Tree planting and management techniques under limited water availability

Guideline for Farmers and Extension Agents

March 2014

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Preface

Tree planting in the drylands posses a big challenge to farmers in arid and semi-arid areas. There is therefore need for better technical information to promote tree planting in water deficient soils. This guideline was compiled based on the results of research activities jointly conducted by Japan International Forestry Promotion and Cooperation Center (JIFPRO) and Kenya Forestry Research Institute (KEFRI). The series of research activities, including literature review as well as field studies, were conducted from the year 2009 to 2014 with the support from the Forestry Agency of Japan.

This guideline demonstrates a better way of re-afforestation in arid and semi-arid areas and the following sections items have been described in a comprehensive manner.

1) The relationship between water and forest (trees)
2) The concept of selection of suitable tree planting site
3) Typical technologies necessary for re-afforestation in arid and semiarid-areas

This publication has been prepared as guideline. We hope and trust that the guideline will be useful for farmers and extension agents who are involved in promoting re-afforestation activities in arid and semi-arid lands.

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Moreover, we would like to express our appreciation to all of the officers of International Forestry Cooperation Office, Forestry Agency of Japan, who led us as a supervisor and counselor.

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1.0 Introduction

Arid and semi-arid land environments are generally very fragile. These lands are associated with low and unreliable rainfall, and relatively high temperature thus resulting in limited water resources and difficulty for establishment of stable farming system. Though rich in natural resources, the increased human pressure on forests and woodlands has created conditions conducive to degradation, deforestation and desertification. There is therefore great demand for re-afforestation technologies that can promote restoration and management of forests. Reforestation and afforestation will not only contribute to natural environment preservation, but also to the improvement of the livelihood of local residents. In the long term, restoration of forest vegetation can improve soil properties, contribute to the local water balance by flood control during rainy season and mitigate drought in dry season. Thus re-afforestation is an extremely important and effective measure to conserve/improve local environment.

Re-afforestation techniques which include appropriate planting and management methods are not always well developed thus causing great challenge to dryland forest rehabilitation.

The objective of guidelines is to provide information for tree planting and management in the drylands under limited water availability. This guideline outlines: Relation between forest and water environment; Selection of appropriate tree planting site; Tree planting and management techniques; Water harvesting techniques; Water conservation techniques.

2.0 Effects of Forests on Water Environment

Forests have high reservoir effect as green dams, but it may not necessarily increase the amount of rainfall. Forests in arid and semi-arid areas play important roles in livelihood of the residents. It is important to promote re-afforestation aggressively in order to reduce pressure on the remaining natural forests. Re-afforestation and management techniques with an emphasis on conservation and efficient use of water resources is therefore required. The design for the re-afforestation should be determined considering the water consumption by the forest at maturity.

To secure a wide range of alternative selection of tree species appropriate planting objectives under different site conditions, growth characteristics of as many plant species as possible should be provided. A long period of

management is necessary to achieve planting objectives due to slow rate of tree growth. Furthermore various types of tree form and forest structure are established depending on different applied management procedures. Long-term prospect is necessary for the selection of tree species for planting in the dry lands.

Rainfall in arid and semi-arid areas is unreliable, hence trees planted must have some drought tolerant ability and tree properties for their sustainability. Re-afforestation techniques must therefore focus on the securing a robust forest vegetation under harsh environment by ensuring a balance between forest water consumption and the control of leaf biomass. This should be based on the selection of adapted tree species that can adjust their leaf biomass to the minimum rainfall during drought.

Re-afforestation should be done after clarifying the aim of forest production. The desirable forest structure and its re-afforestation management methods must take into account the needs of residents, amount of local water resource, and physiological and ecological properties of planted trees. There is need for precise understanding on the relation between water and trees as well as accurate information on propagation techniques of the selected tree species.

3.0 Selection of Suitable Site and Tree Species

3.1 Selection of suitable site

Selection of indigenous tree species should be prioritized for sustainable forest management and for effective use and preservation of water resources. In case of introduction of useful exotic tree species, trees must be managed based on water use properties of each species.

