Contenido

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Water forests

Approach aimed at reducing water scarcity through reforestation with native trees that favor the recharge of groundwater.

"Water is the driving force of all nature".

Leonardo Da Vinci.

Introduction

Water is one of the resources that suffers the most pressure due to the irrational use that humans make of it as a direct or indirect tide. In general, the poor management and use of this resource causes, in a direct way, the contamination of the diverse sources of water by domestic, agricultural and industrial wastes. And indirectly, by the felling of trees that affects the recharge of the groundwater table. Consequently, the availability of good quality water for human consumption and food production is dramatically reduced in an increasingly accelerated manner.

Water in the world is an increasingly scarce resource. "Water use has been increasing at an annual rate of 1% worldwide since the 1980s, driven by a combination of population growth, socio-economic development and changing consumption patterns. Global demand for water is expected to continue to increase at a similar rate until 2050, representing an increase of 20 to 30 per cent above the current level of water use, mainly due to increased demand in the industrial and domestic sectors. More than 2 billion people live in countries experiencing severe water shortages, and approximately 4 billion people experience severe water shortages for at least one month a year. Water scarcity levels will continue to increase as water demand grows and the effects of climate change intensify", UNESCO, 2019.

Faced with this problem, it is urgent to generate strategies whose actions are aimed at reducing the scarcity of water from favoring the recharge of groundwater, this because "groundwater [...], has an important role in the supply of fresh water as it directly affects the hydrological cycle" Zaccagnini, M. 2014. In this context, the creation of water forests through reforestation with native trees that favor the recharge of the water table is proposed as a viable alternative, for which the implementation of community nurseries that allow the reproduction of species with the active participation of the inhabitants of the communities of the region is required, with the purpose of strengthening reforestation actions from the local perspective. In addition, the reforestation process should include complementary actions for soil conservation.

Consequently, water forests constitute an educational space oriented to environmental education with global awareness and local action.

In this document, the procedure for the implementation of Water Forests is proposed.

What are water forests?

Water forests are a method to encourage the recharge of groundwater, and the gradual restoration of structural characteristics and ecological processes of natural forests. Its main objective is to regularize the water cycle and increase the availability of water in the aquifers, to the benefit of the population.

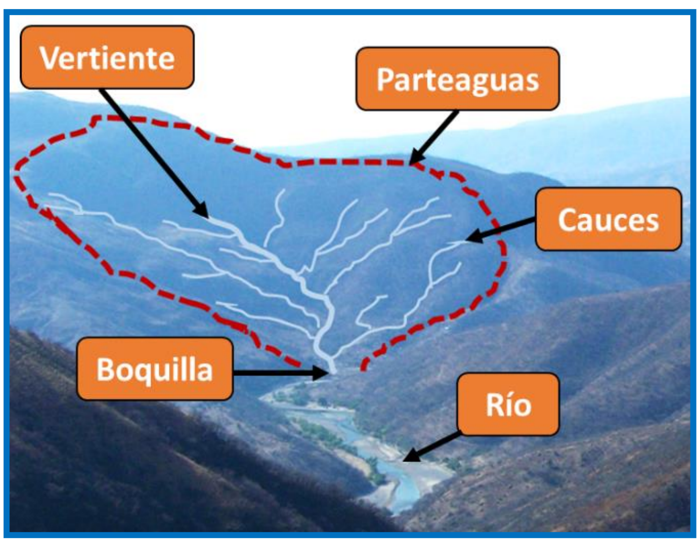
"Groundwater plays an increasingly important role [...], thanks to its physical characteristics that allow it to be exploited in a versatile way, it functions as storage dams and distribution networks, being possible to extract water at any time of the year from practically any point on the surface of the aquifer. They also function as purifying filters, preserving the quality of the water", CONAGUA, 2018.

In order to ensure that the creation of water forests fulfills the above-mentioned objectives, it is proposed to return to the principles of integrated watershed management, in order to carry out an integral and gradual process with long-term results.

The Basin

Generally speaking, a basin can be said to be an area drained by a system of currents where the runoffs, the product of the precipitations generated on it, converge at an exit point on the earth's surface.

Figure 1. The basin and its constituent parts



Cotler A, E. et. al. (2013) define river basins as naturally defined territories where all socio-ecological processes are intimately linked to each other. And in them, management is understood as a process of planning, implementation and evaluation of actions through the organized and informed participation of the population.

Hydrographic basins are territorial spaces delimited by a watershed (higher parts of mountains) where all the runoffs (streams and/or rivers) converge and flow into a common point also called the basin exit point, which can be a lake (forming a basin called endorreica) or the sea (called an exorreica basin).

In these territories there is a spatial and temporal interrelation and interdependence between the biophysical environment (soil, aquatic and terrestrial ecosystems, crops, water, biodiversity, geomorphological and geological structure), the modes of appropriation (technology and/or markets) and the institutions (social organization, culture, rules and/or laws).

Cardoza V, R., et al. (2007), state that the characteristics of basins, such as shape, size, relief, vegetation, use and exploitation of natural resources directly influence the behaviour of surface runoff and water availability.

"The basin is an appropriate framework for the planning and implementation of measures aimed at correcting environmental impacts generated by a disorderly use of natural resources and where environmental management is facilitated (implementation of programs to improve the standard of living of its inhabitants)" Cardoza V, R., et al. 2007.

Integrated River Basin Management

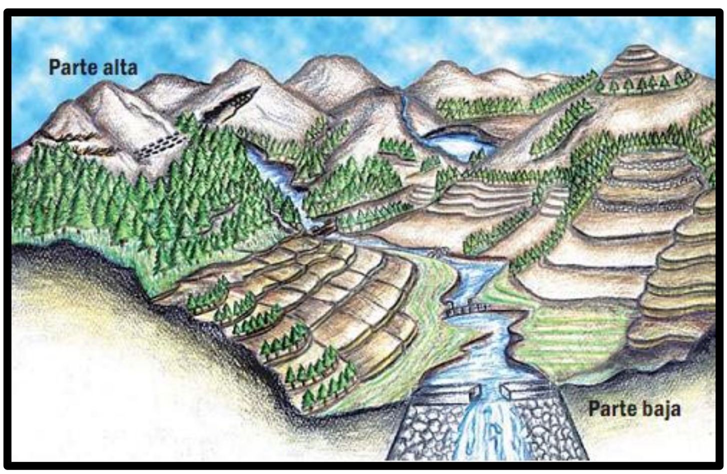
Cotler A, E. et al. (2013) consider integrated watershed management to be a process that seeks the resolution of a complex set of interrelated problems. This process must be adaptive, i.e. it is built and learned from experience, supported by scientific and local information. This process seeks to solve common problems, and therefore requires the concurrence, cooperation and collaboration of diverse actors and institutions with a common vision.

It is very important to point out that the opportunity to carry out an effective basin management begins when its inhabitants are aware of the diverse environmental benefits they obtain from it, either directly or indirectly. Direct benefits such as sources of water, food, medicine, firewood, wood for construction, among others; and indirect benefits such as the creation of soil, the production and accumulation of organic matter, neutralization of some toxic waste to mention a few. In addition, there are other types of benefits called cultural and can be spiritual, recreational or simply aesthetic. Another important aspect is the recognition of the negative impacts generated by the diverse productive activities that are carried out in the zone and that are manifested in all the basin and perhaps with greater impact in the low zones.

Figure 2. Impacts of human activities in a river basin.

Once both the benefits provided by the watershed and the negative impacts of the various productive activities on its proper functioning are recognized, it is easier to visualize the type of actions required in the different parts of the watershed, with the purpose of recovering its proper functioning. Among the most important and of greatest impact are reforestation and soil conservation works, which must be in accordance with the area of the basin where work is intended.

