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IMPROVING CROP PRODUCTION THROUGH RAINWATER HARVESTING: MOROTO DISTRICT CASE STUDY (UGANDA)

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Acronyms

CPATSA	Centro de Pesquia Agropecuaria
ETo	Reference Evapotranspiration
EMBRAPA	Empresa Brasilera dePesquia Agropecuaria
FAO	Food Agricultural Organization
OCHA	Office for Coordination of Humanitarian Affairs
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
WH	Water Harvesting

Dedications

I dedicate this research work to my parents Mr. and Mrs. Obwoya, brothers and sisters.

Acknowledgments

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Not forgetting my relatives and well wishers (Toivo Shivute), I thank you all.

Abstract

Considering the persistently growing pressures on freshwater and soil resources, it becomes increasingly clear that the challenge of feeding tomorrow's world population is to a large extent, about improved water productivity with the present land use.

This study presents water harvesting in rain-fed agriculture and identifies key management challenges in present set of field experiences on the techniques options for increased water productivity in small holder farming in drought-prone areas of the Moroto district in Uganda.

A number of approaches like, analysis of literature review, site selection, and basic socioeconomic context of the site and use of software computer programme **FAO CLIMWAT 2.0,** were used to extract agro climatic data of this district.

Water harvesting techniques that conserve both soil and water were encouraged like; Tie-ridging, Negarim, Planting pits, and macro-catchment technique like small earth dams which suit the karimojong people for watering both livestock and crops , would help them remain on their land.

INTRODUCTION

As land pressure rises, more and more marginal areas in the world are being used for agriculture. Much of this land is located in the arid or semi-arid belts where rain falls irregularly and much of the precious water is soon lost as surface runoff. Recent droughts have highlighted the risks to human beings and livestock, which occur when rains falter or fail.

While irrigation may be the most obvious response to drought, it has proved costly and can only benefit a fortunate few. There is now increasing interest in a low cost alternative - generally referred to as "water harvesting".

Water harvesting (WH) is the collection of runoff for productive purposes. Instead of runoff being left to cause erosion, it is harvested and utilized. In the semi-arid drought-prone areas, where it is already practiced, water harvesting is a directly productive form of soil and water conservation. Both yields and reliability of production can be significantly improved with this method.

WH can be considered as a rudimentary form of irrigation. The difference is that with WH the farmer (or more usually, the agro-pastoralist) has no control over timing. Runoff can only be harvested when it rains. In regions where crops are entirely rain fed, a reduction of 50% in the seasonal rainfall, for example, may result in a total crop failure. If, however, the available rain can be concentrated on a smaller area, reasonable yields will still be received. Of course in a year of severe drought there may be no runoff to collect, but an efficient water harvesting system will improve plant growth in the majority of years.

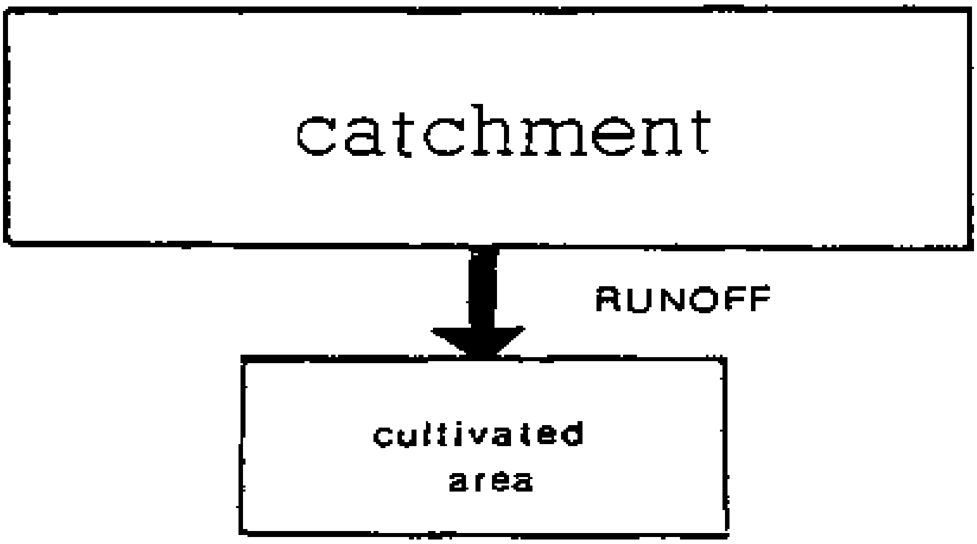

Figure 1: The principle of water harvesting

Historical perspectives of Water Harvesting

Various forms of water harvesting (WH) have been used traditionally throughout the centuries. Some of the very earliest agriculture, in the Middle East, was based on techniques such as diversion of "wadi" flow (spate flow from normally dry watercourses) onto agricultural fields. In the Negev Desert of Israel, WH systems dating back 4000 years or more have been discovered (Evanari et al**.,** 1971). These schemes involved the clearing of hillsides from vegetation to increase runoff, which was then directed to fields on the plains.

Floodwater farming has been practised in the desert areas of Arizona and northwest New Mexico for at least the last 1000 years (Zaunderer and Hutchinson, 1988). The Hopi Indians on the Colorado Plateau cultivated fields situated at the mouth of ephemeral streams. Where the streams fan out, these fields are called "Akchin". Pacey and Cullis (1986) describe micro-catchment techniques for tree growing, used in southern Tunisia, which were discovered in the nineteenth century by travelers. In the "Khadin" system of India, floodwater is impounded behind earth bunds, and crops then planted into the residual moisture when the water infiltrates.

The importance of traditional, small scale systems of WH in Sub-Saharan Africa is just beginning to be recognized (Critchley and Reij, 1989). Simple stone lines are used, for example, in some West African countries, notably Burkina Faso, and earth bunding systems are found in Eastern Sudan and the Central Rangelands of Somalia.

Recent developments of Water Harvesting

A growing awareness of the potential of water harvesting for crop production arose in the 1970s and 1980s, with the widespread droughts in Africa leaving a trail of crop failures. The stimulus was the well-documented work on WH in the Negev Desert of Israel (Evanari et al., 1971).

However much of the experience with WH gained in countries such as Israel, USA and Australia has limited relevance to resource-poor areas in the semi-arid regions of Africa and Asia. In Israel, research emphasis is on the hydrological aspects of micro catchments for fruit trees such as almonds and pistachio nuts. In the USA and Australia, WH techniques are mainly applied for domestic and livestock water supply, and research is directed towards improving runoff yields from treated catchment surfaces.

A number of WH projects have been set up in Sub-Saharan Africa during the past decade. Their objectives have been to combat the effects of drought by improving plant production (usually annual food crops), and in certain areas rehabilitating abandoned and degraded land (Critchley and Reij, 1989). However, few of the projects have succeeded in combining technical efficiency with low cost and acceptability to the local farmers or agro pastoralists. This is partially due to the lack of technical "know how" but also often due to the selection of an inappropriate approach with regard to the prevailing socio-economic conditions.

Future directions when developing Appropriate Techniques

Appropriate systems should ideally evolve from the experience of traditional techniques - where these exist. They should also be based on lessons learned from the shortcomings of previous projects. Above all, it is necessary that the systems are appreciated by the communities where they are introduced. Without popular participation and support, projects are unlikely to succeed. Water harvesting technology is especially relevant to the semi-arid and arid areas where the problems of environmental degradation, drought and population pressures are most evident. It is an important component of the package of remedies for these problem zones, and there is no doubt that implementation of WH techniques will expand.

CHAPTER ONE: BACKGROUND

1.1 Location

Uganda is a landlocked country in East Africa. Uganda lies astride the Equator, between latitudes 4^{o} 12´ N and 1^{o} 29´ S and longitudes 29^{o} 34´ W, and 35^{o} 0´ E. Temperatures are in the range of 15^{o} - 30^{o} C.

It is bordered on the East by Kenya, on the North by Sudan, on the West by the Democratic Republic of the Congo, on the South West by Rwanda, and on the South by Tanzania (Figure 2). The Southern part of the country includes a substantial portion of Lake Victoria, within which it shares borders with Kenya and Tanzania.
Uganda takes its name from the Buganda Kingdom, which encompassed a portion of the south of the country including the capital Kampala.

1.1.1 Terrain

More than two-thirds of the country is a plateau, lying between 1000 - 2500 m a.s.l.

