	Caroubier siliqueux
Cercis siliquastrum	زمزريق	Judas tree	Arbre de Judée
Crataegus azoralus	زعرور شائع	Azarole	Azerolier
Crataegus monogyna	زعرور أحمر	One-styled hawthorn	Aubépine à un style
Cupressus sempervirens	ثرو/ شريين	Cypress	Cyprès
Eleagnus angustifolia	زيزفون	Russian olive / oleaster	Olivier de boheme
Fraxinus ornus	دردار مزهر	Ash	Frêne fleuri
Fraxinus angustifolia subsp. *syriaca* (synonym *Fraxinus syriaca*)	دردار سوري	Syrian ash	Frêne syrien
Juglans regia	الجوز	Common walnut	Noyer commun
Juniperus drupacea	دفران / أرار سوري	Syrian juniper	Génévrier de syrie
Juniperus excelsa	لزّاب	Grecian Juniper	Genévrier élevé
Juniperus foetidissima	عرعر كريه الرائحة / عرعر المنتن	Foetid or stinking Juniper	Genévrier fétide
Juniperus oxycedrus	عرعر كادي	Prickly or cade Juniper	Genévrier oxycèdre
Laurus nobilis	غار	Laurel	Laurier noble
Malus trilobata	تفاح برّي / محايلس	Three-lobed apple	Pommier trilobé
Ostrya carpinifolia	شّريك / قنّابية أو مرّان	Hop hornbean	Charm houblon
Pinus brutia	صنوبر برّي	calabrian pine	Pin de calabre
Pinus halepensis	صنوبر حلبي	Aleppo pine	Pin d'alèpe
Pinus pinea	صنوبر مثمر	Stone pine	Pin parasol, pin pignon
Pyrus syriaca	إجاص سوري	Syrian pear	Poirier de Syrie
Pistacia palaestina	بطم	Palestine pistachio	Pistachier de palestine
Pistacia lentiscus	مستكة	Mastic tree	Pistachier lentisque
Platanus orientalis	دلب	Oriental plane tree	Platane d'orient
Populus alba	حور ابيض	White poplar	Peuplier blanc
Populus nigra	حور اسود	Black poplar	Peuplier noir
Populus tremula	حور مرتجف الاوراق	Common aspen	Peuplier tremble
Prunus korchinskii	لوز برّي	Wild almond	Amandier sauvage
Prunus ursina	خوخ الدب	Bear plum	Prunier des ours
Quercus brantii look	برانتى / ليكّ سنديان	Brant's oak	Chêne de Brant
Quercus calliprinos	سنديان	kermes oak	Chêne vert, kermès
Quercus cedrorum	بلوط أرزي	Cedars oak	Cedres chene
Quercus cerris var. pseudocerris	العذر/ بلّوط اشعر	Turkey oak	Chêne chevelu, lombard
Quercus infectoria	ملّول	Cyprus oak	Chêne tinctorial
Quercus ithaburensis	سنديان عادي	Oak of Mount Tabour	Chêne vélani

Table 13 List of Lebanon's forest naive tree species

Quercus kotschyana	بلّوط كوتشي	--	Chêne de Kotschy
Salix alba	صفصاف ابيض	White willow	Saule blanc
Salix pedicellata (synonym *Salix libani*)	صفصاف لبناني	Lebanese willon	Saule libanais
Sorbus graeca (synonym *Sorbus flabellifolia*)	غبيراء مروحية الورق	Fan-leaved service tree	Sorbier à feuilles en éventail
Sorbus torminalis	غبيراء المغص	Wild service tree	Sorbier torminal
Styrax officinalis	اللبنة / الحوز	Storax	Aliboufier officinal
Ulmus minor	دردار	Field elm	Orme du champ

For better guidance towards the selection of most appropriate native tree and shrub species, Annexes 2 and 3 lists and details native tree species and some of the shrub species to facilitate their use in an agroforestry system. For each tree/shrub species, the following information is detailed:

- Botanical description relevant to its use in agroforestry practices i.e., **crown shape, leaf persistence, height at maturity**,
- Ecological requirements and tolerance spectrum i.e., **climate and soil suitability**, **tolerance to limiting environmental conditions** e.g., drought, pollution, frost, etc.
- Physiological characteristics i.e., **rate of growth, time to ultimate height, life span,**
- **Products** and **services*** that it can provide.

LEBANON'S FRUIT TREE SPECIES

Fruit orchards are typical agricultural plantation in Lebanon: different varieties of olive trees, diverse Rosaceae species, i.e., apple, apricot, cherry, almond, peach plum, etc., and other high-value fruit trees, i.e., mulberry, pomegranate, chestnut, walnut, etc. Fruit trees are a vital element in Agroforestry systems, that ensures an essential part of the land productivity through the products and by-products that fruit trees provide. Some of the climate-suitable for Lebanon fruit species are listed in the following table, their characteristics and planting requirements.

Table 14 List and characteristics of Lebanon's suitable forest tree species

Tree Name	Tree Size	Life Span	Plantation Season	Flowering Season	Harvesting Season	Pruning Season	Fruit Trees Compatibility	Monoecious Or Dioecious	Soil Characteristics
Almond	4-10 Meters	25 - 30 Years	Spring and Summer	February March	August till September	End of summer	Peach Asian Plum Apricot	Monoecious	Well drained Fertile pH: 6-7
Plum	4-5 Meters	10 - 15 Years	Late winter and Early spring	January February	May till August	June July	Peach Cherry Damsons	Monoecious	Well drained pH: 6.5
Cherry	10 Meters	15 – 30 Years	Late fall and Early spring	March April	June July	July August	Apple Asian Pears Blueberries	Monoecious	Well drained loam soil pH: 6.0 to 6.5
Chestnut	10 Meters	800 Years	Spring	Mid-June Early July	Mid-September till November	Late September Or Early October	Sweet Chestnut Apple	Monoecious	Sandy soil pH: 4.5 - 6.5 Well drained
Jujube	7- 10 Meters	4 – 5 Years	Late Spring	November December	October	January February	Not available	Monoecious	Lighter soil pH:4.5-8.4
Pomegranate	4 – 7 Meters	12 – 15 Years	July August	April till June	December January	January February	Blueberries Kiwi	Monoecious	Well drained pH: 5.5-7.0
Apricot	8 – 12 Meters	40 -150 Years	Spring	February March	Late July till August	January May	Apple Peach Nectarine	Monoecious	Loamy soil pH:6.5-8.0
Fig	10 -12 Meters	12 -15 Years	Spring	Mid Spring	June till September	March or April	Not available	Monoecious	Well drained soil High lime content pH: 6.0- 6.5
Loquat	5-10 Meters	20-30 Years	Late Winter and Spring	Autumn and Late Winter	March till May	June or July	Lemon	Monoecious	Acid soil pH: 5.5- 6.5
Walnut	30-37 Meters	250 Years	Fall	April till May	Early September Till Early November	January till March	Quince Peach Nectarine	Monoecious	Moist soil pH neutral: 7.0 Well drained

Table 14 List and characteristics of Lebanon's suitable forest tree species

Orange	5- 7 Meters	50 - 60 Years	Early to mid-Spring	April	Depend on species	Late summer or early Autumn	Lemon	Dioecious	Full sunshine Moist soil pH: 5.0 – 6.5
Avocado	4- 15 Meters	200 - 400 Years	March till June	Late winter till Early summer	September	Between January and May	Avocado (Depending on type)	Monoecious	Loamy soil Well drained pH: 5.0 -7.0
Peach	5 Meters	12 Years	Spring	Spring Months	Late June till August	Early Spring	Apricot Nectarine Pear	Monoecious	Very fertile Well drained Sandy soils pH: 6.5- 7.0
Olive	3-12 Meters	500 years	Spring and Fall Might be planted in summer also	April and May	Late August till November	Late winter or Early Spring	-	Monoecious	Extremely well drained Rocky soil pH: 5.5- 8.0
Kiwi	4- 7 Meters	3 years	January	Spring	Late October to Early November	Winter	Lemon Grapes	Dioecious	Well drained pH: 5.0 – 6.5
Apple	7.5-10 Meters	50 – 80 years	Early Spring	Mid-April and Mid -May	September	Late Winter or Early Spring	Cherry Nectarine Peach	Dioecious	Well drained soil pH: 5.8 – 7.0
Grapes	24 Meters	50 – 100 Years Maybe more	Early Spring	May	Late Summer till Early Fall	February and March Pruned also early April	Kiwi Mulberry	Dioecious	5.5 – 8.5 for PH Deep Well drained
Clementine	7 Meters	50 Years	Spring or Fall	April	November to January	Late Winter to Early Spring	-	Dioecious	Sandy soil Well drained pH: 6.0 – 7.0
Lemon	8 Meters	50 Years	Late winter or Early Spring	Early Spring	March January	Late Winter or Early Spring	Orange	Monoecious	well drained pH: 5.5 – 6.5

CHAPTER V. AGROFORESTRY IMPLEMENTATION: INCORPORATING THE HERBACEOUS COMPONENT

This component inhabits the understory of the agroforestry system, and consists of either seasonal crops, pasture, forage, melliferous, cover crops, medicinal, aromatic herbs or a mixture and diversity of several categories. This section will detail the benefits and list some recommended species for seasonal crops, cover crops, medicinal and aromatic plants and melliferous herbs. Forage and pasture species details are available in Chapter VI when the animal component is discussed.

V.1. SEASONAL CROPS

Alley cropping systems can host a very wide range of crops, choose crops that are adapted in a similar habitat region, diversity of crops in the alleys is recommended. Shade tolerant crops are recommended to be planted close to the tree line, while crops that are sun demanding are planted in the middle of the alley. Mixing crops in one location adds to the resilience of the whole cropping system against diseases in a mechanism called camouflage, where insects loose traction of plant host among the diversity of plants. The below table details climatic requirements for common seasonal crops, their benefits and their compatibility to each other in intercropping.

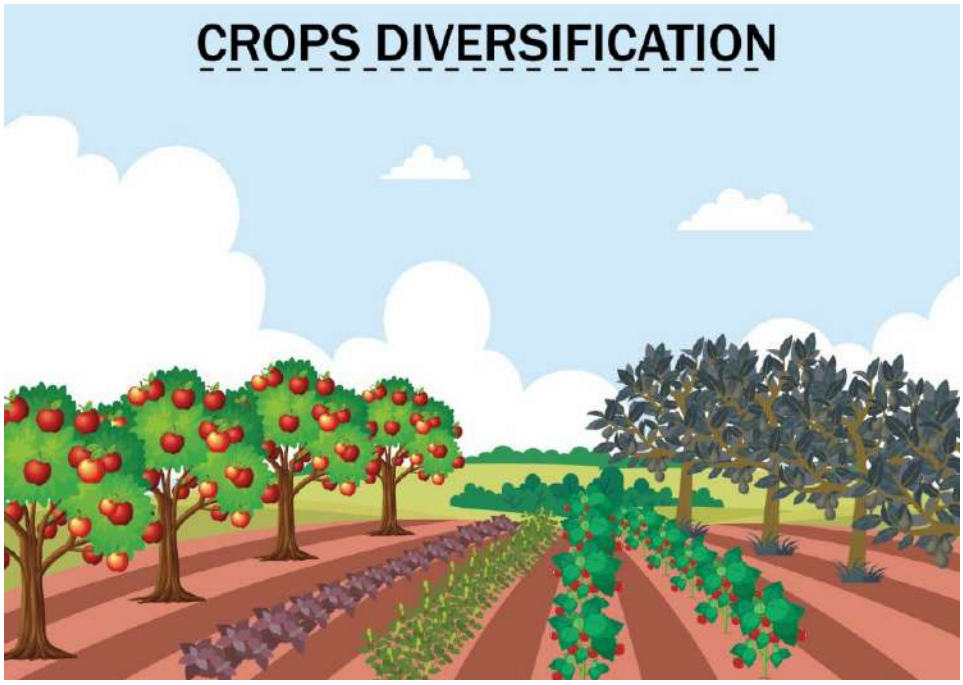


Figure 46 Diversification of seasonal crops in Agroforestry systems

Table 15 Seasonal crops requirements, compatibility, and services

Name	Shade or Sun tolerance	Cool or Warm	Compatibility in intercropping	Nitrogen Fixing	Insect Repellant	Soil Fertility
Potatoes	Sun Tolerance	Cool Season	Broccoli Cauliflower Kale		✓	✓
Carrots	Sun Tolerance and Partial Shade	Cool Season	Beans Tomatoes	✓		
Chickpeas	Sun Tolerance	Cool Season	Corn	✓	✓	
Peanuts	Sun Tolerance	Warm Season	Cabbage Celery	✓		
Lentils	Sun Tolerance	Cool Season	Potatoes Cucumber	✓		
Lupinus	Sun Tolerance	Cool Season	Spinach Cucumber	✓		
Tomatoes	Sun Tolerance	Warm Season	Cabbage Cauliflower		✓	
Sorrel	Shade Tolerance	Cool Season	Strawberries		✓	
Cowpeas	Partial Shade Tolerance	Warm Season	Cabbage Broccoli	✓		✓
Radish	Sun Tolerance	Cool Season	Lettuce Tomatoes Onions	✓		✓
Corn	Sun Tolerance	Warm Season	Sunflower Cucumber	✓		✓

V.2. COVER CROPS

Cover crops are crops planted in the wintertime, they are usually a mixture of grass, legumes and other plant species. Cover crops provide a set of benefits:

a. Cut fertilizer costs by acting as green manures, legumes fix gas Nitrogen from air into Nitrogen that can be used by plants. Crops grown in fields after legumes can take up to 30 to 60 percent of the Nitrogen that the legumes produced.
b. Reduce the need for herbicides, cover crops suppress weeds, they act as a smother crop that outcompetes weeds for water and nutrients, residue or growing leaf canopy that blocks light, alters the frequency of light waves and changes soil surface temperature, a source of root exudates or compounds that provide natural herbicidal effects.

c. Cover crops manage pests by hosting beneficial microbial life that discourages disease, create an inhospitable soil environment for many soil-borne diseases, encourage beneficial insect predators and parasitoids that can reduce insect damage below economic thresholds, produce compounds that reduce nematode pest populations, encourage beneficial nematode species.
d. They improve yields by enhancing soil health, they speed infiltration of excess surface water, relieve compaction and improve structure of over-tilled soil, add organic matter that encourages beneficial soil microbial life.
e. Cover crops prevent soil erosion and conserve soil moisture.

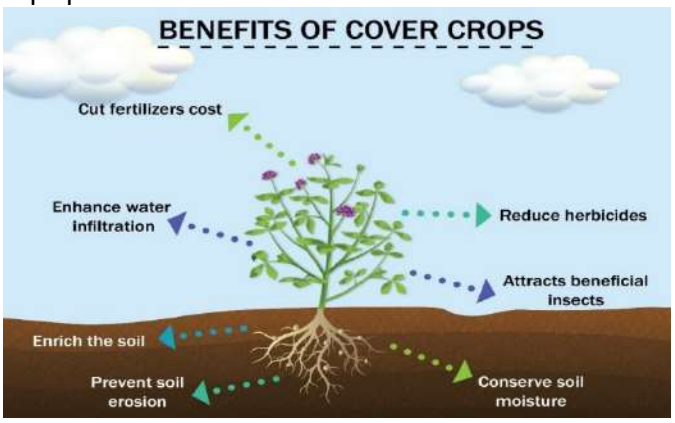


Figure 47 Benefits of cover crops plants

Cover crops choice is dependent on the climatic conditions of the site and on the job needed from the cover crop. For the sake of this report, cover crops are categorized into cold crops and warm crops, within each category, crops for special uses, like Nitrogen fixation, soil builder, erosion controller, subsoil loosener, weed controller, and pest fighter are listed.

Table 16 Cover crops categories and some recommended species

Climate	Nitrogen fixer	Soil fertility enhancer	Erosion controller	Subsoil loosener	Weed fighter	Pest fighter
Cold climate	Winter peas, wooly pod vetch, subterranean clover, Medicago	Medicago, subterranean clover	White clover, barley, rye, annual ryegrass	Sorghum-sudangrass hybrid, sweet colver	Annual ryegrass, sweet colver, rye, woolypod vetch	Sorghum-sudangrass hybrid, rye
Warm climate	Berseem, subterranean clover, woolypod vetch, Medicago	Annual ryegrass, rye, Sorghum-sudangrass hybrid, woolypod vetch	white clover, cowpeas, rye, annual ryegrass,	Sorghum-sudangrass hybrid, sweet clover	Rye, annual ryegrass, berseem, white clover	Sorghum-sudangrass hybrid, crimson clover, rye.

V.3. MEDICINAL AND AROMATIC PLANT SPECIES

Medicinal and Aromatic Plants (MAP's) can play an important role if integrated in the agroforestry system, very little portion of known MAP's are cultivated, there is an increasing global demand for MAP's, if efforts are made to cultivate these species, they will generate income to their owners and help conserve them in nature, since many of the MAP's exist under forest cover and are shade tolerant, their integration in agroforestry make an excellent opportunity.

Many scientific studies have shown repellent effects of MAP's on certain plant pests, also many aromatic plant horticultural oils showed possible alternatives to chemical pesticides and insecticides, at the same time they show little effects on the beneficial insects.

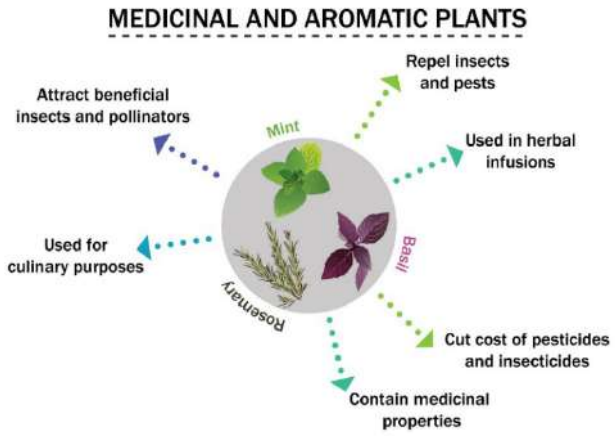


Figure 48 Benefits of Medicinal and Aromatic Plants

When planted in integration with seasonal crops to provide beneficial services and improve yields, the choice of intercropped crops and aromatic herbs is crucial to provide the needed compatibility. The below tables detail the compatibility and incompatibility between crops and aromatic herbs and the expected advantages and disadvantages when intercropping specific herbs and crops.

