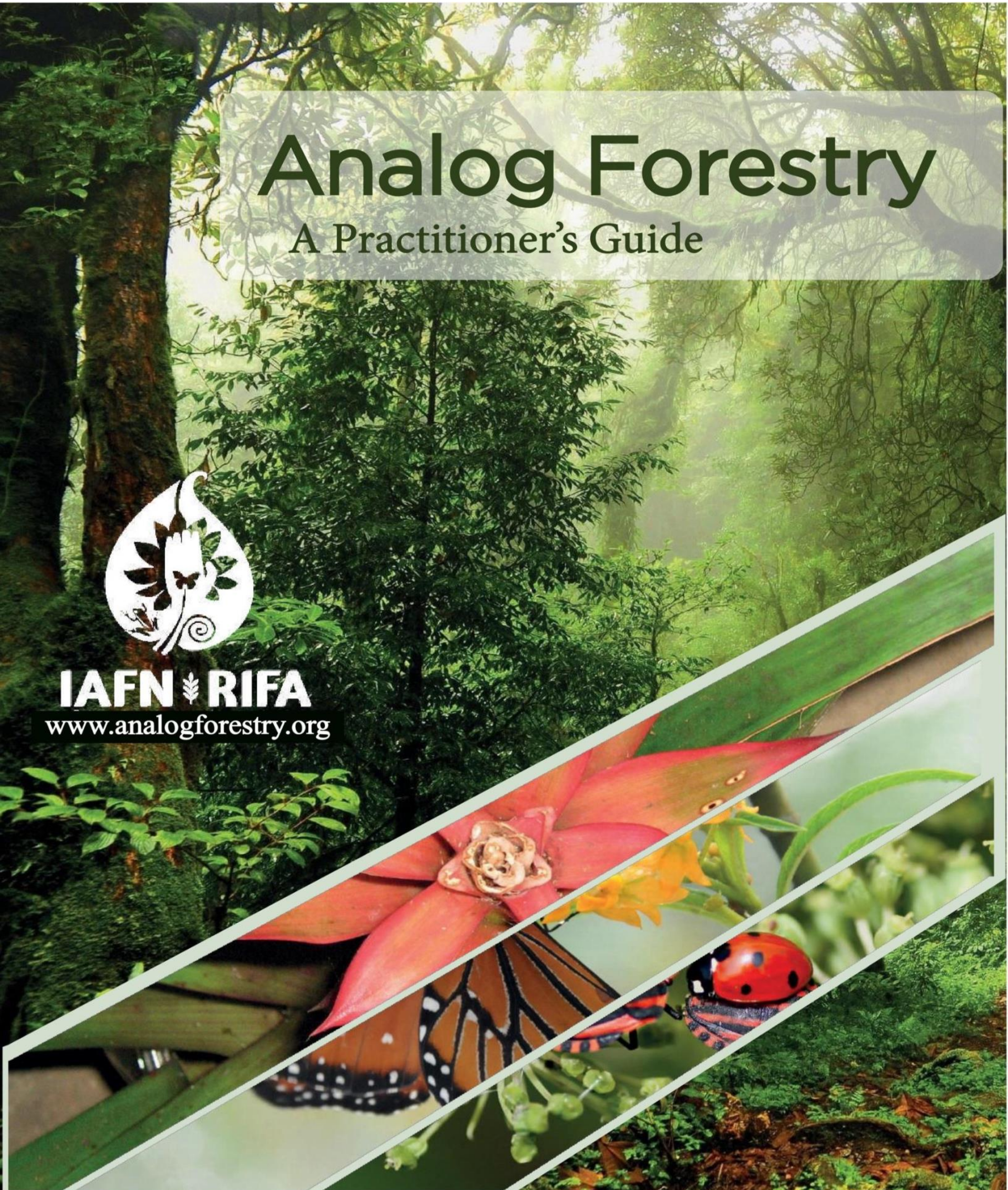
Analog Forestry

A Practitioner's Guide



IAFN RIFA

www.analogforestry.org

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International Analog Forestry Network

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INDEX

Foreword

Biodiversity conservation and economic growth are often seen as opposing interests. While there is evidence that many traditional communities lived for centuries under small-scale and sustainable farming systems, the drive for developed nation status has called for farming systems that emphasize specialization (monocropping) and high dependence on external inputs (hybrids, chemical pesticides and fertilizers). Biodiversity conservation however, cannot be considered a secondary objective; industrially developed nations have already learned this lesson. As more lands are converted to "modern" farming systems, the survival of precious indigenous plant and animal species are relegated to the confines of protected natural areas. Even this situation is compromised as demand for wildlife and precious hardwoods drive rural households to extract these illegally from protected forests.

Analog Forestry (AF) is a methodology that seeks to balance these competing interests. The term is new in theory but shows that it is possible for biodiversity and ecological resilience to be enhanced in farmers' plots, while at the same time providing adequate and sustainable economic returns for farm households over the long term.

In practice the concept is not entirely new. Home gardens and Forest gardens are traditional forms of crop cultivation in many countries. Patches of cultivated land dominated by trees and perennials resemble forests, providing economic products as well as a pleasant living environment in rural communities. What is different about Analog Forestry is the deliberate design that mimics natural forests both in structure and ecological function, and the encouragement towards maturity as well as in design to promote non-target crops and native biodiversity. AF can affect land use planning, watershed conservation, and empower ecosystems and communities to adapt more efficiently to the effects of global climate change.

This accessible Guide has been compiled at the Secretariat of the International Analog Forestry Network (IAFN), Costa Rica. It is based on previous work by Analog Forestry Senior Scientist, Dr. Ranil Senanayake, Counterpart International, Falls Brook Centre, and CATIE University. It will be used to disseminate the concept of Analog Forestry to a broad audience. Herein we illustrate how the principles and techniques of AF may be applied in a standardized way.

Last, but not least, we acknowledge the contributions, whether direct or indirect, of people and institutions unmentioned elsewhere in this Guide who have contributed to our understanding of Analog Forestry.

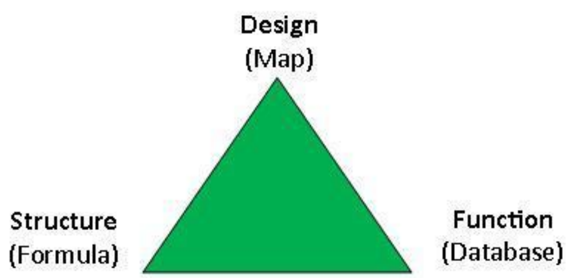
Milo Bekins Faries, IAFN Board of Directors, Costa Rica

What is Analog Forestry?

Analog Forestry (AF) is a system which seeks to establish analog ecosystems with architectural structures and ecological functions similar to the original climax or sub climax vegetation. It also seeks to strengthen rural communities, socially as much as economically, through the use of species that provide commercial products.

Analog forestry is a complex and holistic form of agroforestry that seeks to maintain a functioning tree-dominated ecosystem while providing marketable products that can sustain rural communities, both socially and economically. A certification system (Forest Garden Products) has been developed to market products derived from analog forestry, the FGP label now being recognized in Europe.

Global forest resources are severely depleted because of high demand for agricultural land and forest products. Relative population pressure has a direct effect on agricultural land. Much arable land has been converted to agriculture, while unsustainable land use systems are used in many areas to make a living. At present, not much forest cover can be considered ´natural forest´. Unsustainable agriculture and forestry practices will lead to further exhaustion of soils, falling groundwater tables, pollution of soil and water, and an increased dependency on external inputs such as seeds, fertilizer, and pesticides. Furthermore, the market dependency on a few staple crops makes farmers more susceptible to harvest loss due to droughts, floods and/or pest outbreaks or to price fluctuations in cases where yields are stable.



AF can help local people build sustainable livelihoods. AF is about increasing the resilience and biodiversity of a landscape by making use of natural ecological succession processes (natural succession from barren land/grassland to climax forest) as a model for agricultural and forestry production. It mimics natural forest structures and related ecological functions with an added emphasis on socio-economically valuable species. In this way, AF contributes to biodiversity conservation by restoring degraded landscapes, all the while local communities have access to sustainable livelihoods.

The concept of Analog Forestry was conceived by Dr. Ranil Senanayake in the mid 80s, when it was first implemented in Sri Lanka and was based on the traditional home garden (*Purana Gama*) model. The initial design was done for the restoration of degraded grasslands in Belipola estate and implemented by the NGO Neosynthesis Research Center (NSRC). The model was further refined and applied in Guatemala, Philippines and Viet Nam by Counterpart international and by FURARE in Ecuador.

AF is a relatively new concept; however, most farmers already have some experience in establishing an AF garden without calling it such. For instance, the traditional Vietnamese home garden consisting of multiple species including a tree layer, shrub layer, annual plants, epiphytes and climbers, can also be considered a form of AF.

This guide is written for a diversity of stakeholders, including extension workers and local organizations that are willing to support farmers in improving their agricultural and forestry systems, and applying analog forestry techniques in the field. Although most of the current Analog Forestry projects occur in tropical and neotropical ecosystems, the principles are applicable to most types of forest ecosystems. For instance, a successful AF site has been established in the Acadian Forest of maritime Canada by the Falls Brook Centre and another in the mangrove forest of northeastern Honduras.

This guide describes the implementation of analog forestry through a number of steps. Separate practitioners' manuals have been designed to complement this guide and offer practical sessions and exercises for each of the steps as described here. Supplementary materials can be accessed and downloaded from the International Analog Forestry Network website:
www.analogforestry.org

Introducing the methodology

Analog forestry can be used as a tool and methodology to increase the biodiversity and ecological resilience of a landscape by making use of natural ecological succession and forest functions, consequently strengthening rural livelihoods.

Analog forestry makes use of three restoration goals:

1. **Ecological succession**
2. **Mimicking natural forests**
3. **Landscape ecology**

Ecological succession

When an ecosystem experiences disturbance whether natural or anthropogenic, it eventually undergoes a process of regeneration. Under natural conditions, bare land will become grassland which will slowly evolve to shrubland with pioneer trees, then to pioneer forest, sub-climax forest and finally climax forest if conditions allow. Soil conditions will similarly progress from underdeveloped soils with no humus layers or nutrients to well-developed soils with thick humus layers. This is called *ecological succession*. The sequence of different stages in ecological succession is called seral progression. AF uses natural succession processes, either starting with earlier stages such as barren land/grassland and progressing to climax forest or by enhancing and accelerating maturity in established home gardens for agricultural and silvicultural production, mimicking natural forests.

Often natural forests contain relatively few socio-economically valued species. By planting and promoting socio-economically valuable species to imitate natural forest structures and ecological functions, analog forestry seeks to increase production while strengthening forest functions such as watershed protection, reduced soil erosion, biological control, climate regulation, detoxification and conservation of genetic resources[1]. Analog forestry tries to enhance and use natural forest functions to reduce the need of external inputs such as fertilizers or pesticides, and to conserve and build up the soil, as well as to protect watersheds that are vital for both anthropogenic and non-anthropogenic environments.

Plants in an AF system have access to nutrients through the natural nutrient cycle and are less susceptible to large pest outbreaks. Forest gardens are also the home of natural predators and the increased diversity of the system provides for a better growing environment as well as for better adapted species.

Contrary to common belief, tropical forests grow mainly on soils of extremely low fertility. Forests are possible mainly because of rapid natural nutrient cycling, whereby nutrients stored in the forest biomass (e.g., plants, wood, leaves, fruits and animals) become available when organisms die and decay, thereby releasing the nutrients to be reabsorbed by the forest - as long as a mature soil ecosystem is maintained. Thus, the quality of soil is essential for healthy forest ecosystems, and this is no different in the case of AF.

Landscape ecology and Connectivity

The configurations possible for AF interventions depend on the existing vegetation patches in a landscape. A landscape is composed of a mosaic of different ecosystem patches such as rice fields, annual crop land, tree plantations, rivers, grassland, barren land, natural forests, among others. Each patch offers its own unique ecological function and species composition, which differs from neighboring patches of vegetation. A small isolated patch of natural vegetation is likely to have relatively low biodiversity. If it is located far from other patches of natural forest, then ecological succession towards climax-forest becomes more difficult, or almost impossible, as there are limited opportunities for colonizing organisms from the forest to arrive in and enrich the isolated patch. This concept stems from original research on the theory of island biogeography which discusses the influence of fragmentation on species biodiversity.[1]

It is necessary to study the landscape to identify the different existing ecosystem patches and the possibilities for creating corridors or connections between similar patches. The landscape study can identify marginalized areas where analog forestry can help to restore the ecological resilience of the various patches and the overall landscape. AF can be used to build up the natural resilience of the landscape by creating an analog forest patch that borders the natural forest in order to increase the total vegetation of an area, or to connect two or more fragments of natural forestland with a corridor. If an AF plot is created adjacent to a natural forest patch, the total size of the forest area will be extended, thereby providing a greater range to existing plants and animals. AF corridors facilitate the movement of species between patches and thus facilitate gene flow and the interaction of gene pools. The ultimate goal of analog forestry in a landscape is to develop a network of natural and analogous forest patches to build up the biodiversity and resilience of the landscape.

Understanding the Value of Forests: Ecological Functions of Forests

Forests provide habitat for natural predators, pollinators and seed dispersers. For example, predators of rats (such as cats and snakes) need bushes and woodlands for shelter and reproduction. Without such habitat, natural predators of pests cannot survive and pests can thrive, leading to problems such as rat infestations which can destroy large amounts of crops. Forests also reduce soil loss from erosion or landslides. The different canopy layers, surface litter and humus layer minimize the impact of raindrops on the soil, and the litter layer and extended root network limits the extent to which soil is carried away in runoff. The roots will also facilitate the infiltration of water into the soil. In contrast, raindrops falling on bare ground loosen the soil, and runoff is increased. Heavy rain in bare, hilly areas may result in landslides. The eroded soil will be transported downstream and may cause damage through the silting up of watercourses or dams and other problems. Thus, forests enhance soil ecosystem integrity.

Forests return moisture to the air through *transpiration* and *evaporation*. Transpiration is the release of water vapor to the atmosphere through the pores of trees and other plants, while evaporation is the transformation of water to vapor from the surface of plants, especially leaf surfaces, soil, rivers and other water sources into the air because of heating. Forests return 50 to 90% of the intercepted precipitation in the form of rain back to the air through evapo-transpiration, while only 30% of the precipitation falling on bare soil returns to the air, the remaining 70% is lost

[1] MacArthur, R.H. and E.O, Wilson (1967, reprinted 2001). The Theory of Island Biogeography. Princeton University Press. ISBN 0-691-08836-5 (PBK).

as erosion-enhancing runoff. Forests are thus cloud generators and provide a positive influence on the total rainfall and its effectiveness, especially in areas that are located further inland. Moist air, which is carried inland by winds from the sea, falls on the land in the form of rain. If this rain is intercepted by the forest, the forest will return most of the water back to the air, where winds will take it further inland, where it can fall again as rain. If forests are cleared the likelihood of rain is reduced, resulting in the risk of consequent droughts which will affect agricultural yields.

Finally, forests can also act as natural purification systems that store and recycle or break down certain toxic materials (such as chemical pollutants or dust). The forests intercept the toxic components and store and/or recycle them through natural processes on the forest floor or through leaf pores to then be further degraded by sunlight. This process of leaf detoxification is called *phytoremediation* and is part of a larger subset of ecosystem decontamination known as *bioremediation*. See Figure 1 for a visual description of this process.