Figure 3. Integrated River Basin Management (FIGURE from CONAFOR manual)



Importance of reforestation with native trees

The adaptability, health, vigour and productivity of each species will be greater the closer the environmental conditions are to those of its environment of origin Ruíz B I. (ed). (2002). In this context, reforestation with native trees acquires viability as a means to achieve the restoration of the water cycle and the recharge of aquifers. Simultaneously, ecosystem restoration can also be achieved because most species provide numerous benefits, such as providing shade, organic matter, shelter and shelter for wildlife, etc., and also perform various ecological functions, such as nitrogen fixation through symbiosis with some microorganisms.

Arriaga et al. (1994), state that at the national level, the results clearly show that a new methodology is needed that includes the use of native species, which would not only contribute to the conservation of native germplasm in situ and ex situ, but also because using species appropriate to the environmental conditions could ensure greater success of this practice, in addition to awakening the interest of the population by reforesting with plants that provide them with some benefit.

In relation to the above, it is convenient to remember that a native forest is a natural ecosystem formed by several endemic species of a territory, where a great variety of trees and shrubs interact with other organisms such as birds, insects, mammals, reptiles, fish and soil microorganisms. In addition to hosting great biodiversity, native forests provide environmental, social and economic services that are important to society in general. Some of these services are: oxygen production, carbon sequestration, temperature regulation, erosion reduction, scenic beauty, etc.

Native trees protect the soil from erosion and act as a regulator of the water cycle, because foliage, bark and leaves cushion the impact of raindrops favoring the slow infiltration of it into the groundwater mantos increasing groundwater flow. Part of this water is used by the various species for their own metabolism and another part is transpired back into the atmosphere in the form of steam, which could lead to increased rainfall.

This ensures the supply of water for the restoration of the ecosystem, human consumption and the development of agricultural and productive activities.

In the reforestation with native trees not only the biological aspect is taken care of, also the social, cultural and economic dynamics of a region are involved, this due to the close relation that exists between the vegetal species and the advantage and management that the populations do of these species.

In this context, it is pertinent to implement community nurseries for the production of native trees, with the purpose of reforesting areas that have been degraded.

Creation of Water Forests

The first step in the creation of water forests consists of identifying the basin, delimiting it and defining the priority areas for reforestation with the aim of gathering the necessary information to know their environmental and social characteristics, in order to start the process of selecting the most suitable species for groundwater recharge and best suited to the conditions of the region.

In relation to the above, in Ethnobotanical exploration and its Methodology, Hernández, X. 2001, raises the importance of consulting the diverse sources of information to be located not only in space, but also in time and culture where the botanical species is found from which we seek to obtain some benefit.

"Locating oneself in space refers to specifying the area of distribution and the limiting ecological conditions [...]. To be located in time refers to trying to delimit the most appropriate time in relation to the availability of propagation material (seed or cuttings) [...], if it is convenient to be located in time, taking into account date of fructification, length of said period [...], longevity of the seed, among the most important details".

With respect to the location in the cultural context, its importance is emphasized because the inhabitants of the region represent a thinking population, a population that has sought to satisfy multiple needs taking advantage of the diverse resources at its disposal, and consequently have accumulated abundant empirical information through the centuries. In this context, Hernandez X. 2001, states that it is widely recommended to obtain information from the local population in the same field of facts.

From the perspective of integrated watershed management, once the areas of work have been defined

Selection of species for reforestation

For the selection process of the appropriate species to be used in reforestation, it is essential to have the greatest amount and diversity of information possible for each species, in such a way that this information allows choosing only those species that on the one hand are well adapted to the conditions of the region, and on the other, that have the necessary characteristics to meet the objective of contributing to the recharge of groundwater.

The main objective of reforestation with native trees is to favor the recharge of groundwater, and adjacently the conservation of soils.

In this sense, it is of vital importance to choose the appropriate species for the fulfillment of this objective.

It is also essential to consider that the selected species should be able to develop well under the particular conditions of the site. This means that, in this case, the climatic requirements and tolerances of the appropriate species for groundwater recharge must be compatible with the environmental conditions prevailing in the reforestation site.

According to Ruiz B I. (ed). (2002), the most important factors to take into account are:

Temperature:

In the tropics and at the local level, temperature is not as relevant for the adaptation of species as the availability of humidity. What is important to consider is that at higher elevations, frost completely eliminates most tropical species.

Precipitation:

The moisture needs of trees differ considerably from one species to another, which is why it is essential for species selection to take into account the total annual amount and seasonal distribution of rainfall.

In this case, the most important considerations are the duration and severity of the dry season. However, rainfall is not the only determinant of moisture availability. Soil water retention capacity and evaporation rates are also critical.

As for soils, the main properties affecting species selection are depth, fertility structure and acidity.

Depth:

The depth available for root growth is of paramount importance in species selection. Species that do not tolerate drought or have shallow roots should not be planted in shallow soils. Similarly, very humid or flooded places should be planted with species tolerant to flooded and poorly aerated soils.

Structure:

Soil structure will affect water movement and retention, aeration and root penetrability. Heavy, compact muds retain more water than sandy soils, but sandy soils favour root development.

Fertility:

Few of the soils available for forests in the tropics are very fertile. Tolerance to infertile soils is a good characteristic of species for planting.

Acidity:

The productivity of some species is limited by excessive acidity or alkalinity. In particular acid soils cause symptoms of aluminum toxicity in some species. In alkaline soils species may suffer from iron chlorosis.

Other factors that could influence plantation survival are: the nature of the existing vegetation at the planting site (e.g., for how long and how recently it has been cut), environmental pollution, whether from air, water or soil, grazing and fires.

It is worth mentioning that Ruíz B I. (ed). (2002), points out that when environmental degradation is very advanced, both native and exotic species are in a very different environment from that of origin and therefore both would have to adapt to a place under adverse conditions.

It is important to fully identify the limiting factors as it is possible to implement actions to solve them.

In this context, the participation of the inhabitants of the region in the compilation and analysis of information is indispensable in order to achieve a good selection of native species, suitable for reforestation.

The selection should also consider the benefits that the species bring to the ecosystem and to the population. As well as the knowledge that the population has regarding the management of each species.

List of forest species that favor the recharge of aquifers

A list of previously selected species is presented, based on bibliographic research, considering their presence and distribution in the areas of interest, and mainly their characteristics that favor the recharge of groundwater.

Tabla 1. Especies propuestas con base en la investigación bibliográfica

No.	Nombre científico	Nombre (s) común
1	*Acer negundo L*.	Maple Mexicano
2	*Alnus acuminata*	Abedul, Aile, Aliso, Elite, Palo de águila, Nok
3	*Taxodium mucronatum*	Ahuhuete
4	*Platanus mexicana*	Alamo
5	*Liquidambar styraciflua*	Sots –té,Cozote, Liquidambar, Quirambor
6	*Olmediella betschleriana*	*Huececilla*, Zapote blanco
7	*Chiranthodendron pentadactylon*	*Lechillo, Palo liso,* Árbol de la manita
8	*Prunus brachybotrya*	Canelillo, Puc. Escobo
9	*Prunus rhamnoides*	Coralillo
10	*Prunus barbata*	Tecunthé
11	*Prunus serótina*	*Capulín, Cerezo*
12	*Magnolia sharpie*	Magnolia
13	*Cornus disciflora*	Botoncillo
14	*Myrsine juergensenii*	Tilil
15	*Cornus excelsa*	Aceitunillo
16	*Meliosma dentata*	Aguacatillo, Cupanda, Palo aguacate
17	*Cornus excelsa*	Isbón, Tzop
18	*Fraxinus uhdei*	fresno y Madre de agua
19	*Buddleja cordata Kunth*	*Tepozan, Tzelepat*
20	*Montanoa leucantha*	*Kail*
21	*Quercus crispipilis*	*Encino blanco, Chiquinib*

Process for the selection of native species for reforestation

The first step in the selection of native species, in conjunction with the region's inhabitants, consists of reviewing the list of proposed species and making an analysis to determine the viability of each one, and based on this choose the most suitable ones. The objective is to include in the analysis the knowledge of the species that the inhabitants have accumulated through the management experiences they have carried out for the use of the species.

Collecting and analyzing the information for the selection of species will be done through the matrix of species and requirements (the corresponding format is presented in Annex I).