Even within a limited range, water retention capacity of soil varies depending on slight differences of geography and parent rocks, and thereby the tree species and the number of trees that can be planted are limited. Generally, lands suitable for growth of trees are also suitable for growth of crops and in such lands agricultural production activities are generally prioritized.

If some surplus lands with similar weather and soil conditions with productive croplands are available, they can be suitable planting sites. It is also expected that lands that are not suitable for agriculture due to high slope angle despite the same weather and soil conditions with crop lands, can be used for forest tree establishment.

For the lands with low agricultural productivity due to water shortage, water availability can be improved by measures such as micro- catchments, if sufficient materials and funds are available. It is important to consider whether soil has poor water retention capacity and this can be improved by mixing them with organic matters. There is also need to consider whether profits proportional to the investment can be obtained.

Addition to the woodlot, tree planting to demarcate the boundaries of own land, and also to prevent break-in of livestock, can be a strong incentive for local residents to plant trees.

The sites should be accessible making it easy for individual farmers to take care and maintain the trees planted with less effort. A low risk of illegal cutting is also an important requirement.

If watering is necessary for plant growth, it is indispensable to acquire water-use rights from the local community.

Local community members are also important actors in promoting re-afforestation activities. They can participate actively in tree planting on the mountain ridge for prevention of soil erosion in agricultural land, protection of river bank, and generating funds for management and maintenance of public facilities such as schools.

3.2 Selection of suitable tree species

In any area, selection of appropriate tree species suitable for the natural environment of respective region is imperative in order to make tree planting successful. The key for success in tropical semi-arid areas is to select highly drought-tolerant tree species.

Standard of the selection is also based on the uses of the tree species. “Multi-purpose trees" are important plantation trees. As trees are often planted as part of agroforestry, it is necessary to grasp properties of respective trees and consider planting and management methods to reduce competition with other plants over water.

Selection should also focus on tree species that are on the verge of depletion due to over exploitation as fuel wood and also tree species retained intentionally by residents for traditional use.

“Potential Habitat” of eighteen drought-tolerant tree species in total that have been planted preferentially in arid and semi-arid areas and for which past research papers are available were analyzed in trial base through this project. The methodology and result of the analysis is introduced to another guideline named “Guidelines for re-afforestation and water conservation in drylands”. The species include both indigenous and exotic tree species namely: *Acacia senegal, Acacia tortilis, Acacia xanthophroea, Azadirachta indica, Balanites aegyptiaca, Combretum acleatum, Combretum collinum, Combretum molle, Combretum shumannii, Eucalyptus camaldulensis,*

Eucalyptus globulus, Eucalyptus saligna, Faidherbia albida, Melia volkensii, Senna siamea, Senna singuneana, Senna spectabilis and Tamarindus indica. The species local names and uses are given in Table1.

Table 1: Recommended species for planting in dry areas, their local names and uses