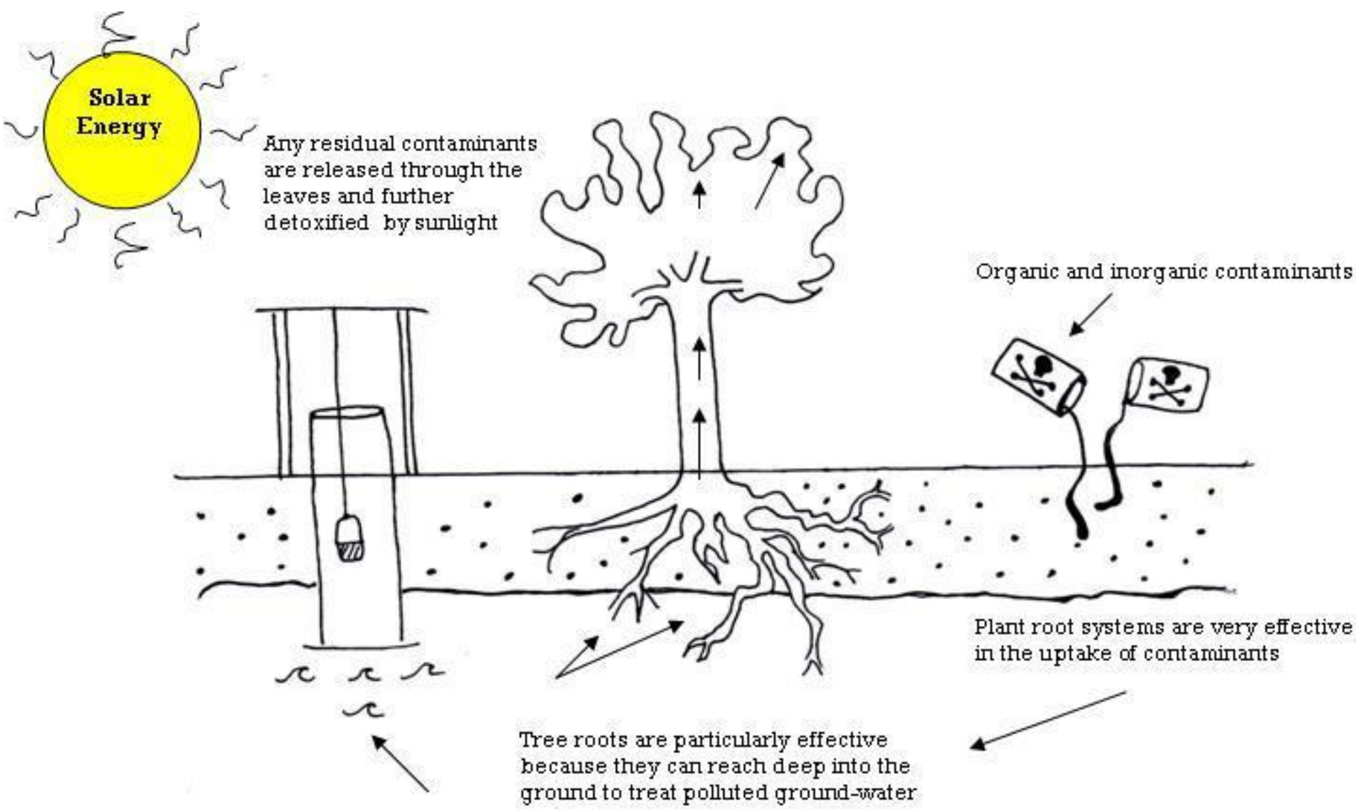


Figure 1: A simplified depiction of phytoremediation – detoxification by plant communities

12 Basic principles of Analog Forestry

Baseline 1

1) Observe and record: Where am I? In what type of forest? What species are present?

2) Understand and evaluate: Learn about the area, from both scientific and traditional standpoints.

3) Know your land: Examine the landscape´s features, water systems, soil, and ecosystems, terrestrial and aquatic.

Design 2

4) Map out flow and reservoir systems: Graphically represent the flows of water, sun, and wind.

5) Identify levels of yield: Identify the capacity of the land. How much could you harvest in each area?

Management 3

6) Be guided by landscape needs: Knowing your land and its surroundings are important for making a design.

7) Follow ecological succession: Imitate and accelerate the phases of the natural evolution of a forest. From a pasture, thicket, to a forest.

8) Utilize ecological processes: Designs can benefit from interactions occurring between elements of the ecosystem.

9) Value biodiversity: Increasing biodiversity species will increase ecosystem function and provide valuable services and forest garden products.

10) Respect maturity: Mature forests are some of the most productive ecosystems, and are the goal of Analog Forestry.

11) Reduce ratio of external energy in production: Minimize the use of fossil fuels. Encourage the recycling of nutrients and the use of natural fertilizers. How can we maintain a closed cycle within the plot?

Individual & collective expression 4

12) Respond creatively: Prepare yourself for the unexpected and be conscious that there are multiple pathways to success.

The twelve basic principles of analog forestry are aligned with the three goals mentioned above: **Ecological succession, mimicking natural forests** and **landscape ecology**. These are further described below.

1) Observe and record

The mature ecosystem of any area represents the outcome of eons of experience in dealing with the climate and impacts in that place. Record the species and structural ecosystems present in the area under treatment. The initial data will assist in setting a baseline against which future observations and their changes can be evaluated. Recording is also of importance in evaluating the management activity and in maintaining a historical record. A survey of the vegetation structure on the land provides a preliminary record of the ecosystem under treatment. Identifying the structure of the system will demonstrate a wide range of different architectural responses (forms) varying from trees to vines.

The Analog Forestry technique is focused on increasing our powers of observation for a given ecosystem to include as much perspective as possible. All the effects of climate, water, wind, human and animal intervention can be better understood by simply observing the site. The diagnostic survey of vegetation types, also known as a "physiognomic formula" is crucial in identifying the structure of the existing forest (see page 16, for this formula). With a combination of measurement and common sense, one can come to some significant conclusions regarding a landscape. It is important to understand that ecosystems are in constant flux. Observations recorded at one point in time are liable to be altered in the face of environmental change.

2) Understand and Evaluate

Understand the ecosystem being observed from as many perspectives as possible. A synthesis of many variables will always yield better choices of the species and patterns to be used in design. This is the time when the observations and records must be synthesized with as much scientific and traditional knowledge as possible. The generation of a database of the vegetation species that are, were, and might be present in the area, is a critical part of recording and should be started from the beginning of an AF project.

Deepen your observation skills by using your recorded data to understand the relationships and interactions between the elements in the ecosystem being observed. The ecosystem will always have certain common physiognomic and taxonomic features. The patterns revealed by these relationships both by the scientific and traditional information, always yields better choices for the species and patterns to be used in the design.

3) Know your Land

A powerful tool in understanding the land is a carefully drawn-out map that identifies the most pertinent features of the farm. Mapping the land is best done if developed as a series of overlays. Once the physical boundaries have been mapped, overlays that demarcate the contours, hedges, fence lines, vegetation, soils, wind direction, water flow, and then existing infrastructure are some useful variables. The farm map or farm plan should reflect not only the current situation but also the desired future condition.

Creating a map based on all of your measurements that identifies the pertinent features of the farm is an invaluable tool that helps one to better understand the land. Know the land in terms of its soil quality and soil biodiversity. The soil ecosystem is probably the most valuable asset of the farm. The soil, as much as the trees, crops or livestock upon it, is a constantly changing, living organism. This should be considered a very important part in creating overlays for farm maps and plans.

4) Map out flow and reservoir systems

Every landscape has flow systems (solid, liquid, gas and genetic) that produce distinct patterns. Usually, the direction of flow in solids, liquids and gases are governed by gravity, resulting in very characteristic drainage patterns of water or soil flow on land. Similarly, wind moving across the landscape produces significant patterns as well. Conversely, genes usually follow existing corridors of ecosystems appropriate to a species.

The understanding of flow systems across the farm or land area to be managed is important for pre-design preparations. Cutting across flow systems is usually not productive. Following, augmenting, or ameliorating flow systems to improve the ecosystem being designed such as a crop or organism under management, will improve productivity.

Understanding the energy flows through the landscape is an essential tool in design and may be included as an overlay on the base map. These flows include the gravitational effect of water on soil erosion or the effect of wind on fire and genetic material, among others. The patterns of sun exposure, water flow, erosion, damaging winds, fires, and genetic flow, can all be identified by understanding how energy moves across a landscape.

5) Identify levels of yield

The yield required will differ depending on the priorities of the landowner or manager. If the goal is conservation, the yield will be measured by increases in the target species and ecological functions, whereas if the goal is economic gain, the yield will be measured in terms of income or production. If the demand for yield is focused on a single crop, the higher the yield required the more the production system would move towards a single species monoculture. This cannot be sustained in the ecosystem over the long term, and should be considered during the planning phase. Thus, a deeper knowledge of levels of yield both in terms of individual species and ecosystem services is important regardless of the economic goals.

6) Be Guided by Landscape Needs

All farming land will be part of a natural landscape mosaic. The boundaries of which are often set by definition. A common criterion to delineate a landscape is the location of a watershed. Once identified, each landscape can be divided into various land use types such as open fields, tree coverage, homesteads, roads, streams etc. A landscape will often have many vegetation components ranging from mature native climax forest to open meadows. In fragmented landscapes patches of remnant vegetation are often the only habitat left for indigenous biodiversity.

During the design process, defining the species of trees to be used in the context of reforestation, ensures that the species chosen will also be a food source for other groups of organisms not addressed in the management plan. A similar recognition of the value of hierarchical structuring using abiotic, biotic and cultural subsystems has provided a planning framework for urban planners and developers in urban ecosystems.

In completing a design, it is important to know what your neighbours are doing with their land and how that may affect the area you are working with. Know your boundaries, respect theirs, and observe the natural or anthropogenic transitions between different parts of the landscape

7) Follow Ecological Succession

In the development of a forest system, maturity brings changes in the trophic web, which is demonstrated by changes in species composition. All these successional stages maintain about an equal number of species at each level, but the composition of the species represents changes with the transitioning vegetation. In designing for structure, the seral stage that is best suited for the crops chosen provides the model. Thus, if the crops in question are annuals, such as cereals, beans, squashes etc. the pioneer stages are desired. If the crops in question are perennials such as coffee, fruit etc., the later seral stages provide the model. Pioneer stages in most ecosystems are diverse and incorporate a range of plant types capable of high productivity, a pattern often reflected in traditional agriculture. The early seral stages of forest ecosystems provide the next step in structural growth.

Emulating the structure of an ecosystem as it matures is one of the keys to designing Analog Forests. Every stage, be it pasture or climax forest, has a unique diversity in each bioregion. The pioneer stages in most ecosystems are diverse and incorporate a range of plant types capable of high productivity, a pattern often reflected in traditional agriculture. Using the patterns provided by natural systems and implementing them in the landscape will provide for a high yielding polyculture; all the while attempting to mimic ecosystem growth towards mature forest. In any seral stage, continued structural improvement of the ecosystem according to the climax formula and database species can take place.

8) Utilize Ecological Processes

Incorporation of ecological processes into an Analog Forest design always contributes to furthering system stability. All ecosystems are driven by a series of processes, some of which are significantly important and contribute to maintaining overall stability and productivity. Ecological processes in every ecosystem allow for increases in efficiency through management.

The identification of key processes will enable the design of an effective and elegant model. Some to consider are: Edge effects - whereby the ecotone or the boundary between two ecosystems facilitates a higher biodiversity; keystone species - species on which the persistence of a large number of other species on the ecosystem depends and whose impacts are greater than would be expected from its relative abundance or total biomass; and the use of indicator species - organisms that correspond to a certain level or state of biodiversity,

By observing and understanding the ecological processes that contribute to a mature ecological system, one can increase the stability and yields of this system. Ecosystems, in cooperation with the living organisms within, create their own fertility and do their own mulching. Making compost, mulching, using cover crops and introducing or attracting native animal species are a few examples of managed ecological processes.

9) Value Biodiversity

Biodiversity has been perceived in many ways over the ages. It provides variety on our planet and has been the source of human inspiration across cultures and ages. Biodiversity provides the material as well as the indicators for sustainable land management. In modern times it is an invaluable management tool, as the level of biodiversity is an extremely useful measure of ecosystem health. Biodiversity measures have also been correlated with environmental stability. Similar patterns have been found in studies on the sustainability of certain agricultural and forestry practices.

The beauty and wonder of the living world cannot have meaning in the marketplace. As a consequence, the value of biodiversity has been neglected in the name of establishing monocultures of economic expediency. In this way, through the creation of examples of healthy ecosystems on degraded lands, we can improve yields and encourage policy changes that embrace beneficial management methods.

10) Respect Maturity

Maturity is the end condition all ecosystems tend to develop towards. It represents the ability to stay sustainable in a given geographical site. Seral succession or the gradual changing of species and structures in an ecosystem as it moves towards maturity is a singularly important consideration in design. Maturity is a *process* more than an *end condition*. Mature ecosystems are usually higher in biomass, though not necessarily in biodiversity, than less mature systems. As maturity confers stability, every element of a landscape that can mature should be encouraged to do so. The term *climax* is often used to denote the end state of seral succession in tree-dominated ecosystems. This mature or climax forest structure serves as a living example of natural beauty that we strive to mimic in Analog Forest systems.

11) Reduce ratio of external energy in production

All ecosystems rely on energy to maintain their integrity. In agricultural ecosystems, productivity is a goal and energy is used to meet this goal. Often energy subsidies from outside the farm have to be provided. As an increase in energy flows tend to organize and simplify systems, increases in external energy inputs impact both biodiversity and sustainability. Energy increases in an ecosystem represent a measure by which ecosystem modification plans can be addressed.

One of the primary goals of implementing a sustainable landscape design is to decrease the external inputs in the landscape or farm. We mimic nature where all inputs for the system are provided by the system internally.

12) Respond creatively

In the end, every artist has to use the palette at hand. The database may be incomplete, the maps may be poor. Often, data on the region may be lacking, familiarity with landscapes or ecosystems are often superior to poor data. Every landscape and its associated ecosystems will have unique characteristics, some at a level significant for design, others not. Every landscape and ecosystem have nestled within it many more. Management and monitoring have to proceed on a decided scale.

Responding to landscape change must be biased towards system biodiversity rather than on time-based action. Furthermore, the choice of species and their pattern of placement will reflect on landscape aesthetics. All this requires the designer to respond skillfully and creatively. The natural beauty embodied in the multi-layered systems of any mature ecosystem provides the designer with endless possibilities for creatively cultivating the landscape. The future farm plan and map can thus also be considered an aesthetic and personal design that is not static, but very much dynamic.