Table 17 Desired intercropping of compatible aromatic plants and crops

MAP scientific name	MAP common name	Crops	Advantages
Ocimum basilicum	Basil	Tomatoes, Oregano, Peppers	Repels flies and mosquitoes
Matricaria chamomilla	Chamomile	Cabbage, Onion, Cucumber	Attracts beneficial insects and pollinators
Allium sativum	Garlic	Most Plants (Tomatoes, Carrots, Broccoli…)	Repels aphid and loopers
Mentha sp.	Mint	Peas, Kale, Tomatoes	Remove aphids, ants, and attracts bees

Table 17 Desired intercropping of compatible aromatic plants and crops

Allium schoenoprasum	Chives	Carrots, Tomatoes	Remove aphids
Artemisia dracunculus	Tarragon	Eggplant	Improves eggplant flavor
Coriandrum sativum	Cilantro	Caraway, Spinach, anise	Remove spider mites
Salvia officinalis	Sage	Rosemary	Remove bad beetles or flies
Anethum graveolens	Dill	Corn, Lettuce, Cucumber	Discourage and remove aphids
Salvia rosmarinus	Rosemary	Beans, Peppers, Broccoli	Deters variety of pests
Nepeta cataria	Catnip	Pumpkins, squash, Hyssop	Attracts bees,
Lavendula	Lavender	Cauliflower	Attracts butterflies, Remove harmful pests
Anethum graveolens	Dill	Lettuce, Onions	Improves flavor
Ocimum basilicum	Basil	Asparagus	Remove Asparagus beetles

Table 18 Undesired integration of incompatible aromatic plants and crops

MAP scientific name	**MAP Common name**	**Crops**	**Disadvantages**
Artemisia absinthium	Wormwood	Any crop	Damage any crop nearby and can be toxic
Foeniculum sp.	Fennel	Any crop	Prevent crops from growing well, Impact their flavor
Pimpinella anisum	Anise	Carrots	Inhibition of carrots growth
Anethum graveolens	Dill	Tomatoes	Can be detrimental to tomatoes
Salvia officinalis	Sage	Cucumber, Onions	Restricts growth of cucumber and onions
Allium sativum	Garlic	Peas, Beans	inhibit peas and beans growth
Mentha sp.	Mint	Asparagus	Mint attracts asparagus beetles

V.4. MELLIFEROUS SPECIES

Melliferous plant species are widely studied, identified, and used in agroforestry projects, in addition to their supply of honey dew and pollen for honeybees, they also play an important role in attracting predator insects by providing these insects with shelter, and food especially in the season when their target insects don't exist. When planning for honey production, whether in an apiculture with trees practice or as a separate

agroforestry production, an integration of melliferous trees, shrubs and herbs can be integrated to enhance honey yields.

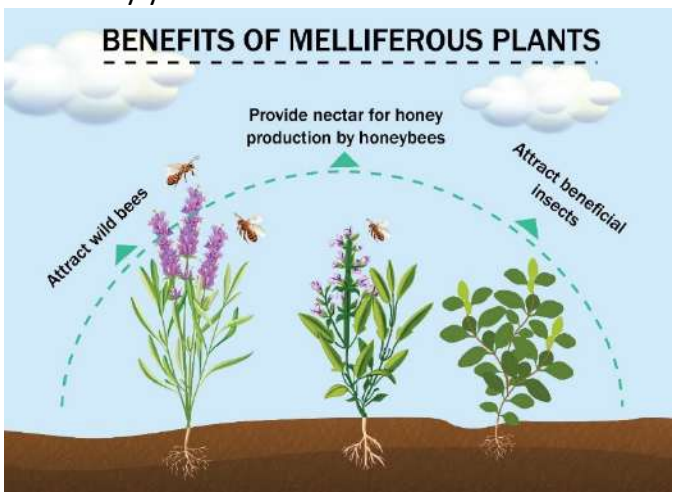


Figure 49 Benefits of melliferous species

Many flowering trees and shrub species are considered in the category of Melliferous species, mentioning tree families of Rosaceae, Asteraceae, Ericaceae, Cistaceae (for specific melliferous tree species, refer to Annex 5.

Herbaceous melliferous species are recommended to be planted along with tree melliferous species to maximize nectar availability and hence increase honey production. The following table lists some of Lebanon's suitable melliferous shrubs herbs, their corresponding altitude range as well as their flowering seasons.

Table 19 Geographic distribution of melliferous native herb species of Lebanon and corresponding flowering period

		Flowering period											
Melliferous species Latin Name	**Altitude range**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Berberis libanotica	1400-2000												
Capparis Spinosa Camesers	0-1400												
Cistus criticus	0-2000												
Cistus salvifolius	0-2000												
Cotoneaster nummularia	1400-2000												
Origanum ehrenbergii	500-1200												
Origanum syriacum	0-2000												
Prunus prostrata	1400-2000												
Rhamnus punctata	0-1400												
Salvia fruticosa	0-1000												
Salix alba	0-1500												

Table 19 Geographic distribution of melliferous native herb species of Lebanon and corresponding flowering period

Thymbra spicata	500-1000												
Jenista iydia	1000-2000												
Foeniculum vulgare Mill.	0-1200												
Phlomis longifolia	0-1000												
Rhamnus alaternus	0-1400												
Vitex agnus-castus	0-700												
Erica nummularifolia	500-1000												
Ephedra campylopoda	0-700												
Nepeta italica	1000-1500												
Lavandula stoechas	0-1200												

CHAPTER VI. AGROFORESTRY IMPLEMENTATION: INTEGRATING THE ANIMAL COMPONENT

VI.1. BENEFITS OF THE ANIMAL COMPONENT

Silvopastoral and Agrisilvopastoral systems call for the integration of animal components on the same lands along with trees and herbs. Many advantages can be listed from this combination such as: increased and diversified income, better land use, soil stabilization, maintenance of soil fertility, and potentially improved plantation crop yield through weed control, nitrogen fixation and nutrient recycling. Based on the benefits expected from the animal component, animals are classified in these guidelines as productive (to produce animal products), protective (to contribute direct services to the agroforestry system) and Eco-touristic (to promote Eco-touristic aspects and contribute to an additional source of income). Examples of animals within each category and their corresponding benefits are listed in the following table.

Table 20 Products and services provided by the animal component in Agroforestry

Category	Example	Outcome
Production/ bioavailable protein/ Food security	Chicken	Meat, Eggs
	Cows, Sheep, Goats	Meat, Eggs, Milk, Dairy products, Animal fur, Leather
	Deer	Meat, touristic attraction
	Bees	Honey, Beeswax, Propolis, Nectar, Pollen, Royal jelly
	Pigs	Meat, Ham, Bacon, Sausages, etc.
Services	Horses, Donkeys, Mules	On farm power: Transportation of goods and workers/farmer, plowing, etc.
	Dogs	Guarding, Shepherding
	Livestock and poultry	Tree Pruning and weeds clearing Grazing promotes the health and biodiversity of grasslands and reduces fire risks
	Livestock, poultry, rabbits	Organic type of fertilizers enhancing the soil quality (animal manure)
	Poultry	Insect control, and selective weeding in between trees and vegetables (selective if trained to eat only weeds, as their green roughage in the first six weeks of age).
	Livestock and poultry	Cleaning of fallen fruit/nuts, other organic wastes
	Pigs, chickens, turkeys,	scratching and digging for planting
	Bees	Pollinator
	Every animal component	Economic diversification and enhanced welfare for the farmer
Tourism	Horses	Horseback riding, Aesthetic.
	Deer, Rabbits, Geese, Ducks	Aesthetic aspect, Awareness and informative tours
	Bees	Apiary tourism, Therapeutic purposes

In these guidelines, 2 main Silvopastoral practices will be detailed: Poultry and Livestock (sheep, goat and cattle) production.
Refer back to the agroforestry design and agroforestry implementation chapters III and IV and follow the steps towards designing and implementing a sustainable agroforestry site. It is always important to diversify animal species, diversity of animal species can exponentially increase the benefits of animal existence in the land for many reasons; first, different animals have different grazing habits, by having more than one animal species, the pasture will be utilized to the maximum extent. Second, some animal species benefit other animals by controlling some bad effects on them for example chicken can control insect proliferation on the feces of large animals. Third, by having more than one animal species in one place the farmer will have more than one income from the same land.

VI.2. IMPLEMENTATION

For a successful establishment of the animal component in Agroforestry (whether chicken or livestock or any other), the following scheme elaborates the practical land preparation steps for producing the desired pasture and/or forage on the land. Whether it is livestock, broiler or any other animals, preparing the land before planting forage is the same. The following steps are mandatory for a good yield.

Figure 50 Steps for preparing a pasture/forage field

1. **Assess soil conditions:**

Study the soil capability in terms of nutrients and water holding capacity, and water availability in choosing which crop to be used. In low water holding capacity soil and less water availability, use deep rooted crops. In slop areas also use deep root crops in combination of sod grasses or alfalfa grass mixture. The grass could be tall fescue, perennial rye grass or KY bluegrass. Good soil fertility is essential, in free range pasture soil fertility is more or less maintained by animal excretion. However, soil tests should be made in order to make sure plant nutrients are being met, soil structure is of a good shape and soil organic matter is high enough to support water holding capacity and fertility. In any way, supplementing the soil with plenty of organic matter from the beginning is a good start.

2. **Prepare an adequate seedbed:**

Prepare an adequate seedbed where the soil should be tilled to incorporate additives, destroy weeds and level the soil surface by reducing ridges and depressions, any perennial planting would last for several years without tillage, for this reason good soil shape is established only once and for all.

3. **Choose good quality and good mixture of forage seeds:**

Use high quality seeds, high germination rate, weed free and improved varieties that are adapted to the location where to be planted. Stay away from genetically modified species (only alfalfa is a potential). It is important to choose suitable species for the local climatic and edaphic conditions of the land. Legume crops are nitrogen fixers, make sure they are able to play this role by choosing the best nitrogen fixing varieties.

4. **Plant seeds:**

Seeds of legumes and grasses should be planted at a depth of 1 to 1.5 cm, whatever seeding method is used these depths should be respected. Moreover, uniform seed distribution should be done during seeding. The seed rate should be managed according to weather conditions in the area planted: less water precipitation, less seed rate should be used. Seed timing is affected by precipitation. Seed bed preparation must be accomplished just before the planting/seeding time: after the first rain (at least 5 mm), wait for few days until the soil dries a little to allow for planting and sow your seeds. This will help seeds germinate properly and benefit from the moisture presence to establish.

5. **Manage the plant-animal interaction:**

Apply rotational grazing according to each animal species' needs, the most important thing to take into account is not to allow grazing before the plants reach at least 12 cm high.

Table 21 Timetable for managing the animal component

Step 1	Early fall	Improve soil by adding compost (5 tons per 1000 m^2) or if a soil test is done, the needed quantity until the soil organic content is 10%, then plow to mix the compost with the soil.
Step 2	Late fall	Plant the selected forage species by spreading the seeds evenly at a depth of 1 to 1.5 cm and keep them rain fed. *
Step 3	Spring	Have the animals graze them in rotation at spaced intervals of duration enough until the grasses and legumes are 4 inch high.
Step 4	Spring summer	If water is available irrigate as mush water availability allows, or until soil moisture is at about 60 % of water holding capacity.
Step 5	Early fall of the consecutive years	Add soil amendments as needed to the surface, such as compost, just after a grazing rotation so that the new flush of grasses and legumes are not affected by the smell or taste of the material used.

* different forages for different kinds of animals could be mixed and planted in the same place if the decision to raise more than one animal species together.

Best practices for planting forage grass species

1. Plant a full ration to the animals to get most of the nutrients they need: a mixture of grasses and legumes and herbs.
2. The grasses are the main source of carbohydrates, and the legumes are the main source of proteins. From each type of forage, grasses and legumes, the more diverse each type is, the more beneficial the mixture is:

    - Better adaptation across fields that have diverse topography, soil types or salinity levels.
    - Forage production is more consistent across the season because each species' production peaks at different dates
    - More efficient use of soil moisture and nutrients.
    - Animal gains may be greater due to a more balanced diet.
    - mixed stands may have greater longevity, with more adapted species replacing less suited species over time, and
    - less susceptibility to insect and disease infestations.

3. Never increase the quantity of legumes in a pasture by more than 10% in order to avoid the problem of bloating in animals.

VI.3. POULTRY PRODUCTION

VI.3.1. BENEFITS

Growing free range chicken and birds under Agroforestry systems has been reported to have many benefits when compared to traditional poultry production. The diverse crops when adopting agroforestry systems generate good forage quality, adding to that the invertebrates available on field provide a clean diet for the birds free of synthetic feed such as amino acids and antibiotics and ensures clean eggs and meat production. The presence of trees and high-quality forage crops in Agroforestry Silvopastoral/Agrisilvopastoral systems brings a leverage for free range poultry production:

- Reduced feather pecking when more tree cover is available.
- Reduced risk of avian influenza for birds in the free-range area. Where regulations don't allow for free range, mesh tunnels could be constructed to prevent the interaction of free-range birds with wild birds.
- Safety from predators and more sheltered from sun and the elements so they can venture further away from the huts and eat more forage (flying predators are not considered a critical danger to free range poultry in Lebanon).
- Reduced risk of parasitic contamination due to the better distribution of hens across the range area.
- 20% reduction in feed consumption and increased egg production for hens having access to grass resulted in a comparison with hens raised under conventional conditions.

- Good supply of carotene, vitamins and other nutrients, especially high amount of protein up to 19% as dry matter basis from alfalfa. Percentages are always presented for dry matter since moisture differs from one sample to another even if they are going to consume them fresh.
- Reduced risk of growth impairments associated with less methionine deficiency through foraging for organically reared broilers.
- benefit of forage consumption is that plant matter is typically high in both vitamins and minerals; moreover, forages contain components such as fiber, protein, energy, and other compounds such as carotenoids and n-3 fatty acids having important metabolic functions in all animals, including poultry.
- Supply of supplemental minerals from forage, and the calcium found in plants such as alfalfa is highly bioavailable.
- Reduced costs of production since poultry digestive system can utilize calcium from forages as efficiently as calcium from more common sources such as limestone or oyster shell.

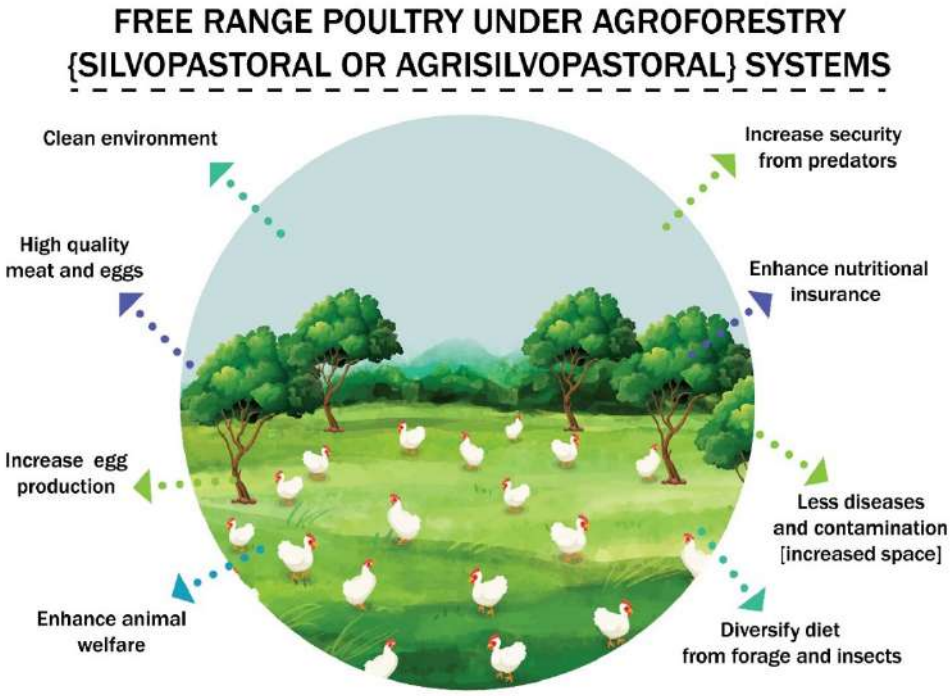


Figure 51 Benefits of free-range poultry under Agroforestry systems

VI.3.2. FORAGE SPECIES SELECTION

When choosing species for a free-range poultry under Agroforestry systems, a set of criteria should be taken into consideration:

- The Agroforestry system should provide pasture all year round.
- The system must include perennial species that would regenerate every other year.
- Trees and forage species must be suitable to the local climatic conditions (cold, dry, hot, etc.).

- The longer the growing season of a forage, the better, i.e., alfalfa and tall fescue are recommended as a mix of legume and grass.
- The high grazing tolerance of forage species, i.e., the ability of forage to recover from grazing, trampling, biting and scratching of the chicken.
- The ability of forage species to attract a variety of different types of insects.
- A mixture of forage species is the best recommendation to provide high nutritional values and attract a variety of insects to be available for chickens to hunt.
- Species must be chosen according to water availability in the area, rain-fed species for areas of water scarcity.

A large range of forages, such as alfalfa, perennial ryegrass, red clover, and grass meals are valuable sources of fibers, xanthophyll and can be successfully used in diets as natural pigmenting agents. The following table lists some of the main forage species used for poultry along with their characteristics and planting guidelines.

Table 22 Forage species for poultry production

Species	Characteristics	Planting density (if planted alone) *
KY bluegrass	A cool-season, perennial grass	1.5 kg per du late summer or fall
Perennial ryegrass	A cool-season, perennial grass	2.5 kg per du late summer or fall
White clover	A cool-season, perennial legume	0.25 kg/du
Alfalfa	Native to warmer temperate climate, perennial legume	Very resilient, especially to droughts, Alfalfa can be sown in spring or fall
Chicory	Chicory plant (Cichorium intybus) is an herbaceous biennial. Perennial plant of the daisy family. Recommended for dry areas.	Seeds can be started indoors five to six weeks before they are moved outdoors. In warm climates, sowing outdoors or transplanting occurs September through March

* If blended with other crops, percentage calculations must be made.

Supplemental ration for the birds: around 70% of the birds feed should be provided in addition to what they are pasturing from the green plants. This ration should provide energy, protein and other essential minerals. The below table shows a recommended mixture of supplemental feed for free-range poultry production.

Table 23 Recommended supplement percentages

Type of supplement	Percentage in %	Benefits
Corn	60	Provide the amount of energy
Peanut meal	11.5	Good source of protein
Soybean meal	6.5	High in protein content
Roasted soybean	5.5	Adding vitamins and oil
Bone and meat meal	7	A highly concentrated protein, rich in essential minerals calcium and phosphorous
Fish meal	4	Adds more minerals and it is high in protein, and high in vitamins A and
Alfalfa	2.5	Organic vitamin A
Kelp meal	1.44	Mineral supplement
brewer's yeast	0.65	Supplies riboflavin and the entire B complex vitamins
Probiotics	0.91	Source of beneficial microorganisms

VI.4. LIVESTOCK PRODUCTION

VI.4.1. BENEFITS

Integrating trees (forest and/or fruit) with grazing livestock (goat, sheep, cow, pigs, etc.) on the same land through Silvopastoral or Agrisilvopastoral systems bring multiple advantages to the farmers, practitioners and landowners. These systems are created by introducing forage and animals into woodland or tree plantations, or by introducing trees into a pastureland or a rangeland. This combination of growing trees, forage and livestock deliberately on the same piece of land provides economic and environmental opportunities:

- Improved animals' comfort through the shade provided by the trees is a direct contributor to animals' performance and productivity. Trees create a sheltered microclimate to protect animals from heat and cold stresses.
- Improved animals' health through diverse diets explored from their surrounding environment, varying through the seasons and through the sources. Tree forage have higher micronutrients than grasses which benefit the health of the animals and reduce risks of contaminations.
- Increased carrying capacity of the land, i.e., the number of animals a land can support in total, since the quantity and quality of forage available on the land (from trees and grasses) increase, thereby increasing the number of animals that the land can support.
- Enhanced soil fertility is associated with the nitrogen-fixing forage species and animal manure which improve the soil fertility and hence trees nutrition and productivity. Animals on Agroforestry lands help in reducing fertilizer needs.