1.1.2 Lakes and Rivers

Uganda is a well watered country. Nearly one-fifth of the total area, or 44,000 square kilometres, is open water or swampland. Four of East Africa's Great Lakes-Lake Victoria , Lake Kyoga, Lake Albert, and Lake Edward-lie within Uganda or on its borders. Lake Victoria dominates the South-eastern corner of the nation, with almost one-half of its 10,200-square-kilometer area lying inside Ugandan territory. It is the second largest inland freshwater lake in the world after Lake Superior, and feeds the upper waters of the Nile River, which is referred to in this region as the Victoria Nile.

1.1.3 Climate

Uganda enjoys a tropical climate tempered by the altitude. The country is generally flat though the average altitude is about 1000 m a.s.l. Due to the rather high altitude, temperatures range between 21 and 25° C. The hottest period is from December to February when temperatures rise to 29° C. The country experiences two rainy seasons: April to May and October to November, with April being the wettest months. The Northern part has a wet season lasting from April to October. It is semi arid in the Northeastern part of the country.

1.1.4 Area

Total: 236,040 km^2

Land: 199,710 km^2

Water: 36,330 km^2

1.1.5 Land use

Arable land: 25%

Permanent crops: 9%

Forests and woodland: 28%

Other: 29%

Figure 2: Map of Uganda

1.2 Economy

Uganda's economy is agriculture based, with agriculture employing over 80% of the population and generating 90% of export earnings. Coffee is the main export crop, with tea and cotton as other agricultural products. Uganda also has mineral deposits of copper and cobalt, which contributed 30% of export earnings during the 1960s, although the mining sector is now only a minor contributor to the economy.

The upheavals of the 1970s and the troubles of the 1980s left the economy in disarray. However, economic reforms that began in 1986 have resulted in important progress. The government made significant strides in liberalizing markets and releasing government influence during the 1990s, although some administrative controls remained in 2003. Monopolies were abolished in the coffee, cotton, power generation, and telecommunications sectors and restrictions on foreign exchange were removed. Reforms improved the economy and gained the confidence of international lending agencies.

The economy has posted growth rates in the GDP averaging 6.9% from 1988–1998, and 6% from 1998–2003. Consequently, the economy has almost doubled. Still, Uganda is one of the poorest countries in the world, heavily dependent on foreign aid (approximately 55% of government spending in 1998). High growth rates are necessary to balance the population growth rate of over 3%. The government in 2003 was known for its sound fiscal management. World coffee prices recovered in 2003, which brought in revenue. New property developments have been fueled by an influx of foreign investment, which has provided testimony of confidence in Uganda's economy. Ugandan Asians, who had been expelled by Idi Amin in 1972, have had their property restored and have brought business back into the country.

One of the first African nations hit by HIV/AIDS, Uganda had by 2003 witnessed a drop in infection rates over the previous decade. However, Uganda's continued involvement in the civil war in the Democratic Republic of the Congo compromised the progress Uganda has made on many other fronts.

Though the country is a relatively new nation, it has had to endure years of political instability and upheaval. Since the current government took over in 1986, the nation has been stable with two notable exceptions the ongoing conflict in the North with the LRA and the issues in the North-Eastern region of Karamoja.

1.3 Existing Situation in Moroto District

The Karimojong is the generic name given to those who inhabit the district of Moroto, they are unlike any other tribal group in Uganda. Many distinctive differences set them apart from the rest of the country. The Karamojong practice subsistence crop production and semi nomadic animal rearing.

1.3.1 Location

Moroto district is situated in the North-eastern part of Uganda .The district lies approximately between Latitudes 1°53'N, 3°5’N and Longitudes 33°38'E, 34°56’E.

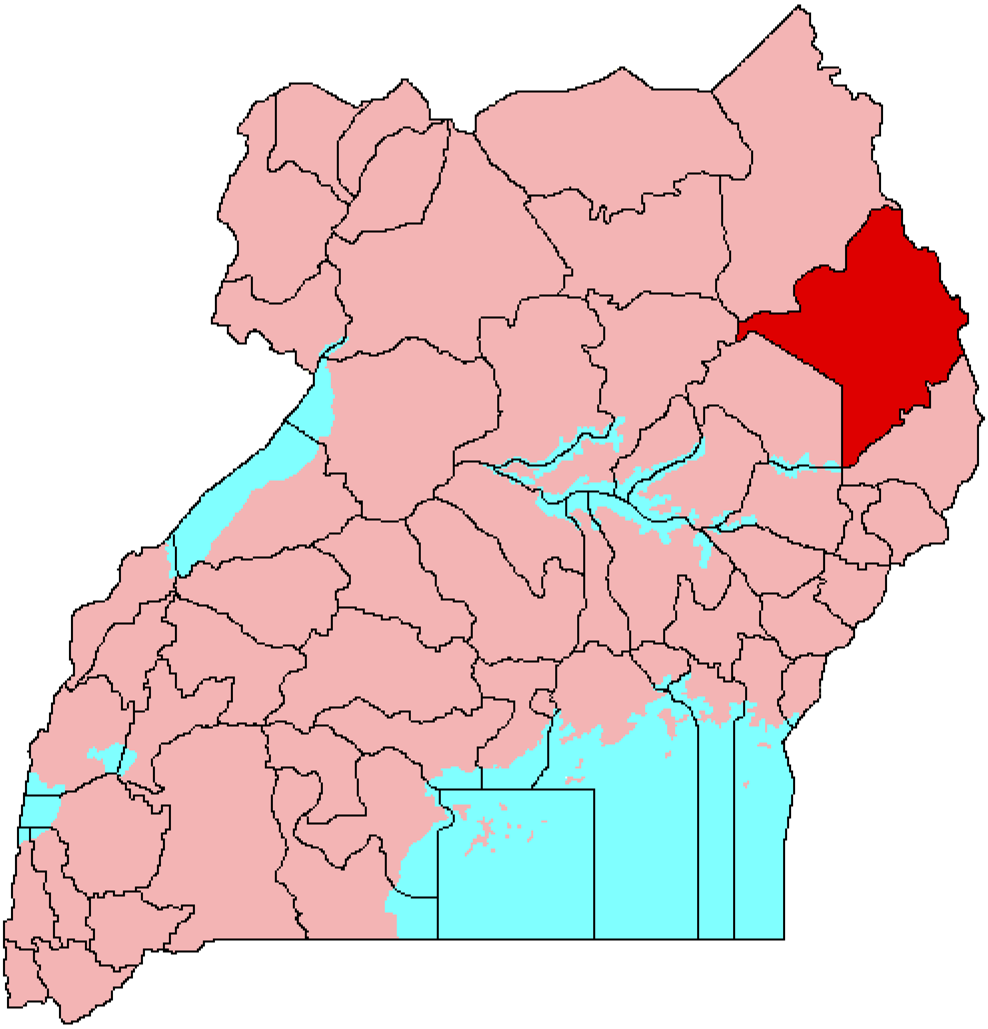

Figure 3: Location of Moroto District

1.3.2 Vegetation

The vegetation cover in Moroto district is typically semi-arid with dominant savannah grass species. The main vegetation includes forests at high altitude (dry montane forests, savannah woodland, semi-ever green thickets). Forests are found on localized patches, like on hills and Mountains such as Mount Moroto.

1.3.3 Topography

The topography has been briefly described by Wayland and Brasnett (1938). The district consists essentially of plain rising eastwards and northwards to the hilly land, bordering the escarpments above the Turkana district of Kenya, some of the land in the south-west is below 1000 m, but most of the district lies above this altitude.

1.3.4 Climatic Data

Moroto's climate is characterized by poor, uneven and erratic rainfall ranging from 500-900 mm per annum fluctuating between semi-arid to dry sub-humid. The precipitation that falls usually comes from April to September. In the recent years, rains have been inadequate and severe crop failure with one annual cropping season which is normally between April and September.

During the rainy season, Karamoja has more intense rainfall than the rest of the country, but with short duration.

1.3.5 Land use and Human environment

About 3,500 km^2 is available for cultivation after making allowance for game reserve and parks (4900 km^2) and mountains (100 km^2). The population density on arable land is 23 persons per km^2.

1.3.5.1 Main soil types

Sandy loams, clay loams and sandy clay are the various soil types in the district.

1.3.5.2 Crops Grown

The Karimojong are agro-pastoralists, growing crops especially vegetables, sorghum and millet which is gaining prominence alongside livestock rearing.