Implementing Analog Forestry

The first step in the implementation of an analog forest is to carry out a complete and rapid assessment of the surrounding and target areas. The information gathered through an assessment is important in the design and planning of analog ecosystems as it will provide the practitioner with knowledge of the environmental, social and geographic conditions of the area and the particularities of the target lots. The AF methodology can be implemented in ecosystems within the landscape, community, farm, or backyard. If the target area is large, several landscape elements should be considered in the design, including biological corridors, buffer zones, watersheds, topography and forest reserves, among others. When the target area is small, such as a smallholder farm, we can use more specific criteria like contour lines, slope, and soil and vegetation characteristics, among others. **Fill out the following table to create a comprehensive preliminary analysis of social-economic, geographic and biological conditions at the site.**

Table 1: Preliminary Analysis of the Analog Forestry Site

1. General data	**2. Geographic location**
Project	Province/Department
Organization/Property	Localization
Country	GPS Location
3. Characteristics of the environment	
a) Environmental	**b) Physical**

Average/annual temperature		**Topography**	
Altitude		**Form**	**Slope**
Life zone		□ Flat	0-2%
Average/annual relative humidity		□ Hilly	2-8%
Annual rainfall		□ Mountainous	8-16%

Bodies of water			
Streams	**Lakes/Lagoons**	**Rivers**	**Marsh**

c) Soil use			
Agriculture	**Livestock**	**Forest**	**Nature Ecosystem**
□ Industrial □Conventional □ Traditional □ Family Use □ Community	□ Pasture	□ Traditional □ Polycultivates □ Monocultivates □ Forest gardens □ Arboretum □ Family Use	□ Forest (Type) ___________________ □ Savannah □ Mangrove □ Wasteland □ Others __________________

d) Socio-cultural aspects				
Characteristics				
□ Ethnic Groups	□ Farmers	□ Settler	□ Indigenous Groups	□ Others

e) Economic aspects
Principal economic activity of the area (Briefly describe):

Step 1: Physiognomic Formula of the original forest ecosystem and the area to be treated

This step is part of a two-fold approach to evaluate the structure of an ecosystem. Physiognomy describes the aspect and character of elements of the existing vegetation. In the case of AF, two indicators are taken into account:

- Seral Stages
- Physiognomic status of the vegetation

Seral Stages

The natural evolution that takes place in an ecosystem according to its own internal dynamic is called ecological succession. The succession process leads to a more stable and resilient ecosystem; this is described as a process of maturation. In each state the complexity of the vegetation structure increases. Parallelly, the soil stability, depth, and biodiversity also increase. The optimum state towards which the successive stages develop is called climax.

The transformation from the original ground cover vegetation to more diverse shade producing plants, bushes and trees occurs in successive stages over time as plants compete for light, water, nutrients and space (Senanayake, 1998). Eventually, low shade tolerant plants will give way to higher canopy trees and shade tolerant plants in a process known as *seral stage succession*.

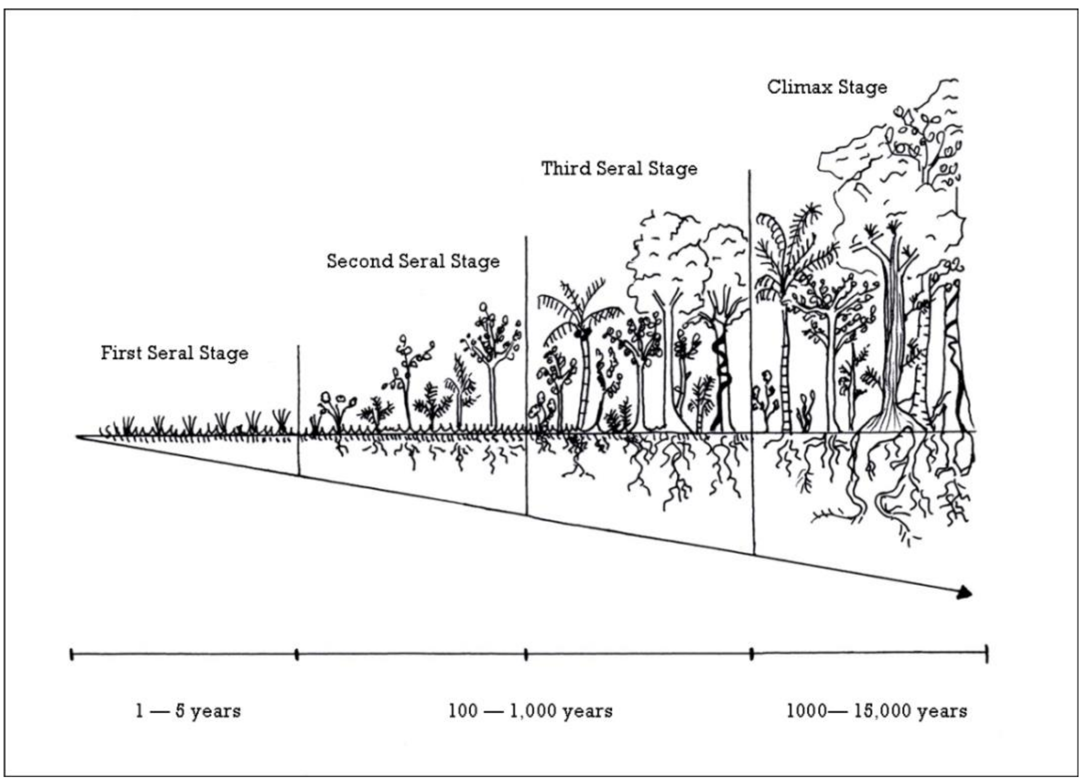


Figure 2. Over time, successive seral stages provide increasing soil development, biodiversity and canopy cover.

1st seral stage: Grasses dominate

In this first stage grasses dominate, the topsoil is not developed, and only plants with a shallow rooting system can survive.

2nd seral stage: Shrub land and pioneer trees

In this stage shrubs gradually dominate with pioneer tree species while grasses disappear. The soil structure is improved and a new topsoil layer and a deeper rooting system are under development.

3rd seral stage: Pioneer Forest

In this stage the pioneer trees will grow and form the main canopy. This canopy will create the conditions necessary for seedlings and saplings of sub-climax species that need shade when young. The soil structure and the new topsoil layer and rooting systems are further improved.

4th seral stage: Sub-climax Forest

In this stage the site is inhabited by more diverse plant and animal species. The forest structure is becoming more complex and several forest layers are formed (i.e., herb layer, shrub layer, lower canopy and upper canopy). The topsoil continues to develop with the beginnings of humus formation.

5th seral stage: Climax Forest

At this stage all the different forest layers are formed and the highest possible level of biodiversity is reached. The soil is well developed with a thick humus layer. In general, natural seral progression to climax forest can take anywhere from 50 to 1,000 years. In Analog Forestry it is also necessary to follow a seral progression. One goal of Analog Forestry is to speed up the development of the seral stages. Sometimes the land may have already been planted with trees and resembles a pioneer or sub-climax stage. Here the addition of missing elements and/or growth forms (for example, climbers and epiphytes such as orchids) is used to help develop the agricultural/forest land towards higher maturity. However, the imposition of fast-growing woody species such as teak in conventional reforestation plantation models is not encouraged.

Formula for the physiognomic description of the vegetation

The second step in structure evaluation is the description of the physiognomic status of the vegetative community present in the target area. The Physiognomic Formula is a tool used to describe the physiognomy of a system, or its outward appearance, in order to characterize it by recording the species and ecosystems present in the area under treatment. The initial data will assist in setting a baseline against which future observations and changes can be evaluated, as outlined in the first principle of AF. Recording is also important in evaluating the management activity and in maintaining a management history.

It is important to record the Physiognomic Formula for the vegetation types on the land. The structure of the system will demonstrate a wide range of different architectural responses varying from trees to lianas. The provision of a suitable structure is addressed via the growth habit of the species being evaluated for use. While it is useful to appreciate that there may be differences between juvenile and adult forms, the primary design consideration will center on the adult form.

Thus, as described by the IAFN´s growth form categories below, a plant species can be identified as woody trees, vines and epiphytes, among others.

The application of the Physiognomic Formula of the vegetation allows us to obtain a quick and easy description (in symbols) of the structure of the arboreal and non-arboreal components present in the target area. The symbols described in table 3 below represent types of plants in order to simplify the growth form categories to create Physiognomic Formulas for AF sites.

Table 3. Physiognomic Formula variables and symbol

A. Growthform categories

1.Basic growth forms	Symbol
Woody plants(Trees and shrubs)	
Broadleaf evergreen (simple or compound leaves)	V
Broadleaf deciduous (simple or compound leaves)	D
Needle evergreen	E
Needle deciduous	N
Aphyllies (without leaves)	O

2.Other growth forms (non woody)	Symbol
Palms	P
Rhysomatous plants (Banano, heliconia, etc.)	R
Succulents (Cactus)	S
Bamboo	B
Rosette plants (agave, terrestrial bromilia, etc.)	K
Ferns	F
Epiphytes	X
Vines and creepers (lianas)	C
Lichen and mosses	L
Herbaceous plants	
Grasses (wheat, corn, sugar cane, rice, etc.)	G
Annual herbaceous plants (melon, pumpkin, caléndula)	A
Perennial herbaceous plants (oregano, chilies)	H

B. Structure categories

1.Height (Stratification)	Symbol
>45+	9
35 - 45 m	8
20 - 35	7
10 - 20 m	6
5 - 10 m	5
2 - 5 m	4
0.6 - 2 m	3
0.1 - 0.5 m	2
< 0.1 m	1

2.Coverage	Symbol
Continuous (>75%)	c
Interrupted (>51 – 75%)	i
Patches (>26 - 50%)	p
Rare (>6 a 25%)	r
Sporadic (>1 – 5%)	b
Almost absent (<1 %)	a

In this technique the highest canopy layer will be described first, followed by lower layers. For example, an upper canopy or stratus layer consisting of broadleaf evergreen trees of 30 m in height that covers 60% will be described as V7i. A lower continuous canopy of broadleaf deciduous trees of 10 m is described as D5c and a layer of scattered rattan plants would be R4b. For climbers the maximum height that they reach is recorded as the *height class*, while for epiphytes it is the height at which they are *found*.

For example, a plot of natural forest in Costa Rica is described as:

V9b, V8r, V7r, V6p, V5i, V4c; P6b, P5r, P4p; R4r; C1-8c; X4-9c; L1-9c

This formula describes a very Humid Tropical Forest in Costa Rica, with an average rainfall of 6350 mm per year. This primary forest has 5 canopies of Evergreen trees (V). Of these, the highest stratum is more than 45 meters high and has sporadic coverage (1-5%). While the palms (P) have three floors from 2 to 20 meters. Rhizomatous plants (Heliconia) have a single canopy between 2 to 5 meters. The vines (C) have a height range from the ground to 45+ meters and the cover is continuous. Epiphytes (X) have a height from 10 to 45+ meters. While the Mosses and Lichens (L) have a continuous cover and height from the ground (rocks) to the highest canopy.

Note that, to facilitate the use of the formula, which has a subjective level, it is not necessary to record exactly each tree present, but rather what type of forest predominates. For example, in a forest where the vast majority of trees are broad-leaved evergreen, the symbol V would be used to mark the different canopies, even though there are a few trees with other shapes (needles, compound-leaved deciduous). If there is a significant presence of two or more different types of tree species (i.e., compound -leaved evergreen and compound-leaved deciduous), the two symbols can be used in the same formula (ex. V8r, V7i, V6c, D7b, D6r ... etc.).

The formulas are useful to concisely describe the structure and the seral stage of the forest, compared to lengthy descriptions that would otherwise be necessary. Also, the formula will make it easier to identify the next seral stage. Therefore, it serves to describe the different stages of natural succession that occur in the landscape. It is also possible to visually describe forest fragments using vertical and horizontal perspectives. A vertical profile can help to visualize the different upper layers, weeds and other life forms. The horizontal profile shows the vegetation space seen from above, both shown in Illustration 3.

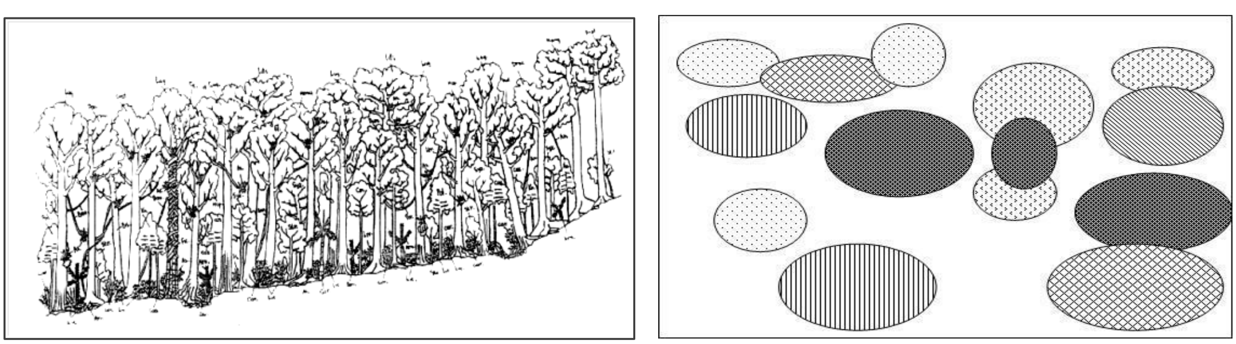


Figure 3. Vertical profile (left) of a forest showing the different canopy levels found. Horizontal (right) profile of a forest showing species found in the selected area. Size of the object indicates relative abundance.

Landscape study is useful for collecting general data on the climate, soil, and plant and animal species that exist. The data collected can influence the plan of choosing the species which make ecological succession possible. Once the Formula of the climax or reference forest (F1) has been established, the same exercise must be done to determine the Physiognomic formula of our plot (F2).

Step 2: Preliminary Gap Analysis

In order to assess the missing species in the plot (F2), it is necessary to carry out a "gap" analysis between what exists, and what is to be replicated. This requires a simple process of elimination. Based on what was seen in steps 1 and 2, first observe the (approximate) Physiognomic Formula of the existing vegetation in the mature or climax forest (F1) and compare it with the formula of the degraded area to be designed (F2). In this way, the gap is determined by the following formula:

Gap Analysis = F1 – F2. Thus, (existing – degraded = gap analysis). This is best illustrated through an example:

Physiognomic Formula of the mature natural forest close to the site (F1)

V9b, V8r, V7r, V6p, V5i, V4c; P6b, P5r, P4p; R4r; C1-8c; X4-9c; L1-9c

(Indicate the main species that are identified in each formula code or the main codes only)

Physiognomic Formula of the site where Analog Forestry will be established / the degraded parcel (F2)

V7r, V5i, V4p; R4r; C1-7r; X3-6r; G2i; A3r; L1-7c

(Indicate the main species that are identified in each formula code)

Gap Analysis (F1-F2)

V9b, V8r, V6p, V5i > c, V4p > c; P6b, P5r, P4r; C1-8r > c; X3-6r > c

To calculate the gap:

a) The categories present in F1 but not in F2 go directly to the gap formula (in this case V9b, V8r, V6p, etc.).

b) The categories present in F2 but not in F1 are excluded from the gap, for example, in this case the plot to be intervened has grasses not present in the mature forest (G2i and A3r).

c) If there is a canopy of the same type present in the mature forest and in the plot to be intervened, the gap is the difference in coverage between the two. This difference is indicated with the use of an arrow indicating the current coverage (plot to intervene) desired coverage (mature forest): V5i >c

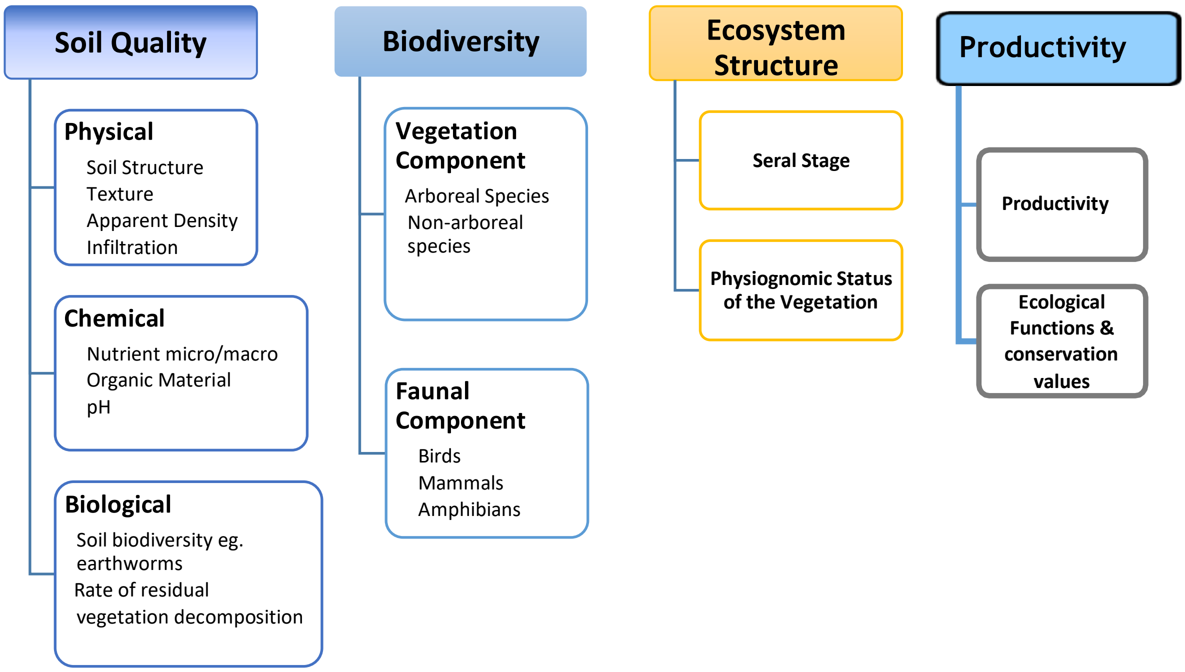
Box 1: Summary of Formula Methodology

1.) Go to the area to be evaluated (a native forest in the climax or sub-climax state).
2.) Define the number of canopy layers that exist in the forest. It is helpful to identify trees which act as points of reference. You may even label them.
3.) Determine the height of each canopy.
4.) Determine the coverage of each canopy.
5.) Separate each stratum with a coma (,).
6.) After describing the final canopy layer (the lowest) separate with a semicolon (;).
7.) Sequentially describe next growth forms, separating each with a semicolon (;): grasses, ferns, lichens, vines, succulents, bamboos, palms, etc… For each continue to describe the type of plant, height, and coverage.