	Scientific name	Local Name	Uses
01	*Acacia senegal*	King'ola[1)], Kikwata, Mgunga[2)], Enderkesi[4)], Mung'oora[7)], Ekunoit[8)]	②③④⑤⑥⑧⑨⑩
02	*Acacia tortilis*	Mulaa[1)], Mgunga[2)], Oltepesi[4)], Mugaa[5)], Mugaa[7)], Ewoi[8)]	①②③④⑥⑦⑧⑨⑪⑫⑬⑭⑮
03	*Acacia xanthophroea*	Kimweya, Musewa[1)], Murera[3)], Olerai[4)], Murera[6)]	①②③④⑥⑧⑩⑨⑮
04	*Azadirachta indica*	Neem[1)], Mkilifi[2)]	①②③④⑥⑧⑨⑬⑮
05	*Balanites aegyptiaca*	Mulului[1)], Mjunju[2)], Olng'oswa, Olokwai[4)], Mububua[5)], Muboobua[7)], Eroronyit[8)]	①②③④⑤⑦⑧⑩
06	*Combretum acleatum*	Muthigoora, Mucigi[7)], Ekabekebeke[8)]	②⑦⑧⑨⑫
07	*Combretum collinum*	Itithi, Mutithi[1)], Ekimeng'[8)]	②③④⑧⑨⑬
08	*Combretum molle*	Muama[1)], Mukura, Murema[3)], Olmaroroi, Emaroroi[4)], Murama[6), 7)], Ekamiro, Eguyen[8)]	①②③④⑤⑧⑨
09	*Combretum shumannii*	Mgongolo, Mpera mwitu, Mgurure[2)]	①②③⑤⑧⑨
10	*Eucalyptus camaldulensis*	Musanduku[1)], Mubau, Munyua mai[3)]	①②③④⑨⑪⑬⑮
11	*Eucalyptus globulus*	Mubau, Munyua mai, Muringamu[3)]	①②③④⑧⑨
12	*Eucalyptus saligna*	Musilikina[1)], Mtinbao [2)], Mubau, Munyua mai, Muringamu[3)]	①②③④⑧⑨⑬
13	*Faidherbia albida*	Olasiti, Olsati, Olerai[4)], Edurukoit, Ekurichenait[8)]	①②③⑥⑦⑪⑫⑬
14	*Melia volkensii*	Mukau[1)], Mukau[2)], Mukau[7)]	①②⑥⑧⑨⑬
15	*Senna siamea*	Ikengeta[1)]	①②③④⑧⑨⑪⑬⑮
16	*Senna singuneana*	Mukengeka, Munyunga nai[1)], Mbaraka[2)]	⑧⑪
17	*Senna spectabilis*	Mhomba[2)], Muchingiri[3)]	②③④⑤⑨⑬⑮
18	*Tamarindus indica*	Kithumula, Kikwasu[1)], Mkwaju, Msisi[2)], Oloisijoi[4)], Muthithi[5), 6), 7)], Epeduru[8)]	①②③⑥⑦⑧⑨⑪⑬⑮

Key for the local languages: 1) Kamba, 2) Kiswahili, 3) Kikuyu, 4) Maasai, 5) Mbeere, 6) Meru, 7) Tharaka, 8) Turkana
Key for the uses: ①timber, ②firewood, ③charcoal, ④poles, ⑤tools, ⑥fodder, ⑦food, ⑧medicine, ⑨bee forage, ⑩gum/resin, ⑪tannin/dye, ⑫fiber, ⑬shade, ⑭live fence, ⑮ornamental

4.0 Tree planting and management techniques

4.1 Nurturing of seedlings

Survival of trees in the dry lands can be enhanced through nurturing of high quality seedlings and hardening of the seedlings.

4.1.1 Nurturing of high quality seedlings

Following operation in appropriate way should be done for the development of high quality seedlings such as: Selection of variety suitable for local environment; Selection of high quality seeds; Pre-emergence treatment of seeds; Preparation of high-quality soil; Selection of plastic pot of appropriate size and shape; Watering and weeding in appropriate timing.

4.1.2 Hardening technique

Hardening is a technique that makes seedlings drought resistant by strengthening of the stem and leaves and promoting development of cuticle layer of leaves (Fig. 1). Hardening up of seedling is achieved through water rationing (reducing watering to 1/2 then to 1/3 of the normal amount) and increasing solar radiation. This process is essential and should be started at least 2 weeks before planting. The root system development within the pots is also promoted and the balance between above-ground parts and underground parts (T-R ratio) will be improved to ideal ratio, through these processes.

4.1.3 Root pruning

Sunken beds are often used in arid and semi-arid areas to conserve soil moisture (Photo 1). However, thickened roots sometimes will develop into the soil accumulated between pots. Cutting of the thick roots must be avoided to ensure high seedling survival rate. This can be attained through changing the positions of the pots on a regular basis and cutting the roots that extend outside of the pots before they grow thick.

Photo 1: Seedlings growing up on a Sunken bed

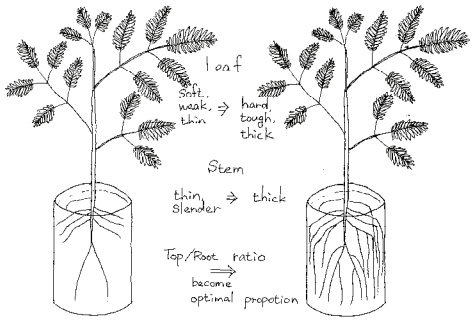


Fig 1: Benefit from hardening treatment

4.2 Tree planting

4.2.1 Planting density

Tree spacing and the number of trees that can be planted are limited by the rainfall amount. In case of *Melia volkensii* planting in Kenya, 5 by 5m interval is used in areas with annual rainfall below 900 mm (agro-climatic zone V-2; mean annual temperature: 21 to 23°C) while 15 to 20 m interval is used in areas with annual rainfall of about 450 mm (agro-climatic zone V-1; 23 to 29°C).