- Improved forage quality and lengthened growing season ensured by the presence of trees (especially forest trees) which enhance the microclimate for the forage species. Trees will compensate for the absence of grass forages in the very hot and dry seasons, to ensure a grazing continuity.
- Optimized utilization of marginal lands/rangelands to increase their productivity and improve their ecosystems by introducing trees, diversifying vegetation, enhancing wildlife and reducing erosion risks.

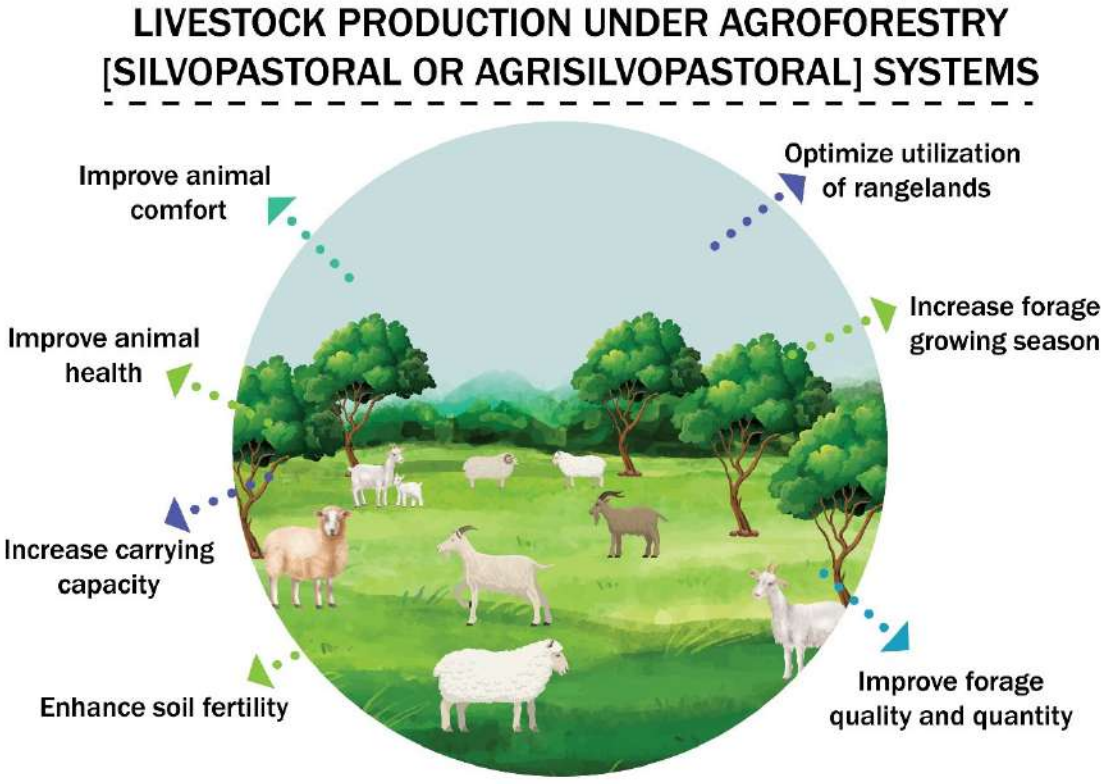


Figure 52 Benefits of livestock grazing under Agroforestry systems

VI.4.2. FORAGE SPECIES SELECTION

In Silvopastoral and Agrisilvopastoral systems integrating trees and grazing livestock (goats, sheep, cows etc.), animals can graze on grass and/or tree forages of the same land.

- **Grass forage species**

Forage species used for livestock are the same used for poultry. Forage species selection is factor to the local climate of the land, water availability and animal stocking rate. Refer to the poultry section Table 23, for the grass forage species.

- **Tree forage species**

Another feed source for goats and sheep other than grasses and legumes, is fodder trees and shrubs, which are valuable feed source especially in winter and in the summer dry season of semi desert ecosystem. Many tree genera have been studied for their nutritional value as fodder crops, of these genera are *Quercus, Arbutus, Robinia, Ceratonia, Fraxinus, Acer, Salix, Populus*, *Colutea.*

It is recommended that native trees and shrubs of the above-mentioned genera be used and studied in designing Silvopastoral systems.
These trees and shrubs can be used as fodder in any way of the following methods:

- Coppicing is a traditional method of woodland management which exploits the capacity of many species of trees to put out new shoots from their stump or roots if cut down. In a coppiced wood, which is called a copse, young tree stems are repeatedly cut down to near ground level, resulting in a stool.
- Pollarding is a pruning system involving the removal of the upper branches of a tree, which promotes the growth of a dense head of foliage and branches.
- Shredding is achieved by cutting lower lateral branches resulting in a 5–7-m-trunk with branches longwise.

VI.4.3. BLOATING IN LIVESTOCK

Bloat is a potentially lethal expansion of the stomach in ruminant animals, which can occur after they have eaten large quantities of legume forage. During digestion, legumes can create a stable foam in the rumen that blocks the normal escape of gas. Distention of the stomach creates breathing difficulties that can be lethal. To avoid bloating:

- Don’t plant more than 30% of the land with legumes.
- Deed some hay or other fibrous feed before turning the animals into fresh field so that they don’t feed too many legumes if they are hungry.
- Don’t let the animals into the pasture when it is still wet, let the dew dry up first.
- During the summertime let the alfalfa bloom first. This will lower soluble protein content and so prevent bloat.
- Give animals small areas to pasture this will have them eat down into the portion of the plant that is less digestible sooner and thereby reducing the risk of bloating.

CHAPTER VII.
DRAWBACKS OF AGROFORESTRY AND SOLUTIONS

VII.1. POTENTIAL NEGATIVE INTERACTIONS BETWEEN AGROFORESTRY COMPONENTS

Since all plant components in an Agroforestry system use the same resources for growth such as space, light, nutrients, water, negative interactions such as competition are likely to occur. The following section details those potential negative interactions and provide possible solutions to overcome them.

VII.1.1. AT THE TREE-CROP INTERFACE

1. **Increased competition**

Trees compete with annual crops for nutrients, growing space, solar energy, mineral elements and soil moisture and may significantly reduce the yields of favored food crops. To minimize this drawback, deep-rooted tree species are chosen to avoid nutrient and moisture competition with shallow-rooted crops. Likewise, trees with narrow and medium sized crowns are likely to be less competitive in suppressing neighboring vegetation and might be also more effective in light interception due to the large vertical crown depth. Prescribed pruning of branches could be also practiced, and a well planning of inter and intra-row spaces based on species used is essential.

2. **Potential for accelerated nutrient loss**

Trees serve as nutrient pumps that deposit nutrients on the soil surface through litter fall, branches (and twigs) decomposition and rain ash. This nutrient deposit can be lost to wind and water erosion, excessive overstorey shading and annual crop senescence. Establishing efficient windbreaks to avoid climatic leaching of nutrients is most effective to prevent nutrient losses, while adopting crop rotations and alternation of cover crops in between seasons to regularly fertilize the soil.

3. **Mechanical damage from cultivation and harvest**

Cultivation and harvesting operations can cause mechanical damage to mixed agroforestry crops, especially for mixtures that include high-value tree species. Mechanical damage to the tree species is potentially great during the early stages of the tree crop rotation and is potentially more damaging to the associated crops as the trees grow larger and thinning or harvesting operations are required. Mechanization of tillage could be challenging when the spacing between tree and crop component is irregular (intercropping practices). Planning inter and intra-spaces between trees and crops is the solution to avoid any competition and damages.

4. **Allelopathy**

Seed germination and plant growth can be inhibited by the release of naturally occurring compounds from roots and aerial tissues of other plants. These allelopathic detrimental effects of one plant on other plants is a potential disadvantage of agroforestry plant combinations. It is critically important to study the compatibility of the species at the design and species selection phases to avoid any allelopathic undesired effects.

5. **Habitat or alternative hosts for pests**

The effect of plant associations on pest and disease incidence is a potentially important but rather unexplored area.

- When in proximity to other crops, trees can provide a habitat for pests of all sorts, which is particularly true for tree and cereal combinations for example. Cereals are attractive food for rodents, birds and insects and the presence of additional bird habitats in trees can result in increased bird damage to untended grain crops.
- Home gardens can provide an improved habitat for rodents, snakes, mosquitoes and other insects and disease pests.
- Bacterial and fungal diseases may increase in shaded, more humid environments. However, reduced temperature and humidity fluctuations under shade can also have a suppressing effect on pests and diseases.

Adopting Integrated Pest Management practices (c.f. section below) while planning and managing adequately the Agroforestry system, studying closely the requirements of each component is the basis toward overcoming this barrier. The balance between positive and negative effects will have to be assessed for each situation. Including plant species with insect repellent properties could also help in reducing the occurrence of pests. Diverse cropping schemes, i.e., the combination of rows consisting of different crop species may help to disorient pests from their target or host.

VII.1.2. AT THE TREE-ANIMAL INTERFACE

Silvopastoral and Agrosilvopastoral systems, which integrate livestock, crops and trees could also experience negative interactions:

- **Toxic components:**

The low quality of, or toxic components within, tree fodder can adversely affect livestock production. While tree fodder holds great promise, especially as a dry-season supplement in semi-arid areas, its value should not be overestimated. Many species contain secondary compounds that reduce the feed value. It is advised to study the nutritional composition of tree or grass fodders to avoid any animal malnutrition or undesired effects.

- **Trees Damage:**

Mechanical damage of trees, especially for tree species with palatable foliage or deterioration of soil properties, e.g., through compaction, can have a negative impact on the woody perennial component. The damage to trees (especially at early establishment phases) and crop components from livestock, needs a careful management (fencing, rotational grazing, cut and carry practices) to prevent livestock from physically damaging the tree crops.

VII.2. MANAGEMENT PRACTICES TO REDUCE POTENTIAL NEGATIVE INTERACTIONS

The magnitude of interactions between trees and other agroforestry components depends on the characteristics of the species, their planting density, and spatial arrangement and management of the trees. Monitoring and managing plant densities and arrangements is probably the most efficient method for capitalizing on beneficial effects of trees while reducing negative interactions with the other components.

In some cases, for example, when trees are used as support for crops, the planting density of the trees is determined by the planting density of the crops. In these cases, choosing a wider plant spacing for trees with larger crowns may not be a valid option; under such conditions, knowledge of the light transmission characteristics of tree crowns and the options for tree management is important.

Several desirable attributes could be identified for “the tree” in agroforestry systems; however, it is not always possible to choose tree species having all these desirable attributes, either because other plants are already established, or because production or protection goals favor the choice of other species.

Whenever a tree species with all the desired characteristics is not available (which is most likely to be the case), tree crowns and roots can be manipulated mainly by pruning and thinning.

Other common management operations are fertilization, application of mulch and manure, cut-and-carry fodder systems, and confinement or rotation of the animals.

The objective of management practices is to increase the production of the desired products and to decrease competition among components. In many cases, one agricultural practice will accomplish both goals simultaneously, e.g., pruning trees in alley cropping and applying the pruned (and ground) biomass to the soil. While the removal of parts, or all of the crowns will obviously reduce the tree's competitive ability, it will automatically increase the growth of the associated intercrop by providing green manure and by allowing more light to reach the crop.

Below-ground competition may also be reduced by pruning-induced root die-back. These practices also apply to pruning or pollarding operations on trees grown for shade or as live supports, such as legumes. Under conditions of severe below-ground competition, root pruning operations or trenching may eliminate, or at least strongly reduce, the negative effects of the trees on the intercrop.

Tree species with large thick leaves and high rates of biomass production will require more intensive pruning than trees with a less dense canopy.

VII.3. DISEASES AND INTEGRATED PEST MANAGEMENT OPTIONS

With the diversity of species in an agroforestry system comes an inherent diversity of pests, most often higher than in a monoculture system. Managing those pests properly is key to maintaining good production while protecting the soil and surrounding environment.

Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests and/or their damage through a combination of techniques, including biological, cultural, and habitat manipulation techniques[1]. With a good IPM program, chemical pesticides are only introduced when monitoring shows high risk of infestations and other cultural or biological practices are not available to prevent pest outbreaks. Pesticides are used according to clear guidelines and treatments are localized to affect only the target organism. The selection of the pest control material as well as its application method are made in a way to minimize the risks to human health, beneficial and nontarget organisms, and the environment.

Developing a good IPM program for an Agroforestry system always start with a clear understanding that the goal of pest management is NOT to eliminate the pest, BUT rather to prevent crop damage by reducing pest population below the Economic Threshold.

A good IPM plan should always include the following key parameters in the below sequence[2]:

- Pest identification.
- Monitoring.
- Management.
- Post-treatment monitoring.

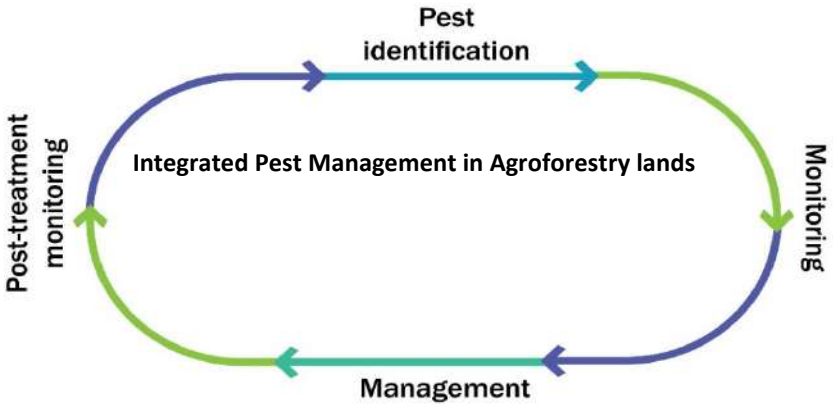


Figure 53 Steps of an Integrated Pest Management

[1] UC IPM, 2022. https://www2.ipm.ucanr.edu/What-is-IPM/

[2] Holly, L.M., and Ryan, M.R. 2004. Integrated Pest Management (IPM) and Wildlife. USDA, NRCS. Fish and Wildlife Habitat Management Leaflet. Nb. 24.
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18487.wba

VII.3.1. PEST IDENTIFICATION

Agroforestry systems are inherently rich in species. Aside from the productive plant and animal species, this includes a wide array of insects, pathogens, weeds and parasitic plants and microorganisms. While a lot of those are beneficial for the ecosystem and needed to create an equilibrium, some can negatively affect the farm's production either by damaging crops, reducing plant or animal health, or competing over resources, thus reducing productivity.

When establishing an agroforestry system, it is essential for the landowner to be familiar with the pests associated with their crops and herds. Information on pests associated with each crop or animal species is available for free either online or in documents and leaflets available at the Ministry of Agriculture Extension Centers or agricultural research centers.

- *What to look for and record?*

For every crop species in an agroforestry system, the landowner should know:

a. Which pests (insects, pathogens, microorganisms, parasitic plants) can affect the crop species?
b. What is the recorded severity of each: how bad it can cause damage to the crop?
c. What are the suitable conditions for the pest to grow? Usually, most pests thrive better in high humidity and warm conditions.
d. What life stages of the pest are most damaging? And how they align with the seasonality of the crop?

Understanding well the pests in an agroforestry system facilitates drastically pest management and allows for more targeted interventions, which leads to higher management success at a reduced cost.

VII.3.2. MONITORING

Monitoring is by far the most important step in a successful IPM. Monitoring or scouting should be done around the year and data on pest population should be recorded to identify trends and prevent outbreaks before they occur. In a well-grown agroforestry system, weekly scouting helps monitor all pests and support decision-making for IPM.

Nowadays, there is a huge array of monitoring tools available for all farmers and that can facilitate the monitoring process. While visually checking the trees and plants for symptoms is still important, setting different types of traps and monitoring devices in the land can make the monitoring job easy.

Monitoring traps are usually used for insect pests, and they come in multiple forms and work in different ways (Figure 55). It is important for the farmer to understand the use and efficacy of each type of trap as well as identify the existing pests to match the correct trap type. Below is a brief description of the common types of traps and in Figure 56*Figure 55* a chart showing the efficacy of each by insect group.

- **Yellow sticky traps:**

They are the most commonly used type of traps in agricultural and agroforestry systems. They are used to monitor several flying pests including aphids, whiteflies, leaf miner adults, moths, fruit flies and many more.

Figure 54 Yellow sticky trap

Traps are composed of a yellow cardboard or plastic sheet with adhesive glue. They are easy to find at agricultural stores or can even be made by the farmer. Traps are usually distributed at the rate of 1-2 traps every 100 m^2 and can be hung on tree branches or on poles around and within the land.

Since most insects are known to be attracted to the yellow color, flying insects will fly directly into a yellow sticky trap and get stuck on the glue. When purchasing them, landowners are recommended to order the ones with the grid. With the high number of insects that would get stuck on the glue, the grid will help count them easily and keep track of the counts.

Recommendations: Change sticky traps on a weekly or bi-weekly basis and check them regularly for key insects, such as fruit flies when fruit trees are present in the agroforestry system, or whiteflies when vegetable crops are grown.
In agroforestry systems where thrips might be an issue, blue sticky traps can be added as well.

- **Malaise traps**

Malaise traps are large tent-like structures made of netting material (Figure 55-A). Since insects tend to fly upward, once an insect enters the tent, it will move to the upper side of the tent where a trapping cup is set with a narrow opening that captures the insect and does not allow it to fly back out. The cup then needs to be checked weekly and emptied and insects inside counted and identified. If the farmer/practitioner is not familiar with the insects trapped, he/she can refer to the closest entomologist, Agriculture extension center or to the internet resources to know whether the insect trapped is a potential pest of the planted crops. Because of their designs, Malaise traps are expected mostly to capture insects with some level of flight capacity. Crawling insects are very rarely caught in this type of traps.

- **Light traps**

Light traps (Figure 55-B) range from very simple settings such as a light and a white bedsheet set in front of it to highly sophisticated light trapping chambers made of plexi or other material. Light traps are used to attract insects flying at night such as moths, beetles, and flies. Some of those can be serious pests in an agroforestry system.

- *What to do in case of budget limitations?*

When farmers, landowners or practitioners cannot afford to buy a light trap neither to spend a night in their field watching insects get stuck on a cotton bedsheet, they can simply set a light bulb inside a plastic container closed from the top with a small opening from the bottom and hang it on one of your trees.