Step 3: Ecological Evaluation

The ecological evaluation is a tool to assess the degree of impact of different types of land use on the area to be treated. **To place a value on these areas, we have to take into account four variables: soil, structure, biodiversity and productivity.** We define a scale where **1** is the most degraded land, and **6** is the most mature ecosystem. Numbers will give the measure on which our area of treatment is and the priority for action. The lower numbers will require our most immediate attention. When prioritizing areas for treatment, they can be ´zoned' according to these values:

Criteria for the Ecological Evaluation



The resource assessment for any management zone should be carried out by the Analog Forestry group that will be managing the zone. A first assessment should include preparing a description of the existing vegetation using the formula process described in steps 1 and 2.

When the vegetation is at a low seral stage there is no need to spend a lot of effort and resources in making sample plots and detailed resource assessments. Discussions with the group about the availability of existing socio-economically valuable species (for timber, fuel wood, medicinal plants, timber for construction and or tools, fibers, etc.), will provide enough detail for making detailed Analog forestry plans. If the forest is more complex and at a higher seral stage, it is recommended to carry evaluations using sample plots and describe the existing vegetation and other features in more detail. The Analog Forestry plan should take into account the existing vegetation and socio-economically valuable species for future plans for the plot.
A simple straightforward way to conduct ecological valuation is by using a checklist of indicators with an approximate range of variables. The process may also be more scientific depending on the needs of the project leaders or communities involved, please see the Appendix attached.

Table 4: Indicator Checklist for Ecological Valuations

Value	Soil - Soil Profile	Value	Soil - Apparent Density
1 to 2	Almost absent topsoil	1 to 2	Very compacted
3 to 4	Thin topsoil	3 to 4	Compacted
5 to 6	Deep topsoil	5 to 6	Not compacted
Value	**Soil - Macroorganisms**	**Value**	**Biodiversity - Fauna**
1 to 2	No signs of biological activity, no beneficial macroorganisms observed.	1 to 2	Very little visible presence or diversity of plants, reptiles, mammals, insects, amphibians
3 to 4	Some beneficial macroorganisms observed in small quantities, such as worms and arthropods.	3 to 4	Some visible presence and diversity of fauna.
5 to 6	Abundance of beneficial macroorganisms such as worms and arthropods	5 to 6	Visibly abundant presence and diversity of fauna.

Value	Biodiversity - Flora
1 to 2	Very little tree and non– tree species variability (one to three species maximum).
3 to 4	Little variability among species (more than 5 tree species present and few species in the understory).
5 to 6	High variability of both tree and non-tree species, more than 10 tree species and presence of epiphytes, soft-leaf shade plants and large plants in the understory.
Value	**Structure - Seral Stage**
1	Stage 1 - grasslands
2	Low vegetation, less than one year old
3	Low trees and bushes
4	Various trees, undergrowth with bushes and herbaceous species
5	Young secondary forest, high diversity of species
6	Secondary forest with a diversity of strata, presence of epiphytes, lichens, etc.

Value	Structure - Complexity
1 to 2	Ecosystem of little complexity, little diversity of species and few interactions between elements
3 to 4	Moderately complex ecosystem, species diversity and interactions between elements
5 to 6	Ecosystem with a complexity comparable to a natural climax forest, abundant diversity of species and interactions between elements
Value	**Productivity - Economic**
1 to 2	No productive system exists
3 to 4	A productive subsistence and/or market system exists, but does not meet all the objectives of the landowner
5 to 6	The productive system meets the landowner's subsistence and/or market objectives
Value	**Productivity - Ecological Functions***
1 to 2	Ecological functions are weak and no system for scientific study, carbon sequestration or tourism exists
3 to 4	Some ecological functions exist (eg. purifying water, soil conservation, habitat,etc.) or some systems are developing for scientific studies, carbon sequestration or tourism
5 to 6	Strong and stable ecological functions and/or stable systems for scientific study, carbon sequestration or tourism

Soil Quality

The concept of soil quality is based on the premise that management can degrade, stabilize or improve soil ecosystem functions. Soil quality comprises physical, chemical, and biological components and their interactions.

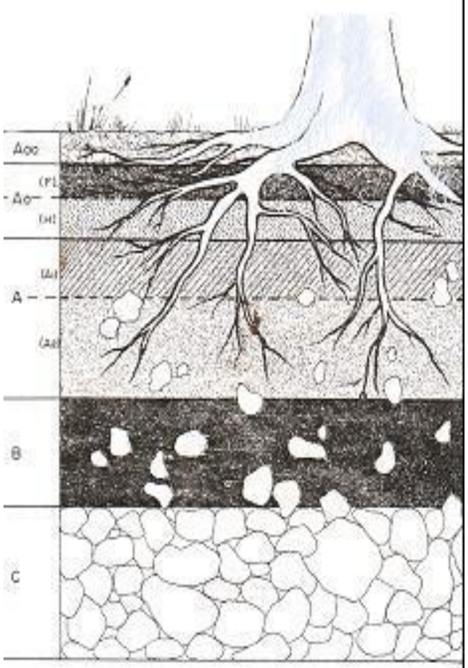
Physical Indicators

The study of the soil profile allows us to determine two of the physical indicators of soil quality:

- Structure
- The nature of the soil profile

The following figure shows a forest soil profile in order to provide a reference point for the identification of horizons.

Table 5. Description of horizons present in the soil profile



HORIZONS	DESCRIPTION
Aoo	Upper layer containing leaf litter.
Ao	Organic matter partly decomposed. This is the most active and biologically diverse layer, also the richest in nutrients. This layer is divided into two levels: F and H. **F** is the level made up of partly decomposed leaf litter with high microbial diversity. **H** is the underlying level of humus containing decomposed organic material.
A	Is the upper mineral soil layer, which has lost materials due to water filtration. This eluvial[2] horizon is also subdivided in two levels: A1 and A2. **A1** Is rich in organic matter and darkly colored. **A2** Is light in color and subject to maximum leeching.
B	Is an alluvial[3] horizon with organic matter and clay build-up deposited by water filtration. It is usually a darker color than the other horizons.
C	Un-weathered parent material.

[2] Eluvial: out washed.
[3] Iluvial: in washed.

Depth of the upper horizon

Depth of the upper horizon is important for potential productivity, since it determines the water accumulation, nutrient supply for plant growth and organic carbon content.

Measuring the depth of the superficial horizon across time provides a good estimate of soil lost or gained. A reduction in the thickness of the upper horizon is usually the result of wind or water erosion, material deposition or terrain leveling.

a.) Texture

Texture is an important characteristic because it affects soil fertility and it helps to determine the rate of water consumption, water accumulation in the soil, suitability for agriculture, and degree of aeration.

b.) Apparent Density – Compaction

The higher the density, the smaller the porous space for water movement, growth, root penetration, and seedling development becomes.

Apparent density is a dynamic property that varies with soil structure. This condition can be altered by cultivation, animal stumping, agricultural machinery and weather (i.e., raindrop impact).

Compacted soil strata have high apparent densities, restrict root growth and inhibit air and water movement across the soil. High organic matter quantities improve this physical characteristic because it is much lighter than mineral matter.

c.) Infiltration

Infiltration determines the washing potential, productivity and susceptibility to erosion, since it causes flooding in flat areas or erosion by runoff in sloped lands. The speed at which water enters the soil is the infiltration speed, which depends on soil type, structure, and water content. When the measurements are taken, soils should have similar humidity content.

Box 2: Testing Soil in the Field

For a preliminary procedure to determine soil quality, dig a ‘soil pit’ that is 50 centimeters high and wide (19 inches) wide and tall. This should be done for each ´zone´ of AF treatment. Examine them briefly for the abovementioned criteria, such as texture, apparent density and infiltration, as well as observe presence of insects and worms.

See Appendix 1 for further detail on the physical indicators of soil quality.

Chemical Indicators

The chemical indicators proposed refer to factors that influence the soil-vegetation relationship, water quality, the soil's buffer properties, as well as nutrient and water availability for plants and microorganisms.

The chemical indicators considered are:

a. Nutrients- micro/macro
b. Organic matter
c. pH

a.) Nutrients N, P, K (Macro)

Nutrients available to the plant, loss of N potential, productivity and environmental quality indicators.

Micronutrient status can often be determined by leaf coloration or discoloration of local plant community structures.

b.) Organic Matter

Organic matter determines soil fertility, stability and erosion. This is the single most important factor in determining the sustainability of the forest above it.

c.) Soil pH

Soil pH measures acidity or alkalinity and affects nutrient availability, micro-organism activity and mineral solubility.

Temperature and precipitation are important factors that influence soil pH, which control leaching intensity and weathering of soil minerals.

Acidity is usually associated with leached soils and alkalinity is generally present in drier regions.

In general, fungi perform their functions within a wide range of pH values, but bacteria and actinomycetes perform better at intermediate or high pH levels.

See Appendix 2 for more detail on the chemical indicators of soil quality.

Biological Indicators

Biological properties can be used as soil quality indicators since they reflect the state of the ecosystem.

The biological indicators considered are:

a. Soil Biodiversity i.e., earthworms
b. Rate of decomposition of vegetation residues

a. Soil biodiversity

Earthworms generally increase microbial activity and the soil's chemical fertility. They improve physical characteristics as well as soil quality by increasing nutrient availability, speeding up organic matter decomposition, eliminating certain plagues or noxious organisms, and increasing the number of microorganisms. Earthworm populations can vary with site characteristics (nutrient availability and soil conditions), seasonal factors and species involved. These populations vary widely across time and space from less than 10 to more than 10,000 individuals by square meter (Curry, 1998).

Earthworms excavate through the soil improving infiltration and their excretions improve aggregation. Earthworms also break-down big pieces of residue enabling other soil organisms to use them.

b.) Decomposition rate of vegetation residues

Vegetation residue decomposition determines biological activity.

See Appendix 3 for more detail on the biological indicators of soil quality.

Biodiversity

"*Biological diversity means the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (Article 2 of the Convention of Biological Diversity).

Biodiversity has been perceived in many ways over the ages. In modern times it is invaluable as a management tool as the level of biodiversity is an extremely useful measure of the health of ecosystems. Biodiversity measures have also been correlated with environmental stability. A loss of biodiversity for instance, suggests a loss in ecological stability (Senanayake, 2000).

For AF uses, it is best to use *Alpha* measures of biodiversity, meaning the count of species present. The indicators considered to evaluate biodiversity are:

a. Vegetation Component:
- Arboreal species
- Non arboreal species

b. Fauna Component
- Birds
- Mammals
- Amphibians
- Insects

a. Vegetation component

Arboreal and non-arboreal species are considered within the vegetation component, and within these, it is important to identify keystone species.

The monitoring strategy will depend on the resources available. The measure of arboreal and non-arboreal species will be done through visual observation, however, transects, plots, and taking of samples could be used as well. If known, endemic species and their conservation status according to the World Conservation Union (IUCN) should be highlighted in the planning (Carlos Samaniego, 2006. Comments in Paper).

Keystone Species

The ecological identity of a forest can often be defined by a few keystone species. These are species without which the equilibrium and thereby the nature of any ecosystem changes. In a forest situation keystone species are those which provide architectural or biological stability to that forest ecosystem

The biological system is maintained by species which provide and regulate the flow of energy within the ecosystem. Every stage of forest succession contains its keystone species. In early seral stages of tropical forests species like *Erythrina, Cecropia*, *Macaranga* and *Trema* are pioneer species. They are fast growing, potentially invasive and have leaves that are highly palatable, often pock-marked with holes made by herbivorous insects (Ewel, 1980). They also produce great quantities of nectar in floral and extrafloral organs that feed a wide diversity of insects. These support populations of insectivorous vertebrates such as birds and reptiles, which in turn support their predators. Every forest has its own complex of such serial keystone species that lend it stability.

b. Fauna component

The fauna associated with an ecosystem is another indicator of its status and dynamics over time. There are specialized species that have co-evolved with their surroundings, while others have more general functions. By observing this type of behavior, it is possible to reach conclusions regarding the way in which a site is changing.

Monitoring or evaluation of the fauna component has to be carried on through observation and verification of the presence of: birds, mammals, amphibians and insects. The food and habitat requirements of these animals can then be incorporated in the Analog Forestry plan and/or the monitoring plan, while the presence of animals can be used as an indicator for success in imitating the natural forest. Consider the soil food web below (Figure 4) that illustrates the interactions between different organisms both subterraneous and aboveground.

Box 3: Keystone Species in Honduras

Red Mangrove

Mangrove trees have long exposed roots that reach into coastal waters and tidal swamps. They are extremely tolerant to saline conditions and can survive fluctuating water levels. They create stability in coastal soil ecosystems protecting them from erosion and nutrient loss. In addition, they create habitat for a wide variety of fauna ranging from birds to mammals, reptiles, and arthropods.

In this way, mangroves are keystone species in that they affect the structure and function of their ecosystems in a number of ways. The IAFN works on the restoration of mangrove forests on the coast of northeastern Honduras to protect the nearby communities from storm water surges and flooding.