4.2.2 Planting hole size

Typical size of planting holes for trees is from 30 cm in diameter x 30 cm in depth to 45 cm x 45 cm. Planting holes within this size range are

generally used in dry areas such as Kitui, Kenya. The planting holes should be dug and partially covered before the end of the dry season to ensure sufficient water infiltration down to the bottom of the hole at the start of the rainy season. Early preparation of the holes is necessary as it may take a long time if the number of trees to be planted is large.

4.2.3 Tree planting

To ensure that seedlings have a long growth period in order to promote sufficient root development and obtain high survival rate, tree planting should be carried out when standardized accumulative rainfall amount has been obtained. The standard of the accumulative rainfall amount is about 100 mm. Fine roots suffer more or less damage when planting and this will be a significant factor that decreases the survival rate especially in arid areas. To improve the survival rate, it is recommended to trim off branches leaving the top 2 or 3 branches to ensure good balance between transpiration and water absorption in case of broad-leaved trees.

4.3 Management of planted trees

4.3.1 Prevention of forest fire

Since most of the causes of forest fires are man-made, it is important to create awareness and obtain understanding and cooperation of local communities regarding forest fire prevention, and to provide systems for monitoring fire outbreaks and firefighting.

4.3.2 Protection from browsing damage by livestock

The most reliable measure is to enclose each planting site by fence. However, this cost high and is not practical sometimes. It is therefore necessary to obtain understanding and cooperation of local communities and make rules of grazing and taking measures to secure livestock feed e.g. planting of fodder trees.

4.4 Harvesting

4.4.1 Felling cycle and timing

In order to maximize benefits, it is important to make a plan for management of a site with good understanding on demands and commodity standards in each region. Although the market value at a particular time and fluctuation of demand are significant factors to determine felling timing, it is also important to focus on water competition with crops if trees are planted within agricultural lands.

5.0 Water Harvesting Techniques

5.1 Micro-catchment

This technology can be applied in areas with annual rainfall of 200 to 750 mm. Various types of microcatchments including U-shape, V-shape and W-shape are used depending on rainfall amount and slope condition (Fig. 2-5). U-shape is expected to also benefit plants other than the planted trees. V-shape is effective in concentrating water on one point, and is suitable for areas with more severe dry conditions. W-shape consist of connected V-shape mounds to harvest all surface runoff in the area and this type of microcatchments is used in extremely dry areas. In general, trees are planted inside of the mound on which water is concentrated. However, tree species such as *Melia volkensii* should be planted outside of the mound since they are prone to root rot when subjected to waterlogged conditions. The position of planting the tree should therefore be determined according to characteristics of the tree species and the soil type.