Differences in rainfall patterns have resulted into variations in crops planted, with decreased crop diversity in areas with less consistent rainfall. In Rupa sub-county in Matheniko County, for example, the main crops are maize and sorghum. Much greater diversity exists in parts of Iriri sub-county in neighboring Bokora, where maize and sorghum are supplemented by millet, beans, groundnuts, simsim (sesame), sunflower, vegetables, yams sweet potatoes, cowpeas, rice, and cassava, among others.

Most of the population of Moroto subsists through agro-pastoral or strictly pastoral livelihoods; few Karimojong have livelihoods that are not linked to the pastoral tradition. In the agro-pastoral areas, the lack of irrigation means the population is dependent on wet-season cultivation and semi-nomadic pastoralism. Unlike many other regions in Uganda, Karamoja has only one cropping season, which is normally between April and September (Uganda: OCHA Situation Report No.1-Focus on Karamoja, 2008).

1.3.5.3 Water sources

The main sources of protected water in the districts are hand pump bore holes although a number of them are dysfunctional or functioning in poor mechanical conditions. Alternative to boreholes are the traditional unprotected sources (springs, seasonal rivers water ponds). The households do not harvest rainfall water which could alleviate temporal and spatial water scarcity and provide safe water for basic human needs during the rainy season.

1.3.5.4 Population

According to the 2001 UNDP Human Development report, the district had the lowest human development index: about 0.24 compared to other districts in Uganda.

Moroto has the worst social indicators compared to other regions in Uganda. This district occupies the worst positions in the ranking by district of the Human Development Index and the Human Poverty Index. Lack of development and the appalling poverty levels in the region are, to a large extent, due to the widespread insecurity in the area. Related to this factor is the ancient tradition of cattle rustling together with the long term neglect of the region by successive governments.

1.3.5.5 Gender and equity

The Karimojong culture marginalises women from decision making. Women have different and crucial interests in decision making because of unique needs that directly affect their lives (such as provision of safe water). Women have a low opinion of themselves and lack forums to express their needs so they have limited access to decision making within project allocation and planning cycles.

1.3.5.6 Land Tenure system

Lease hold is the form of land tenure existing in urban areas of Moroto district. Land is leased by the Municipal council.

Customary land tenure system exists in the rural areas of Karamoja, which leads to land fragmentation. Men control land and not the women, and only men can own land.

1.4 Problem statement

The Karimojong move their cattle from place to place with the hope of finding pastures and water during the dry seasons. During such times crops have failed to mature and therefore increasing the situation of food insecurity in the district as much of the harvest is lost due to crop failure. Water harvesting approach can contribute to the enhancement of water availability in this drought-prone region.

1.5 Objectives of the study

The objective of the study was:

- To promote water harvesting techniques: that will supplement water for the rain fed crops to improve their yields and hence increasing crop production and income generating activities.
- To realise some guidelines that should be followed when implementing appropriate water harvesting technique.

CHAPTER TWO: LITERATURE REVIEW

2.1 Preamble

A relatively high percentage of the population in sub-Saharan Africa makes their living from rain fed agriculture and depends, to a large extent, on small-holder subsistence agriculture for their livelihood security (e.g., Malawi 90%, Botswana 76%, Kenya 85% and Zimbabwe 70-80% of the population).

An estimated 38% of the populations in sub-Saharan Africa (roughly 260 million people) live in drought condition (UNDP/UNSO, 1997). The large increase in food production and household income, needed in sub-Saharan Africa, has to be achieved through an increase in biomass produced per unit of land and per unit of water. The rain fed agriculture impacts the overall agriculture production in developing countries and the rainfall influences the water balance in irrigated agriculture. Low productivity in rain fed agriculture is essentially related to inadequate rainwater management strategies.

Like for many of Uganda’s neighbors, in the East and central Africa region, rainfall is the primary determinant of crop production in Uganda. However, rainfall is highly variable in the most parts of the country in terms of length of the rainy season and the amount of rainfall (DWD, 1995). Drought has occurred in various parts of the Uganda many times, seriously affecting crop production, food market prices and ultimately, the cost of living (NEMA, 2001). This uncertainty, regarding agricultural production as well as investments in agricultural improvements, has caused concerns in both local authorities and world bodies alike, which have been collaborating to combat drought.

2.2 Rain water harvesting

Rainwater harvesting refers to the collection and concentration of runoff water from a runoff area into a run-on area, to be either directly applied to a cropping area and stored in the soil profile for direct uptake by crops and trees (that is runoff farming) or stored in an on-farm water reservoir for the future productive uses like domestic consumption, livestock watering, aquaculture, irrigation and for recharging of ground water aquifers.

Water harvesting is a proven technology to increase food security in drought prone areas. Erosion control and recharge of ground water are the additional advantages of water harvesting techniques.

2.2.1 Rain Water harvesting techniques

There are two major types of rain water harvesting:

- Micro catchments water harvesting: is a method of collecting surface runoff (sheet and rill flow) from small catchments area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a single tree or bush or annual crops (Prinz, 2001). It is implemented in areas receiving annual rainfall of more than 200 mm for tree planting and more than 300 mm annual rainfall for crop production.
- Macro catchments water harvesting is also called “water harvesting along slopes” or harvesting from “external catchments systems” (Pacey & Cullis, 1986). In this case, the runoff from hill slope catchments is conveyed to the cropping area, which is located below the hill foot on a flat terrain. Macro catchment water harvesting is implemented in areas receiving annual rainfall equivalent or greater than 300 mm. Slope of the catchment’s area ranges from 5-50% and the cropping area is either terraced or in a flat terrain (<10% slope).

Rain water harvesting provides many advantages over irrigation schemes which are; they are simple and inexpensive to construct using local materials and manpower. The runoff water has a low salt content and, because it does not have to be pumped or transported, is relatively inexpensive.

2.2.1.1 Micro catchment water harvesting techniques

2.2.1.1.1 Contour bunds

These are constructed in relatively low rainfall areas having annual rainfall of less than 600 mm, particularly in areas having light textured soils. They are essentially meant for storing rainwater received during a period of 24 hours at 10 years recurrence interval. The major considerations are maximum depth of water to be impounded, design depth of flow over waste weir and desired free board.

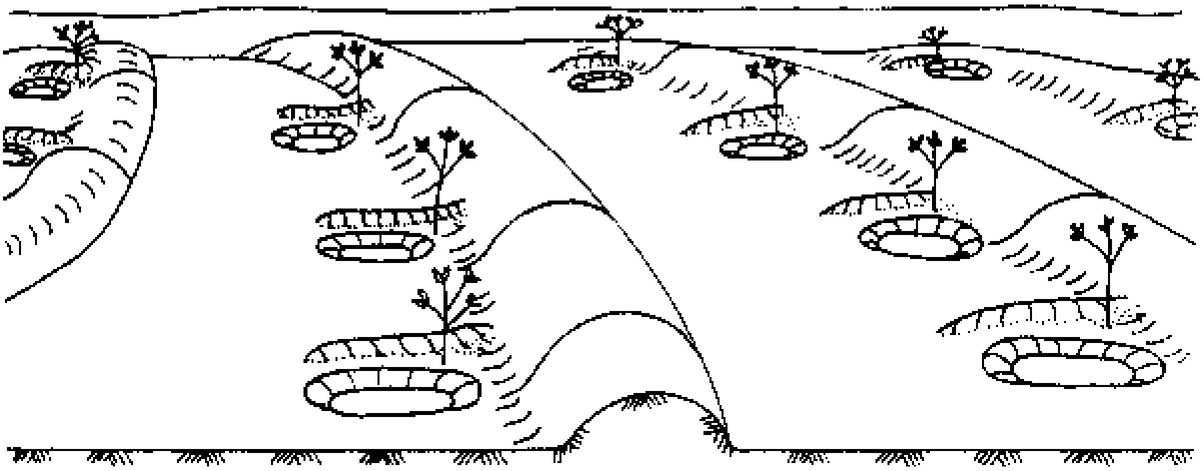

Figure 4: Layout of contour bunds

Table I: Technical details for contour bunds

Suitability	Tree planting
Soils	Deep soils, 1.5 m-2 m
Slopes	Flat up to 5%
Topography	Even, without gullies/rills
Rainfall	200 mm- 750 mm

- **Limitations**

Contour bunds are not suitable for uneven or eroded land as overtopping of excess water with subsequent breakage may occur at low spots.