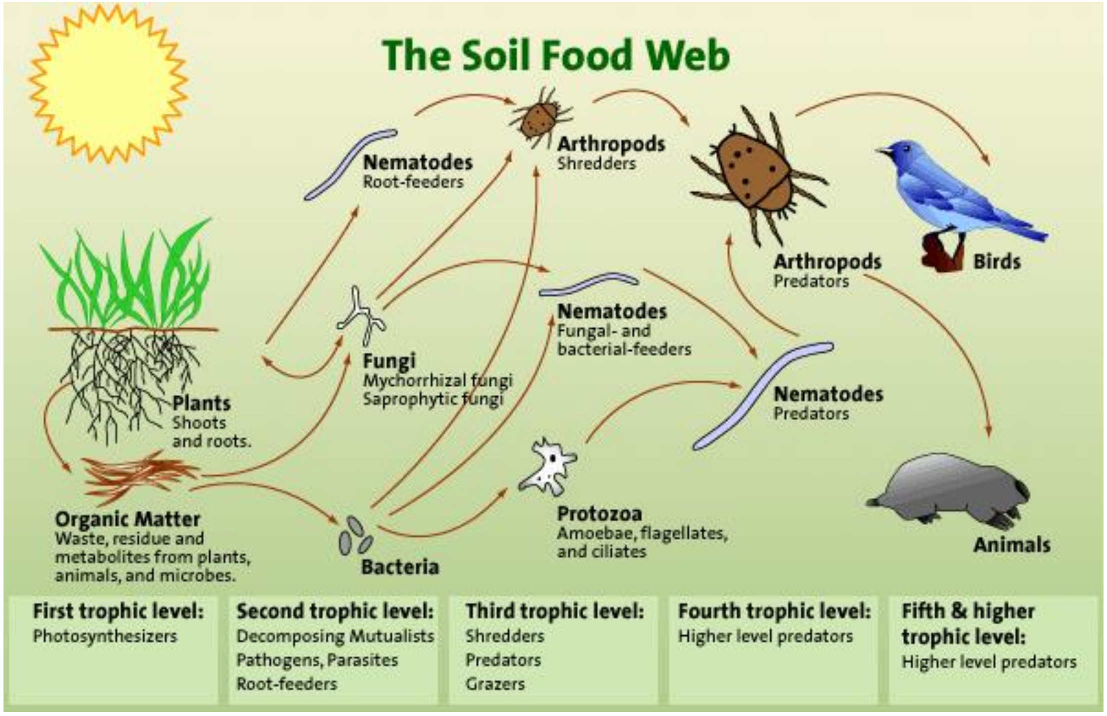


Figure 4. Soil food web illustrating interactions of organisms within soil[4]

Ecosystem structure

This refers to seral structure and ecological succession.

Productivity

We evaluate productivity both in terms of production for commercialization or self-consumption, both in terms of ecological functions and conservation values.

Analysis of information gathered from the indicators in the ecological evaluation:

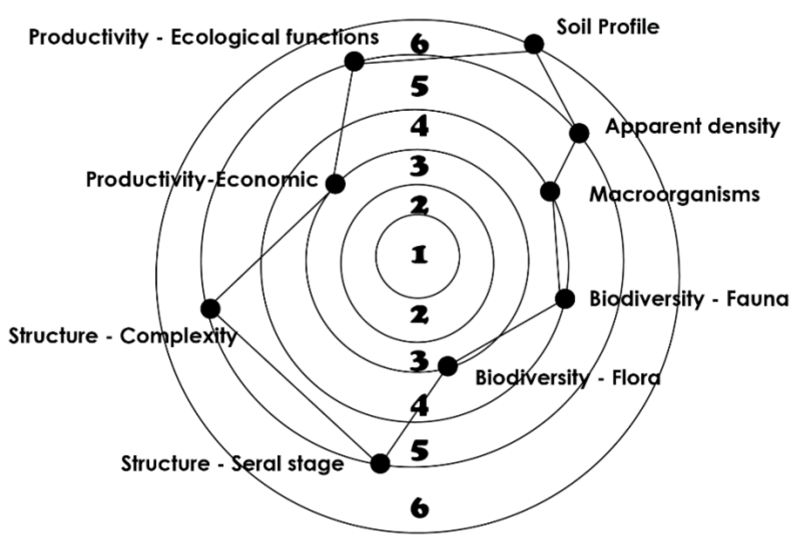
The following evaluation graph can serve to compare various landscapes and land use types at the same time to determine which needs the most attention. It can also be a tool to monitor the progress of a restoration site after initiation. It indicates which parts of the system are the weakest.

This chart can be drawn using the results of the ecological evaluation.

[4] Anon, 2009. The Soil Food web Approach. Soil Food web Inc. Accessed: February 23rd, 2012. Available at: http://www.soilfoodweb.com/sfi_approach1.html

i.) Draw 6 circles one inside the other, as shown below.
ii.) Write down the value of each topic in the corresponding circle.
iii.) Draw a line between each value, connecting them all.
iv.) The overall goal is to achieve values as close to 6 as possible, indicating a healthy ecosystem.

Figure 5: Spider graph with environmental indicators and their values



The areas that have the lowest values (points closest to the middle) indicate priority treatment areas.

After assigning values to each indicator, they are added up and divided by the numbers of indicators; the result is an average for Soil Quality, Biodiversity, Structure and Productivity in the target area. Each individual area value is then analyzed in order to get the evaluation of the ecosystem.

Indicators for Soil Quality, Biodiversity, Structure and Productivity lower than 3 are considered below the **sustainability threshold** and therefore require actions that improve those areas with low-value indicators. [5]

[5] Altieri, M.A., and Nicholls, Clara Inés. 2002. Un Método agroecológico rápido para la evaluación de la sostenibilidad de cafetales. Manejo Integrado de Plagas y Agroecología, Costa Rica, Nº. 64 p.17-24.

A chart of the plot values allows visualizing the value of the agro-ecosystem in regard to the value 3 thresholds of Soil Quality, Biodiversity, Structure and Productivity. **The closer the average value is to 6, the more sustainable the system is**.

This type of analysis enables the identification of the **weak** areas (values lower than 3), and to make recommendations and rank the type of necessary ecological interventions to correct soil attributes or change tendencies in the analog ecosystem. This information also allows one to perform comparative studies among analog systems regarding the species health criteria.

Example of indicator analysis and evaluation:

This example is the result of an exercise applied to a conventional agroforestry system, in which the evaluation concluded that it was just above the sustainability threshold, therefore the weak indicators need to be improved. The following forestry system contains cocoa trees (3 arboreal species) planted 4 years before the evaluation.

Characteristics of the forestry system in question:

Type of Characteristic		
Physical	**Climatic**	**Soil**
○ Irregular topography ○ Slope: 25 % ○ Tree cover: 50 %	○ Average annual temperature: 24 º C ○ Annual precipitation: 3500 mm ○ Average environmental humidity: 85%	○ Texture: clay sand ○ pH: 5.6 ○ Upper horizon depth: 9 cm.

Table 6. Sample Evaluation of the Sustainability of the Analog Forestry System

FORM FOR RECORDING DATA OF THE ECOLOGICAL EVALUATION

Name:		Date:
Parcel:		Lot N°
Location:		Province:
Altitude:		Geographic Coordinates:
Median annual rainfall	mm	Country:
Median annual temperature:	C	Ecosystem:

INDICATORS			SUSTAINABILITY VALUE
1. SOIL QUALITY INDICATORS		**AVERAGE SOIL**	Sum of the averages divided by four. 3,73
	Value	Sum of indicator values divided by three. 4,3	
a. Soil Profile	4		
b. Apparent Density	4		
c. Microorganisms	5		
Total	13		
2. BIODIVERSITY INDICATORS		**AVERAGE BIODIVERSITY**	
a. FLORA		Sum of flora total value and fauna average, divided by two. 4,12	
	Value		
Presence of both tree and non-tree species	4		
Total	4		
e. FAUNA			
	Value		
Birds	5		
Mammals	3		
Amphibians and/or reptiles	4		
Insects	5		
Total	17		
Fauna average (fauna values divided by four)	4,25		
3. STRUCTURE INDICATORS		**AVERAGE STRUCTURE**	
	Value	Sum of indicator values divided by two. 3	
a. Seral Stage	3		
b. Complexity	3		
Total	6		
4. PRODUCTIVITY INDICATORS		**AVERAGE PRODUCTIVITY**	
	Value	Sum of indicator values divided by two. 3,5	
a. Economic productivity	4		
b. Ecological functions	3		
Total	7	**TOTAL**	
		3,73	

Interpreting the Results of the Ecological Evaluation

The table above shows that the soil quality criteria are deficient in the texture, nutrients, and pH indicators, all of which are barely at the sustainability level. This is understandable given the high precipitation and scarce diversity of soil-improving species. It is also evident that the indicators for apparent density, infiltration, and organic matter are above the sustainability level, which means that the soil is not compacted, and infiltration is good which prevents runoff-caused erosion. This is due to the presence of tree species, which have made draining channels with their root systems allowing water to flow through.

The biological indicators such as earthworms and decomposition of organic matter are above the sustainability level as a result of constant incorporation of vegetal biomass to the system from the trees, which allows for a considerable population and biological activity, improving organic matter decomposition. The biodiversity indicator is above the sustainability level because cocoa is the dominant species with only three arboreal species for permanent shadow.

Step 4: Mapping

A powerful tool in understanding the land is a carefully drawn-out map that identifies the most pertinent features of the farm. Mapping the land can be very efficient if developed as a series of overlays. The farm design will later take each of these variables into account.

Prior to the development of maps, it is important to have a general understanding of the area or work zone. For this, one must count on the help of cartographic plans as well as the participation of the community. Mapping is an exercise that consists of drawing the contours of the property and pointing out the principal elements within it. Consider that the landscape is a combination of characteristics and aspects that are internal and external to the land area determined by diverse factors such as: relief, climate, soils, wind direction, water flow, and vegetation cover. Once the physical boundaries have been mapped, overlays that demarcate the contours, the hedges, and fence lines are also some useful variables. It is beneficial to map at the **landscape level** instead of just the AF treatment site to acquire a more holistic understanding of the environment. This could include neighboring farms, roads, rivers, etc.

Dividing mapping in several steps is recommended:

Biophysical Maps (topography and contour)

Identify the **hydrological flow**, the **topography**, **direction of winds**, and the movement of the **sun**, as these factors influence the area to be treated.

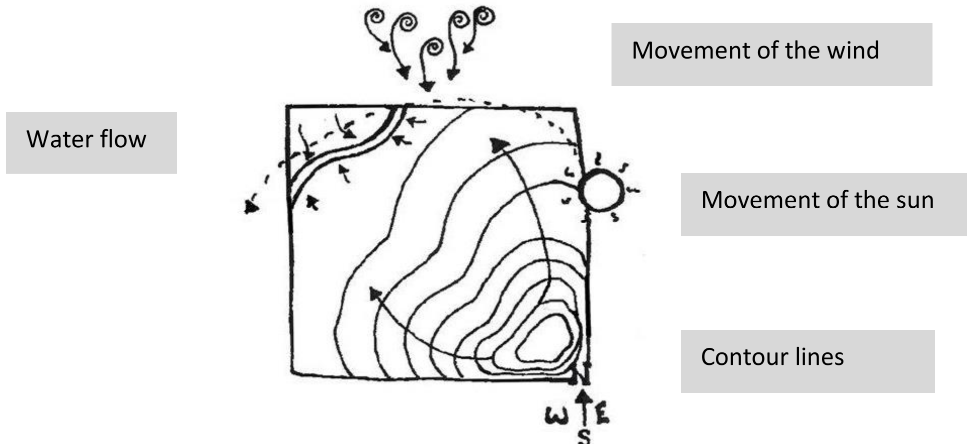


Figure 6. Biophysical map showing contour lines, natural paths, water flow, and the movement of the sun.

Current land use map

One way of differentiating landscape elements is to divide the area into different patterns of land use such as pasture, crops, forest, human settlement, etc., and use symbols to represent these areas. This map will show the attributes of the degraded plot that is to be restored. The farm plan can include the household map if the household lies within the farm. If the household is remote, then only the farm should be mapped.

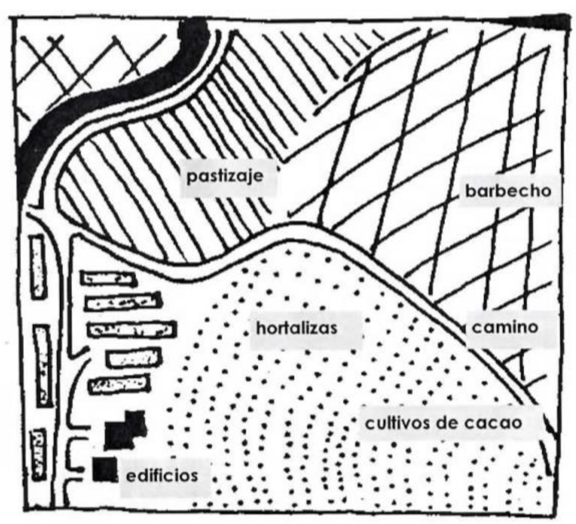


Figure 7: Existing land use map.

This map shows the relative locations of buildings, existing cultivation patches (different crops indicated by pattern), roads, paths, and neighboring plots. It is also very valuable to include the variability in soil types, if possible. This would follow data obtained during the ecological evaluation and can be illustrated by incorporating the different 'zones' described in the map.

It is important to carefully choose symbols or layout legends so that all parties involved in the AF site will be able to interpret the maps.

When each of these maps are finished, they can be overlapped to obtain a landscape map, which permits us to understand the state of the ecosystem characteristics and geographical positioning that will be used as a base for the integrated property design. (Figure 8 below).

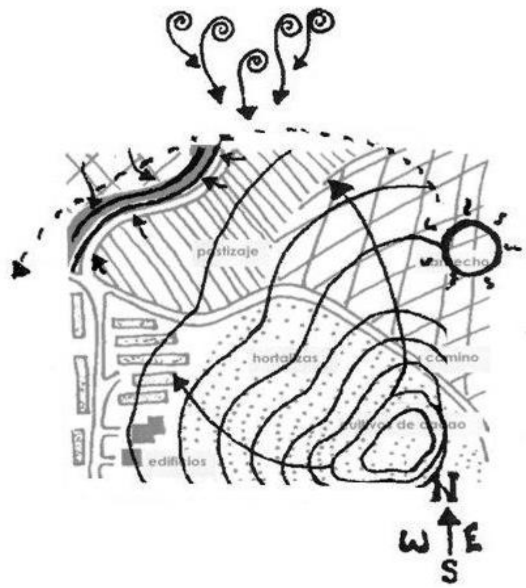


Figure 8. Overlay of biophysical and existing land-use maps.

Step 5: Identify and Prioritize Treatment Areas

As described earlier in the section addressing the basic principles of AF, the study of the landscape is important to identify the most suitable locations for restoration interventions. By describing the landscape patches that surround the community, suitable locations for AF within the community area or property can be identified in various ways. Think about the following methods to seek intervention sites:

Identify

1.) Identify locations that border a natural forest patch in order to extend the size of the natural forest and thus provide a greater range for both plant and animal species.
2.) Identify the need for the formation of an AF corridor to connect two or more natural forest patches and to facilitate gene flow and the interaction of gene pools.
3.) Identify patches of barren land where Analog Forestry interventions can be used to restore the ecological resilience of the plot and landscape.