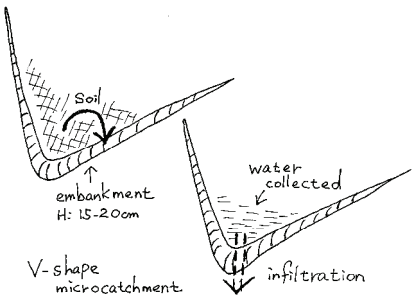


Fig. 2: Proceeding & concept of MC

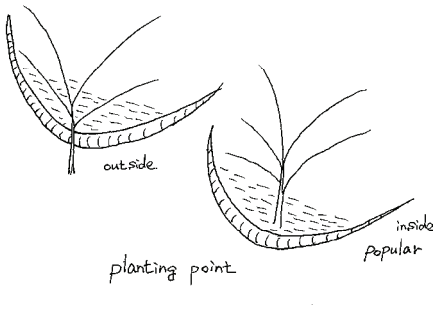


Fig. 3: Planting point

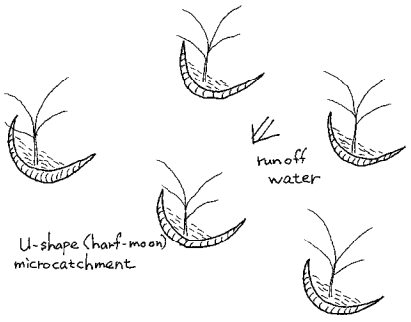


Fig. 4: An arrangement of U-shape MC

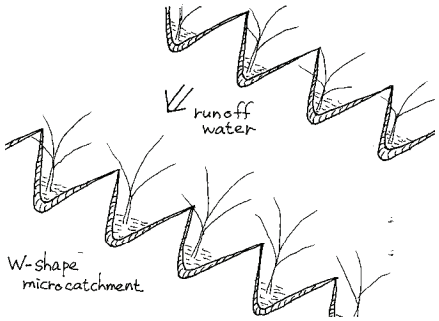
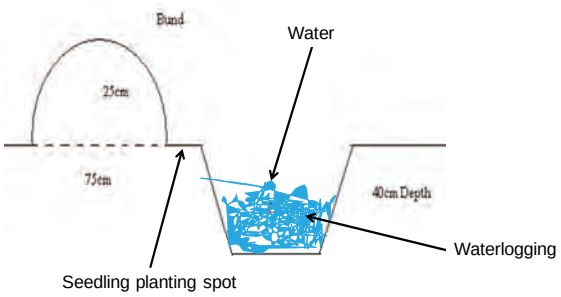


Fig. 5: An arrangement of W-shape MC

5.2 Negarim system

This consists of compartments separated by mound established continuously within a certain area. The area of 1 sq m within the compartment is dug down to the depth of 50 cm as the water storage section and the removed soil is used for the mound part (Photo 2 and3, Fig. 6). One

side of the water storage section has ramped part and trees are planted there. This technique is applicable in areas with annual rainfall of 150 mm or below, and can be applied in the land of slope angle between flat to 5%.



: Negarim water catchment

Photo 2: An arrangement of Negarim MC (Upper left)

Photo 3: Concept of Negarim MC (Left)

Fig. 6: Structure of Negarim MC (Upper right)

5.3 Contour ridge

This technique is used for planting trees within agricultural lands with the aim of supplying water to crops as well (Fig. 1 and Photo 4). This technique is effective for areas with annual rainfall of 350 to 700 mm and may be applied in regions with rainfall as low as 200 mm if tree planting is the primary purpose.

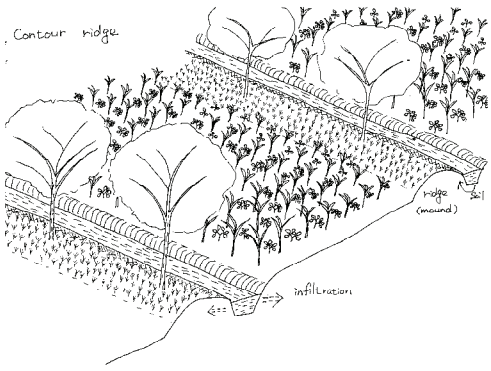


Fig. 7: Concept of contour ridge

Photo 4: An example of contour ridge

5.4 Bench terracing

This technique promotes soil infiltration of surface runoff water by reshaping the land into the terrace shape in steep terrains (Fig. 8 and Photo

5). The technique is used for areas with annual rainfall of 100 to 600 mm, and slope angle between 20 and 50%.

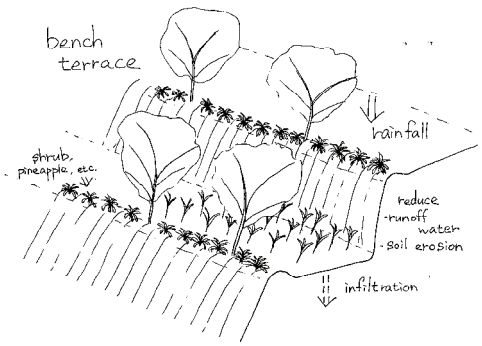


Fig. 8: Concept of bench terrace

Photo 5: An example of bench terrace

5.5 Fanya-juu terracing

This is an improved version of the “Bench terracing” (Photo 6 and 7). The technique can be applied where annual rainfall is 700 mm or higher, and the slope angle is 5 to 20%.