- **Overall Configuration**

The overall layout consists of a series of parallel, or almost parallel, earth bunds approximately on the contour at a spacing of between 5 and 10 metres.

The bunds are formed with soil excavated from an adjacent parallel furrow on their upslope side. Small earth ties perpendicular to the bund on the upslope side subdivide the system into micro catchments. Infiltration pits are excavated in the junction between ties and bunds. A diversion ditch protects the system where necessary.

- **Maintenance**

As with Negarim micro catchments, maintenance will in most cases be limited to repair of damage to bunds early in the first season. It is essential that any breaches -which are unlikely unless the scheme crosses existing rills - are repaired immediately and the repaired section compacted. Damage is frequently caused if animals invade the plots. Grass should be allowed to develop on the bunds, thus assisting consolidation with their roots.

- **Husbandry**

The majority of the husbandry factors noted under Negarim micro catchments also apply to this system: there are, however, certain differences.

Tree seedlings, of at least 30 cm height, should be planted immediately after the first runoff has been harvested. The seedlings are planted in the space between the infiltration pit and the cross-tie. It is advisable to plant an extra seedling in the bottom of the pit for the eventuality of a very dry year. Manure or compost can be added to the planting pit to improve fertility and water holding capacity.

One important advantage of contour bunds for tree establishment is that oxen or mechanized cultivation can take place between the bunds, allowing crops or fodder to be produced before the trees becomes productive. However, this has the disadvantage of reducing the amount of runoff reaching the trees.

- **Socio-economic factors**

Contour bunds for trees are mainly made by machine; costs of bund construction can be relatively low and implementation fast, especially where plots are large and even and the kind of mechanization well adapted.

However, as with all mechanization in areas with limited resources, there is a question mark about future sustainability. Experience has shown that very often the machines come abruptly to a halt when the project itself ends.

Another aspect that must be addressed is the management after the scheme has been established (which is usually done under the auspices of a development project). This is an issue which has to be seriously considered during the planning phase. Management of a large afforestation block by the local community is, in most cases, a new challenge and failure or success will depend on acceptance of the technique by the rural population.

2.2.1.1.2 Contour bench terraces

These are used both on hill slopes as well as on degraded and barren waste lands for soil and moisture conservation and afforestation purposes. The trenches break the slope and reduce the velocity of surface runoff. It can be used in all slopes irrespective of rainfall conditions (i.e., in both high and low rainfall conditions), varying soil types and depths.

Specifications: trenches can be continuous or interrupted. The interrupted ones can be in series or staggered, continuous one is used for moisture conservation in low rainfall areas and requires careful layouts.

2.2.1.1.3 Negarim (pitting) technique

These are diamond shaped micro-catchments enclosed by earthen bunds (walls), with an infiltration pit at the lowest corner. They are one way to harvest rainwater runoff and deliver it to fruit trees such as citrus, paw paws and mangoes.

Table II: Technical details for Negarim Technique

Suitability	Mainly tree planting
Soils	Deep soil, 1.5m- 2m
Slopes	From flat to 5%
Topography	Need not be even
Rainfall	As low as 150 mm per annum

- **Overall configuration**

Each microcatchment consists of a catchment area and an infiltration pit (cultivated area). The shape of each unit is normally square, but the appearance from above is of a network of diamond shapes with infiltration pits in the lowest corners (Figure 5).

- **Limitations**

While Negarim micro catchments are well suited for hand construction, they cannot easily be mechanized. Once the trees are planted, it is not possible to operate and cultivate with machines between the tree lines.

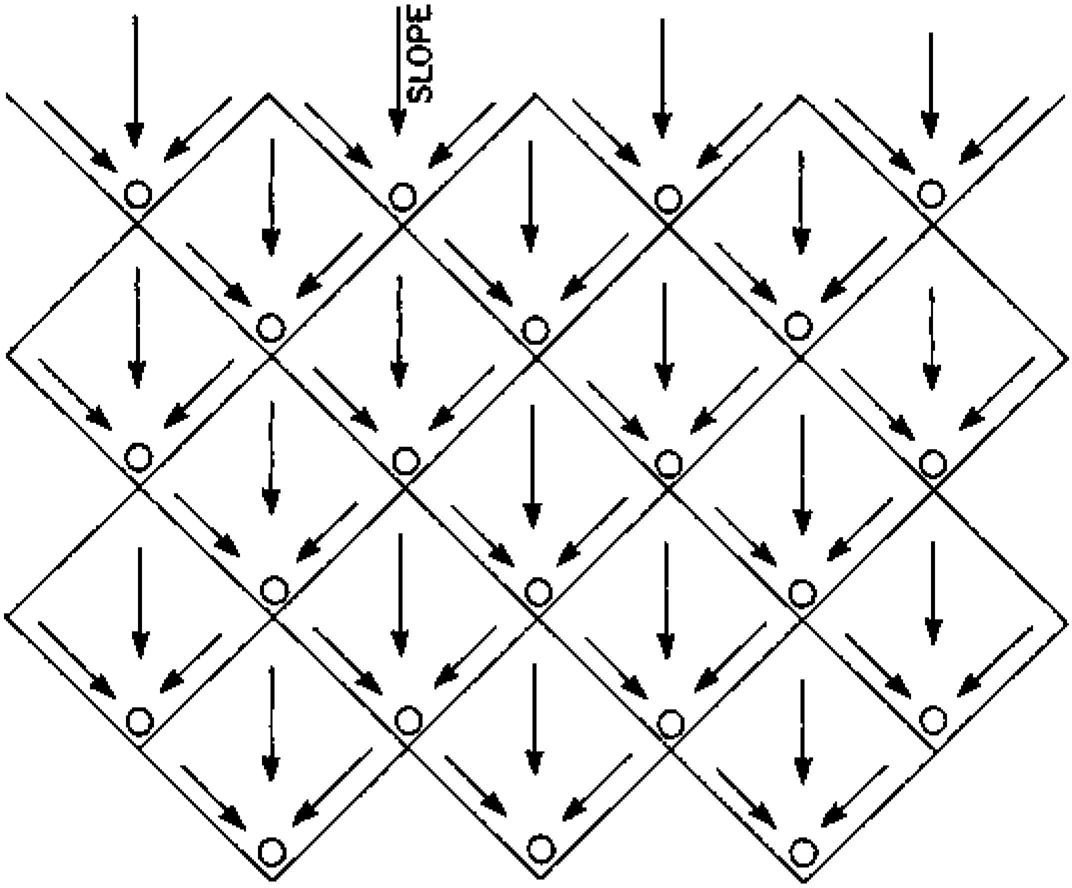

Figure 5: Negarim micro catchments - field layout

2.2.1.1.4 Planting pits

These are also known as zai (or zay) pits or 5x9 pits depending on shape and size. The method involves growing field crops in holes of various sizes. The zai system has been practiced for many years in the Sahelian region of West Africa. In Kenya, planting pits are not commonly used, although trials by researchers and farmers have produced good results, showing that the system has great potential for improving crop production in dry areas. Planting pits increase crop yields by a combination of moisture conservation and harvesting of runoff from the spaces between the pits. In addition, soil fertility is restored since the manure and fertilizer cannot be lost through surface runoff.

Planting pits are recommended for relatively low rainfall areas, or where moisture conservation is desired, to enable a crop survive drought and increase production.

Figure 6: Banana plant growing in planting pits

2.2.1.1.5 Semi-circular Bunds

Semi-circular bunds are earth embankments in the shape of a semi-circle with the tips of the bunds on the contour, as seen in Figure 7. Semi-circular bunds, of varying dimensions, are used mainly for rangeland rehabilitation or fodder production. This technique is also useful for growing trees and shrubs and, in some cases, has been used for growing crops. Depending on the slope of the catchment area, the technique may be changed. Semi-circular bunds (the term "demi-lune" is used in Francophone Africa) are recommended as a quick and easy method of improving rangelands in semi-arid areas. Semi-circular bunds are more efficient in terms of impounded area to bund volume than other equivalent structures - such as trapezoidal bunds**.**

Table III: Technical details for Semi-circular bunds

Suitability	For range land improvement
Soils	Not too shallow or saline
Slopes	Below 2%
Topography	Not stated
Rainfall	200-750 mm

- **Limitation**

The main limitation of semi-circular bunds is that construction cannot easily be mechanized.