Prioritize

Furthermore, the landscape study can help to prioritize areas for Analog Forestry interventions. This applies especially to areas that need further protection or special management, such as watersheds, wind breaks, landslides and other areas susceptible to erosion are all suitable landscape patches for Analog Forestry. *Consulting the gap analysis and the landscape maps will facilitate this process.*

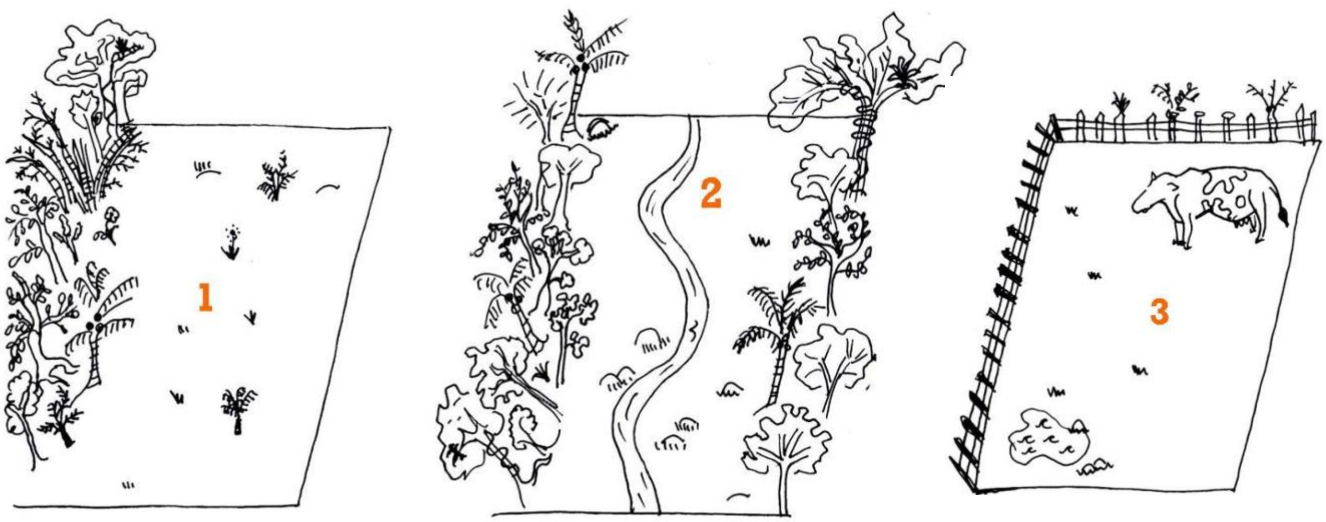


Figure 9. Identifying sites for AF intervention

Step 6: Database variables: Investigate characteristics and functions of species

Mimicking a natural forest structure through the use of socio-economically valuable species requires a thorough knowledge of the various desirable species available, in order to select plants that will complement rather than compete with each other. A plant species database with relevant information about plants as well as animals can assist in the identification and selection of suitable plants for use in the forest garden. In addition to being a tool for designing Analog Forestry interventions, the database also brings together information, from the community itself, about plants and animals that are not identified or found in publications. The database will also give the community a sense of ownership in the project design and demonstrate to them how local knowledge and current scientific knowledge can be brought together for better planning.

The IAFN has developed a comprehensive database which is available upon request. A database can be simple or complex depending on your needs. A database is developed with the aim to provide a tool for identifying or selecting appropriate species that can be used for Analog Forestry planning. Naturally a database will never be complete, as new species will need to be added, while information about species already entered may be modified and updated as new insight and information becomes available.

Meetings should be held in the communities or by the project leaders if the project is private, to assess and analyze the existing database to determine species of interest that can be planted in the area. After potential species are selected, the addition of species to the database should be considered. Things to be considered include other species that would be suitable for Analog Forestry and what we know about these species. Species identified for possible use in the Analog Forestry system in the community are not necessarily the species that will be planted in the plots. The actual species to be planted depends on the decision of the user groups and the details developed in the Analog Forestry plan for the site (see Table 7).

Box 4: AF Database used in Vietnam

The database used by Counterpart's Forest Garden project in Vietnam, for example, contains the following fields for each species entered - name (scientific and local names), life form, height, canopy crown (heavy, medium, light), root system (fibrous, taproot, buttresses), root action (influence of the roots on the soil), nitrogen fixation, use purpose, trophic relations (animals that use the plant for food including primary consumers that eat the plant, and secondary consumers that eat insects and animals attracted to the plant, microhabitat (name of plant/ animals that use the plant as shelter or support), required living environment (soil depth, soil fertility, soil humidity, humus content, light/shade), growth rate, propagation, flowering season and fruiting season.

The database is a reference for all structural, ecological, social, and economical attributes of interest for each species being considered in an AF design. It is a way to prioritize species according to their importance for the farmer. By studying the species characteristics in the natural forest, it can be determined which exotic species could be appropriate for use in an analog system.

Databases built with the local community will:

1. Determine the scope and depth of knowledge the community possesses.
2. Generate ownership over the process of analog restoration that this will impart

There is a wide array of criteria to include in such a database. For example, it could be important to have information about the following characteristics of potential plants that the International Analog Forestry Network has developed:

> Scientific name, common name 1, common name 2, original ecosystem, Physiognomic Formula, leaf type, stage of ecological succession, canopy coverage, type of soil preference, tree effect on soil, salt tolerance, water requirement, minimum rainfall

for growth, acidity or alkaline preference, ecological uses, economic uses, human uses, fruiting period, flower color, flower period, trophic ecological uses, OM aggregate potential, social-cultural aspects, country of origin, country reporting, seed treatment, Holdridge Life Zones, status of conservation, site in man-made ecosystems, ecosystem site , production age, growth.

The following is an example from part of a database done by participants in the AF course that took place at CATIE, Costa Rica, in February 2007. It was a part of the development of a design for a demonstration site at CATIE:

Table 7: Sample database with a subset of categories and possible entries.

Scientific Name	Common Name	Growth form (symbol as in FF)	Human Uses	Ecological Functions	Propagation
Mangifera indica	Mango	V6 Tree	Edible fruit, timber medicinal	protects the soil	seed, grafting
Cocos nucífera	Coconut	P7 Palm	Food, fiber handicrafts leaves for thatching, Timber	Provides shade, Support birds	Seed
Teobroma cacao	Cocoa	V3 Small tree	Edible fruit, Chocolate from nut	Green matter, hosts orchids, bromelias	Seed
Pasiflora edulis	Passion fruit	L (1-4) Vine	Edible fruit, edible and medicinal leaves	Flowers attract bees and others. Fruit feeds small rodents	Seed, cutting

Step 7: Conduct 2nd gap analysis according to project´s choice of species

Selecting species

The selection of suitable plant species for Analog Forestry depends on the vision developed and the actual situation. If a vision is developed that in the future ultimately results in a complex forest structure, while the current situation is still in the first seral stages, the easiest way to start designing the plan is by listing the potential species to be used by growth form and seral stage, drawing on the information in the database.

After candidate species have been listed by growth form and seral stage, their individual characteristics need to be analyzed in order to determine if they can be grown together and will complement each other, or if there are serious incompatibility issues. Information useful for analyzing species characteristics can be found in the database. After reviewing the species characteristics, some species may have to be rejected because of incompatibility or other issues.

Box 5: Case Study – Long term benefits of planting indigenous tree species in Costa Rica

Many farmers live with uncertain levels of income and must seek short term benefits. They often cannot afford the luxury of waiting for long-term returns from products such as timber, especially from slower growing indigenous tree species such as Cristóbal (*Platymiscium curuense*) or Cocobolo (*Dalbergia retusa*). However, timber from indigenous tree species is usually very valuable and planting such species is a good way to build up capital over the long-term and to ensure the availability of good quality timber for home construction or other purposes for future generations.

Step 8: Analog Forest Farm Design

The Analog Forestry plan for each zone is developed based on the outcomes of the resource assessment, the vision developed and information available from the database. The development of the plan consists of three sub-steps related to the selection of species, soil improvement and management activities.

The soil is the foundation for plant growth. When the soil is degraded, the ability of plants to grow is diminished. If the ecosystem assessment reveals that the soil is poor, measures should be taken to speed up soil improvement. As described in the section on basic principles of Analog Forestry, the soil will naturally develop with the progression of the ecological succession stages, but several measures can be taken to speed up the process. Management techniques that use organic matter to contribute to soil improvement include mulching, use of green manure and the planting of hedgerows on contour lines.

1. First, based on the current landscape map, analyze the changes necessary to ameliorate the site (soil, etc.) and then discuss the desired goals for the end of production, restoration, or overall goals; all the while taking into account the early stages of an AF site.

2. Raising awareness to achieve the desired goal requires several steps- theoretical and practical-, a long-term vision for planning actions and patience given that after the planning and planting, the growth stage takes time. For example, the farmer may have as an objective: subsistence food crops, biological conservation, carbon production, eco-tourism, spices/medicinal plants, essential oils, etc.

3. Importantly, mapping must show long term planning from planting to maturity. It is recommended to develop several mappings that represent vegetative growth through time within two, five, ten years, and so on.

    - An aspect to consider is the width of tree canopy as their shadow affects the growth of other species underneath. Although trees that reach V8 level climax height are desirable, a continuous canopy may impede the growth of production crops.

- Another significant aspect is the speed of growth. Consider the short-, medium-, and long-term objectives of the farm in respect to the natural development of vegetation, and plan accordingly.

- If the end objective is commercial, you should consider the level of investment of resources and known yield for different species, before selecting them from the database or nursery.

4. After objectively assessing the work and the AF species suitable for the land, you can begin to collect seeds. Treatments include a detailed list of all of the species you plan to plant, and their approximate locations. To do this, it is easier to consult the Gap Analysis mentioned above. This list of species (both native and exotic) should come from the database list of species and the design should consider: species type according to the formula height and coverage. This will enable the designer to judge the distancing in the design. This map may also include proposed infrastructural additions such as composting piles, nurseries, etc.… The farm map or farm plan should reflect not only the current situation but also the desired future condition. Please see Figure 10 below for an idea of how a community-drawn farm plan can look.

A helpful activity is to fill out a socio-economic study of the farm showing past, present, and desired future production uses. Questions to be answered to this end are illustrated comprehensively in Appendix 4.

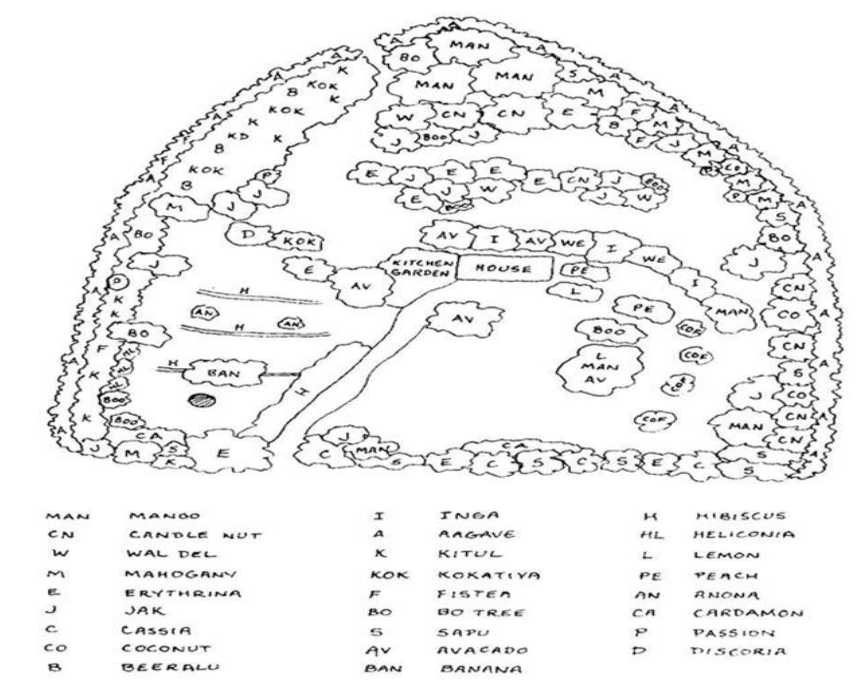


Figure 10: Design map of a potential Analog Forest farm. In it is included: infrastructure reference points, species to be planted (symbols) and locations, as well as neighboring land use.

Establishing Analog Forestry and forest gardens is especially time consuming in the first years. Detailed work plans should be made to schedule activities for soil improvement, planting (new species and enrichment planting), and other management activities such as clearance of undesirable species, weeding, pruning, thinning, and protection. After the initial two or three years, the forest garden will become less labor intensive as it becomes more and more self-maintaining. See Appendix 5 for a sample schedule of activities that can be tailored to the farm's needs over time.

Growing Soil: Secrets to Healthy Plants

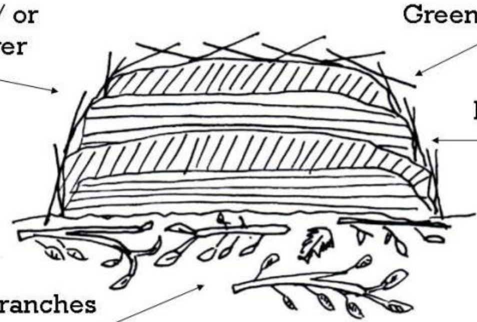
What is soil? Healthy soil looks chocolate brown and feels crumbly, loamy, rich and tilth. While it seems light, it's densely charged magnetically, minerally, and elementally.   Two grams of backyard soil contain millions of bacteria and fungi, thousands of protozoa and nematodes, hundreds of ciliates, flagellates, amoebas, algae, and even some micro arthropods and earthworms. Soil is alive with organic matter and microorganisms who burrow, feed, multiply, excrete, and decay—releasing essential plant soluble minerals, nutrients, and fluids in the process. The feeding, mating and predation cycles of all these microorganisms in a balanced soil creates a perfect habitat for healthy plants to thrive. By feeding the soil rather than the plants we build a long-lasting ecology that is both durable and resilient.

There are seven main groups of organisms at work in our soils at a given time: Bacteria, Fungi, Actinos, Protozoa, Nematodes, Arthropods, and Earthworms. Together, all of these critters create a circle of life, a feeding chain that we are a part of.   They form the soil food web that relies on diversity for resiliency. Creating the conditions for beneficial organisms to thrive allows them to make a nutrient rich medium that strengthens plant growth and immunity for our gardens and orchards.

Making compost and soil is an acceleration of the natural dynamic forces that create abundant, self-fertile meadows, prairies, and forests.   It is really helpful as you get started on a piece of land to submit soil samples to a laboratory in order to better understand the structure of your soil or that of a client if you are consulting. Sampling is done to determine the mineral and the biological content of soil or compost and the results come with recommendations for how to improve the quality of your soil.

Compost Methods:

1). Backyard Compost Piles: For those who do not worry about weed seeds and have little or no time, then piling up a sandwiched layer of equal amounts of green yard waste/kitchen scraps and brown leaves/cardboard/straw/ in a corner of the yard and letting it decompose for a few months is one option.   Be sure to water it to sponge-like consistency and cover with straw and a tarp (or in the tropics, tin). Pile it on top of small branches and leaves to allow good airflow, keeping it aerated. You can also use poles or branches to poke holes to aerate the pile. This will produce compost, not the highest quality, but better than sending these resources to the landfill. **NOTE: if it does not smell, then that is a good sign.**



Do **not** Compost

Cooked food
Fish
Meat
Coal ash
Cat or dog faeces
Diapers
Diseased plants
(soil-borne illness)

Do Compost

Green
Grass cuttings
Fresh plant trimmings
Weeds (avoid seeds)
Animal manure (herbivores)
Kitchen scraps (peels, tea bags, etc)

Brown
Dried leaves
Hay
Straw
Wood shavings
Paper products (cardboard, egg cartons, etc..)

2). Heated Layered Pile*:* Piles that are mixed and watered properly and that have a minimum measurement of one cubic yard will heat up to 130-160 F degrees at which temperature most or all of the weed seeds in the pile will be sterilized. The heat generated in the pile comes from the friction of the microbes at work decomposing and feeding on the elements in the pile. The critical elements of effective compost piles are the correct ratio of carbon to nitrogen, optimum moisture and proper size.

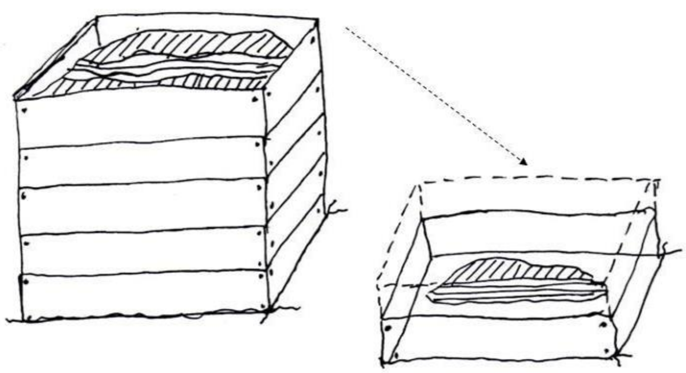
C: N Ratio*:* The goal is to establish a carbon to nitrogen ratio of about 30:1. A good rule of thumb is: green materials (grass clippings, fresh plant trimmings, kitchen waste, and manure) are all high in nitrogen. Brown items (dried leaves, hay, straw and wood shavings) are all high in carbon. Add roughly half brown and half green for proper C:N ratio.