From this exercise, some species may be discarded or new ones may be included. The objective will be to select jointly with the inhabitants those species that present qualities for the recharge of phreatic mantles and greater possibilities of adapting and surviving.

The second step will be the verification of information in the field. A field trip is necessary to complement the analysis based on field observations.

Factors for obtaining vegetative material for propagation

Once the most suitable native species for reforestation have been selected, another exercise should be carried out with the inhabitants of the region to determine the process by which the vegetative material for propagation will be obtained.

It is at this point that information on how the selected species are propagated, the time when seed is available for collection, or the time when stakes are recommended should be collected and analysed from a local perspective. Likewise, available information regarding local and historical management of the species should be collected in order to plan and schedule the collection and preparation of vegetative reproductive material. At this point it is determined if the seed requires any pre-germinative treatment.

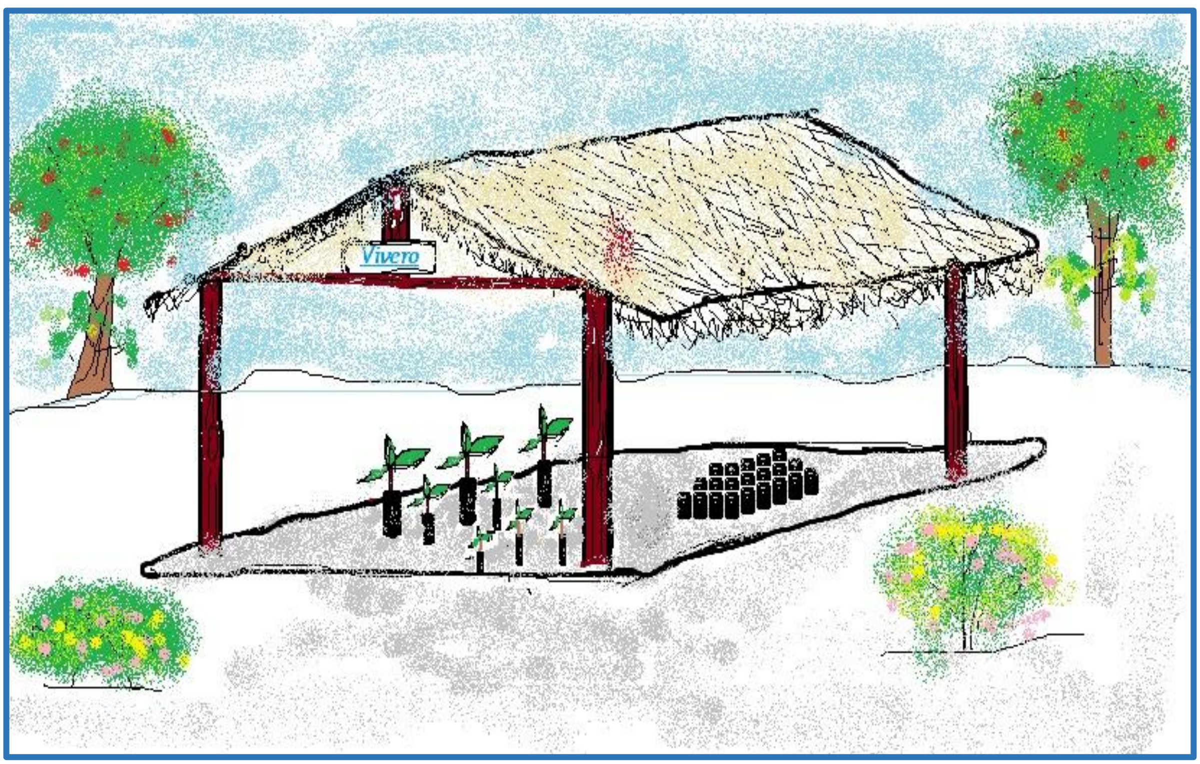
Figure 4. Determination of the time of greatest availability of seed for collection.

Obtaining this information and analyzing it will be done through the planning matrix for the propagation of species (Annex II).

Implementation of community nurseries

A community nursery is a space with adequate infrastructure and equipment for the production of seedlings for reforestation. It also constitutes an educational space, as it allows for training and dialogue with local people who will be in charge of its management. For its construction and management, it is intended to take advantage as much as possible of available local resources, such as construction materials: wood, stone, earth, fibers, etc; local knowledge and labor, among others. And only in those cases where it is strictly necessary will external resources and materials be used.

Figure 5. Nursery construction with local materials.



The minimum infrastructure and equipment required for the proper functioning of the nursery consists of a protective cover (greenhouse, macrotunnel, shade mesh, etc.), germination benches, cellar, classroom, irrigation system, as well as containers or trays for germination and transplanting.

It is also required to have a source and water storage system.

Propagation of native species.

1. Collection, cleaning, selection and preparation of the seed:

It is advisable to harvest the seed directly from the tree and select it based on outstanding physical characteristics in terms of best shape (i.e., take care not to deform), color intensity and larger size. Another important aspect to consider is the good sanitary state of the seed or vegetative material, for this, it must be verified that the seed does not present physical lesions, or damages by some type of plague or microorganism.

Figure 6. Collection of seed directly from the tree.

In addition, it is advisable to take into consideration the knowledge that local people have regarding the reproduction of the species.

It is necessary to find out if the seed requires any type of pre-germinative treatment (stratification or scarification).

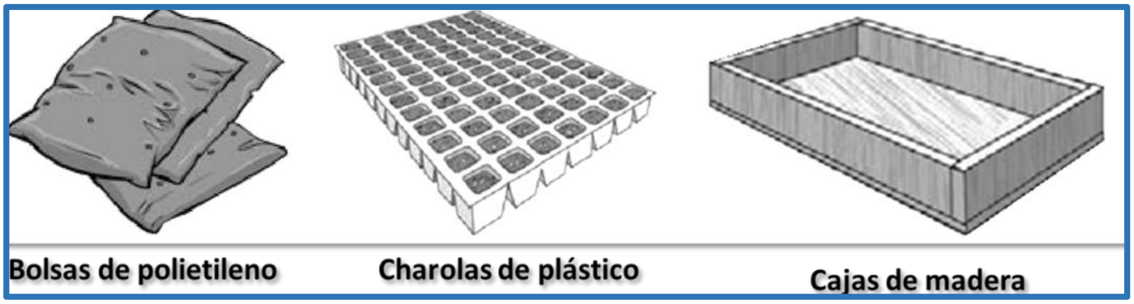
Figure 7. Disposal of damaged seeds

Due to the possibility of working with species that do not have abundant information for cultivation and management, it is recommended to sow as soon as possible, in order to avoid losing the viability of the seed.

2.-Selection of the type of container or germinating tray to be used:

For this it is recommended to consider the characteristics of the species that is going to reproduce in terms of growth habits and based on it decide the type of container that could be used. It is recommended to consider the characteristics of the species to be reproduced in terms of growth habits and based on this decide the type of container that could be used, from containers made of natural materials such as pieces of bamboo, tree bark, coconut shell or some other fruit of thick shell, etc., to specialized containers such as germinating trays or polyethylene bags. The use of reuse materials (e.g. PET bottles, aluminium cans or other materials, unicel cups, etc.) can also be considered, depending on the availability of these materials in the locality.)

Figure 8. Various containers for seed germination.



Another viable option, depending on the characteristics of the species and growth habits, is the implementation of seedlings for germination or rooting and their subsequent transplant to polyethylene bags or other reuse materials, where the seedlings will remain until the moment of their transplant to the definitive site.

3. Preparation of the sowing substrate:

In general terms, loamy soil is required, i.e. soft, fluffy and loose for proper root development. Some authors recommend a mixture of two parts of clay soil with one part of sand respectively (mixture 2:1). It can also be considered the option of obtaining the soil from the site where the trees grow and sifting it very well, in the same way the sand is obtained, preferably from the edge of the streams in the area, and the mixture is prepared.