Recommendations: Light traps should be checked in the morning when they're set and are mostly efficient in the summer during the insect flight season.

- **Pan traps**

Pan traps (Figure 55-C) are one of the easiest traps to make. Farmers can use any old pan they have, fill it with a liquid (soapy water, propylene glycol or saline solution). Insects mistake the liquid for food, land on the pan to drink and get trapped in the liquid.
Pan traps capture different types of flying insect including aphids, flies, thrips, beetles and even some types of grasshoppers. However, these traps can also capture bees and parasitic wasps, so they are not recommended if your agroforestry system includes beehives.

Recommendations: The liquid in the pan should be changed weekly for better results and the pans should be set in open areas where they are easily seen by insects.

- **Pitfall traps**

Pitfall traps (Figure 55-D) are used to capture ground dwelling insects. Although very limited species of ground dwelling insects are pests and the majority are good for your agroforestry system, it is good to set a few in your land to identify the species present, and in some cases to know if you have enough beneficial insects in your land. To make a pitfall trap, bring any deep cup, fill it with 1-2cm of soapy water, dig a hole the depth of the cup and set it inside the whole so the surface of the cup is well aligned with your garden floor. Insects walking on the land, especially at night, would fall in the trap automatically and get trapped into the liquid inside.

- **Beating sheets**

Beating sheets (Figure 55-E) are farmer's best friend when walking through the agroforestry system. They help identify those little creatures living on the plants and that rarely fly to get captured by other types of traps or walk on the ground to fall in a pitfall trap.
A beating sheet can be any white paper, but better to use a paper with grid if you are keen on counting your insect population. Walk through the field in a diagonal way, with a little stick in the right hand and a beating sheet in the left. Place the sheet under the branch of any tree or plant to be checked and beat it gently to displace insects walking and feeding on it. Check what falls on the sheet and record it immediately. Clean the sheet and keep moving.

Recommendations: Doing this exercise once a week can ensure you prevent any pest outbreak as it gives you a good feel of the types and numbers of pests you have. If you can afford to do it weekly, try to do it at least once a month during the growing season.

- **Acoustic Monitors**

If you are a technology driven person and would like to test a new monitoring method, this would be your preferred monitoring tool. Acoustic monitors (Figure 55-F) provide a passive, non-destructive method to detect and identify insects. Insects generate bioacoustics signals for their communication or as a result of their movement. The monitors are able to capture and record those signals and a specific software can help identifying the insects emitting them.

- **Active visual surveys**

This is the lowest cost monitoring method. However, to be able to properly implement active visual surveys (Figure 55-G), the farmer needs to be familiar with all pest species. Active visual surveys include looking for symptoms as well as signs of insects, the latter including the insect itself, different life stages of that insect, or by-products of the insect such as honeydew, fecal material, or grown-out skins.

Recommendations: To make your active visual surveys more effective and practical, mark a few plants of each crop or tree species in your agroforestry system and go back to them regularly. Check the upper and underside of leaves, twigs, inside the flowers and the ground underneath the plant for any pest signs.

The advantage of this method is that it can help also identify fungal problems such as mildew or rot.

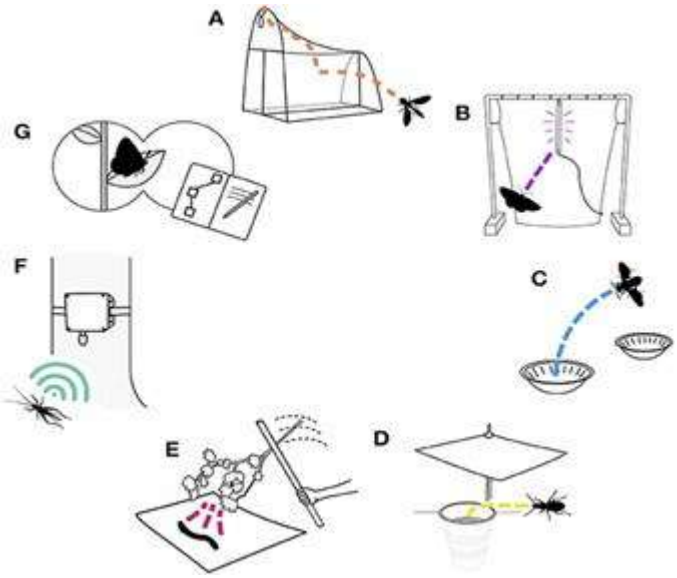


Figure 55 Different types of traps[3]

[3] Montgomery GA, Belitz MW, Guralnick RP and Tingley MW (2021) Standards and Best Practices for Monitoring and Benchmarking Insects. Front. Ecol. Evol. 8:579193. doi: 10.3389/fevo.2020.579193

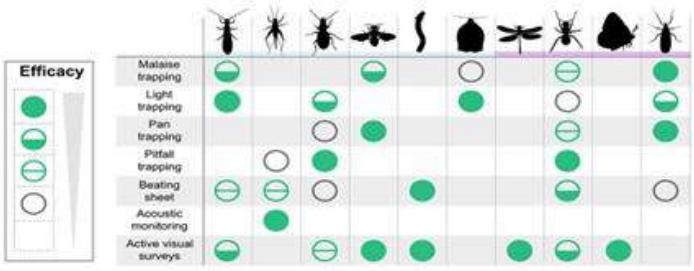


Figure 56 Efficacy level of different types of traps by insect group[4]

VII.3.3. MANAGEMENT

If you are expecting that this section of the guidelines will give you a magic recipe that you can apply each time and win your battle against pests, you are starting on the wrong foot! Managing pests in every system, and more so in an agroforestry system, requires patience, knowledge, and logic. Remember that the goal is to reduce the pest population below the economic threshold! All insects are needed at a certain level for the equilibrium of the system. We just need to keep them under check!

Integrated pest management is a toolkit that provides you with an array of options and you will then need to decide each time on which tool to use for better results.

- *How to choose the right IPM tool?*

Choosing the right tool starts by weighing your factors including:

- Pest or pests that you want to manage.
- Their current life stage and mobility level.
- The host plant the pest is damaging and the type of damage.
- The impact of the tool on the soil, the site microenvironment, and other beneficial organisms.
- The cost of management vis a vis the benefit.

In all cases, farmers should avoid disturbing high-use wildlife areas, especially during the breeding and nesting season5. Birds and small mammals and reptiles can help reduce pest problems if protected around your land.

a. **Proper cultural practices:**

Managing pests in an agroforestry system can start by studying well your cultural practices. **Proper cultural practices** can help create, maintain, and enhance habitats for beneficial insects and wildlife and target the pests at their weak points. Cultural practices should be aimed at modifying the suitable living conditions for the pests.

---

[4] Montgomery GA, Belitz MW, Guralnick RP and Tingley MW (2021) Standards and Best Practices for Monitoring and Benchmarking Insects. Front. Ecol. Evol. 8:579193. doi: 10.3389/fevo.2020.579193

5 Holly, L.M., and Ryan, M.R. 2004. Integrated Pest Management (IPM) and Wildlife. USDA, NRCS. Fish and Wildlife Habitat Management Leaflet. Nb. 24.
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18487.wba

Examples of good cultural practices that can reduce pest problems in your agroforestry system include, but are not limited to:

- Alternating your crop species over the rows to disrupt continuity. Alternation should be well studied as to have completely different host families in adjacent rows and not just different species that might still harbor the same pests. insect repellent aromatic plants can be planted in middle rows and on field edges.
- Placing your plants in the right wind/sun direction as to reduce humidity and allow for better air circulation. Most insects and pathogens thrive better in damp and darker areas.
- Pruning your trees well to reduce humidity within the tree, remove any infected or infested branches and support better tree health to allow the tree to fight any attacking pests.
- Rotating seasonal crops. Do not plant the same crop in the same area/row over several seasons. Some insects and pathogens overwinter in the ground under the plants and will come back to attack your crop the next season. Rotating with non-host plants can lead to insect starvation and population reduction.
- Adjust planting and harvesting dates if possible, to avoid coinciding with pest life cycle.
- Conservation tillage leaving at least 30% residue cover can help protect the newly planted seedlings
- Sanitation: sanitation is a very important practice in every agricultural activity. Sanitation includes several key points: 1) clean infested plant residues from your field and dispose of them by burning them properly if heavily infested or disposing off them away from your agroforestry field; 2) do not leave infested or infected fruits on your trees, but rather harvest them into a different container and feed them to animals or use them in pasteurized compost; 3) use all pruning and cleaning residues in composting or animal feeding or other economic uses and do not leave them stacked in your field as they might become the source of infestation for new pests; 4) sanitize your pruning and harvesting tools and material when used between trees or fields to avoid spreading infections, especially when you have pathogenic problems.

b. **Biological control:**

The second step in managing your pest problems is understanding their natural enemies, i.e., what other insects or pathogens or birds can feed or kill your pest in the natural environment and improving the conditions for those natural enemies to grow or introducing them into your system if they are not present. **Biological control** has become a very widely used management tool in every system where pesticides are being avoided and biological control methods has been developed largely by multinational companies across the world.

Biological control agents can be either predators (they feed on the pest), parasitoids (they parasitize the pest and feed inside it or on it without instantly killing it) or pathogens (they

infect the pest and cause later its death). Predators can range from insects such as ladybeetles and ants, to birds, bats, and larger mammals. Parasitoids are usually tiny wasps that lay eggs on or inside the body of the insect pest. When the eggs hatch, the larvae will feed on the pest and kill it. Parasitoids are not dangerous to humans or animals. Pathogens are viruses, bacteria, nematodes, or fungi that can infect the insect or fungal pest and lead to its death.

- *How effective are biological control agents in Agroforestry systems?*

Those biological control agents usually require certain types of habitats to thrive. Ensuring that their habitat is available on your site will make your pest management much easier. Agroforestry systems are easier than others in this regard as the design of the systems usually considers those types of habitats, whether it be windbreaks, alley cropping or forest/riparian buffer zones, those sections are usually the best place to grow a good population of biological control agents. The key is however to ensure that those sections are never treated with pesticides or largely disturbed.

The monitoring tools summarized earlier can help you detect predators and parasitoids available in your land. Lands with wider windbreaks or edges with native vegetation are usually found to have better populations of beneficial biological control agents.

In cases where your counts of biological control agents are low or when you are dealing with a new pest for which biological control agents are not yet identified nor established, more elaborate biological control means can be applied, such as releasing beneficial insects (however this can only be done with proper studies and can be highly expensive) or spraying bio-pesticides such as *Bacillus thuringiensis* which is the most widely used commercial biological control agent that helps in controlling pest caterpillars. However, applications should be done at the right life stage of the pest and in a localized targeted manner to avoid affecting other beneficial caterpillars in your system.

Birds and bats can also be very useful in helping you reduce your pest problems. When combined with other management practices, birds can help reduce insect populations. Bats also play key ecological roles, eating night-flying insects, pollinating flowers and dispersing seeds. Reducing hunting around your land can drastically reduce your management costs.

You might also consider setting proper nesting areas for bats and birds within or close to your land to ensure their continuous presence. Artificial nesting/roosts are designed to encourage owls and bats into areas where there are few roosting sites, lack of natural hollows or other nesting preferences. Several studies have shown how adding barn owl nests boxes in agricultural lands help farmers with their pest control. Since barn owls are sensitive to disturbance, it's best to place boxes in quiet locations. You can provide a box inside barns, on trees, the outside of buildings, or on poles. There are 3 types of barn owl nest boxes depending on the location, interior, exterior, and on poles (Figures 57, 58 and 59). Similarly, can be done for bats (Annex 6); caution must be advised as high cases bat deaths from overheating in black-colored boxes have occurred, it is important to take microclimate characteristics into consideration when setting up a bat-box scheme. If lampposts will be added in/around the plots, the type of light emitted should be taken into consideration. The best light would be red-emitting LED lights. These lights will help

not to distract bats from their natural flight routes due to being attracted to the high number of insects under regular white lights.

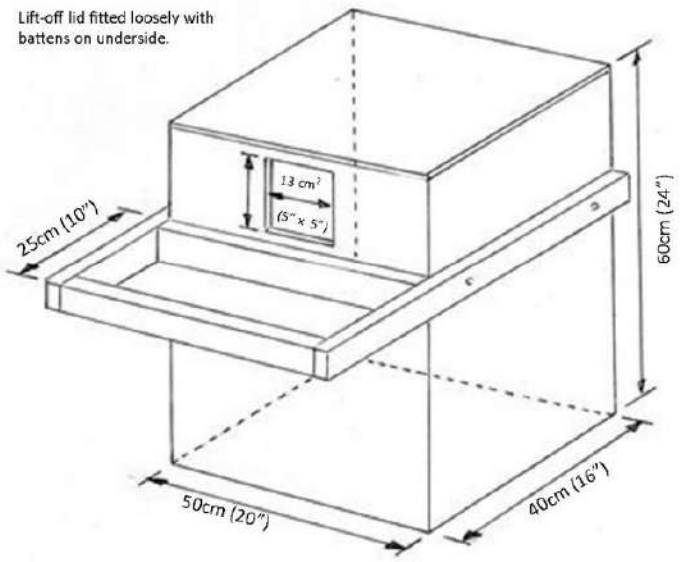


Figure 57 Plan for interior barn owl nest box
Reference: Barn Owl Trust

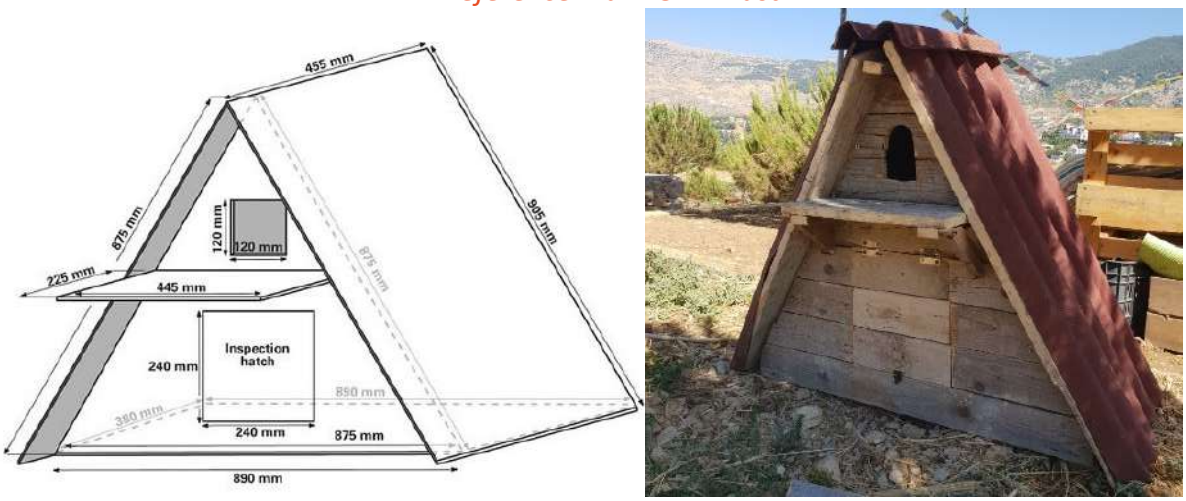


Figure 58 Plan for exterior barn owl nest box (on the left); Exterior barn owl tested in a local farm in Chouf district (on the right)
Reference: RSPB, UK

BARN OWL TRUST POLE BOX DESIGN - Images of the construction of this box can be viewed at **barnowltrust.org.uk**

DRAWING NOT TO SCALE

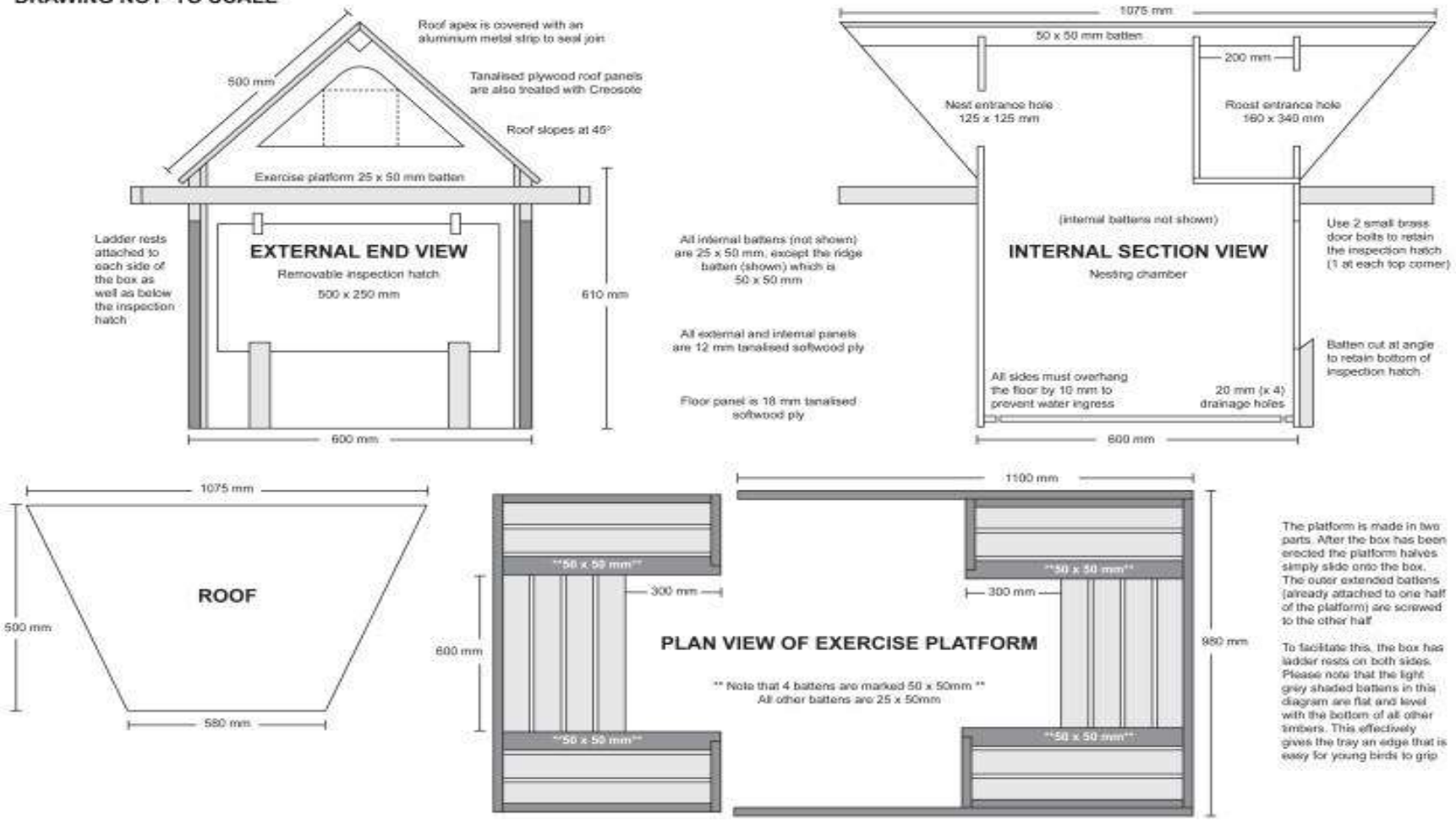


Figure 59 Pole design nest box
Reference: Barn Owl Trust

- *How to mitigate human-wildlife conflicts?*

One of the main human-wildlife conflicts that occurs on farms is when foxes attack chickens. Farmers usually take harmful action towards to the foxes due to causing loss to their livelihood. Thankfully, there are ways to deter foxes without harming them so that they continue to perform their ecosystem services. Setting up a steal wire fences (Figure 60) around your chicken pen is the best action forward. Foxes can jump up to 180cm and then have been found to use their claws to climb higher. Therefore, an overhang needs to be added to top of the fence. They are also known to be great diggers where they can dig 15-20 cm underground. Therefore, the fences depth needs to be at 30 cm as well as adding an outside apron to assist deterring the foxes from pushing the fences inward. If low grade welded mesh is only affordable hole size needs to be 1.3 cm x 2.5 cm in diameter.