Moisture*:* The moisture level of the pile should be like a sponge that you have just wrung out. Be sure to water thoroughly as you make it, it is very important that the whole pile is humid but not wet, to create optimum conditions for the microbes to thrive.

Size*:* At least 40 inches on each side and 40 inches deep to ensure proper temperature to kill off unwanted seeds. Mix all ingredients really well either as you build the pile or after it is all layered if you have a tractor or a whole lot of people.

Ingredients: There are many different amendments we could add to the pile as we build it. Among these are, small quantities of finished compost as inoculants, or various minerals, liquid humate or fish or seaweed to help feed the biology that is digesting your pile.

Turn the original pile into the 2nd container when full or monthly



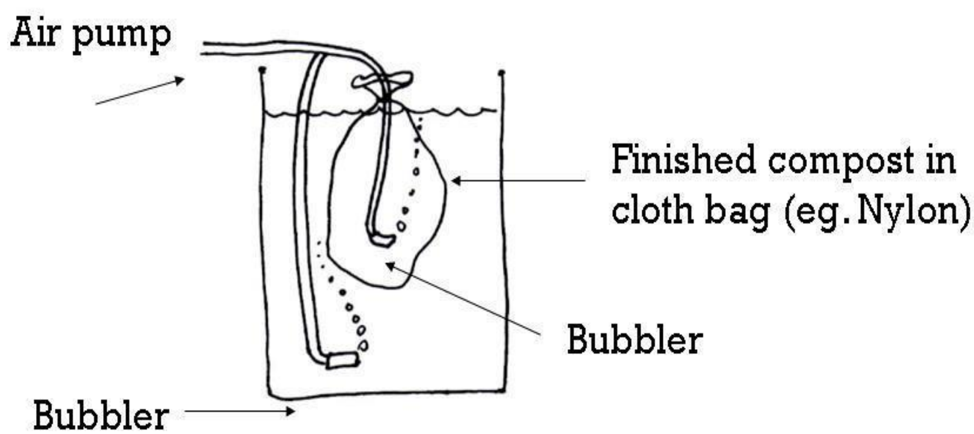
Turning the Pile: The pile can be turned after it heats up for the first time and begins to cool (about 3-4 weeks later). This will help all the material in the pile to break down more uniformly. Piles that are turned less have more nitrogen; piles that are turned more have more humus.

3). Composting in Place*:* The sheet mulch method of composting eliminates the need to build compost piles outside the garden and achieves the creation of compost in the place where the bed will be. The method of creating compost piles in caps is a very effective structure for producing good soil.

4). Composting with worms/vermiculture*:* Earthworms are amazing decomposers, they consume rotted kitchen waste, manure, cardboard and many other substances. They consume at least half their body weight every day, and produce a fine soil as these foods pass through their guts. The compost produced by worms is very high in beneficial microbes that live in the worms' stomach. They are microbes that promote plant growth. There are many different commercially available devices for helping to raise worms. The most important thing to consider is the harvesting of the material.

5). Containment: There are many different methods for containing compost. For gardeners, there are commercially produced containers that range from $50-$150. If not turned frequently, these units may not aerate properly and so anaerobic conditions arise, where non-beneficial organisms may multiply. We can also use four pallets screwed together and lined with chicken wire, or four bales of hay lined up side to side to form a square, then fill in the center with the layers. We recommend filling these containers, building a second container, and turning the original pile into the second container once a month or so to aerate and accelerate aerobic digestion and decomposition. We turn the pile for texture and to make sure anaerobic conditions do not arise within the pile. Larger scale operations use a windrow method to make it easy to access with a tractor or compost turning device.

6). Aerobic Compost Tea: Compost tea is a living brew of aerobic microorganisms that when used as a foliar spray can help to prevent or treat fungal infections and when used as a soil soak can help balance the biology of the soil. It is created by suspending a “tea bag”, with finished compost in a tank of water, adding nutrients, and then aerating the water thoroughly for 24 hours or more. The resulting liquid is a highly concentrated soil food that can be applied at the rate of 5 gallons per acre as a foliar spray or 5 gallons per ¼ acre as a soil soak. For successful compost tea brewing, having properly prepared compost is the key, worm castings work very well as does finished compost. If you have any doubts about the quality of the compost you are using, it is very wise to submit samples to a lab for biological testing. Most soils are deficient in the fungal element. Soaking compost with humic-acid and fish emulsion increases the fungi in a compost tea brew product and can be applied to leaves, soil, and compost piles to enhance diverse beneficial microbes in the soil biology.



Monitoring and evaluation

Monitoring and evaluation seek to identify difficulties, solutions and best practices for the implementation of an Analog Forestry system. Monitoring is the systematic and ongoing collection of information over time which can be used to assess the progress made. Monitoring is important to assess whether the Analog Forestry plan is implemented as planned and to assess whether the Analog Forestry interventions will lead to the desired results. Monitoring can help identify difficulties at an early stage, so the strategies and activities can be adjusted to reduce problems and avoid later failures. Monitoring can also help to identify solutions and best practices; this is important if the intervention is to be replicated elsewhere.

There are different levels of monitoring. Compliance monitoring is needed to assess whether all the planned activities are being carried out properly. Impact monitoring is needed to assess if the implemented activities will or have led to foreseen as well as unforeseen impacts, such as soil improvement, increased incomes and increased biodiversity. Relevant impact indicators for Analog Forestry systems can include:

- The reappearance of keystone flora or fauna species recorded in Step 1, describing the climax stage of a forest
- The presence and development of a humus layer
- The growth rate and crop productivity of several species
- Increased economic returns
- Development of the seral stages

For each zone, relevant impact indicators should be identified based on the Analog Forestry plan and the developed vision. An evaluation is an assessment of progress and achievements made. In the context of Analog Forestry, an evaluation looks at the background, objectives for the Analog Forestry zone, results achieved and activities implemented in the zone with the goal to draw lessons that may guide future interventions to become more effective and efficient. Please see Appendix 6 for a detailed sample plan for monitoring purposes.

Community land use planning is essential in many places because residential areas are generally concentrated and agricultural and forest lands are scattered over the community area. Furthermore, land use options as identified in the land use plans are fixed and need to be implemented in the field once the plan is approved by the relevant authorities. Changing land use options is difficult and essentially only possible when a new plan is prepared.

The current land use in a community should be assessed before starting to develop the community land use plan. A number of secondary documents may be available that contain relevant information about current land uses such as socio-economic statistics, areas under agricultural production and production yields and areas managed by various organizations and management boards. These documents can often be obtained from the community and/or commune authorities. After collecting existing secondary data, the data need to be updated. PRA techniques such as 3D modeling, transects and interviews can help visualize and facilitate discussion on the existing land use situation in the field.

A final 3D model can be used for future reference and discussions and should show the major features of the community (such as roads, residential areas and rivers), different land uses, forest status, boundaries of different land tenures/occupants (boundaries of the community, boundaries and other subdivisions within the community, administrative boundaries of State Forest Enterprises , Protection Forest Management Boards, Protected Areas, and lands allocated to households and organizations), and boundaries of "production forests", "protection forests" and "special-use forests", if desired.

Nurseries & Seed Production

The nursery is the location where various good quality, low-cost plant species are produced. It is here that plants complete their first stage of growth to be later transplanted into their determined location.

Types of nurseries

A. For their duration:
   - Temporary
   - Permanent

B. For their end result:
   - Commercial
   - Educational
   - Experimental
   - Communal
   - Institutional
   - Family based

Technical aspects to consider for nursery site selection:

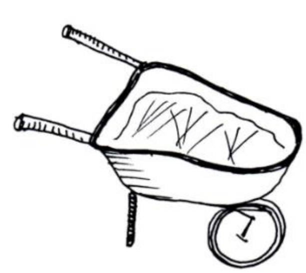
- Available access
- Water supply
- Terrain topography with slope from 2 to 5%
- Soil (best when light, deep, with good drainage and neutral pH)
- Proximity to resources of the zone: earth, organic matter, construction materials (bamboo, wood etc.)
- Location close to a dwelling to facilitate care and surveillance

Essential materials and tools:

- Shovels
- Bars
- Rakes
- Pick
- Pails
- Shade netting
- Seeds
- Register book
- Wheelbarrows
- Measuring tape
- Rope
- Stakes
- Plastic bags
- Hoe
- Sprinkler
- Water holding tank
- Pruning shears
- Machetes

Nursery Elements

A. Shaded plots
B. Germination beds
C. Production area for bare root plants
D. Composts
E. Vermiculture
F. Production area for vegetables and medicinal plants
G. Reproduction area for non-arboreal species: epiphytes, heliconias, ornamentals, etc.
H. Water Reservoir



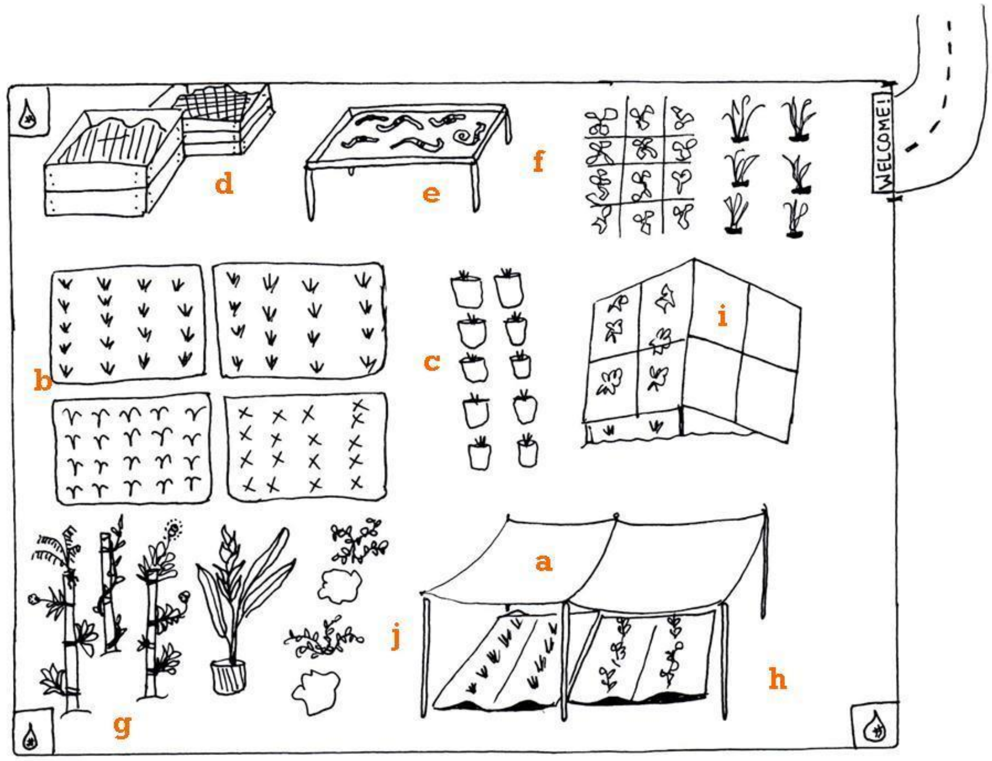


Figure 11. Sample nursery design

Figure 11 above shows a sample design and layout for nurseries. The elements are matched with the letters above. This is a flexible design and will be dependent on the resources and funding available for the AF project, in addition to its ecological and economic objectives. The establishment of a nursery should also consider elements such as proximity to the AF restoration plot, water sources, shade, and ease of access, among others.

Steps to follow in plant production

Tree selection

These trees must have desired characteristics to transmit to new plants, whether they are timber or fruit trees. In the case of timber trees, they must be mature, neither very old nor very young, have a well-formed canopy, be large with a straight trunk, and free of plagues and disease. Fruit trees must have well-formed canopies, leafy, with low branching and not very young nor very old, free of plague and disease, and have an abundance of fruit. These trees can benefit us through seed production or provision of seedlings through natural regeneration.

Seed collection

Seeds collected must be free of impurities, skins, and pulp. There are fleshy seeds whose viability is short lived and should be sown as soon as possible (example Zapote, Tangara, etc.). Once the seeds have been collected, they are dried in a location where they are not exposed to direct sun. They thus will have a longer viability and can be stored for more time.

Substrate preparation

The type of substrate that is prepared determines the success of the plants that will be produced. The materials used for substrate preparation are: sand, forest soil, humus, or compost. The proportions of these for substrate preparation will vary according to the type of soil.

Sowing

Sowing is the process of placing seeds in the substrate or ground and burying them in a pit so that they germinate. There are various forms of sowing:

- By wind: uniform dispersion of seeds over the substrate
- Furrows: Place seeds in rows, with spacing depending on the seed size
- Direct sowing into pots

Planting the Plot!

The first step prior to the planting is determining the soil condition. Generally, farmers work with soil that is from the B or C horizon, that is to say eroded soil.

In this case, some of the following must be done:

Soil conservation practices:

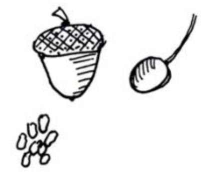
- Contour planting
- Cover crops
- Collection strips
- Living fences (preferably planting nitrogen fixing species like *Erythrinas* and *Gliricidia sepium*)

Mechanical Practices:

- Absorption trenches
- Deviation trenches
- Lateral irrigation ditches
- Settling trenches

Planting consists of putting good quality plants that have characteristics such as: health, growth, lignification, among other important aspects. The location of the species within the plot is followed according to the plot map and design.

Exchanging seeds



The IAFN promotes seed exchange among farmers and organizations from distinct communities, regions, countries, and continents.

Seed exchange is very important because it lowers the cost of procuring useful seeds from their original location. It permits farmers to have access to quality seeds, economic potential, and reinforces the feeling of cooperation and exchange among rural communities. All exchange of genetic material is sacred and includes a serious commitment from both the giver and the receiver. Seed exchange is also a way to pass on and maintain valuable traditional knowledge.

The holes must be 40 x 40 cm with much organic material added to guarantee optimal rooting development of the seedlings

It is indispensable to minimize the risks that are brought about with the use of exotic species. For this reason, the IAFN has established as a prerequisite to the exchange, the use of an ecological screening and formula for samples of new species, paying close attention to the mode of reproduction.

Requirements for exchanging seeds

There are two principal considerations when deciding to introduce exotic species:

1. How successful this species will be in the new community, and
2. How much will their presence favor other members of the community

These ecological considerations are evaluated through an ecological risk assessment process, whose application is recommended for each species that may be exchanged.

Treating Seeds

- Seeds must be cleaned of pulp and treated to avoid disease
- Phytosanitary regulations indicate that seeds must be dried, disinfected and stored in sealed bags.
- Species introduction can be damaging if the best precautions are not taken. Avoid dispersing seeds that are virus carriers.
- Pass the approval of the phytosanitary departments of each country.

Information exchange

Attached to the seeds that are to be exchanged must be a card consisting of the following information:

Information card

Name:
Plant characteristics:
Uses:
Ecological Functions:
Elevation:
Structure:
Height:
Minimum conditions for plantation:

Marketing

By growing new species or varieties, the Analog Forestry farmer may be able to access or create new market opportunities. As the initial volume of the new products will be small, the risks to the farmer in marketing such products will also be small. The new and emerging markets for organic, ecological friendly and fair-trade products may create opportunities for adding value through certification or labeling of products from analog forest farms. The possibility of higher premiums paid for products in these markets may provide an incentive for wholesalers and exporters to seek out the products from Analog Forestry farmers.