- **Overall configuration**

The two designs of semi-circular bunds considered here differ in the size of structure and in field layout. Design **"a"** has bunds with radii of 6 metres, and design "b" has bunds with radii of 20 metres. In both designs the semi-circular bunds are constructed in staggered lines with runoff producing catchments between structures.

Design "a" is a short slope catchment technique, and is not designed to use runoff from outside the treated area, or to accommodate overflow. Design **"b"** is also a short slope catchment system, but can accommodate limited runoff from an external source. Overflow occurs around the tips of the bund which are set on the contour.

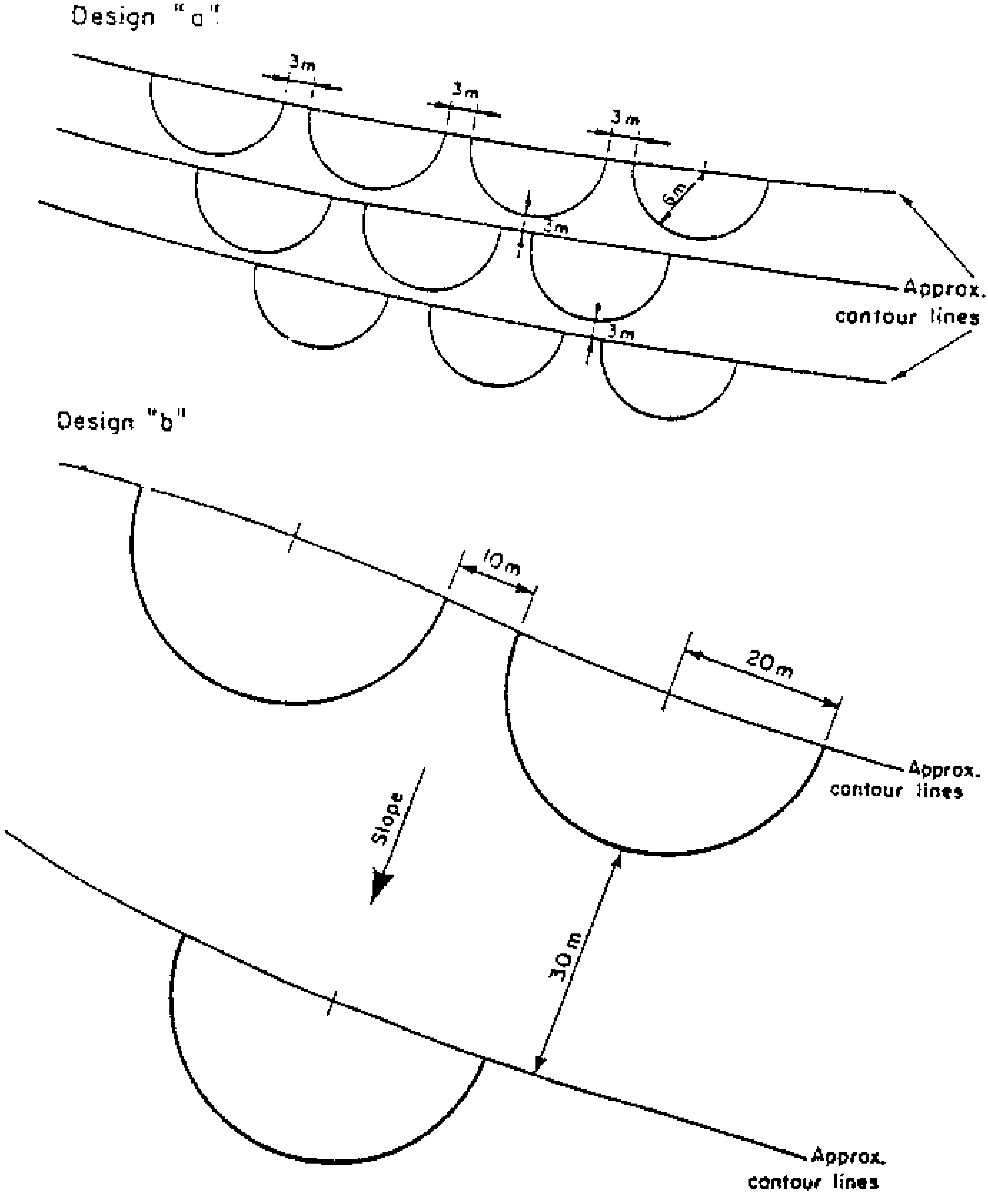

Figure 7: Semicircular Bunds, Field layout

- **Maintenance**

As with all earthen structures, the most critical period for semi-circular bunds is when rainstorms occur just after construction, since at this time the bunds are not yet fully consolidated. Any breakages must be repaired immediately. If damage occurs, it is recommended that a diversion ditch is provided if not already constructed. Semi-circular bunds which are used for fodder production normally need repairs of initial breaches only. This is because in the course of time, a dense network of the perennial grasses will protect the bunds against erosion and damage. The situation is different if animals have access into the bunded area and are allowed to graze. In this case, regular inspections and maintenance (repair) of bund damages will be necessary.

- **Husbandry**

It may be possible to allow the already existing vegetation to develop - provided it consists of desirable species or perennial rootstock. In most cases, however, it will be more appropriate to re-seed with seed from outside. Local collection of perennial grass seed from useful species can also be appropriate provided the seed is taken from "virgin land". Together with grass, trees and shrub seedlings may be planted within the bunds.

- **Socio-economic Factors**

Water harvesting for range improvement and for fodder production will mainly be applied in areas where the majority of the inhabitants are agro-pastoralists - at least in the Sub-Saharan Africa context.

Controlled grazing is also essential to maintain good quality rangeland, and the bunded area must be rested periodically for it to regenerate, so that natural reseeding can take place.

2.2.1.1.6 Contour stone bunds

Contour stone bunds are used to slow down and filter runoff, thereby increasing infiltration and capturing sediment. The water and sediment harvested lead directly to improved crop performance. This technique is well suited to small scale application on farmer's fields and, given an adequate supply of stones, can be implemented quickly and cheaply.

Making bunds - or merely lines - of stones is a traditional practice in parts of Sahelian West Africa, notably in Burkina Faso. Improved construction and alignment along the contour makes the technique considerably more effective. The great advantage of systems based on stone is that there is no need for spillways, where potentially damaging flows are concentrated. The filtering effect of the semi-permeable barrier along its full length gives a better spread of runoff than earth bunds are able to do. Furthermore, stone bunds require much less maintenance.

Stone bunding techniques for water harvesting (as opposed to stone bunding for hillside terracing, a much more widespread technique) is best developed in Yatenga Province of Burkina Faso. It has proved an effective technique, which is popular and quickly mastered by villagers.

. Table IV: Technical details for Contour – stone Bunds

Suitability	Crop production
Soils	Agricultural soils
Slopes	Preferably below 2 %
Topography	Need not be completely even
Rainfall	200-750 mm

- **Resources**

There must be good local supply of stones to the sited area.

- **Overall configuration**

Stone bunds follow the contour, or the approximate contour, across fields or grazing land. The spacing between bunds ranges normally between 15 and 30 m depending largely on the amount of stone and labour available. There is no need for diversion ditches or provision of spillways.