As far as possible it is convenient to experiment with mixtures tested by local people for the reproduction of their plants, it is common to find that such mixtures include the use of fertile soil (possibly from the same forest), with some type of local organic fertilizer such as anthill soil and bat guano, among others, in addition to the use of sediments or soil from river banks.

It is widely recommended to wet the substrate before using it. In order to determine the adequate humidity it is possible to use the test of the fist that consists of taking a fist of substrate and squeeze it softly with the objective of observing the runoff of the water, if they only drain a few drops it means that the degree of humidity is adequate, if on the contrary a jet of water drains it means that it has too much water and it will be necessary to extend it and to wait for it to lose humidity or to add a little more of dry mixture.

Figure 9. Substrate Preparation.

4. Filling of containers or germinating trays:

Once the substrate is prepared, proceed to fill the containers flush, and then tap gently so that the substrate is accommodated and there are no gaps. After this, if necessary add a little more substrate, the ideal is to leave a free space of approximately 1.5 cm, this in order to prevent the containers are too full and the substrate is thrown during watering.

Figure 10. Filling polyethylene bags.

5.- Covered sowing and watering:

Previously it was verified if the seed requires some process of scarification or pre germinative treatment.

To make the sowing of the seed, a hole is made in the middle of the container with the support of a stake, the depth depends on the species and the size of the seed (considering that the recommendation is not to exceed three times the size of the same).

Figure 11. The sowing depth should not exceed 3 times the size of the seed.

The seed is placed in the hole, covered and watered. The irrigation must be done taking care that the substrate is perfectly wet so that it does not lack the humidity that is required for the germination of the seed.

Figure 12. Watering with a watering can to wet the substrate well.

6. Process of germination:

Depending on the species, this process can last between 3 and 15 days and even more, in general terms it is suggested to cover the containers or germinating trays (to give them darkness), and to place them in a place with semi shade, later they should be checked every day to make sure that there is no lack of humidity to the substrate and to uncover as soon as the first seedlings begin to appear. This step is very important to avoid the phenomenon of etiolation that consists in the lengthening of the plant in search of light, which is not desirable because if this happens the plant I will not be able to develop properly.

Figure 13. Process of germination and growth of seedlings in trays.

7. Bag transplant:

If the germination was made in seedbeds or germinating trays, the germinated plants will have to be transplanted, to polyethylene bags (or some other available container), when they reach a height of 10 to 15 centimeters and have their first pair of mature leaves. Once transplanted it is advisable to place them preferably in a semi shaded place as they would be in nature.

Figure 14. Small trees transplanted to polyethylene bags and protected with shade mesh.

Figure 15.Tree transplanted to polyethylene bags and protected with mesh.

8. Management of the plantin:

From the transplant it is required to revise frequently the seedlings to make the necessary irrigations and weeds.

Soil and water conservation works

The implementation of soil conservation works as part of the reforestation process is fundamental because soils fulfill indispensable functions for the functioning of both ecosystems and human life that coexist in the area.

Cotler A, E. et al. (2013) state that the best known function of soil is to support and supply nutrients to plants, "however, soil fulfills other equally important functions such as constituting a filtering medium that allows the recharge of aquifers also influencing water quality. It is also the medium in which biogeochemical cycles are carried out and carbon is sequestered (reducing its release into the atmosphere as CO2, one of the main "greenhouse" gases responsible for climate change)". They also stress that soils are also habitats for a multitude of organisms, from microscopic cells to small mammals and reptiles, thus contributing to maintaining a wide diversity.

As part of the educational process, it is vitally important to know that soils take hundreds of years to form or renew, and for that reason, their loss or degradation becomes more relevant.

In this context, "the watershed approach contributes to linking soil formation and loss processes with other components such as water and vegetation, and makes it possible to plan actions that conserve all the elements of a watershed, including soil". Cotler A, E. et al. (2013).

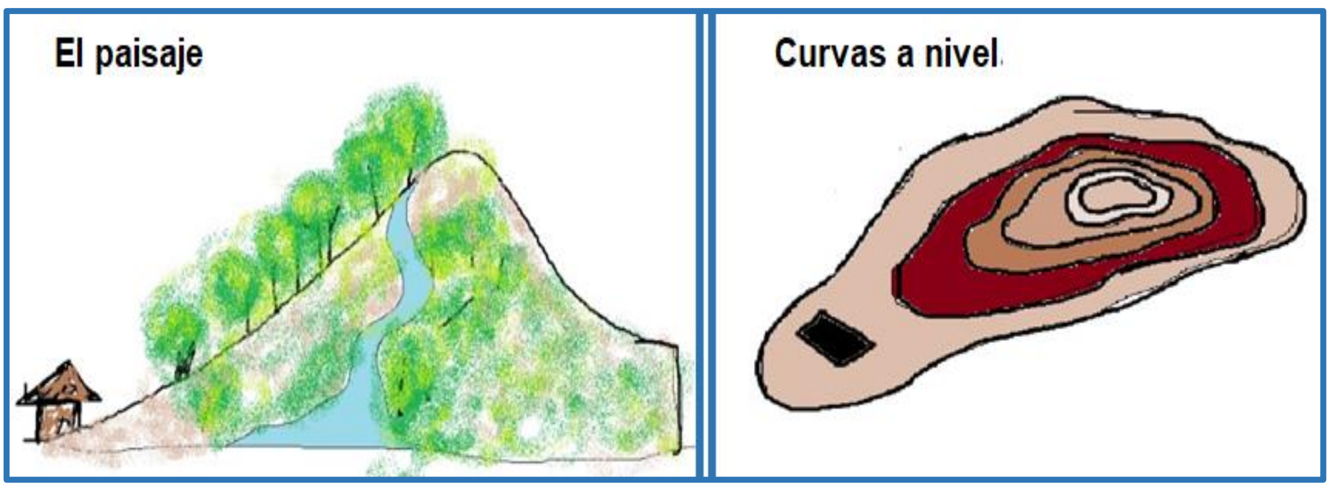
Figure 16. Rainwater harvesting and reforestation with native species.

The contour lines

Contour lines are imaginary lines on the surface of the earth that connect those points that have the same elevation (vertical height) with respect to sea level.

A level curve is obtained by drawing a line perpendicular to the slope, in which all points are aligned at the same level. By Therefore, the use of contour lines in the planting of trees and the construction of soil and water conservation works is very useful to reduce erosion and increase water retention.

Figure 17. Representation of the landscape and contour lines



Several techniques and instruments have been developed for drawing contour lines, however, due to their practicality and low cost, the use of the "A" appliance is proposed.

The "A" appliance is a tool in the form of a capital "A", which can be easily constructed and used.

Figure 18. Apparatus "A".

Construction of device "A".

The construction of apparatus "A" consists of obtaining three straight rods, nailing them and calibrating them, for which the following procedure must be carried out:

1. Obtain two straight rods 2 meters long and approximately 5 cm in diameter. And a rod 1.20 meters long by 5 cm in diameter.

2. Place the two 2-meter-long rods in a "V" shape and nail 10 centimeters where the two ends meet. It is suggested to leave the nail slightly out to be able to tie the plumb line from there.

Figure 19. Joining of the 2 meter rods.

Measure and place a mark just in the middle of each two-meter stick, then open the rods 2 meters from end to end and nail the third stick on the previous marks.

Figure 20. Placement of the crossbar.

4. At the end of a rope a plumb line is tied (it can be a stone, a bottle or some other heavy object), the other end of the rope is tied to the nail that was slightly out taking care that the plumb line passes under the crossbar.

Figure 21. Placement of the plummet made with a PET bottle, filled with earth.

Note: The plummet made with rope and stone can be replaced by the bubble level, as this allows for greater precision in drawing curves at level.

Calibration of the "A" appliance

For the proper calibration of the "A" device, the following procedure must be followed:

1. Mark two fixed points on the ground, 2 metres apart.

2. Place the apparatus "A" on the two previous points and mark on the crosshead exactly where the plumb line crosses.

3. Turn the appliance over at the same fixed points (on the ground) and mark again on the crossbar the point where the plumb line crosses.