The goal of certification is to improve the environmental, social and economic aspects of natural resource management by ensuring market access for responsibly produced products. There are several certification schemes that are relevant to Analog Forestry, including:

- Forest management certification
- Social certification
- Organic certification and
- Product quality certification

Forest Garden Products (FGPs)

What are FGPs?

Forest Garden Products are crops grown by farmers whose practices have been certified to contribute to agricultural sustainability, biodiversity conservation and environmental stability. FGPs are collected exclusively from these forests.

What is FGP Certification?

Certification is a promise to the consumer that guarantees the origin and quality of the products. The certification of FGPs provides an important economic incentive for the development of Analog Forestry. This certification system was established by the Neo Synthesis Research Center (NSRC) in Sri Lanka to support farmers that were in the transition process from traditional agriculture to Analog Forestry and to an increase in biodiversity and vegetative structure.

The certification of FGPs is designed to confirm the increase of biodiversity, biomass, and sustainability of the landscape, objectives that go beyond typical organic certification systems. In addition, this certification system is designed with the objective of creating reservoirs for the long-term sequestration of carbon. Within this certification, there is a guarantee to the consumer:

- Clean products (without chemical additives)
- Products with high nutritional value
- Products elaborated following Analog Forestry practices or similar silvicultural practices

Certification of FGPs also takes into account social aspects, assuring:

- Equality for the producer
- Better access to markets
- Fair prices and value-added to the farmer
- Recognition of the effort of the producer

To be FGP certified, the producers have to outline a ´Whole Plan Farm Design´ that must be approved by certifiers. The outlines are similar to the guidelines offered by the IAFN but include FGP-specific requirements. See requirements in Appendix 7.

Box 6: FGPs in Sri Lanka

In Sri Lanka, products from analog forests are certified and labeled as "Forest Garden Products." The price obtained by farmers growing these products through AF is much higher than the price obtained by farmers growing the same agricultural products conventionally with chemical fertilizers and chemical pesticides. For example, the price for conventionally produced Kitul Palm Syrup is US $ 1.00 in Sri Lanka while forest garden certified products sell for US $ 2.00 locally and US $ 3.50 in Europe. Similarly, the price for conventionally grown Guarana in Brazil is now US $ 18.00 a kilo while the certified product is exported at US $ 35.00 a kilo.

** All figures quoted were prevailing in June 2005*

Apart from the socio-economic benefits derived from Analog Forestry, it is important not to forget that ecological restoration also seeks to improve landscape aesthetics by emulating productive undisturbed primary forest. Figure 12 below demonstrates the stark visual contrast at the landscape level between AF and conventional land use practices in the Mirahawatte area of Sri Lanka. This forest design improves landscape aesthetics, biodiversity, essential ecological characteristics, as well as market opportunities for the community. [8]

[8] Senanayake, Ranil. 2002. Analog Forestry as an Art Form. Aesthetic Studies Conference, Royal Asiatic Society, Colombo, Sri Lanka.

Figure 12: Comparison of AF landscape aesthetics (right) and conventional land use (left)

APPENDIX 1: SOIL PROFILE EVALUATION

METHODOLOGY

Materials

- Measuring tape
- Wide shovel
- Stakes to define the sampling area

Procedure

- Define the sampling area

- Make a cross section cut of the soil of at least 1 meter sq. by 1 meter deep that allows easy observation of soil horizons.

- Identify and measure the horizons. Focus on:
  - Color changes
  - Biological characteristics (many, a few, no activity)
  - Abundance of roots (many, some, few)
  - Stains (many, few, no stains)
  - Texture (Sandy, silt, clay or loam)

SOIL TEXTURE EVALUATION

Determination of soil texture in the field using the hand method: a homogeneous paste is made by wetting the sample and kneading it by hand. Once this has been done the sample is pressed between the thumb and index finger until a thin layer is formed. This layer is observed to detect whether it is shiny, if it is smooth or scaly, or if it is rough to the touch.

If the sample is sandy:

It is rough and abrasive to the touch, it does not shine and has no cohesion; no thin layer is formed.

If the sample is silt:

It is smooth to the touch; a layer with scales is formed and is not sticky or plastic

If the sample is clay:
The layer formed has cohesion, plasticity, shines and is sticky depending on the moisture content.

Once the percentage of each component has been estimated it is possible to determine the soil class using the textural triangle. See image below:
www.pr.nres.usda.gov

3. EVALUATION OF SOIL INFILTRATION

TABLE 1. Infiltration and compaction indicators

Value	Characteristic
1	**Impermeable:** Compact soil, it floods
5	**Slow infiltration**: Presence of a thin compact layer, water infiltrates slowly.
10	**Moderate infiltration**, non-compact soil, water infiltrates easily

* If a more precise estimation of this indicator is needed, it is possible to include ranks according to the characteristics of the surroundings and the soils under observation.

METHODOLOGY

Materials

- 6 inch diameter ring
- Plastic wrap
- Plastic bottle or graduated cylinder- 500 ml
- Distilled water
- Chronometer or Schedule programmer

Procedure

- Put and fix the ring on the trial site to prevent water loss
- Cover the ring with a plastic pouch
- Pour 444 mL (1 inch) of distilled water in the ring covered with plastic
- Remove the plastic cover, pulling carefully outwards, leaving the water inside the ring
- Afterwards register the time (in minutes) for the 444 mL (1 inch of water) to penetrate the soil.
- Stop the chronometer when the surface becomes shiny, that is, when the water has totally infiltrated and record the time (in minutes)

EVALUATION OF APPARENT DENSITY

TABLE 2: Indicators of soil apparent density and root growth based on soil texture

SOIL TEXTURE	IDEAL Da (g/cm3)	AFFECTS ROOT GROWTH Da (g/cm3)	LIMITS ROOT GROWTH Da (g/cm3)
Sand, sandy-loam	< 1.60	1.69	>1.80
Loamy-sand, loam	< 1.40	1.63	>1.80
Loam-clay-sandy, loam, loamy-clay	< 1.40	1.60	> 1.75
Silty, loam-clay	< 1.30	1.60	> 1.75
Loam-silty, loam-clay-silt	< 1.40	1.55	> 1.65
Clay-sandy, clay-silty, some loam-clay (35- 45% clay)	< 1.10	1.39	> 1.58
Clay (>45% clay)	< 1.10	1.39	> 1.47
Value	**10**	**5**	**1**

METHODOLOGY
Materials

- 3 inch diameter ring (7.62 cm)
- Mace
- Wood block
- Gardening scoop
- Wide blade knife
- Ziplock bags and permanent marker
- High precision scale (down to 0,1 g)
- Measuring cup 1/8 cup (30mL)
- Paper cup
- 18 inch metal rod
- Oven

Procedure

STEP 1

- Stick the ring in the ground

Using the mace and the wood-block, insert a 3 inch diameter ring (7.62 cm) with the edge downwards 3 inches deep.

In order to measure soil volume accurately, it is necessary to determine the exact depth of the ring. This is done by measuring the height of the ring above the ground. Take four measurements (at roughly similar distances) of the height from the upper ring border to the ground surface and calculate the average.

- Remove the ring
- Remove excess soil. The base of the sample should be flat, cut and levelled.
- Put the sample into a bag and tag it.
- Weigh and record the measurement (i.e. the wet weight)

STEP 2

- Dry and weigh the sample (record the dry weight)

Apparent Density Calculation:

Water content in the soil (g/g)**:**

$$= \frac{\text{(Weight of wet soil – Weight of oven-dried soil)}}{\text{Weight of oven dried soil}}$$

Soil apparent density (g/cm^3) $= \frac{\text{Weight of oven dried soil}}{\text{Soil volume}}$

Soil porosity (%) $= 1 - \frac{\text{(Soil apparent density)}}{2.65}$

Space of pores occupied by water (%) $= \frac{\text{Water content in volume x 100}}{\text{Soil porosity}}$

Water content in volume (g/cm^3)

$$= \text{Water content in soil (g/g) x Apparent density } (g/cm^3)$$

APPENDIX 2: METHODOLOGY FOR EVALUATION OF SOIL CHEMICAL INDICATORS

METHODOLOGY FOR SOIL SAMPLE COLLECTION

SAMPLE SELECTION

- Timing

Stable weather is the best time for sampling because the soil has not been disturbed, allowing for more accurate measurements.

- Factors to take into account in the sampling process

Land lot variability: Soil properties vary naturally across the land lot and even within the same soil type. Therefore, the general characteristics to be considered in each land lot will be the following:

- Differences among soil types
- Differences in growth among species in general
- Differences in slope
- Moist areas versus dry areas (drainage)

Samples must not be collected from dirt roads, ledges, bumps, eroded areas, plant material accumulation areas, dung, places where frequent fires have taken place or swamps (Como tomar muestras de suelo para su análisis químico, Washington Vejarano, INIAP).

- Number of samples

The number of samples depends on the land lot variability.

A minimum of **three samples or measurements** of each soil type combination should be collected. Each sample contains several sub-samples; the number of sub-samples varies according to each land lot conditions. Consequently, the number of samples needed to reach a representative value will change with the variability of the selected land lots.

The samples are collected in zig – zag across the lot, taking into account the above-mentioned considerations in order to obtain more accurate information.

1. EVALUATION OF SOIL NUTRIENTS

TABLE 3: Nutrient indicators N, P, K.

Value	Characteristics for coast	N	P	K	Unit
1	**Low**	< 31	< 8	< 0.2	**N – P** (ppm)
5	**Medium**	31 – 40	8 – 14	0.2 – 0.4	**K** (meq / 100 ml)
10	**High**	> 40	> 14	> 0.4	

National Department of Soil and Water Management, "Pichilingue" Tropical Experimental Station, INIAP, 2002

2. ORGANIC MATTER EVALUATION

TABLE 4: Organic Matter Indicators

Value	Characteristics for coast	Range	Unit
1	Low	< 3.1	**%**
5	Medium	3.1 -5	
10	High	> 5	

National Department of Soil and Water Management, "Pichilingue" Tropical Experimental Station, INIAP, 2002

3. EVALUATION OF SOIL pH

TABLE 5: pH indicators

Value	Characteristics soil for coast	Range	Unit
1	Acid and very acid	<5.5	NA
5	Moderately acid	>5.5 – 6	
10	Optimum	6.0-7.0	

USDA Guide for Soil Quality and Health Evaluation.

METHODOLOGY

Materials

- Measuring cup, 1/8 cup (30ml)
- Plastic bottle
- Buffer mixture for calibration
- Distilled water container
- Pocket pH meter (red with black cap)
- Distilled water

Procedure

- **Measure and record pH level**

It is necessary to periodically calibrate your pH meter. If the meter has not been used for some time, put it in potable water for about 5 minutes before calibrating it or performing measurements.

Insert the pH meter in the upper sector of the mixture and turn it on. Wait until the meter stabilizes (30 seconds), and register the digital reading on the Soil Data worksheet.

- Rinse the Pocket Meter

Rinse the electrode thoroughly with distilled water.

Pack the electrode with a few drops of the buffer mixture pH=7 and put the cap on.

APPENDIX 3: METHODOLOGY FOR BIOLOGICAL INDICATOR EVALUATION

1. EARTHWORM PRESENCE EVALUATION

METHODOLOGY

Materials

- Potable water (2L)
- Garden scoop
- Jar for earthworm collection and cleaning
- Mustard mixture (2 tablespoons of mustard powder in 2 litres of potable water)

Procedure

- Dig a $1m^2$ pit 30 cm deep, trying not to damage the earthworms

- Take apart and count the earthworms

- Register the total number of earthworms (those found in the pit)

TABLE 6: Earthworm presence indicators

USDA Guide for Soil Quality and Health Evaluation

Value	Characteristic	Range	Unit
1	No trace of biological activity, no earthworms observed	0	Earthworms/ m^2
5	Some earthworms and arthropods	5 – 10	
10	Intense biological activity, abundant earthworms and arthropods	> 10	

EVALUATION OF THE STATE OF DECOMPOSITION OF PLANT RESIDUES

TABLE 7. Indicators of Plant Residue Decomposition

Value	Characteristic
1	Presence of organic residues that do not decompose or decompose very slowly
5	Observation of residues in decomposition process
10	Residues in various states of decomposition, old residues well decomposed

USDA Guide for Soil Quality and Health Evaluation

METHODOLOGY:
This indicator will be evaluated through direct observation of the land lot.

APPENDIX 4: SOCIO-ECONOMIC STUDY OF THE FARM

TABLE 8. Criteria to evaluate economic objective of farm for design purposes

Name of the farm:		
Name of the property owner:		
Family information		
Name of family member / other individuals working on the farm	**Age**	**Responsibilities**
Farm location:		
Total area:		
Desired location of Analog Forestry site:		
Previous uses of the farm:		
Present uses of the farm:		
Products and services that the farm sells		
Products of the farm which the family consumes:		
Needs or interests of the farmer, the family and the communities, as the market possibilities exist at a local, national, and international level.		

APPENDIX 5: SCHEDULE FOR AF ACTIVITIES

TABLE 9. Sample activities plan

Activity plan												
	Period 1				Period 2				Period 3			
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land preparation												
Compost preparation												
Seed collection												
Seedling preparation & transplanting												
Planting												
Plantations (transplant plants from the farm nursery or the species produced outside the farm)												
Enhancement of the site (plantations or past planting)												
Fertilization												
Maintenance – cleaning (pruning, surrounded, grass and weed removal, etc)												
Harvest (agricultural products, non-timber forest products, etc.)												
Forest harvesting												
Other:												

Source: Elaborated by Julio González Buitrago Red Iberoamericana de Bosques Modelo 2010.

APPENDIX 6: ANNUAL MONITORING PLAN

TABLE 10: Annual plan on establishment, enhancement, and maintenance of site for monitoring purposes

Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Ago	Sept	Oct	Nov	Dec
Landscape map and initial map of the site												
Physionomic formula determined of the native forest												
Physionomic formula determined of the site at different points in time (before the establishment of the Analog Forestry system, after establishment and annual updates)												
Analysis of the physionomic gap												
Ecological evaluation and monitoring the biodiversity (before AF establishment and after, every 2 years)												
Design of the Analog Forestry site (and after annual updates)												

Source: Adapted from MAG et al. 2006. Cuaderno de Mi Finca

APPENDIX 7: FGP WHOLE FARM PLAN

The information below is the required input from our IAFN Intl. Standards for Forest Garden Products.

The Whole Farm Plan for FGP's (FGFP): This is a detailed map indicating the physical and ecological structures existent on the property. These will also serve to provide a work plan for the establishment of a Forest Garden. Even though the farm plan or mapping may begin to be rough, is it hoped that in all cases the FGFP would demonstrate a sophisticated betterment and conformity over a lapse of 5 years. A complete FGFP must contain the following characteristics as a minimum:

a. Existing drainage patterns
b. Crop patterns
c. Existing infrastructures
d. Existing roads
e. Existing vegetation patterns
f. Ecological evaluation
g. AF design
h. Implementation plan

An exception can be made to the requisites f, g and h to farmers who do not have the capacity or formation to produce an FGFP. An accredited inspector must fix the time period for this.

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International Analog Forestry Network

The International Analog Forestry Network was created in 1996 in response to the need to maintain an exchange of knowledge, experiences and updated information among organizations interested in learning, promoting and applying the Analog Forestry system in their localities.

The main objective of the Network is to achieve the restoration of environmental stability and the biodiversity of ecosystems, through research, design and application of the Analog Forestry system.

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