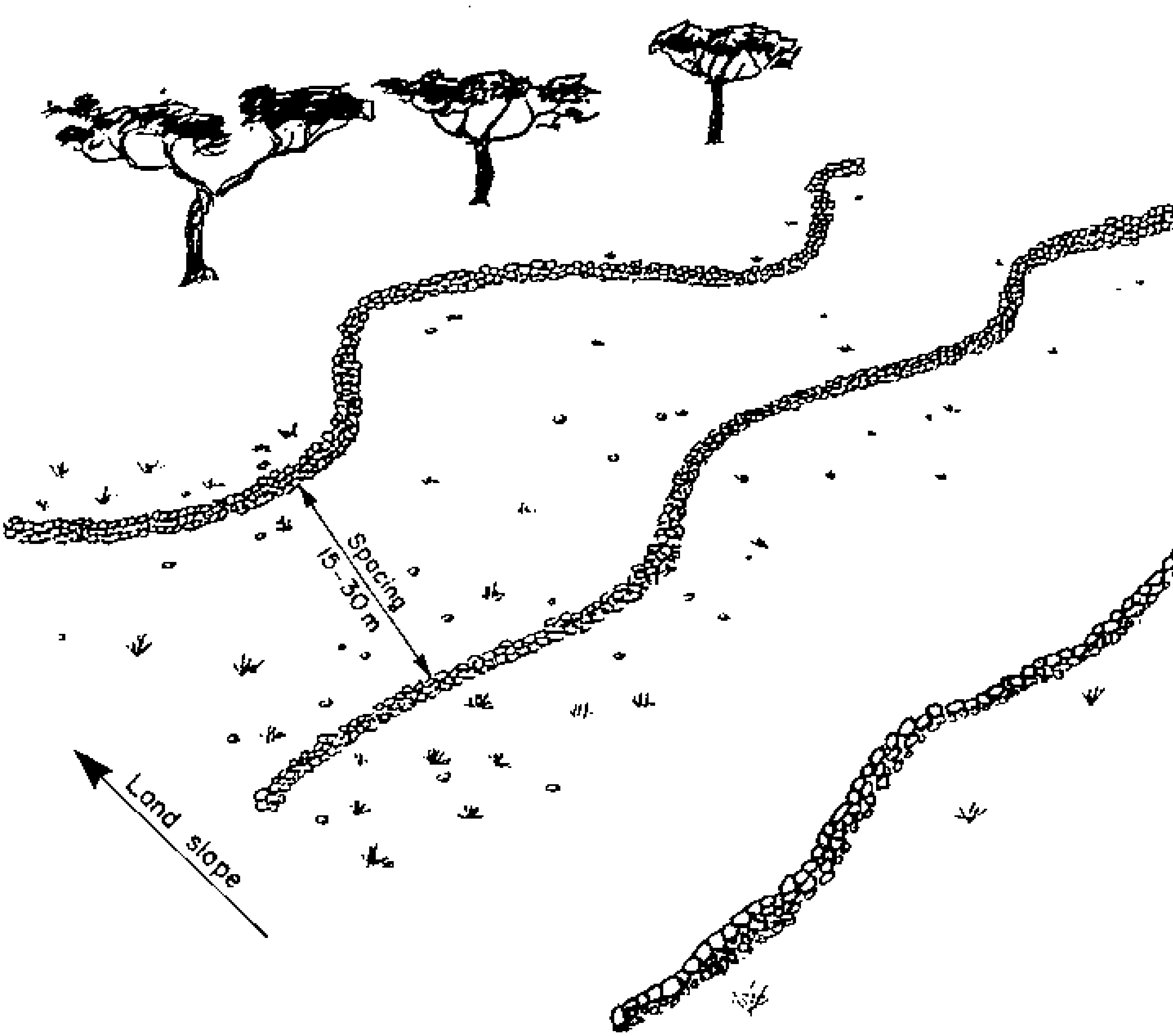

Figure 8: Contour stone bunds: field layout (source: Critchely and Reij, 1989)

2.2.1.1.7 Tie-Ridging

This is an in situ rainwater harvesting technique that has been found to be very efficient in reducing runoff, soil erosion and resulted in effective soil and water conservation (Georgis, 1999).

The system for in situ capture of rainwater using tied ridges has been further developed by EMBRAPA-CPATSA. It consists of ploughing and ridging at 0.75 m row spacing, followed by an operation to tie the ridges with small mounds along each furrow so as to impede the runoff of the rainwater. Tying the ridges is done with an implement designed for use with animal traction (*Figure 9)* and should be undertaken before planting on the ridges.

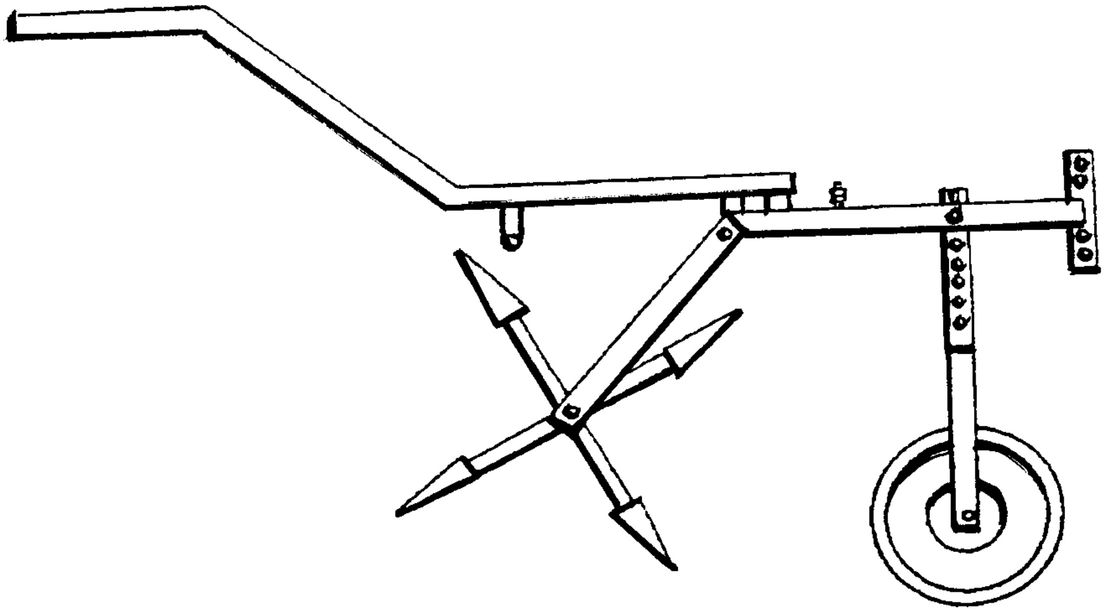

Figure 9: Tie ridge implement

2.2.2.1 Macro catchment water harvesting techniques

2.2.2.1.1 Permeable rock dam

These are floodwaters farming techniques where runoff waters are spread in valley bottoms for improved crop production. Developing gullies are healed at the same time. The structures are typically long, low dam walls across valleys. Permeable rock dams can be considered a form of "terraced wadi", though the latter term is normally used for structures within watercourses in more arid areas.

Table V: Technical details for Permeable rock dams

Suitability	Crop production
Soils	All agricultural soils, poorer soils will be improved by treatment
Slopes	Best below 2 % for effective water spreading
Topography	Wide shallow valley beds
Rainfall	200-750 mm

- **Limitations**

The main limitation of permeable rock dams is that they are particularly site-specific, and require considerable quantities of loose stone as well as the provision of transport.

- **Overall configuration**

A permeable rock dam is a long, low structure, made from loose stone (occasionally some gabion baskets may be used) across a valley floor. The central part of the dam is perpendicular to the watercourse, while the extensions of the wall to either side curve back down the valleys approximately following the contour. The idea is that the runoff which concentrates in the centre of the valley, creating a gully, will be spread across the whole valley floor, thus making conditions more favorable for plant growth. Excess water filters through the dam or over tops during peak flows. Gradually the dam silts up with fertile deposits. Usually a series of dams is built along the same valley floor, giving stability to the valley system as a whole.

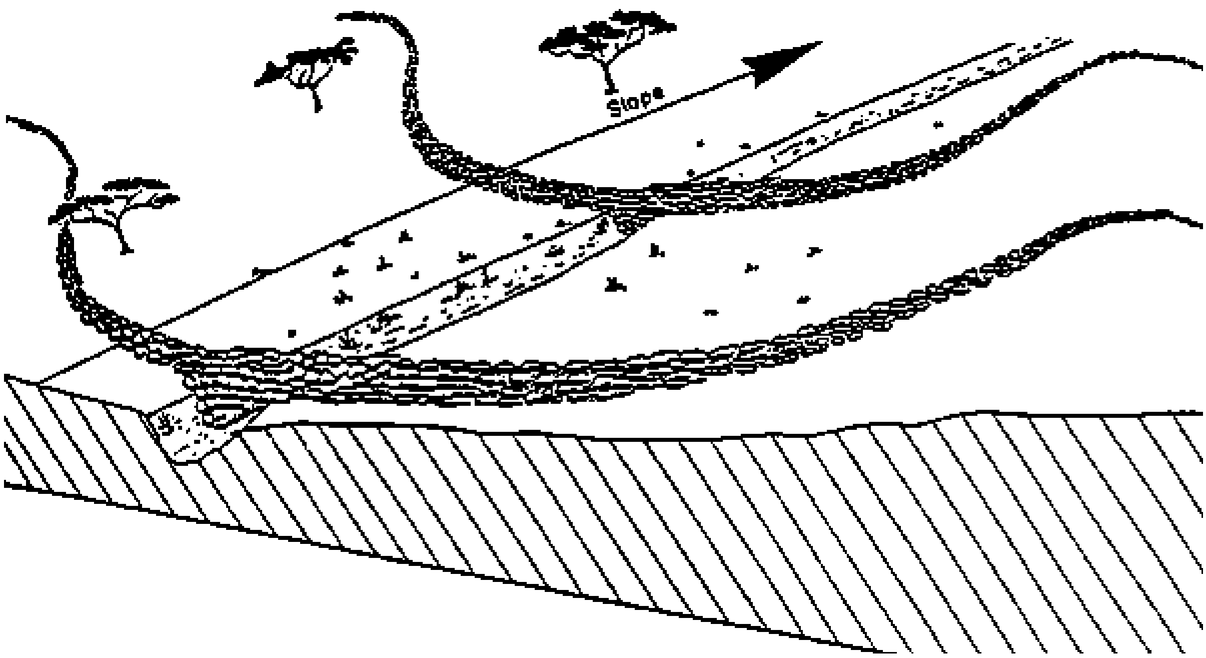

Figure 10: Permeable rock dams: general layout (Source: Critchley and Reij, 1989)