Figure 60 Minimum mesh wire fence dimensions summary

c. **Chemical Control:**

Chemical control comes usually as a last resort in IPM in agroforestry systems when your pest numbers get too high or when you encounter a new invasive pest. In such cases, pesticides can be used only within the prescribed doses and choosing the least toxic pesticides to reduce harm for beneficial insects. NEVER apply pesticides over your whole land. Pesticide applications should be targeted and localized only to your specific crop that you are managing. For better results, your need to understand where your pest is located on your crop/tree and target your spraying to those specific locations. For example, if your pest lives underneath the leaves, your sprayer should be applied upward from ground level to hit those leaf undersides. Never spray during high temperature hours of the day or days. Avoid spraying if wind speed is greater than 10mph and avoid washing your spraying equipment near rivers or water streams.

VII.3.4. POST-TREATMENT MONITORING

Whatever treatment you choose to apply, it is crucial to monitor its efficacy. For post-treatment monitoring, you can use the same monitoring tool you used to identify your pest problem in the first place. For example, if you have an aphid problem that you identified with yellow sticky traps, and your treated with soapy water, replace your yellow sticky trap right after the treatment and monitor it on a weekly basis after the treatment. You should capture much less aphids after the treatment then you did before. If you still have a high number of aphids on your trap, it is an indicator that your treatment was not

efficient, and you need to change tactics and choose another management method. If you have less than half the aphid count pre-treatment, it means you're on the right track.
That doesn't mean however that you should stop here. **Remember that your treatment only reduces the population**! You need to keep monitoring and repeat the treatment once the numbers start going up again.

V.6. THE TIME SCALE OF AGROFORESTRY IN LEBANON

Most agroforestry benefits are owed to the woody perennial component (tree and/or shrub). The services provided by the tree component enhance the environmental setting of the agroforestry system resulting in an increased and sustainable productivity of the herb (crop and/or pasture) and the animal components.
The efficiency and significance of ecological benefits and services provided by the tree component are correlated to the development of the tree biomass (canopy and roots).
When trees are established at a seedling stage in croplands or pasturelands, it may take many years before the system reaches its optimum of positive, services and productivity.
The dynamics of tree growth depend on many variables such as:

- The specific genetic potential of the species in question.
- The abiotic factors of the environment i.e., the climate, the soil.
- The biotic factors of the environment i.e., disease causing organisms, herbivores…
- The ecological interactions with the other agroforestry components.
- The response to intensive management operations.

As a result, agroforestry systems developed in humid tropical environments reach their full efficiency earlier than systems developed in temperate and semi-arid to arid environments.

AGROFORESTRY IN LEBANON AND THE MEDITERRANEAN

In the Mediterranean regions, the long seasonal drought that is simultaneously hot represents a limiting factor for tree growth. Most native Mediterranean trees and shrubs are slow growing species. Thus, Mediterranean agroforestry systems are slower to reach their full efficiency and productivity.
These drawbacks i.e., tree development rate and tree growth rate in the Mediterranean climate can be overcome by the yearly income and revenues from the crops and the animal until the system reaches its full productivity. It is important to emphasize on the numerous products that can be provided by diversifying the herbaceous component of an agroforestry system: food crops, aromatic, ornamentals, medicinal plants, tinctorial plants, fodder crops…
Added to the variety of products and cash income from the herb and the animal components, the reduced costs of establishment, maintenance, reduced needs for fertilizers (when legume species are introduced) and for pesticides (when species with insect repellent properties are used for examples) and the efficient use of land resources to yield products from the growing trees, herbs and animals pay back the farmer until the tree component reaches the optimum of its productivity and services.

CHAPTER VIII. AGROFORESTRY AS A BUSINESS

Establishing Agroforestry systems promises socio-economic advantages when compared to conventional farming systems, through the diversified production of Agroforestry lands, the lowered maintenance costs, the annual distribution of labor, improvement of food security, etc. It is however essential to plan Agroforestry projects from a business perspective for an efficient and productive agricultural model. The following section discusses the economic, financial and marketing aspects that enable a successful and rentable Agroforestry project.

VIII.1. ECONOMIC BUDGETING

Economic budgeting is a decision-making tool used to: report, monitor, analyze, and forecast the financial performance of any established economic agri-business. For agroforestry economic analysis, two main types of budgets are used:

- Enterprise budgets: a detailed list of all costs and revenues for a single business plan or enterprise (i.e., livestock farm) within the system and for a determined planning period.
- Cash flow budgets: a detailed schedule where costs and revenues timelines are mentioned for all individual business plans within the system and summed up to provide a general overview of the full cash flow of the system. The cash flow analysis also accounts for possible risks, predicts cash needs over a time period and facilitates decision making for better profits. In fact, a cash flow budget encompasses multiple business plans within the same land/farm, helping the farmer to identify areas of loss and possible offset revenues.

VIII.2. CATEGORIES OF COSTS IN AN AGROFORESTRY SYSTEM

Establishment costs are usually the first costs incurred in an agroforestry system. They include all costs related to purchase and establishment of the components of the system, including trees, crops, and animals, with their related infrastructure. Agroforestry establishment costs can be high, especially for the tree and animal components. Planning the establishment of an agroforestry system with an economic lens is very important for the sustainability of the operation.

When an agroforestry system is established on cropland, pastureland, or bare/fallow land, the costs could be overwhelming for farmers in poor rural areas, as farmers must bear the high establishment costs of the trees, the crop and pasture species, the animals (if in a Silvopastoral system), fencing and other infrastructure needed, as well as all operational costs of land preparation and first establishment phases. However, one advantage of agroforestry systems is that they don't have to be established fully in the first year, different components of the system can be gradually developed whereby farmers can start growing seasonal crops to generate revenues and can use some of those revenues to increase the tree or animal component gradually on their land. This is why having a clear initial cash flow budget, with at least 5 to 10 years timeline, can support the farmer in taking the right decisions. Gradual establishment is always advisable when

resources are limited, even though it delays slightly the overall benefits of the full system. However, gradual establishment has to be done based on the developed design for the land and economic constraints should at no time shift the farmer from the original land plan.

Other types of costs incurred in an agroforestry system are:

- Fixed cost: attributed to the resources of ownership and shares. These are the fixed costs occurring regardless of any productive activity. Examples of fixed costs include: land leasing cost (if any), insurance, water and electricity payments, etc. Fixed non-cash costs are costs not requiring a cash outlay that are incurred regardless of production but can still be influenced by production. An example of a fixed non-cash cost is the depreciation in value of machinery over time that is accentuated when the machinery is used but is still incurred when not in use.
- Variable cost: attributed to the productive use of resources including all input costs (seeds, compost, hired labor, etc.). For agroforestry systems, variable costs include the cost of 1) establishment, 2) maintenance, 3) harvesting, and 4) marketing. One very common accounting mistake farmers do recurrently is forget to account for their own time spent on the land. However, proper financial planning requires proper accounting of all variable costs, including the farmers time as this time could have been spent in an employment or another productive activity.

Table 24 below summarizes the most common costs bared by farmers when adopting agroforestry systems.

Table 24 Costs of Agroforestry projects

	Cost type	Cost	Example
Fixed Costs	Cash	Ownership and shares	Land, leasing cost, insurance, electricity, water, etc.
	Non-Cash	Depreciation	Machinery, infrastructure
Variable costs	Cash	Establishment	Seeds, Trees, Animals, Machinery, Compost, Water, Labor, etc.
		Maintenance	Pruning tools, Labor, Water, disposal of residues, etc.
		Harvesting	Machinery, Labor, Containers, etc.
		Marketing	Transportation, Advertisement, Free samples, etc.
	Non-Cash	Time	Required period to implement activities

A good financial planning requires a good regular analysis of the costs, a clear understanding of high versus low-cost components, so the farmer can decide to select practices over time based on a combination of the technical and financial input.

VIII.3. SCALE OF PRODUCTION

Agroforestry systems differ in the scale of production and the level of technology input and management. Accordingly, agroforestry systems are classified as commercial, intermediate and subsistence systems.

A. *Commercial agroforestry systems:* refers to medium to large scale production with significant outputs. Land ownership can be either government, corporate, or individual.
B. *Intermediate agroforestry systems:* This system falls between the commercial and subsistence systems. It usually refers to small to medium size farms that integrate perennial and seasonal production, part of which is destined for marketing while the other part covers the family food needs. Usually such systems are found on medium size lands owned by the farmer and where farmers live on or near the land and conduct most of the farm chores themselves with occasional support from paid daily labor.
C. *Subsistence agroforestry systems:* A system where land use is directed toward satisfying farmers' basic needs. They are primarily managed by the owner – occupant and his family. Cash crops, including surplus production of basic commodities, may be a part of these systems but are only supplementary. Most of the agroforestry systems practiced in part of the developing countries fall under the subsistence form, such as "home gardens" found both in thickly populated areas and in rural areas.

VIII.4. MARKETING AGROFORESTRY BUSINESS

Agroforestry models or systems create an enabling environment where landowners can generate income from a wide range of products while protecting and conserving soil and other natural resources and preserving the environment.

To market a business each farmer should abide by the following concepts:

- Understanding the market.
- Conduct a SWOT analysis to analyze current situation.
- Research and select target markets.

VIII.4.1. UNDERSTANDING THE MARKET

At first, farmers should start seeking market information/market analysis to better analyze their business environment and the industry for the product they are intending to sell. This step can be taken through Primary and Secondary information sources summarized in the below table.

Table 25 Sources of information for market analysis

Primary source of information	Secondary source of information
Interviews with producers and value chain actors	Reports and studies of certain products
Observation (attending marketing conferences, visiting farmers markets…)	Online information source
Focus groups	

VIII.4.2. SWOT ANALYSIS

Second, a farmer should perform a SWOT analysis to examine internal (Strengths and Weaknesses) and external factors (Opportunities and Threats) tending to affect his business.

Each farmer should look at his business from a multi-point perspective and identify the strengths evolving his competitiveness on the market and bringing him closer to achieving his goals. For example, continuous supply of products all year long along with competitive prices improve the farmer's competitive state and stand in the market. The ability to provide innovative types of products is another competitive advantage that improves the farmer's ability to access new markets. As for the weaknesses, they are defined as the areas where a business is vulnerable to competitors and influenced by the problems found in the system. Insufficient workforce, seasonal products as well as shortage in distribution channels weakens the business and threatens its sustainability.

Also, farmers should look outside of their businesses to identify issues (opportunities and threats) that cannot be controlled but can be managed to influence their impacts on the business. For example, a farmers' market created in the area is considered as a good opportunity to directly sell products to consumers without interference of middlemen. As for the threats, imported products may threaten the marketing process if sold at a higher quality and lower prices.

In summary, SWOT analysis provides direction and serves as a basis for marketing strategies and development of business plans and should repeated on a yearly basis to measure achievements and evaluate alternatives and come up with contingency plans.

In an agroforestry system, SWOT analyses can be performed individually for each type of product or in groups for all products produced on the system. Individual SWOT analyses and market studies might be more beneficial as they allow for better detailing of all factors and thus a better understanding of the business environment for each individual business opportunity under the system.

For example, the market types and conditions for the dairy products produced by the small ruminant component of an agro-silvopastoral system are completely different in scale, scope and size from those of fruit products. Being able to understand those differences is crucial for the farmer to achieve good profit. Understanding the variability over time of market conditions and selling prices is also important to guide decision-making towards processing versus selling fresh products, or storage versus immediate selling of fresh produce.

VIII.4.3. RESEARCH AND SELECT TARGET MARKETS

This process aims at identifying consumers' preferences and dividing larger markets into small ones in a procedure called segmentation.
Identifying segments and creating profiles for each one directs the farmers, allowing them to identify the most profitable segment towards which production shall be directed.
When selecting the segment, farmers should think about 3 major aspects to directly deliver their products to buyers.

- Distribution: The sales channels that each product will follow
- Location: Where will the product be sold
- Delivery system: How will products reach the buyer

Developing a good business plan and properly identifying market channels are key elements to the success and sustainability of a business. Reducing dependency on middlemen is another crucial aspect for making profit, and it can only be achieved if the farmer invests enough time in understanding and accessing the markets.

VIII.5. ECONOMIC CASE OF AGROFORESTRY

Agroforestry systems are a sustainable management system for land thus they are designed to efficiently utilize on-farm resources and provide more output (e.g., fuel, food, etc.) than the system consumes as farm inputs (e.g., chemicals, labor, and machinery).
The economic case for agroforestry can be considered in three main values:

VIII.5.1. VALUE OF ENHANCED ECOSYSTEM SERVICES

The value of enhanced ecosystem services from agroforestry systems is reflected into the enhancement of the farm conditions (soil improvement and water management) and/or public benefits (whilst flood alleviation and biodiversity enhancement). Agroforestry systems can also have global benefits in terms of carbon sequestration for climate regulation.

VIII.5.2. VALUE OF ENHANCED AGRICULTURE OUTPUTS

The value of enhanced agriculture outputs from agroforestry systems is reflected in the increased yield/ hectare from silvo-arable systems or enhanced feed/meat conversion ratio in Silvopastoral systems.

VIII.5.3. VALUE DERIVED DIRECTLY FROM TREE COMPONENT

The value that can be derived directly from the tree component of agroforestry systems can include timber and fuelwood, non-wood products such as nuts and fruits, and ecosystem services such as carbon sequestration, improved habitat for wildlife, improved air quality and increased water infiltration.

VIII.6. ECONOMIC ANALYSIS OF AGROFORESTRY SYSTEMS

Economic analyses help landowners and farmers make decisions about the allocation of scarce resources in a rational way to meet designated targets and objectives. Decisions may have to be made at different points in time and by different interested parties. Various economic analyses are possible and detailed in the following section.

VIII.6.1. ANALYSES AT DIFFERENT TIMES

Prior economic analysis (*ex-ante*) of a potential agroforestry system gives an idea to the interested parties whether a system that is technically feasible is also economically viable and if so, whether it has a chance of meeting specific objectives, and helps to prioritize the various technology options available.

A subsequent (*ex post*) economic analysis of an agroforestry system that is already established is to determine whether such a system should be readjusted to better meet the objectives or adapt to changing conditions and would indicates the areas of adjustments.

VIII.6.2. ANALYSES FROM DIFFERENT VIEWPOINTS

- *A private economic analysis* (or financial analysis) is not necessarily limited to one farm but could include all farms in a watershed or a rural area. The objectives of the individual or group are considered and reflected in the inputs and outputs to be considered as well as the value given to them. Common objectives for individuals are obtaining higher levels of income and leisure time, as well as avoiding risks that result from widely fluctuating income and consumption.
- *A public economic analysis* takes into consideration the costs and benefits outside the farm or area where the system is present.
- *National objectives* could be reflected in the evaluation of all costs and benefits. They include broader socioeconomic and ecological goals, such as increasing the gross national product, full employment, income distribution among regions and/or groups of individuals and maintaining the natural resource base.

VIII.7. GENERAL APPROACH TO THE ECONOMIC ANALYSIS

The approach should provide guidance to the decision makers since it is the main objective of the economic analysis. Each system (existing or potential) should be examined from the farmer's and the community's (or public) points of view using the following questions:

- Is the production system making the best use of the available resources?
- Is the system technically feasible, given the available labor resources (amount, seasonal distribution, management skills)?
- Is the system economically feasible, given the available capital resources (owned or borrowed)?
- What are the risks involved in the introduction of the system or technology?

To answer these questions, three basic economic principles should be applied:

1. The level of input may be increased if marginal costs do not exceed marginal benefits.
2. An input may be switched from producing one input (e.g., wood) to another (e.g., food crop) if the total benefits from the various output combinations do not diminish.
3. One output may be swapped for another, maintaining the same total cost level, if the total benefits do not diminish.

To capture the full impact of an agroforestry system on a farming system, it is important to look at the development of the existing land use systems over the time as well as the potential development of the alternative agroforestry system, for the following reasons:

- Unlike other production systems, agroforestry systems aim at sustainability of production. Therefore, part of the benefits may be the prevention of the possible decline in the outputs of the existing production system over time. Several scenarios are possible: i) the introduction of an agroforestry system may result in preservation of the production resources, ii) efficient use of production resources, iii) increased productivity of production resources in a sustainable way, all that in comparison to an existing production system.
- One of the main characteristics of agroforestry systems is the delay in the realization of (part of) the benefits while costs must be incurred early. Therefore, a short-term forecast in most instances underestimates the benefits of agroforestry and may therefore show it to be uneconomic. Five-to-ten-year forecasts are usually recommended to have a better understanding of the economic future of the system, although they include assumptions that cannot be controlled as one can never know prices and market conditions far in advance.

VIII.8. TYPES OF ECONOMIC ANALYSIS

The most common analyses to which agroforestry systems are subjected at the private and public levels are:

1. *Labor input analysis*, showing the flow of labor inputs required for the introduction and maintenance of an agroforestry technology. In such an analysis, it is common to establish "who does what" to determine the effect that the introduction of the system may have on the different workers' groups (male, female, children, landless…)
2. *Material input analysis*, showing the flow of material input required for the introduction and maintenance of an agroforestry system.
3. *Cash flow analysis,* showing the flow of cash expenditures and receipts resulting from the introduction and maintenance of an agroforestry system. This analysis should include loans (inflow) and repayments (outflow) when applicable.
4. *Discounted cost / benefit analysis*, determining the profitability of the agroforestry system.