Photo 6: An example of Fanya–juu terracing

Photo 7: A variation of Fanya–juu terracing

5.6 Circular micro-catchment

Planted trees are encircled by a circular mound and water is pooled inside the mound. This technique is primarily used for fruits production within flat land where watering is possible. Application of mulch within this micro-catchment leads to more efficient results.

5.7 Large scale planting holes

By making larger planting holes, the amount of water maintained in soil can be increased (Fig. 9). This is effective in promotion of early development of the root system to the groundwater level. Characteristics and applicable area of each water-harvesting techniques are shown in Table 2

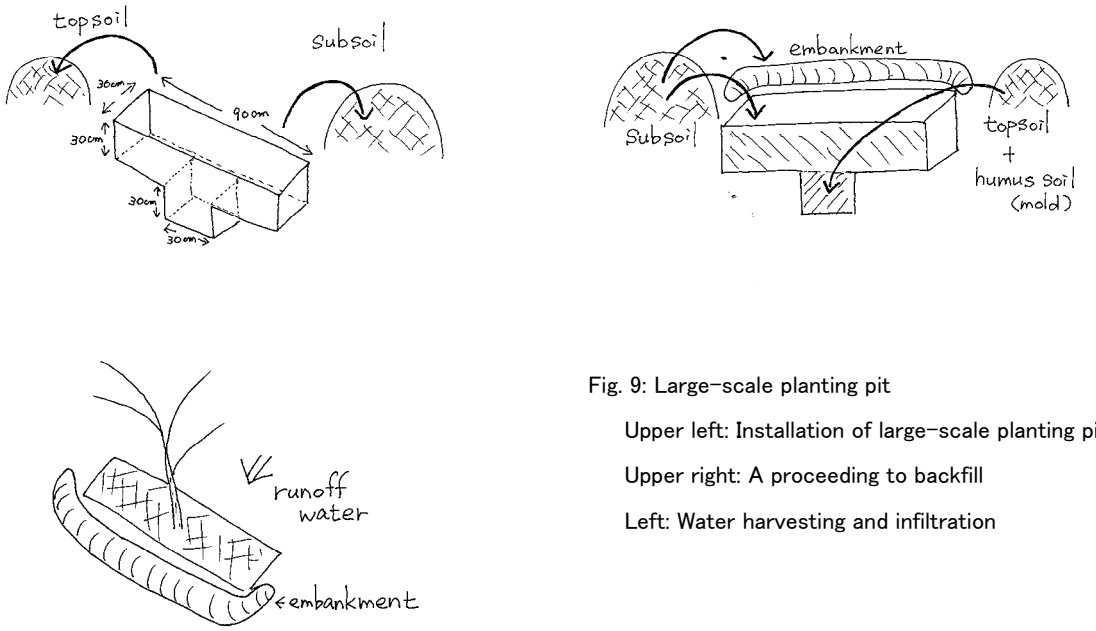


Fig. 9: Large-scale planting pit

Upper left: Installation of large-scale planting pit

Upper right: A proceeding to backfill

Left: Water harvesting and infiltration

Table 2: Characteristics and applicable area of each water-harvesting techniques

	Types of water catchment	Slope	Annual rainfall	Agro-forestry	Labor requirement	Remarks
1.	Negarim	flat - gentle	Feasible even 150mm below	difficult	slightly large	have high adaptability to severe arid condition
2.	Half-moon MC					
1)	W-shape MC	gentle	200-750mm	possible	slightly large	most adaptable to aridcondition among 3 types
2)	V-shape MC	gentle	200-750mm	possible	small	correct run-off water on one point
3)	U-shape MC	gentle	200-750mm	possible	small	improve soil moisture in wide range (comparison with other 2)
4.	Contour ridge	gentle	(200) 350-700mm	optimum	large	mainly use to agro-forestry
5.	Bench terrace	gentle – steep (20-50%)	100-600mm	optimum	very large	mainly use to agro-forestry adaptable to steep terrain
6.	Fanya-juu	gentle (5-20%)	700mm or more	optimum	large	mainly use to agro-forestry
7.	Circular MC	basically flat	basically watering	possible	small	periodically watering is basic requirement
8.	Big hole	flat - gentle	500-600mm (Myanmar)	possible	slightly large	effective in root development as well as soil moisture retention

6.0 Water Conservation Techniques

6.1 Tillage (Soil plowing)

Tillage is practiced in various regions for improvement of physical properties of soil, repression of the reproduction of weed, and inhibiting evaporation due to capillarity.