4. Measure the distance between the two marks, obtain the middle point and mark it on the crossbar, this will be the level point of the appliance.

Figure 22. Place marks on the crossbar to determine the point of level.

Determining the slope of a terrain

Once the site to be worked on has been defined, it is necessary to calculate the slope of the land, since this information is necessary for drawing contour lines, choosing soil and water conservation works, appropriate to the characteristics of the land, and for determining the topological arrangement of the reforestation. In order to obtain the slope of the land, the following procedure is recommended:

Carry out a tour of the terrain in order to define the sampling points in such a way that the measurements are representative of the selected area.

2. Obtain the slope of the points defined for sampling. To determine the slope, place one leg of the apparatus "A" on a predefined point of the terrain, turn the second leg of the apparatus in the direction of the slope.

Figure 23. Appliance A in the direction of the slope of the terrain.

3. Gently turn the appliance foot until the plummet coincides with the level point of the appliance.

Figure 24. Locating the level point with the plumb bob.

4.	Then measure in centimeters the distance between the floor and the leg of the appliance that is kept in the air.

Figure 25. Measurement of the floor to the appliance leg "A".

Note: It is recommended to carry out this operation at least at 5 different points on the ground. The more points measured, the more representative the slope. ´

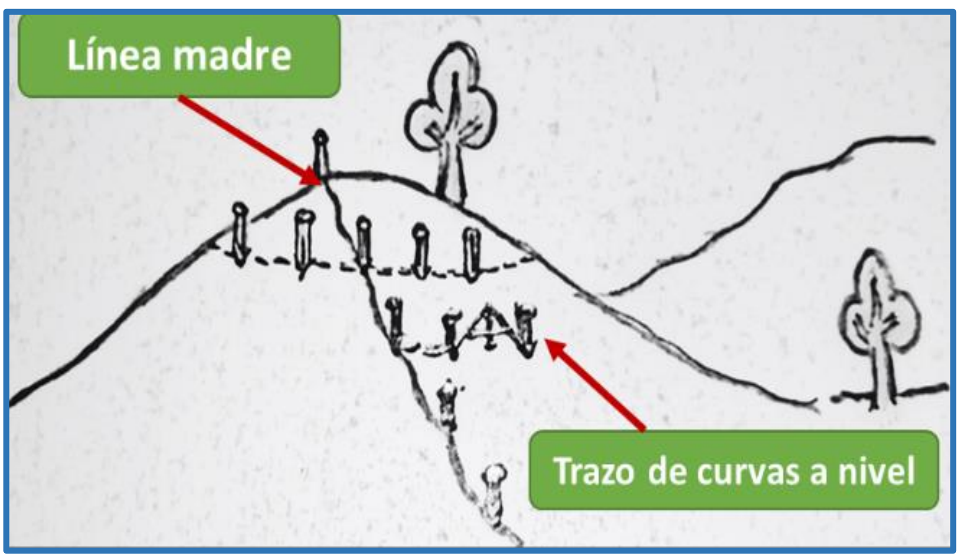
5. Add the distances obtained in each measurement and obtain the average. Add the five distances, the total is divided by five and the average is divided by two and in this way you get the final result that is equivalent to the percentage of the slope of the land.

Procedure for drawing contour lines

The adequate tracing of the contour lines is fundamental for the optimal functioning of the soil and water conservation works that will be built on them, in the same way, it is important for the planting of forest species. The following procedure is required for the correct drawing of contour lines:

1. **Draw the mother line or direction line of the slope**. To do this, the highest point of the terrain is selected, the first stake is driven in and a straight line is drawn, towards the lowest point of the terrain, in the same direction as the slope.

Figure 26. Mother line and level curves with the "A" device.



2. Establish the intervals of the contour lines. On the mother line are marked the points that will determine the intervals between the contour lines, the number of curves will depend

on the degree of slope of the terrain (see the corresponding table). Using the stakes that define the interval, the contour lines are traced with the aid of the "A" device.

Table 2. Interval between level curves according to the % of slope of the land.

Porcentaje de pendiente (%)	**Distancias entre curvas (metros)**
2	30
5	28
8	24
10	20
14	18
16	16
20	14
25	12
30	10
35	8
40	6
45	4

3 3. Drawing of the contour lines. One leg of appliance "A" is placed next to the highest stake of the mother line and the second leg is moved, perpendicular to the slope, until it touches the ground so that the plumb line coincides with the point of level of the appliance**, this means that the points where the two legs of appliance "A" rest are at the same level**. Next to the second leg, another stake is driven in and this procedure is continued to reach the defined area boundary of the terrain.

The line of nailed stakes defines the contour curve. This step is repeated for each of the stakes that form the slope's mother line.

Figure 27. Drawing contour lines with the "A" device.

Note: It is recommended to relocate stakes that are too far away from the line drawn with the "A" device.

Figure 28. Stake relocation.

Construction process of soil and water conservation works

Individual terraces

They are circular-shaped embankments, drawn in curves at a level of one meter in diameter on average. In the central part of them a forest species is established.

Figure 29. Individual terraces and reforestation with forest species.

This type of works are suitable to complement the reforestation process because they are useful for:

- Avoid slope erosion.

- Retain soil from runoff.

- Capture rainwater.

- Maintain greater humidity for the development of forest species.

In addition, they retain and conserve humidity in localized areas, and the most important thing for the objective of the project is that they help to increase the survival of the trees in the reforestation and accelerate their development.

Design elements

Individual terraces should preferably be built in soils with depths of 30 centimetres.

It is recommended to align them on level curves and with a separation interval adequate to the slope of the land and with the density of plants required by each forest species.

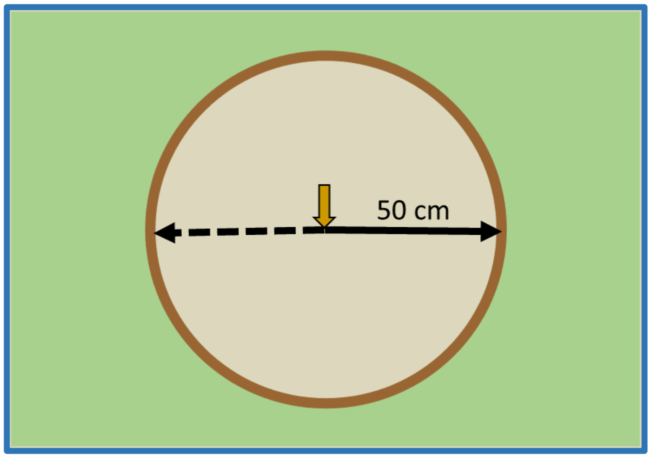
The average size of individual terraces is one metre in diameter where a "circle" of water and soil capture is formed.

Construction process

Individual terraces should have the following average measurements: one meter diameter, 10 centimeters depth of cut, with slopes stabilized with stone or grass. These measures may vary according to the slope and depth of the soil.

1) Draw a circle of one meter in diameter with the help of a stake and a rope 0.5 meters long.

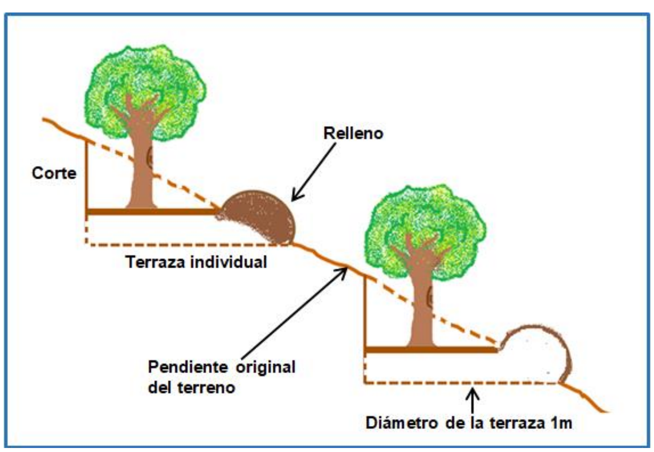
Figure 30. Drawing for the construction of individual terraces.