VIII.8.1. AGROFORESTRY COMPONENT ECONOMIC VALUE

The table below showcases the importance and the economic value of selected agricultural/animal component when infused within a defined agroforestry system:

Table 26 Examples on high-value Agroforestry products and their economic value

Component	Economic Value
Mushroom production in Agroforestry	Positive ecological interaction Protects and enhances sustainability of natural resources Income generating activity
Beekeeping in Agroforestry	Multi service provider (trees, farmers, oil plants …) Pollination services are much more economically valuable than direct beekeeping products Variety of products that generates good levels of income
Sericulture in Agroforestry	Small scale agribusiness for farmers
Agro-industry in Agroforestry	Generation of income from products that have no use in agriculture but essential in industry
Aquiculture in Agroforestry	Significant role in livelihood development Complementarity with other agroforestry components Good source of income for farmers
Herbs and medicinal plants in Agroforestry	Livelihood opportunities through local and international sale
Trees component in agroforestry	Enhanced food security Income generation for farmers and households
Livestock in Agroforestry	Additional source of income

VIII.8.2. VALUE CHAIN AND MARKET ACCESS

Lebanon being a developing country renders marketing agricultural products hard for small scale farmers due to the poor infrastructure and high ramification within the value chain actors i.e., the lack of an organized marketing system leaves the farmers vulnerable to marketing agents who receive a higher percentage of profits just by buying farmers' products at low prices and selling them at much higher prices being the sole marketing agent on the market.

Grouping together to transact a sale is the way that small scale producers should adopt to gain access to markets, sell directly to consumers, and generate higher profits which ensures their sustainability and strengthen their position as the primary actor in the

various agricultural/agribusiness/Agri-industrial value chain. Also, grouping together increases the quantity of products offered compared to the high demand on the market and gives the group the ability to negotiate selling prices leading to higher income that will be later used to develop their systems

Emphasis on ways to improve the 'value chain' for smallholders, such as through establishing seller groups, establishing market information systems, and developing secure means for financial transactions, are very important.

ANNEXES

ANNEX 1. NATIVE TREE SPECIES PER GEOGRAPHIC RANGE

The geomorphology of Lebanon i.e., the presence of two mountainous chains (i.e. the Mount Lebanon and Anti-Lebanon mountain ranges) parallel to the coastal area, divides Lebanon in 4 geographic units: the coastal plain, Mount Lebanon, Bekaa valley and Anti Lebanon range.
In this section, the most common native tree species and some native shrub species are listed according to their natural occurrence per geographic range.
We consider the coastal plain as part of the lowest altitudes (0-500m) of Mount Lebanon range, and we split Mount Lebanon into western and eastern slopes because they diverge in humidity levels.
The geographic distribution of native trees and shrubs:

- **Western slopes of Mount Lebanon range**

List of trees – Western slopes of Mount Lebanon						
	Low Altitudes 0-500m			Mid Altitude 500-1500 m		High Altitude >1500 m
Trees	Limestone	Marl and Marly limestone	Sandstone	Limestone	Sandstone	
Ceratonia siliqua	X					
Quercus calliprinos	X		X	X	X	
Pinus halepensis	X	X				
Styrax officinalis	X	X	X	X	X	
Pistacia paleastina	X	X	X	X	X	
Juniperus oxycedrus	X	X	X	X	X	
Cercis siliquastrum	X			X		
Pyrus syriaca	X	X				
Prunus korchinskii	X	X				
Laurus nobilis	X	X		X		
Pinus brutia		X		X	X	
Cupressus sempervirens		X				
Pinus pinea			X		X	
Quercus infectoria				X	X	

Quercus cerris (>1200m alt.*)*				X		
Crataegus azarolus				X	X	
Arbutus andrachne				X	X	
Acer syriacum				X		
Cupressus sempervirens				X		
Juniperus drupacea, (>1000m alt.),				X		
Ostrya carpinifolia (Humid places and Valleys)				X		
Fraxinus ornus (Humid places and Valleys)				X		
Cedrus libani						X
Abies cilicica						X
Quercus cedrorum						X
Quercus brantii look						X
Acer hyrcanum subsp. Tauricolum (A. tauricolum)						X
Sorbus graeca (S. flabellifolia),						X
Sorbus torminalis						X
Prunus ursina						X
Malus trilobata						X
Juniperus excelsa & Juniperus foetidissima (>1500m)						X

List of shrubs – Western slopes of Mount Lebanon						
	Low Altitudes 0-500m			Mid Altitude 500-1500 m		High Altitude >1500 m
Shrubs	Limestone	Marl and Marly limestone	Sandstone	Limestone	Sandstone	
Pistacia lentiscus	X	X	X			
Myrtus communis	X	X	X	X <800 m	X	
Nerium oleander			x			
: *Phillyrea media (P. latifolia)*				X	X	
Lonicera nummulariifolia				X	X	
Berberis libanotica						X
Prunus prostrata						
Rosa sp.					X	X

- **Eastern slopes of Mount Lebanon range**

At altitudes ranging between 900 & 1400 m, the dominant tree species are oaks (*Quercus calliprinos* and *Q. infectoria*) as well as pines (*Pinus brutia*, *Pinus halepensis* & *P. pinea* on sandy soils) with their floristic cortege i.e. companion tree and shrub species.

Juniper trees dominate at higher altitudes (>1500m).

- **Bekaa valley**

Trees: oaks (*Quercus calliprinos* and *Q. infectoria*), *Acer monspessulanum subsp. microphyllum (A. hermonum)* as well as pines (*Pinus brutia*, *Pinus halepensis* & *P. pinea* on sandy soils) with their floristic cortege i.e. companion tree and shrub species.

Shrubs: *Pistacia atlantica, Rosa* sp.

- **Anti-Lebanon Mountain range**

Trees: At altitudes ranging between 1000 and 1500m, oaks (*Quercus calliprinos* and *Q. infectoria*) dominate, as well as *Acer monspessulanum subsp. microphyllum (A. hermonum), Pyrus syriaca*, *Amygdalus korschinskii, Amygdalus orientalis, Crataegus azarolus*

Above 1500m of altitude, Junipers dominate essentially *Juniperus excelsa*.

Shrubs: *Pistacia atlantica, Rosa* sp.

- **On humid soils, riparian tree species**

On limestone:

In low altitudes:

Trees & shrubs: *Platanus orientalis, Populus* sp.*, Laurus nobilis, Salix alba, Nerium oleander*

In mid and high altitudes:

Trees & shrubs: *Platanus orientalis, Alnus orientalis, Populus* sp., *Ostrya carpinifolia, Fraxinus ornus, Fraxinus syriaca, Ulmus minor, Elaeagnus angustifolia, Salix libani*

On sandstone:

Trees & shrubs: *Alnus orientalis, Salix libani, Rhododendron ponticum var. brachycarpum, Elaeagnus angustifolia,*

ANNEX 2. NATIVE TREE SPECIES IN AGROFORESTRY SYSTEMS – CHARACTERISTICS, SERVICES AND PRODUCTS

* Please note that all trees provide shade, microclimate improvement, erosion prevention, habitat for wildlife and therefore biological control of insects and diseases to some extent. Only additional and distinctive ***services*** of species will be highlighted in this section.
* The *geographic distribution* of the species is limited to Lebanon's range, even if the species' range extends to other areas in the Mediterranean basin or outside.
* When *Light requirements* are not specified within the tolerance spectrum, the species has intermediate needs i.e. it can grow in full light or in shade.

1. *Abies cilicica*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Conical / pyramidal(young), tabular (aging)	Evergreen	35
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Mountainous Mediterranean		1300-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid & cold, northern exposure	Deep & fresh soils, prefers marly limestone.	Heliophilous, frost tolerant
Physiology	**Growth rate**	**Time to ultimate height**	**Life span (years)**
	Slow	> 50	<250
Products	Wood: frames, carpentry, formwork, poles, resin		
Services*			
Uses	Windbreak, intercropping, specimen, silvopasture		

2. *Acer hyrcanum subsp. tauricolum*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Oval	Deciduous	5-6
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Supramediterranean & mountainous Mediterranean		
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid and cold	Indifferent to soil type	Shade tolerant, Frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	20 to 50	25-50

Products	Wood
Services*	
Uses	Hedges (in multiple row windbreaks), specimen, intercropping, ornamental (autumn colors)

3. *Acer monspessulanum subsp. microphyllum*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Round	Deciduous	10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Supra & mountainous Mediterranean & in semi-arid zones (Bekaa)		≈ 800 up to 200
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid, arid and cold	Indifferent to soil type	Frost, heat & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	-	-	
Products	Wood: charcoal		
Services*			
Uses	Hedges, multiple-row windbreaks, specimen, intercropping, ornamental (autumn colors)		

4. *Acer obtusifolium*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Rounded	Evergreen	8
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo-Mediterranean		0-500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid to sub-humid Mediterranean	Indifferent to substrate, mostly found on limestone	Heliophilous, Frost and drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	5 to 10	-
Products	Wood: charcoal		
Services*			
Uses	Ornamental, specimen, intercropping, Hedges (in multiple row windbreaks)		

5. *Alnus orientalis*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Oval	Deciduous	8 to 15
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo, eu, supra and mountainous Mediterranean		Up to 1700
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Along river banks / moist sites	Humid	Heliophilous
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	10 to 20	
Products	Wood		
Services*	Nitrogen fixation (green manure), forage leaves		
Uses	Hedges, screen		

6. *Arbutus andrachne*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
		Evergreen	3 to 5, up to 12
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu & supra-Mediterranean		500 to 800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Dry and sub-humid	Indifferent	Heliophilous, Frost and drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	25-50 years
Products	Wood (turnery: flute, toys, wrists; fine carpentry, handle for tools and umbrella; charcoal) Edible fruits		
Services*			
Uses	Specimen, ornamental, intercropping		

7. *Arbutus unedo,* is rare in Lebanon. It has similar ecology and uses as *A. andrachne.* Its fruits are not very tasty.

8. *Cedrus libani*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Conical (young, spreading (old)	Evergreen	40
	Bioclimatic zone(s)		**Altitude range (m)**

Geographic distribution*	Mountainous Mediterranean (grows better on humid western slopes of Mount Lebanon)		1200-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	tolerates harsh climates (long & cold winters, long & dry summers)	Loose and deep soils, aerated limestone	Heliophilous
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	20 to 50	>1000
Products	Wood: carpentry, frames, cabinetmaking, rotary cutting & wood processing, Resin		
Services*			
Uses	Symbolic tree, specimen, intercropping, hedges		

9. *Celtis australis*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Rounded	Deciduous	Up to 25
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermos, eu & supra-Mediterranean		Up to 1400
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Mediterranean, humid to sub-humid with mild to fresh winters	Prefers deep and loose soils	Heliophilous, frost and drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	10 to 20	>50
Products	Wood: handles for tools, forage forks & agricultural implements, thin shoots are used as walking sticks, excellent fuel. Leaves as occasional forage, edible fruits, a yellow dye is extracted from the bark,		
Services*			
Uses	Ornamental, specimen, intercropping, multiple-row windbreaks, shade-tree		

10. *Ceratonia siliqua*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Broad & hemispheric	Evergreen	8 to 15
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo-Mediterranean		Up to 500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**

	Dry climates, cannot support cold temperatures	dry & rocky sites, grows well on limestone. Tolerates soil salinity (up to 3% of NaCl)	Heliophilous, Drought tolerant (tolerates 6 to 7 months) of drought. Resistant to fires
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	>50
Products	Fruits are used to produce a very nutritious molasses, confectionary, young leaves are a high-quality forage, tanning, fire-break		
Services*	Nitrogen fixation (soil fertilization and green manure), melliferous		
Uses	Specimen, shade tree, intercropping, multiple-row windbreaks PS: avoid planting numerous male trees; male flowers (produced in fall) smell bad.		

11. *Cercis siliquastrum*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	irregular	Deciduous	5 to 10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo-Mediterranean		Up to 800m
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid Mediterranean	Indifferent to soil type	Shade tolerant, frost, heat and drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	20 to 50	> 50
Products	Edible flowers,		
Services*	Nitrogen fixation (soil fertilization and green manure),		
Uses	Ornamental (flowers and leaves), eco-touristic vocations. Specimen, intercropping		

12. *Crataegus azarolus*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Upright	Deciduous	Up to 10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo up to mountainous Mediterranean		Up to 1500-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
			Frost and drought tolerant

Physiology	Growth rate	Time to ultimate height (years)	Life span (years)
	Moderate	10 to 20	-
Products	Edible fruits		
Services*			
Uses	Hedges, living fences, ornamental		

13. *Crataegus monogyna* has a similar ecology as *C. azarolus*. However, it is shrubby (height up to 5 m), it produces red berries that are tasteless.

14. *Cupressus sempervirens*

Botanical description	Crown shape	Leaf persistence	Height at maturity (m)
	Conic (var. *horizontalis*), columnar (var. *stricta*)	Evergreen	> 20m
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo to mountainous Mediterranean		Up to 1700
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Mediterranean, sensitive to frost	Indifferent to substrate, tolerates dry soils and can grow on skeletal soils	Heliophilous. Drought & heat tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	1. 50	<200
Products	Wood: boxes, carpentry, frames, poles Resin		
Services*			
Uses	Windbreaks, ecological restauration, specimen		

15. *Eleagnus angustifolia*

Botanical description	Crown shape	Leaf persistence	Height at maturity (m)
	Oval, spreading	Deciduous	3 to 5
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu & supra-Mediterranean		Up to 1500m
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	It is usually found in riparian environments	Humid	Heliophilous. Frost and drought tolerant. Pollution tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**

	Fast	5 to 10	< 25
Products	Edible fruits, herbal infusions		
Services*	Erosion control		
Uses	Hedges (windbreaks and living fences), screen, specimen, ornamental		

16. *Fraxinus ornus*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Round, oval	Deciduous	10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra & mountainous Mediterranean		500-1500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Resists to cold weather	deep, rich, humid & not very acidic soils. Tolerates relatively dry soils	Heliophilous
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	moderate	10 to 20	25-50
Products	Wood (carpentry, artisan products), fuel, charcoal Leaves as forage, Gummy sap		
Services*			
Uses	Specimen, shade, ornamental, intercropping		

17. *Fraxinus angustifolia subsp. syriaca*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Round	Deciduous	15 to 23
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra & mountainous Mediterranean		500-1500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Tolerates arid climate	deep, rich, humid & not very acidic soils. Tolerates relatively dry soils	Heliophilous, pollution tolerant, drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	>50
Products			
Services*			
Uses	Specimen, shade, intercropping, multiple row windbreaks		

18. *Juglans regia*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Large & round	Deciduous	10-25
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra & mountainous Mediterranean		400-1800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Tolerates cold winters but vulnerable to spring frost	Deep, rich & humid soils	Heliophilous, frost & heat tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	moderate	20 to 50	>50
Products	Wood: cabinet making, turnery, marquetery, carpentry Edible nuts, oil, juglone (herbicide)		
Services*			
Uses	Specimen, shade, intercropping, alley cropping PS: the natural herbicide exuded by tree parts reduce the growth of plants underneath, adequate spacing reduces this inconvenient in agroforestry designs.		

19. *Juniperus drupacea*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Conic, becomes columnar / upright with age	Evergreen	Up to 20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Supra & mountainous Mediterranean		900-1800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Tolerates cold & dry climates	Indifferent to soil nature	Heliophilous, frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	>50	< 250
Products	Fruits used to produce a molasses (pekmez)		
Services*			
Uses	Specimen, ornamental		

20. *Juniperus excelsa*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	conic, becomes round or irregular with age	Evergreen	Up to 20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Mountainous & oro-Mediterranean		1500-2800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	tolerates cold & dry climates	indifferent to soil nature, accommodates to superficial & rocky soils	Frost, heat & drought tolerant.
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	> 50	> 400
Products	Wood (carpentry, timber, charcoal, fuelwood), tar (goudron) Berries (female cones): Gin & artisanal alcoholic drinks		
Services*	Erosion control in difficult mountainous sites		
Uses	Specimen, intercropping, windbreaks,		

21. *Juniperus oxycedrus*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Conical / shrubby	Evergreen	5-8
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo to supra-Mediterranean		400-1800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Tolerates cold & dry climates	indifferent to soil nature, accommodates to superficial & dry soils. Grows on rocky sites	Heliophilous, frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	>50	>250
Products	Wood (pencil manufacturing, turned small objects in marquetry and carpentry) Berries (female cones): edible liquors. Cade oil, tar		
Services*	Erosion control		
Uses	Living fences, multiple-row windbreaks		

22. *Laurus nobilis*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Pyramidal, round	Evergreen	8 to 15
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo, Eu & supra-Mediterranean		Up to 1200
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Hot & temperate	fresh & light, does not prefer limestone	Frost, heat & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	2. 50
Products	Aromatic leaves & fruits: culinary condiment, soap production, oil (cineol)		
Services*			
Uses	Screen, hedges, windbreak, intercropping, ornamental, symbolic		

23. *Malus trilobata*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Upright	Deciduous	15 to 23
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu & mountainous Mediterranean		800 to 2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid & fresh	-	Heliophilous
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	20 to 50	20-50
Products	Edible fruits		
Services*	Could be grafted with other *Malus* varieties		
Uses	Specimen, hedges, windbreak, alley cropping		

24. *Ostrya carpinifolia*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
		Deciduous	Up to 15
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu and supra-Mediterranean on fresh and humid slopes		600 to 1600
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid, temperate winters	Deep & loose limestone on slopes	Frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	5 to 10	25-50
Products	Wood: fuel, charcoal, handles for agricultural tools		
Services*			
Uses	Screen, hedge, specimen, intercropping, multiple-row windbreaks		

25. *Pinus brutia*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	structured in a conical shape, dense	Evergreen	Up to 20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo, eu and supra-Mediterranean		Up to 1700
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	more water demanding than *P. halepensis* & tolerate cold weather.	indifferent to soil substrate	Heliophilous, frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	20 to 50	<200
Products	Wood: frames, carpentry, formwork, boxes, pulpboard and boards		
Services*	Erosion control		
Uses	Windbreak, silvopasture		

26. *Pinus halepensis*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Diffuse	Evergreen	Up to 20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo, eu and supra-Mediterranean		Up to 1500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	optimum development requires precipitations between 350-700mm & T° where the average of winter minima of the coldest month are between -3 & -10°C	prefers marly and limestone, on deep soils easily accessible to its roots. Does not tolerate well poorly drained or sandy soils	Heat, drought & frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	20 to 50	< 200
Products	Wood: frames, carpentry, formwork, boxes, pulpboard and boards		
Services*			
Uses	Windbreak, silvopasture		

27. *Pinus pinea*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Umbrella-like	Evergreen	Up to 25
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermos, eu & supra-Mediterranean		0-1600
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Thermophilic, tolerates cold weather, water demanding (> 700 mm).	Siliceous & sandy soils, preferably not on limestone	Drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	> 50	<200
Products	Wood: boards, frames, boxes Edible seeds, resin		
Services*			
Uses	Silvopasture, intercropping, specimen, ornamental		

28. *Pyrus syriaca*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Round	Deciduous	5 to 10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermos, Eu & supra-Mediterranean		Up to 1800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Grows on dry & stony slopes	Grows on clay and sand	Heliophilous, Frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	20-50
Products	Edible fruits		
Services*			
Uses	Could be grafted with Pyrus varieties		

29. *Pistacia palaestina*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Hemispheric	Deciduous	Up to 8
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Abundant in Eu-Mediterranean zone		500-1000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Mediterranean, semi-arid to humid	not very demanding, prefers limestone	Frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	-	25-50
Products	Wood: charcoal, used as support for vine shoots		
Services*			
Uses	Ornamental, screen, hedges, multiple-row windbreaks		