- **Maintenance**

The design given above, with its low side slopes and wide base, should not require any significant maintenance work provided the described construction method is carefully observed. It will tolerate some over topping in heavy floods. Nevertheless, there may be some stones washed off, which will require replacing, or tunneling of water beneath the bund which will need packing with small stones. No structures in water harvesting system is not maintained and all damage, even small, should be repaired as soon as possible to prevent rapid deterioration.

- **Husbandry**

Permeable rock dams improve conditions for plant growth by spreading water, where moisture availability is a limiting factor. In addition, sediment, which will build up behind the bund over the seasons, is rich in nutrients, and this will further improve the crop growth.

This technique is used exclusively for annual crops. In the sandier soils, which do not retain moisture for long, the most common crops are millet and groundnuts. As the soils become heavier, the crops change to sorghum and maize. Where soils are heavy and impermeable, water logging would affect most crops, and therefore rice is grown in these zones. Within one series of permeable rock dams, several species of crop may be grown, reflecting the variations in soil and drainage conditions.

- **Socio-economic factors**

The implementation of permeable rock dams raises several important socio-economic issues. Many of these are rather specific to this technique. This is because permeable rock dams are characterized by:

a. large quantities of stone required
b. outside assistance often necessary for transport
c. limited number of direct beneficiaries
d. siting is often determined by the people rather than the technicians

As the structures cannot be made by individual farmers, it is necessary to cooperate in construction. It would be ideal if a village committee can be formed to co-ordinate efforts and discuss the situation of priority sites and beneficiaries. It is unrealistic to expect implementation of such a programme without outside help for transport of stones, which should be provided free of charge to the beneficiaries. Long-term sustainability and replicability of the form of development would best be promoted if beneficiaries could establish revolving funds for the hire or purchase of transport.

2.2.2.1.2 **Small earth dams**

Simple earth dams can be built where there is an impervious foundation, such as unfissured rock, or a clay subsoil.

The channel upstream should preferably have a gentle slope, to give a large reservoir for a given height of dam. An ideal dam site is where the valley narrows, to reduce the width of the dam.

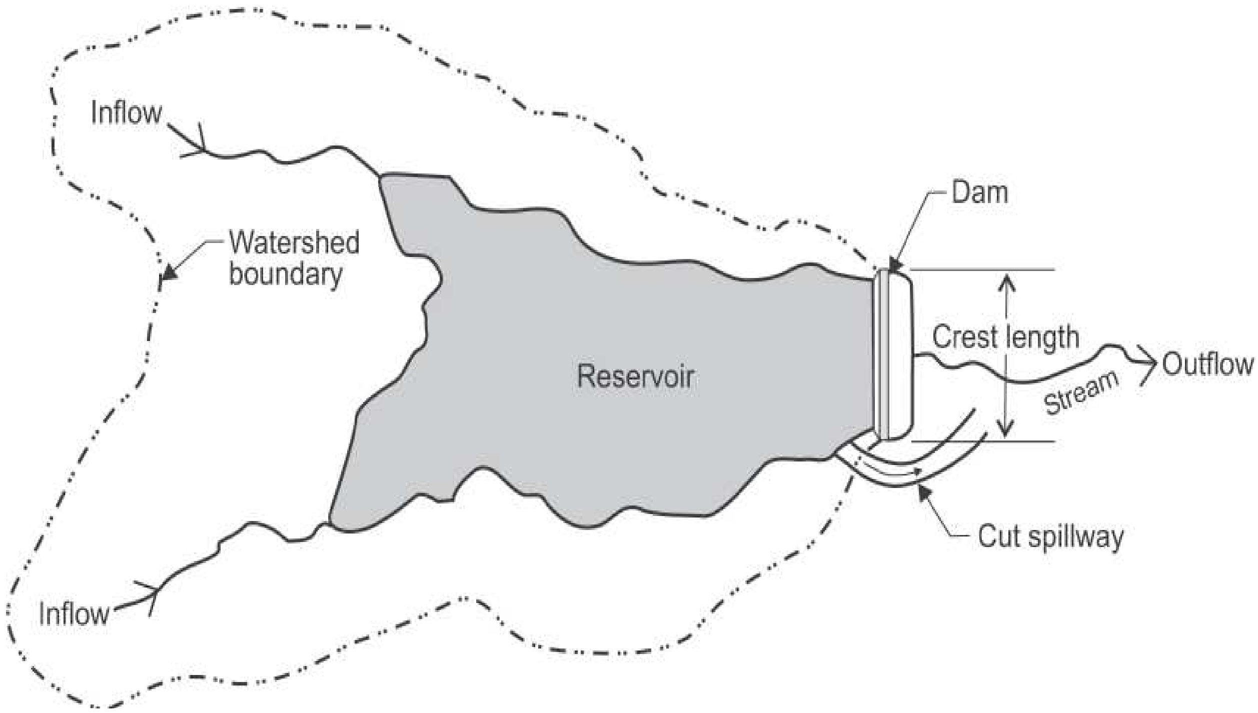

Figure 11: Plan view of dam and reservoir

- **Advantage**

Earth dams can be constructed from materials found on site or nearby. This makes them very cost-effective in regions where the cost of producing or bringing in concrete would be prohibitive.

2.2.2.1.2.2 Basic technical criteria for water harvesting

A water harvesting scheme will only be sustainable if it fits into the socio-economic context of the area, as described at the beginning of this chapter, and also fulfills a number of basic technical criteria, such as:

Slope: the ground slope is a key limiting factor to water harvesting. Water harvesting is not recommended for areas where slopes are greater than 5% due to uneven distribution of run-off and large quantities of earthwork required which is not economical.

Soils: should have the main attributes of soils which are suitable for irrigation: they should be deep, not be saline or sodic and ideally possess inherent fertility. A serious limitation for the application of water harvesting is soils with a sandy texture. If the infiltration rate is higher than the rainfall intensity, no runoff will occur.

Costs: The quantities of earth/stonework involved in construction directly affects the cost of a scheme or, if it is implemented on a self help basis, indicates how labour intensive its construction will be.

CHAPTER THREE: METHODOLOGY

3.1 Methodological Approach

For this research study, a number of approaches were followed:

- Analysis of literature review on the rainwater harvesting techniques that suited semi -arid areas, like Moroto district.
- Site selection
- Basic socioeconomic context of the site
- Technique selection

3.2 Materials

Secondary data from previous activities of areas with similar climatic conditions were used.

The use of a computer programmer Software **FAO CLIMWAT 2.0**. This is a data base that offers agro-climatic data of over 5000 stations.

CLIMWAT provides long-term mean values of seven climatic parameters for a period of at least 30 years.