2) Digging into the top of the circle, depositing and forming a circular board with the excavated soil, may be reinforced with stones or some other available material. The board will allow rainwater to be stored and provide moisture to the forest species to be planted.

3) If the topographic conditions of the terrain allow it, it is recommended to give the terrace a slope against slope within the terrace.

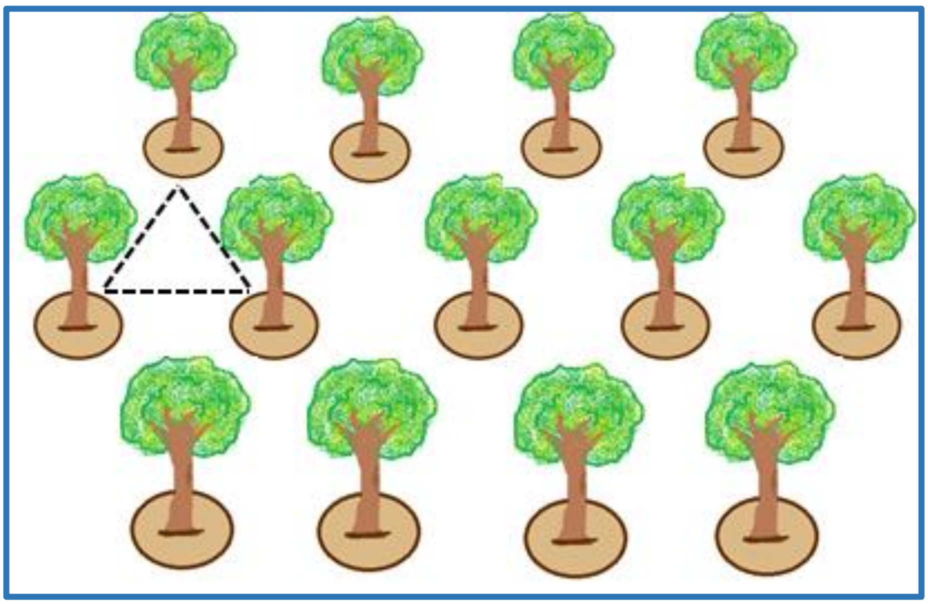
Figure 31. Transverse view of individual terraces.



4) In areas with a high incidence of rainfall, it is recommended to plant each tree close to the board built in the filling area and not in the center of the terrace, in order to avoid rotting due to excess water.

5) An example of recommended distance in the design of individual terraces is 3 meters between cajete and cajete, in "three bolillo" method.

Figure 32. Individual terraces with forest species, in "three bolillo".



Recommendations:

Combine individual terraces with drainage channels that intercept and dislodge excess water in a controlled manner.

Stabilize the slopes in the cutting and filling area by placing stones or cover crops to avoid destruction of the work and malfunction.

Trenches or also known as blind tubs

They are trenches in level curves, two meters long on average and separated by a dividing wall of equal length. The water storage capacity will depend on the vegetation conditions, the type of soil and the amount of rain that is present in each zone.

Figure 33. Trench trenches or blind tubs.

The construction of trenches increases the density of trees because they can be planted on the edges of trenches and in the intermediate sections of trenches. Trenches dose water over time and provide lateral flow to intermediate trees.

This type of work is suitable to complement the reforestation process because they allow:

- Reduce water erosion.

- Intercept surface runoffs.

- **Increase rainwater infiltration.**

- Assist reforestation in the survival of plant species.

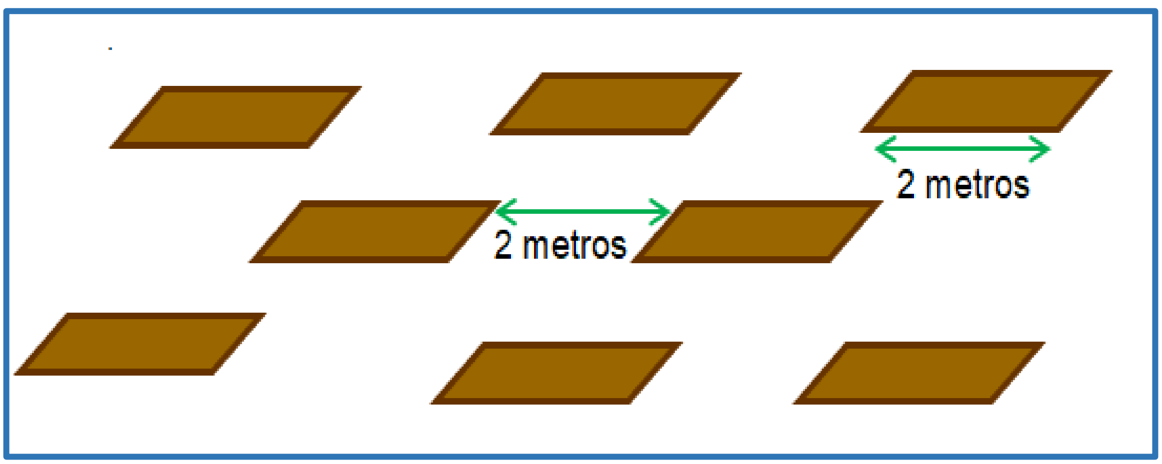
It contributes in an important way to the achievement of the objective of the project because one of its main functions is to favor a greater infiltration of water, in addition to favoring the development of forest species and natural vegetation.

Figure 34. Blind tubs and rainwater harvesting.

Design elements

Trench are constructed following a level curve previously traced with the support of the "A" apparatus, forming a guide line with stakes or powdered lime.

Figure 35. Distribution of trench trenches in "three bolillo" system.



Construction process

The trenches must have the following dimensions, 40 centimeters wide by 40 centimeters deep and 2 meters long, on average, traced to "three bolillo" and separated with a partition wall 2 meters long.

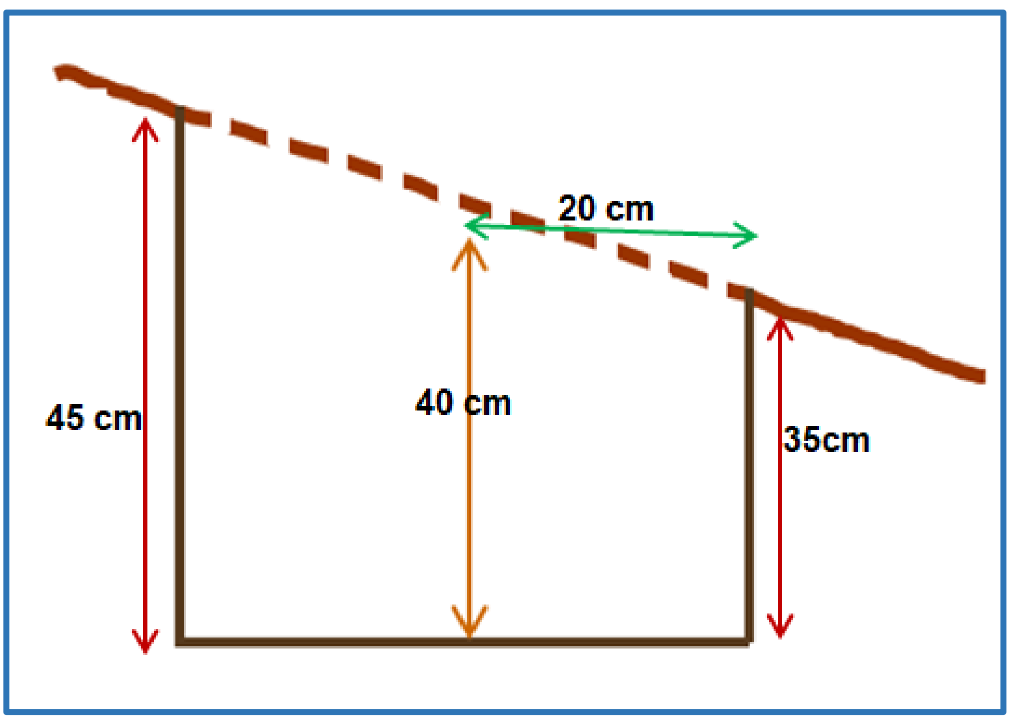
1) A mark is placed on the guide line every 2 metres, corresponding to the distance calculated for each trench. This distance may be modified according to the topographical conditions of each terrain.