30. *Platanus orientalis*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Large & irregular	Deciduous	Up to 30
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo, eu, supra & mountainous Mediterranean		Up to 1700
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Temperate and sunny, survives on a dry or polluted soil	deep, humid soils, can tolerate light soils if they are humid	Frost, heat, drought & pollution tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	20 to 50	25-50
Products	Wood: rotary cutting & carpentry		
Services*			
Uses	Specimen, windbreaks, shade, intercropping		

31. ***Populus alba***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Oval, Columnar (fastigiated)	Deciduous	Up to 30
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra & mountainous Mediterranean		Up to 2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Riparian environments, high plasticity, tolerates cold weather	Aerated & humid, rich in nitrogen	Heliophilous, Frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	10 to 20	25-50
Products	Wood: paper pulp, boards, wrapping, matchsticks, charcoal (…), multiple medicinal uses Leaves: occasional forage		
Services*			
Uses	Ornamental, specimen, windbreaks, screen, silvopasture, intercropping		

32. ***Populus nigra***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Upright & irregular	Deciduous	Up to 30
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra & mountainous Mediterranean		Up to 2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Riparian environments, high plasticity, tolerates cold weather	Aerated & humid, rich in nitrogen	Heliophilous, Frost, heat & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	10 to 20	< 25
Products	Wood: paper pulp, boards, wrapping, matchsticks, charcoal (…), multiple medicinal uses Leaves: occasional forage		
Services*			
Uses	Ornamental, specimen, windbreaks, screen, silvopastures, intercropping		

33. ***Populus tremula***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Pyramidal & fastigiate	Deciduous	Up to 25
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	supra & mountainous Mediterranean		1000-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Resists cold and frost	Prefers deep soils, tolerates clay	Heliophilous, frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Fast	10 to 20	> 50
Products	Wood valued for the fabrication of matchsticks & paper pulp		
Services*			
Uses	Ornamental, specimen, windbreaks, screen, silvopasture, intercropping		

34. ***Prunus korchinskii***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Irregular, diffuse	Deciduous	Up to 8
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermo, eu, supra-Mediterranean		Up to 1800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	High plasticity	Indifferent to soil type	Heliophilous. Frost, heat & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	25-50
Products	Edible fruits & seeds, almond oil, decorative spring shoots		
Services*			
Uses	Ornamental, specimen, alley cropping, intercropping, could be grafted with commercial varieties		

35. *Prunus ursina*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Irregular, very branched	Deciduous	Up to 10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Supra & mountainous Mediterranean		900 to 2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Cold & humid	-	Frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	-	-
Products	Edible fruits, decorative spring shoots		
Services*			
Uses	Specimen, ornamental, hedges, living fences, multiple-row windbreaks, alley cropping intercropping, could be grafted with commercial varieties		

36. *Quercus brantii look*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Rounded	Deciduous	Up to 10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Mountainous Mediterranean, Bekaa		
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Tolerates low temperatures, snow & wind	Deep limestone	Heliophilous, frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	20 to 50	> 500
Products	Wood: fuel, charcoal, handles for tools		
Services*			
Uses	Specimen, alley cropping, hedges, multiple row windbreaks, intercropping, silvopasture		

37. *Quercus calliprinos*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Rounded & dense	Evergreen	Up to 20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Thermos, eu, supra-Mediterranean and presteppic Mediterranean		Up to 1500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Mediterranean, high plasticity, tolerates long droughts	All soil types, found essentially on limestone	Shade tolerant, frost, heat & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	> 50	> 600
Products	Wood: handles, fruit boxes, charcoal (…)		
Services*			
Uses	Specimen, alley cropping, hedges, multiple row windbreaks, intercropping, silvopasture		

38. *Quercus cerris*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	irregular to fastigiate	Deciduous	Up to 25
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Mountainous Mediterranean		1500-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	humid, does not tolerate very dry summers, tolerates well cold winters	Indifferent to soil type	Shade tolerant, frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	> 50	> 300
Products	Wood: carpentry, fuel, charcoal		
Services*			
Uses	Specimen, shade, alley cropping, intercropping, silvopasture, multiple-row windbreaks		

39. ***Quercus infectoria***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Sparse to round	Semi-deciduous	8-10
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra-Mediterranean and presteppic Mediterranean		500-1500
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	humid Mediterranean & sub-humid, cool and temperate	deep soils & limestone	Shade tolerant, drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Slow	20 to 50	> 500
Products	Wood: fuel, charcoal, handles for tools		
Services*			
Uses	Specimen, alley cropping, hedges, multiple row windbreaks, intercropping, silvopasture		

40. *Salix alba*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Ovoid	Deciduous	Up to 20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu, supra & mountainous Mediterranean		500-1800
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Riparian environments, Temperate & humid	Prefers loose and humid soils	Frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	-
Products	Wood: carpentry, wrapping, drawing instruments, hooves, matchsticks, handles, drawing boards, boxes		
Services*	Melliferous		
Uses	Ornamental, specimen, shade, multiple row windbreaks		

41. *Sorbus graeca*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	upright	Deciduous	8 to 15
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Supra & mountainous Mediterranean		1300-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid & fresh	Clay	Frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	20 to 50	-
Products	Edible fruits		
Services*			
Uses	Specimen, hedges, multiple row windbreaks		

42. *Sorbus torminalis*

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Diffuse, upright	Deciduous	15-20
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Supra & mountainous Mediterranean		1300-2000
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Thermophilic, high plasticity	Prefers sandstone, grows on limestone, well drained & loose	Heliophilous, Frost tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	20 to 50	20 to 50
Products	Wood: fuel, charcoal, carpentry, turnery, sculpture, music instruments Fruits (edible, distillery, eau de vie)		
Services*			
Uses	Specimen, hedges, multiple row windbreaks		

43. ***Styrax officinalis***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Rounded	Deciduous	Up to 8
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Eu & supra-mediterranean		500 to 1700
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Humid & temperate Mediterranean	all soil types, found essentially on limestone	Frost & drought tolerant
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
	Moderate	10 to 20	-
Products	Fruits (soap manufacturing, fishing)		
Services*			
Uses	Ornamental, hedges, multiple row windbreaks, specimen		

44. ***Ulmus minor***

Botanical description	**Crown shape**	**Leaf persistence**	**Height at maturity (m)**
	Upright to rounded	Deciduous	20 to 30
Geographic distribution*	**Bioclimatic zone(s)**		**Altitude range (m)**
	Found in Bekaa wetlands		
Ecology	**Climate**	**Soil**	**Tolerance spectrum**
	Riparian environments	-	
Physiology	**Growth rate**	**Time to ultimate height (years)**	**Life span (years)**
Products	Wood: turnery, carpentry		
Services*			
Uses			

ANNEX 3. NATIVE SHRUB SPECIES IN AGROFORESTRY SYSTEMS – CHARACTERISTICS, SERVICES AND PRODUCTS

1. *Pistacia lentiscus*

Botanical description	**Leaf persistence**	**Height at maturity (m)**
	Evergreen	2 to 3
Geographic distribution*	**Bioclimatic zone(s)**	**Altitude range (m)**
	Thermo-Mediterranean	Up to 400
Ecology	Tolerates drought (up to 8 months without precipitations), prefers siliceous soils	
Products	Wood (charcoal), turpentin, resin (mastic)	
Uses	Hedges, specimen, ornamental	

2. *Myrtus communis*

Botanical description	**Leaf persistence**	**Height at maturity (m)**
	Evergreen	1.5 to 3
Geographic distribution*	**Bioclimatic zone(s)**	**Altitude range (m)**
	Thermos & eu-Mediterranean	Up to 800
Ecology	Humid temperate climate, indifferent to soil type	
Products	Edible fruits (liquor, herbal infusion), decorative shoots	
Uses	Hedges, specimen, ornamental	

3. *Rosa sp. (Rosa canina, Rosa Phoenicia, Rosa glutinosa)*

Botanical description	**Leaf persistence**	**Height at maturity (m)**
	Deciduous	5
Geographic distribution*	**Bioclimatic zone(s)**	**Altitude range (m)**
	Eu, supra & mountainous Mediterranean	> 500
Ecology	Tolerates frost	
Products	Decorative spring shoots, edible fruits, eau de rose, jam	
Uses	Living fences, hedges, multiple row windbreaks, ornamental	

4. *Spartium junceum*

Botanical description	**Leaf persistence**	**Height at maturity (m)**
	Deciduous	1.5 to 3
Geographic distribution*	**Bioclimatic zone(s)**	**Altitude range (m)**
	Thermos to mountainous Mediterranean	Up to 1800
Ecology	High plasticity, frost and drought tolerant	
Products		
Uses	Nitrogen fixation (soil fertilization) soil stabilization and erosion control, ornamental, hedges, specimen, pleasant scent	

ANNEX 4 QUICK AND EFFICIENT GUIDE FOR AN APPROPRIATE WOODY PERENNIAL CHOICE

- **Windbreaks:** *Abies cilicica, Populus* sp., *Cupressus sempervirens*, *Platanus orientalis*
- **Soil fertility enhancers:** *Ceratonia siliqua, Cercis siliquastrum, Spartium junceum*
- **Suitable for restorative agroforestry** (i.e., that grow on skeletal soils, rocky sites, to control erosion…): *Cupressus sempervirens, Spartium junceum*
- **Ornamental**: *Cercis siliquastrum, Spartium junceum, Myrtus communis, Rosa* sp*., Prunus korschinskii, Pistacia palaestina, Crataegus azarolus, Arbutus andrachne*
- **Fast growing species***: Populus* sp., *Celtis australis.*
- **Long living species**: *Quercus* sp., *Cedrus libani, Juniperus excelsa*,
- **Species with high ecological plasticity**: *Quercus calliprinos*, *Pinus* sp., *Cupressus sempervirens.*
- **Thermophilic & drought tolerant**: *Ceratonia siliqua, Quercus calliprinos*, *Pinus* sp., *Cupressus sempervirens*

ANNEX 5. LIST OF MELLIFEROUS NATIVE TREE SPECIES

Latin Name	English Common Name	Arabic Common Name	Altitude range	Flowering period											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				1	2	3	4	5	6	7	8	9	10	11	12
***Abies cilicica* (Ant. & Ky.) Carriere**	Fir	شوح	1200-1800												
***Acer monspessulanum* L. ssp. *microphyllum* (Boiss.) Bornm**		قيقب حرمون	1000-2000												
***Acer obtusifolium* Sm.**	Syrian Maple	قيقب سوري	0-1300												
***Acer hyrcanum* Fischer & C.A.Meyer subsp. *tauricola* (Boiss&Balansa) Yalt**		قيقب طوروسى	1500-2000												
***Alnus orientalis* Decne.**	Alder	نغت	0-1500												
***Prunus dulcis* (Mill.) D.A.Webb.**	Almond	لوز مر	500-1300												
Amegdalus orientalis		لوز مر	1000-1200												
***Arbutus andrachne* L.**	Strawberry tree	القطلب	0-1400												
***Cedrus libani* Rich.**	Lebanese Cedar	أرز لبنان	1200-2000												
***Celtis australis* L.**		ميس	0-1200												
***Ceratonia siliqua* L.**	Carob	الخرنوب	0-1000												
***Cercis siliquastrum* L.**	Redbud	زمزريق	0-1300												
Crataegus azarolus	Mediterranean medlar	زعرور	0-2000												
***Crataegus monogyna* Jacq.**	English Hawthorn	زعرور	0-2000												
***Fraxinus angustifolia* Vahl. subsp. *syriaca* (Boiss.) Yalt.**	Ash	الدردار المزهر	500-1100												

Fraxinus ornus			0-1700													
***Juniperus excelsa* M. Bieb.**		لزاب	1100-2800													
Juniperus drupacea Labill.		دفران	1000-1700													
***Juniperus oxycedrus* L.**		عرعر	1000-1800													
***Laurus nobilis* L.**	Laurel	غار	0-1000													
***Malus trilobata* (Labill.) Schn.**			900-1700													
***Myrtus communis* L.**	Myrtle	حب الآس أو الريحان	0-1400													
Ostrya carpinifolia Scop.	Hop hornbeam	مرّان	800-1800													
***Pinus brutia* Ten.**		صنوبر البروتي	0-1700													
***Pinus halepensis* Mill.**	Aleppo pine	صنوبر حلبي	200-700													
***Pinus pinea* L.**	Stone Pine	صنوبر مثمر	0-1500													
***Pistacia terebinthus* L. subsp. *palaestina* (Boiss.) Engler**	Mastic tree or lentisk	بطم العلكي	0-1800													
***Pistacia lentiscus* L.**	Terebinth	مَسْتيك ، ضَرو	0-900													
***Platanus orientalis* L.**	Plane tree	دلب	0-1100													
Prunus ursina L.	Bear Plum	خوخ الدب	800-2000													
***Pyrus syriaca* Boiss.**	Syrian Pear	نجاص بري	100-2000													
Quercus caliprinus		سنديان	0-1800													
***Quercus ithaburensis* Decne**			100-400													
***Q. brantii* Lind. subsp. *look* (Kotschy) Mout.**		بلوط البرنتي	1300-2000													
***Quercus cerris* L.**		العذر أو البلوط الشعري	1000-2000													
***Quercus coccifera* L.**	Oak	سنديان	0-1800													
***Quercus infectoria* Oliv.**	Oak	مللول أو بلوط العفصى	500-2000													
***Rhus coriaria* L.**	Sumac	سماق	0-2000													

Rosa canina	Rose	ورد بري	300-2000														
***Sorbus flabellifolia* Schneider**	White beam	غبيراء مروحية الورق	1400-2000														
***Sorbus torminalis* (L.) Crantz.**	Wild service tree	الغبيراء	1000-2000														
Spartium juncium	Spanish broom	وزال	0-2000														
***Styrax officinalis* L.**	Storax	لبان أو حوز	0-1700														
***Cupressus sempervirens* L.**		سرو	0-2000														
Pistacia atlantica		بطم	1200-1300														
Eleagnus angustifolia		زيزفون	0-2000														
Prunus Mahaleb		محلب	1200-1300														

ANNEX 6. TWO-CHAMBER BAT ROCKET BOX

Adapted from The Bat House Builder's Handbook

Materials (makes one house)

2" diameter (2⅜" outside diameter) steel pole, 20' long
Two 1" x 4" (¾" x 3½" finished) x 8' boards*
Two 1" x 8" (¾" x 7¼" finished) x 8' boards*
Two 1" x 10" (¾" x 9¼" finished) x 6' boards*
24" x 24" x ½" piece of AC exterior plywood
Box of 100 exterior-grade screws, 1¼"
Box of 100 exterior-grade screws, 1⅝"
16 to 32 exterior-grade screws, 2"
20 to 30 roofing nails, ¾"
One quart water-based primer, exterior grade
Two quarts flat, water-based stain or paint, exterior grade
Asphalt shingles or dark galvanized metal
One tube paintable latex caulk
Two ¼" x 4½" carriage bolts, washers and nuts

** Western red cedar or poplar preferred*

Recommended tools

Table saw or circular saw
Caulk gun
Hammer
Tape measure
Square
Jigsaw, keyhole saw or router
Sandpaper or sander
Rasp or wood file
Variable-speed reversing drill
1½" hole saw or spade bit
⅜" and ¼" drill bits
Screwdriver bit for drill

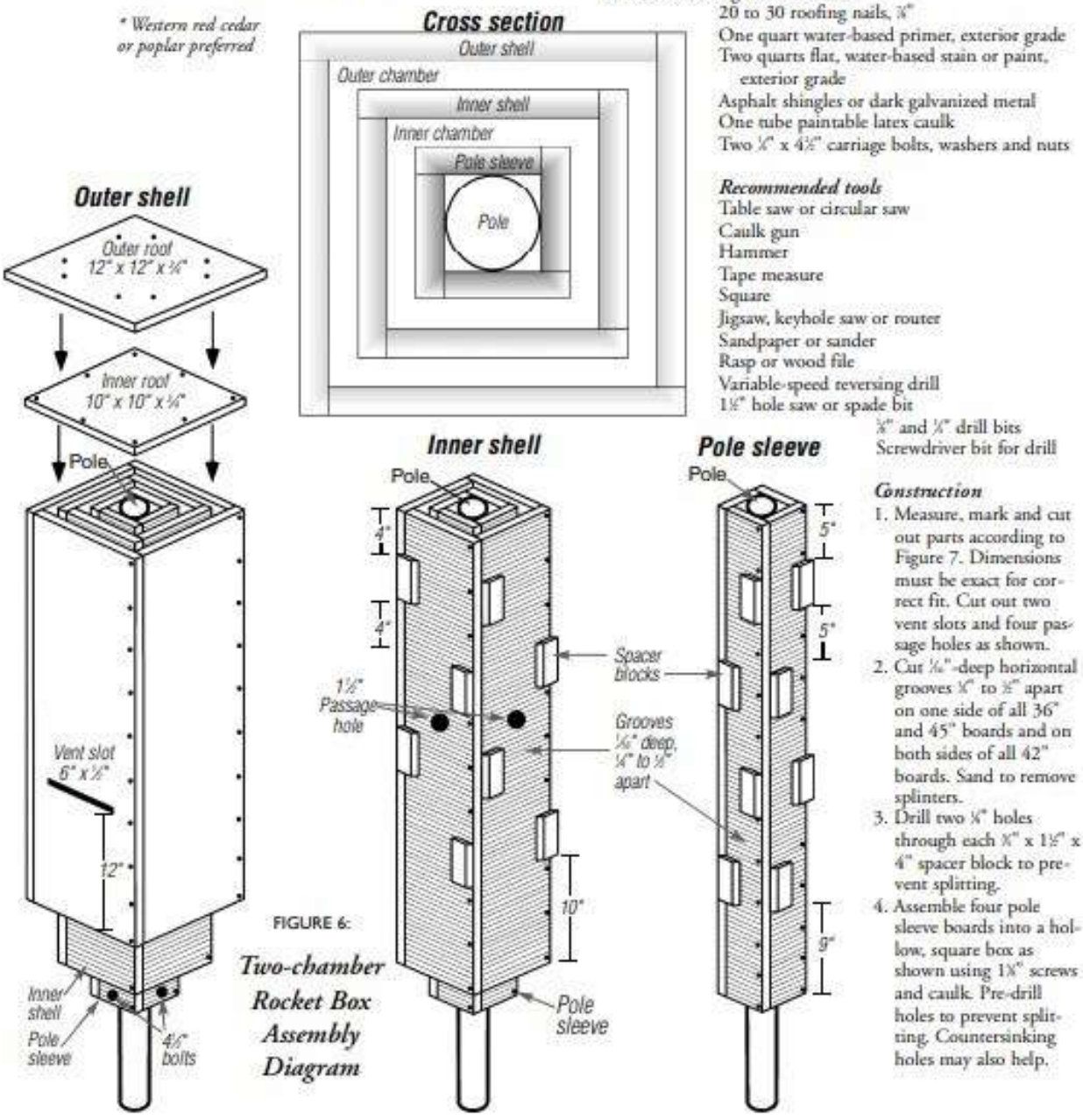


FIGURE 6:
Two-chamber Rocket Box Assembly Diagram

Construction

1. Measure, mark and cut out parts according to Figure 7. Dimensions must be exact for correct fit. Cut out two vent slots and four passage holes as shown.
2. Cut ⅛"-deep horizontal grooves ¼" to ½" apart on one side of all 36" and 45" boards and on both sides of all 42" boards. Sand to remove splinters.
3. Drill two ¼" holes through each ¾" x 1½" x 4" spacer block to prevent splitting.
4. Assemble four pole sleeve boards into a hollow, square box as shown using 1¼" screws and caulk. Pre-drill holes to prevent splitting. Countersinking holes may also help.