However, it is imperative to determine the range of application considering geographical features and application of organic fertilizers

because it has a risk of causing shortage of organic nutrients and soil erosion especially in sloppy lands. In general, for trees, soil under the range of canopies will be plowed up to 30 cm in depth.

6.2 Mulching

Mulching is a technique for suppressing evaporation of soil moisture from soil surface by covering soil surface with tree branches and grasses. However, mulching with organic material may attract termites.

6.3 Cover plants

Plant bodies covering the soil surface are expected to reduce moisture evaporation from the soil surface. The plants that spread wide leaves horizontally across the soil surface like "creeping beans" is suitable to use.

6.4 Complete weeding (Complete weed removal)

This is a technique that was developed during Social Forestry Training Project (SFTP) implemented jointly by JICA and KEFRI in Kitui. Weeds are completely uprooted to reduce water competition with trees and also limit the evaporation of soil moisture due to capillarity. However, complete weeding also poses a risk of causing soil erosion and loss of nutrients as with soil ploughing. It should be applied just around the trees, especially in sloping lands.

7.0 Water Saving Techniques

7.1 Direct sowing

This is a technique that involves sowing the seeds directly at the target point. This technique saves not only water but also nursery materials such as soil by applying this technique.

In West Africa, application of this technique to *Acacia nilotica*, *A. senegal*, *Senna siamea*, *Azadirachta indica*, *Balanites aegyptiaca*, *Moringa oleifera*, *Prosopis juliflora*, *Ziziphus mauritaniana* was reported. Appropriate seed pre- treatment to promote germination is required before sowing depending on the species.

7.2 Direct-planting of cutting

This is a technique which involves direct planting of cuttings from tree branches/ twigs into the target point or area. The technique saves water and nursery materials especially for species such as *Euphorbia turicallii* and *Gliricidia sepium*.

8.0 Other techniques to improve water environment

8.1 Watering (large scale)

In some cases, circular micro-catchments are installed for watering for fruits production. Because a certain amount of water is consumed by watering, consensus building inside the community is required before the application of this facility.

8.2 Watering (small scale)

PVC tubes and plastic bottles are some of the materials used as small-scale facilities for watering. This is applicable only to the range easy to access because regular management is required,.

9.0 Acceleration of natural regeneration by exclosures

Forest vegetation from degraded land can be regenerated by avoiding the pressure from human activities and browsing by domestic animals. This technique was demonstrated through experiment in Turkana, Kenya. The practice must be acceptable to local communities to succeed because the exclosures are usually managed jointly. The exclosures should be protected using community laws, hired guards to patrol the exclosure, fencing with barbed wire or hedges or dead branches of thorn trees. The cost of the enclosure is influenced by types and materials. Materials of low cost are recommended for the practice on a large scale. Existence of mother trees and/ or buried seed in the area of exclosure are mandatory requirement for regeneration.

10.0 Conclusion

Forest management based on the maintenance of local water balance is the fundamental issue for appropriate wood production corresponding to the initial objectives of sustainable development of forestry under persistent water consumption. New systematized techniques for re-afforestation in dry lands are desired to establish and to maintain the open forest with adequate tree density control. Especially to clarify the effects of tree density on the forest development, many kinds of forests which have precise past management history are necessary to compare growth properties under many kinds of site conditions. Then it is the issue of dry land forestry which should be started immediately, because a long time is necessary to establish suitable experimental forests.

Photo 8: An example of tillage for a mango crop

Photo 9:An example of tillage –in an agro–forestry system

Photo 10: Mulching using sawdust

Photo 11: Species of spreading form suitable as a cover plants

Photo 12: Circular micro–catchment

Photo 13: Exclosure using barbed and acacia thorns

Photo 14: A regenerated exclosure fenced with acacia thorns (left) and un–regerated area (right)

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