2) Excavation is carried out with a shovel and a pick, depositing the soil of the excavation downstream, forming a board of equal length to that of the trench, and must be compacted to prevent the current from dragging the soil.

Figure 36. Excavation of blind tubs and planting of forest species on board.

3) In inclined terrain, the depth of 40 centimetres should be measured at half the width of the trench (i.e. at 20 cm). This is because the slope of the terrain can affect the dimensions of the trench at the time of construction.

Figure 37. Excavation of trench trench in sloping terrain.



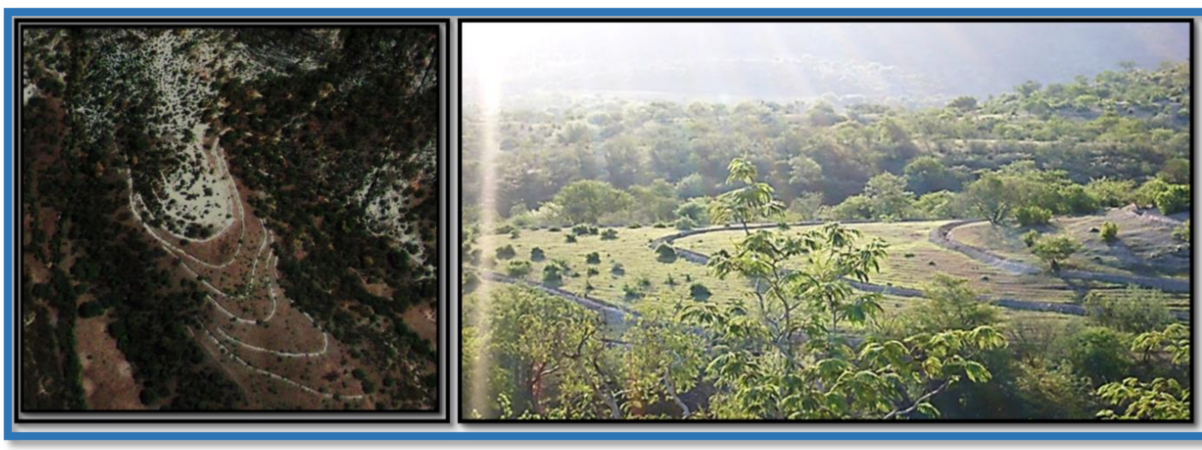
Recommendations

It is recommended to maintain the work to ensure its proper functioning, as sedimentation processes decrease the capacity to collect rainwater and reduce the lifespan for which they were built. Therefore, it is advisable to remove the accumulated sediments during the time required by the plantations to ensure adequate development (five years on average), depending on the characteristics of each species, climatic conditions, and soil conditions.

Trench board systems

They are a set of continuous ditches and embankments that are built following level curves, where the excavation volume is placed downstream to form the board. Ditches and embankments have dividing dikes to control the speed of water flow.

Figure 38. Trench system on board in level curves.



This type of works are very useful for:

- Decrease water erosion.

- To control the speed of runoff.

- Propitiate the infiltration of rainwater.

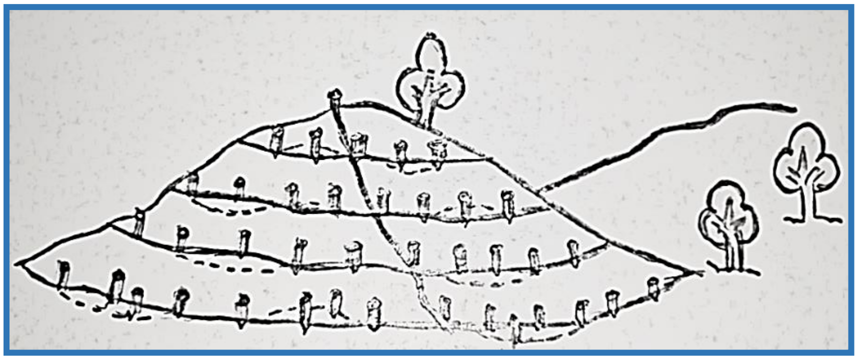
- Retain moisture.

This type of work favors a greater infiltration of water and the development of forest species.

Design elements

Trenches are constructed following a level curve from a guide line or also called a mother line.

Figure 39. Drawing contour lines.



On the guide line a mark is placed every 2 meters, which corresponds to the distance calculated for each trench. This distance can be modified according to the top conditions.

Construction process

The average trench dimensions are 40 centimeters wide by 40 centimeters deep. It is recommended that the bottom is level so that the water does not pool in a certain area.

1) The excavation of the trench begins on the guide line, and with the extracted soil the board is formed, downstream.

Figure 40. Beginning of the excavation on the trace of the cure at a level marked with lime.

2) A dam of approximately 30 or 40 centimeters should be left, every 4 or 5 meters, with the purpose of controlling the speed of runoff and avoiding the formation of a gully in the ditch board. The height of the dyke will be 10 centimeters from the surface, to allow the passage of water from one section of the ditch to another. The distance between the dikes should be shorter as the slope becomes steeper.

Figure 41. Excavation of Bordo trench, with a 40 cm dividing dyke.

Recommendations

- The use of on-board trenches is recommended on terrain with slope ranges from 8% to 48% maximum.

- Avoid excessive azolve in trenches to promote better performance.

- It is recommended to combine board trenches with trench trenches in reforestation practices.

Dead plant material barriers

The arrangement of these materials provides protection for the soil, prevents water erosion, reduces surface runoff and increases the moisture content in the soil, which favours natural regeneration.

Figure 42. Barriers of dead plant material (CONAFOR, 2007).

Figure 43 Barriers of dead plant material (branches and trunks).

These works are useful because they allow:

- Reduce water erosion.

- Decrease the speed of surface runoffs.

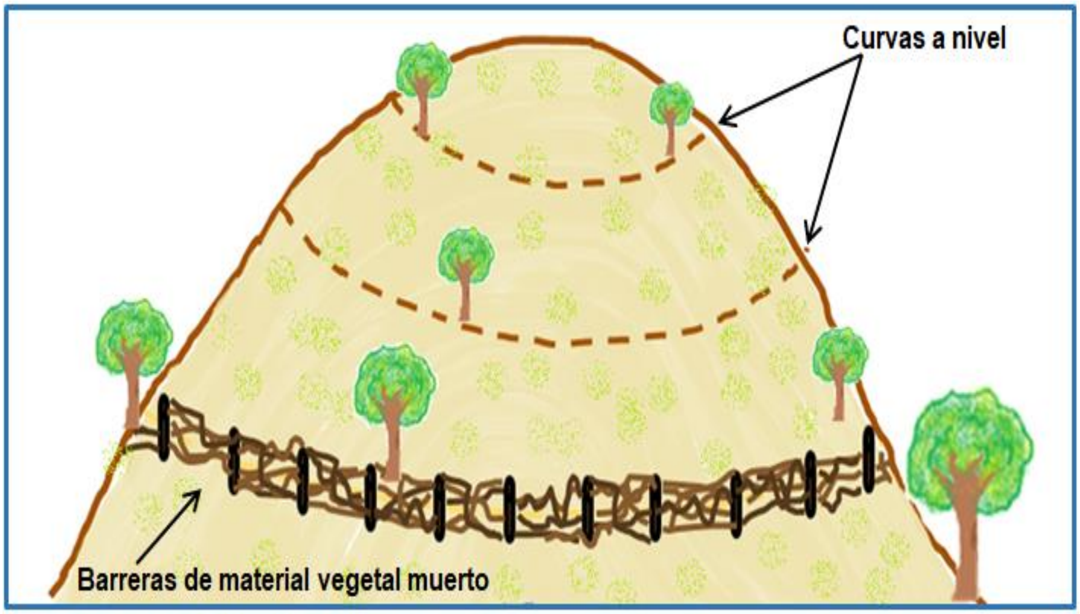
- Increase the infiltration of rainwater.