5. Attach spacer blocks to pole sleeve as shown (four per side) using two 1¼" screws per block. Bottom spacer blocks are 9" up from bottom of pole sleeve. Top spacer blocks are 5" from top. Alternate spacer blocks on left and right sides, 5" apart.
6. Assemble four inner shell boards into a hollow, square box as in step 4.
7. Slide pole sleeve into inner shell until top edges are flush. Bat passage holes will be towards the top. Mark location of spacer blocks. Secure inner shell to pole sleeve with 2" screws through the spacer blocks to ensure no screws protrude into roosting chambers. Pre-drill holes first to avoid splitting spacer blocks (countersinking holes may also help).
8. Attach spacer blocks (4 per side) to inner shell as shown, using two 1¼" screws per block. Bottom spacer blocks are 10" up from the bottom edge of the inner shell. Top spacers are 4" from top. Alternate spacers left and right sides, 4" apart.
9. Assemble four outer-shell boards into a hollow, square box as in step 4. Vent slots are on opposing sides and oriented towards the bottom.
10. Slide finished outer shell over inner shell, so that 6" of inner shell protrudes below outer shell. Mark locations of spacer blocks. Secure outer shell to inner shell as in step 7 (pre-drill holes first). Ensure that no screws protrude into the roosting chambers.
11. Caulking first, attach inner roof to box with 1¼" screws. Carefully drive screws into top edges of shells to prevent screws from entering roosting chambers.
12. Center and attach outer roof to inner roof with 1¼" screws, caulking first.
13. Paint or stain exterior three times (use primer for first coat). Cover roof with shingles or dark galvanized metal.
14. Slide completed rocket box over pole. One inch up from the bottom edge of pole sleeve, drill a ¼" hole all the way through pole and sleeve. Rotate box and pole 90° and drill another ¼" hole, 2 inches from the bottom, through pole and sleeve. Secure box to pole with two 4½" bolts, washers and nuts. Orient vent slots north and south during installation.

Optional modifications to the rocket box

1. For extra mounting height, insert a 4½" bolt and nut about halfway up through pole sleeve after completing step 5.
2. For extra heat-holding capacity, create a compartment in upper half of pole sleeve with a 2½"-square piece of leftover plywood. Fill upper half of sleeve with sand, gravel or dirt, and seal with another piece of plywood flush with top.
3. In warmer climates, a larger outer roof with more overhang can be used for additional shading.

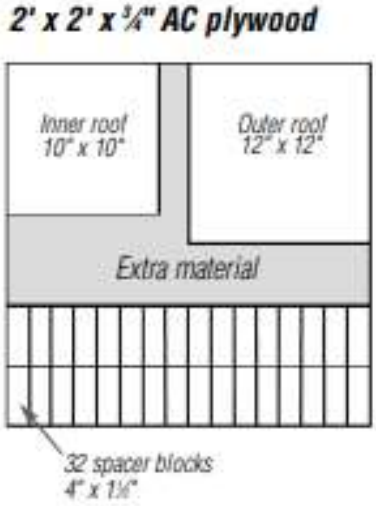
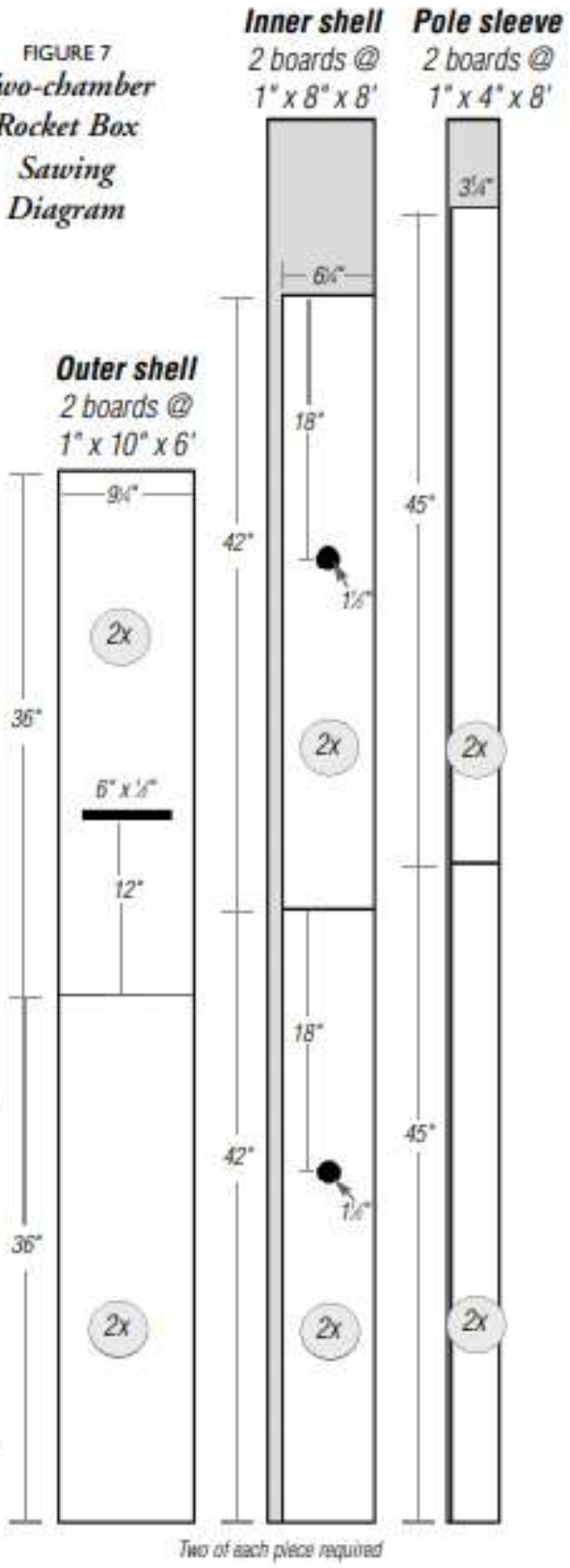
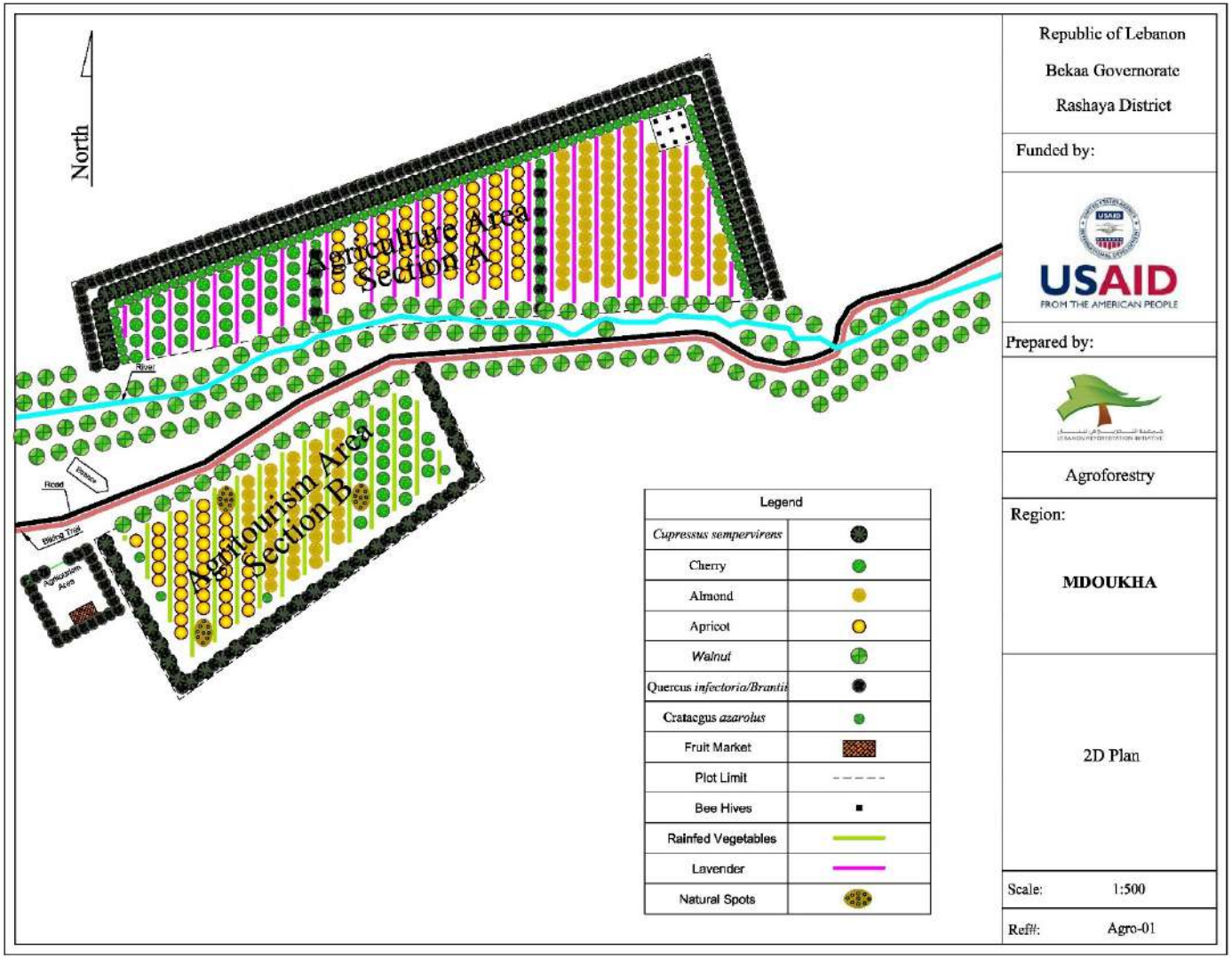


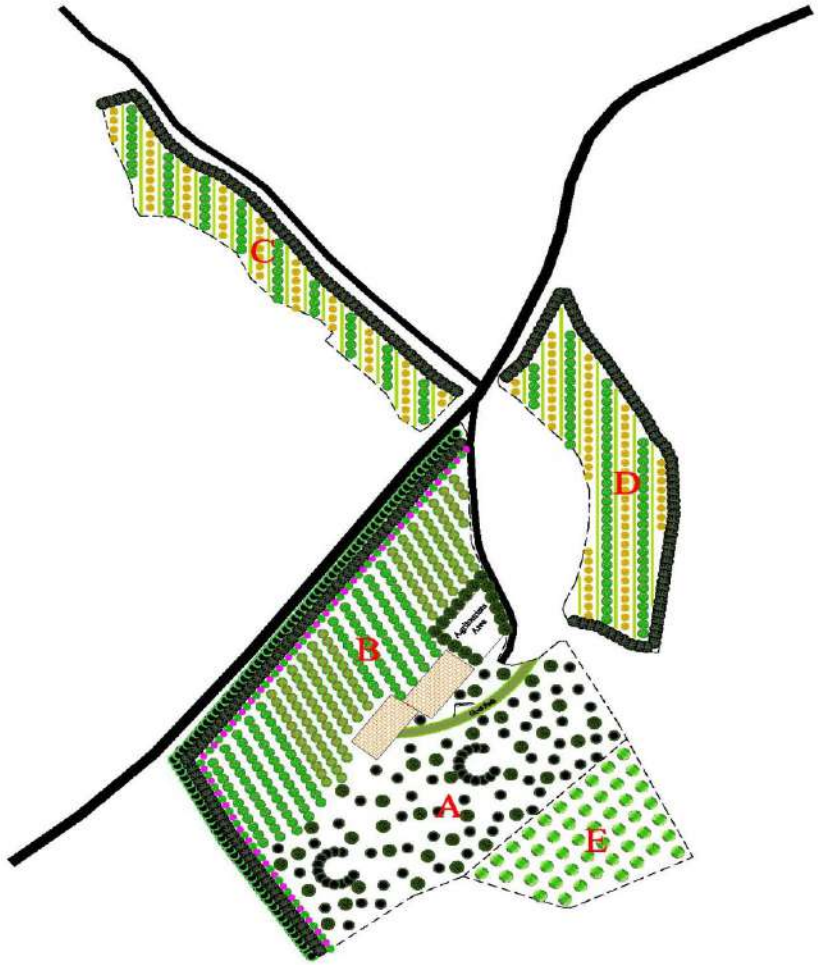
FIGURE 7
Two-chamber Rocket Box Sawing Diagram



ANNEX 7 CASE STUDIES OF PILOTING AGROFORESTRY IN LEBANON



North



Legend		
Quercus calliprinos / brevifi		95 Pcs
Quercus infectoria		78 Pcs
Cherry		240 Pcs
Almond		124 Pcs
Plum		120 Pcs
Celtis australis		52 Pcs
Chestnut		47 Pcs
Cupressus sempervirens		238 Pcs
Crataegus azarolus		45 Pcs
Rosa canina		45 Pcs
Rainfed Vegetables		
Fodder / Legumes		
Farm		
Plot Limit		

Republic of Lebanon

Bekaa Governorate

Rashaya District

Funded by:

USAID
FROM THE AMERICAN PEOPLE

Prepared by:

LEBANON REFORESTATION INITIATIVE

Agroforestry

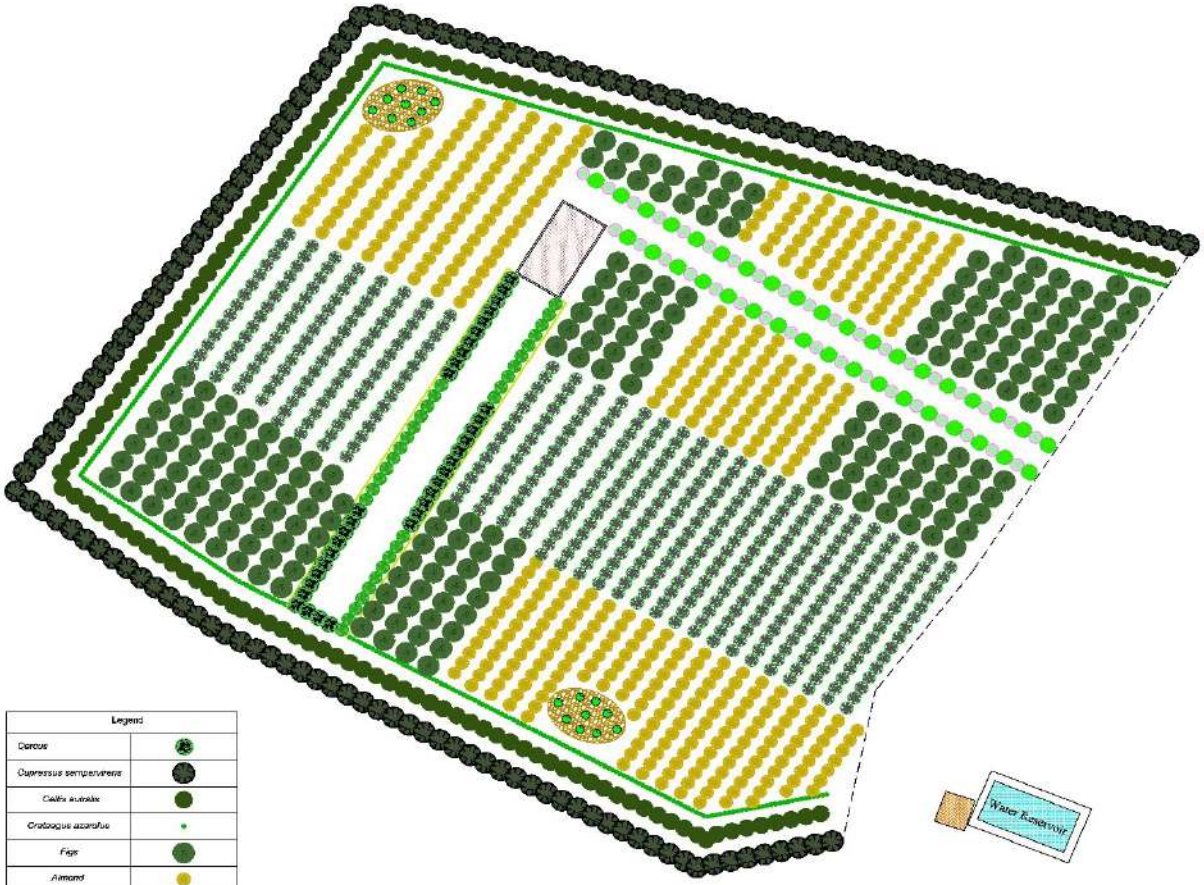
Region:

BAKKA

2D Plan

Scale: 1:800

Ref#: Agro-04



Legend	
Cercus	
Cupressus sempervirens	
Celtis australis	
Crataegus azarolus	
Figs	
Almond	
Jujube	
Prunus	
Pine Tree	
Chicken coop	
Guest House	
Plot Limit	
Natural Spots	
Water Reservoir	

Republic of Lebanon
Baalbek-Hermel Governorate
Baalbek District

Funded by:

USAID
FROM THE AMERICAN PEOPLE

Prepared by:

LEBANON REFORESTATION INITIATIVE

Agroforestry

Region:

MAQNE

2D Plan

Scale: 1:500

Ref#: Agro-03-Rev02

CONSULTED REFERENCES

Agroforestry classification and management. Kenneth G. MacDicken and Napoleon T. Vergara. 1990. John Wiley & sons. USA.

Agroforestry notes. http://nac.unl.edu/afnotes/

Agroforestry. FAO website resources. http://www.fao.org/forestry/agroforestry/en/

An introduction to agroforestry. Nair P.K.R. 1993. Kluwer academic publishers.

EU & MOA, 1999. Le fascicule des essences forestières du Liban. Projet d'assistance à la protection de la couverture végétale au Liban).

MOA, PNUE, Khouzami et al. 1996. Etude de la diversité biologique du Liban, Flore terrestre. Projet GF/6105-92-72)

Nair, P.K.R. (1993) An Introduction to Agroforestry. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Paule Mouterde. 1966. Nouvelle Flore du Liban et de la Syrie. Tomes I et II. Editions de l'imprimerie catholique. Beyrouth.

Ramesh Umran and C.K. Jain. 2010. Agroforestry: Systems and Practices. Oxford book company. Jaipur.