In addition they allow the retention of azolves and favor the natural regeneration.

Design elements

Cords of material should be formed following contour lines in the terrain, perpendicular to the slope, in order to reduce the speed and amount of surface runoff, while intercepting possible materials and azolves that erode uphill.

Figure 44. Construction of barriers in contour lines.



Construction process

The cords will be placed over the curve at level and to determine the spacing between the cords, consideration should also be given to the slope of the terrain, the erosion present and the amount of material available to accommodate.

The maximum recommended length of cords is 50 meters, cords should be discontinuous every 50 meters to avoid the risk of fire propagation. The distance between two fractions of the same cord should be 4 to 5 meters. The width of the belt should be less than 40 centimeters, it is recommended that the height of the belt does not exceed 40 centimeters.

1) Start the cordon of the material on the guide curve. The material is placed on the ground, pruning the branches and sectioning the largest trunks, ensuring that the cord does not exceed one meter in height.

2) When the cordon crosses a gully or a stream, a morillo dam must be built on it or the thickest trunks must be placed.

Figure 45. Construction of a small morillo dam on the bed of a stream.

Recommendations

As far as possible, the thickest material should be cordoned off and the thinnest debris should be left on the stretch between cords in order to protect the soil.

Determination of the soil and water conservation works to be constructed.

To determine the type of soil conservation work that will be built at each site, the slope of the land, the type of erosion present, the vegetation cover, the current use of the land and the material available in the area, among others, should be taken into account.

The compilation and analysis of the terrain information must be done jointly with the inhabitants of the locality using the matrix for the determination of soil conservation works (Annex III).

The information poured into the matrix must be corroborated through a field trip where observations will be made from the current conditions of the proposed site and from the results the definitive determination of the soil conservation works that will be carried out will be made.

Reforestation

In order to carry out reforestation, it is necessary to make the necessary preparations in advance, to determine the work areas, the topological arrangement of the plantation, to integrate work teams and to prepare the land.

In this regard, Arriaga et al. (1994) indicate that the minimum environmental characteristics for attempting reforestation are:

Soil depth of at least 30 cm.

Soil texture that allows adequate infiltration (non-compacted soils).

3. Existence of an herbaceous stratum that at least covers 80% of the land.

4. Forms of erosion that are within the permissible, or otherwise that can be controlled with soil conservation practices.

Land Preparation

For this activity, consideration should be given to carrying out soil conservation work (appropriate to the characteristics of the area), which will complement the reforestation process, as this activity forms part of the preparation of the land.

In the event that due to the particular conditions of the area, no type of soil conservation work is going to be built, the preparation of the land will be done in the following manner, the area must be cleaned and a stock with dimensions of 20 centimeters wide, 20 centimeters long and 30 centimeters deep, as a minimum, depending on the size of the seedling. It is advisable to have the soil prepared beforehand and in case it is necessary to carry out an irrigation the day before the reforestation, with the purpose that the soil has the adequate humidity to facilitate the root development of the plant.

Figure 46.

Reforestation with native species in ditch board system.

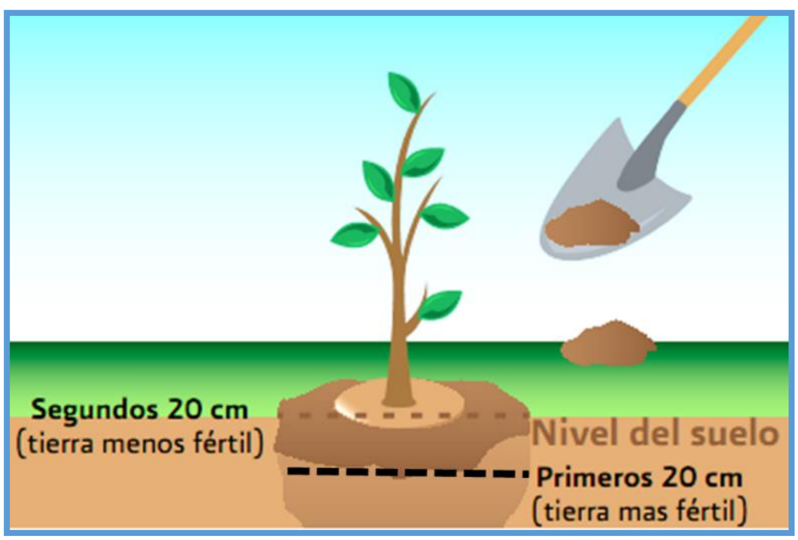
Figure 47. Excavation of a common strain of 40X40X40 (CONAFOR 2010).

Establishment of the plantation

The establishment of the definitive plantation should preferably take place at the beginning of the rainy season.

At the time of transplanting to the final site, the polyethylene bag or container should be removed taking care not to destroy the root ball and mistreat the roots.

Figure 48. Transplant in the definitive place (CONAFOR 2010).



It is recommended that before placing the tree in the stock, add the superficial soil, which is the most fertile, with the objective that the plant has greater availability of nutrients, if possible you can add a little compost or some other organic fertilizer. After the plant has been placed, it is filled with the deepest soil and lightly tamped around the plant.

The plant is placed on the stock in such a way that the upper part of the root ball is flush with the soil, then filled with the extracted soil and tamped around the plant.

Follow-up

After reforestation, it is necessary to program tours through the different work areas in order to monitor plant development, detect possible problems and carry out the following maintenance activities, with the objective of favoring the good development of the species:

1. Keep the shrubs free of weeds, shrubs and undesirable trees (this to avoid competition for water and nutrients).

2. Eliminate diseased trees and control pests and diseases.

3. Leave only the trees that have more vigor and health. This allows to regulate the distribution of the space and to improve its development.

4. Build firebreak spaces to protect plantations.

The maintenance activities of the soil and water conservation works associated with reforestation should also be programmed in order to guarantee their proper functioning.

Summary and recommendations

The construction of water forests requires a series of activities, which must be carried out jointly with the inhabitants of the localities of the area.

1. Delimitation of the basin and definition of work areas
2. Selection of native species for reforestation and definition of associated soil conservation works.
3. Implementation of community nurseries.
4. Construction of soil and water conservation works.
5. Reforestation with native species.

6. Monitoring and maintenance of works and reforestation.

In the implementation of the Water Forests, an educational process is required, transversal, that facilitates the achievement of the objectives of the project. Therefore, it is essential that each and every one of the activities mentioned above be accompanied by training actions with the objective that participants are fully involved throughout the process of building water forests.

Anexos

Anexo I. Matriz para selección de especies.

Selección de especies nativas para reforestación

No	Especie	Requerimientos	Condiciones del terreno para la reforestación						Calificación
			Temperatura	Humedad	Suelo			Otros factores que podrían afectar	
					Profundidad	Estructura	Fertilidad		
1									
2									

3									
4									
5									

Calificación:	
0	Si no hay las condiciones adecuadas en el lugar destinado a reforestación.
1	Si las condiciones son parciales o la especie es tolerante.
2	Si hay buenas condiciones para el desarrollo adecuado de la especie

Anexo II. Matriz de planeación para la propagación de especies.

PLANEACIÓN PARA LA PROPAGACIÓN DE ESPECIES

No.	Especie	Forma de propagación	Fecha para recolección de semilla	Fecha para recolección de estacas	Tratamiento pregerminativo	Siembra
1						

2						
3						
4						

Anexo III. Matriz para la determinación de obras de conservación de suelo y agua.

OBRAS DE CONSERVACIÓN DE SUELO Y AGUA							
No.	Paraje	Pendiente (ladera, ondulado, plano)	Erosión presente (Hídrica, eólica, cárcavas)	Cubierta vegetal presente (hierba, arbustos, árboles)	Uso actual (pastoreo, leña, recreativo, etc.)	Material disponible (Piedras, Ramas, troncos)	OCSy A (Propuesta)
1							
2							
3							
4							
5							

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