Namely, these climatic parameters are:

• Mean daily maximum temperature in °C

• Mean daily minimum temperature in °C

• Mean relative humidity in %

• Mean wind speed in km/day

• Mean sunshine hours per day

• Mean solar radiation in MJ/m2/day

• Monthly rainfall in mm/month

• Monthly effective rainfall in mm/month

• Reference evapotranspiration calculated with the Penman-Monteith method in mm/day

The above information was used to extract climatic data of Moroto District. The available soil type information and other existing socioeconomic conditions on ground about the district, was then used in coming up with the appropriate water harvesting techniques.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

Table VI: ETo (penman-Monteith), Monthly Rainfall and Monthly effective rain (USDA, Method) in Moroto District

MONTHS	**ETo [mm/day]**	**Monthly rain fall [mm/month]**	**Monthly effective Rainfall [mm/month]**
JAN	4.64	8	0
FEB	4.81	30	28.56
MAR	4.71	74	65.24
APR	**4.14**	**123**	**98.79**
MAY	**3.74**	**149**	**113.48**
JUN	**3.66**	**90**	**77.04**
JUL	**3.35**	**136**	**106.41**
AUG	**3.64**	**106**	**88.02**
SEP	**4.14**	**51**	**46.84**
OCT	4.21	47	43.47
NOV	4.1	49	45.16
DEC	4.26	25	24
TOTAL		888	737.01

Table VII: Climatic parameters of Moroto District

MONTHS	**MAX. TEMP [°C]**	**MIN TEMP [°C]**	**REL HUMD [%]**	**WIND SPEED [km/day]**	**SUNSHINE [hrs/day]**	**SOLAR RAD [MJ/m²/day]**	**ETo [mm/day]**	**AVERAGE MONTHLY TEMP [°C]**
JAN	30.7	15.7	52.4	138.2	8.69	21.76	4.64	23.2
FEB	31.2	16.5	51.2	121	8.67	22.64	4.81	22.75
MARCH	30.3	17	56.7	121	8.04	22.09	4.71	23.65
APRIL	28.8	16.6	67.2	112.3	7.08	20.17	4.14	22.7
MAY	27.7	15.6	74.6	95	7.38	19.71	3.74	21.65
JUNE	27.5	15.1	74.1	95	7.9	19.83	3.66	21.3
JULY	27	15.3	74.6	77.8	6.35	17.82	3.35	21.15
AUGUST	27.1	15	73.6	95	6.95	19.46	3.64	21.05
SEPT	29.1	14.8	66.2	95	7.82	21.42	4.14	21.95
OCT	28.8	15.2	64.5	112.3	7.8	21.3	4.21	22
NOV	29.1	15.3	61.7	112.3	7.75	20.5	4.1	22.2
DEC	29.6	15.6	58.3	121	8.51	21.09	4.26	22.6

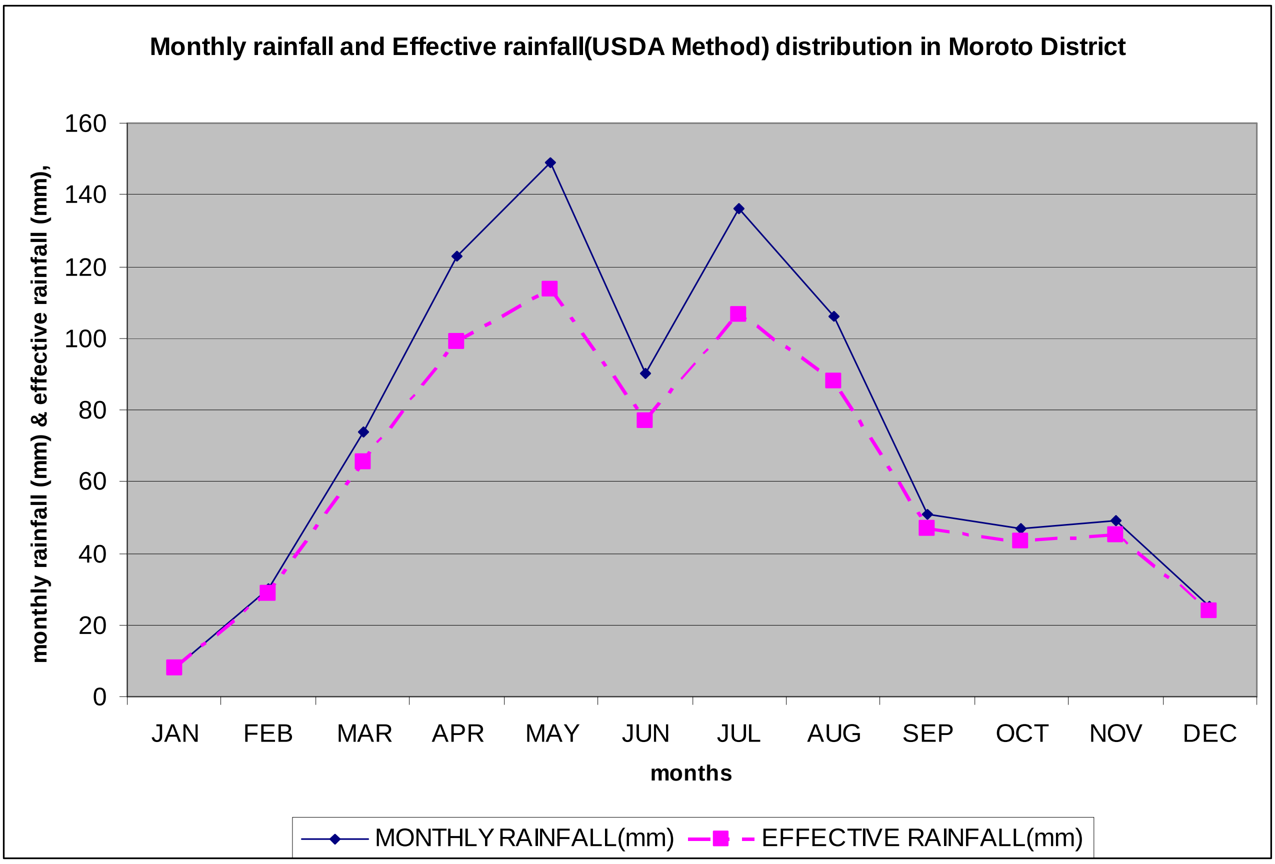

Figure 12: Monthly rainfall and Effective rainfall for Moroto District

4.1 Rainfall Distribution in Moroto District

There is a marked variability of rainfall distribution throughout the year (***Table VI& Figure 12)***. The rain season is from April to September with intense precipitation around the months of May and July.

Moroto therefore receives a monomodal type of rainfall, during those stated months.

Looking at ***figure 12*** (precipitation and Effective rainfall of Moroto District), this district has only one cropping season, which normally is between April and September, considering the fact that the population is dependent on wet season cultivation.

This means the other dry months from October towards March, no cultivation takes place, because no reliable rains are received to support crop production.

Despite, the intense rains within the months of April to September, the effective rainfall received is roughly 530mm for the total growing season, which is not adequate to guarantee a satisfactory crop yields for the main food crop grown, by the population of Moroto, which are sorghum and maize. The above crops are grown from April and harvested late August, and during these months, the effective rains received is less than the crop water requirements, which are ranging within 450-650 (mm/total growing season) and 500-800 (mm/total growing season) for sorghum and maize respectively (FAO Irrigation Water Management Training Manual No.3 / Rome (Italy), 1986).Depending on varieties, growing crops under such water stress conditions where the effective rain is less than the crop water requirement, greatly affects final yield, because the growing crop is unable to take up soil nutrients, due to soil moisture stress at its initial developmental, mid and grain filling stages.

Therefore this calls for the need of rainwater harvesting techniques like contour bunds, tie ridging, Negarims and so many others that help conserve soil moisture, reduce soil erosion and eventually reduces total crop failures, by meeting the crop water requirements for the total growing season.

In semi-arid drought prone countries where rainwater harvesting is already practiced, water harvesting is a directly productive form of soil and water conservation. Both yields and reliability of production can be significantly improved with this method. Instead of the runoff being left to cause erosion, it is harvested and utilized. For the case of Moroto, the population practices uncontrolled grazing of animals, which degrades the environment, for example the soils, exposing it to erosion agents like rainwater, man, wind and animals.

A water harvesting technique like semicircular bunds, which is good for rangeland improvement and fodder production can be used where the majority of the communities are agro-pastoralists.

This is beneficial to both their animals because the fodder provide pasture and also helps in acting as protective layer or buffer between the atmosphere and the soil.

CHAPTER FIVE: GUIDE LINES

5.1 Topographic surveys

The purpose of this survey is to gather survey data about the natural and man- made features of the land, as well as its elevations. From this information, a three dimensional map may be prepared. The work consists of the following:

1. establishing horizontal and vertical field control that will serve as framework of the survey
2. determining enough horizontal location and elevation (usually called side shots) of the ground points
3. locating natural and man-made features that may be required by purpose of the survey
4. computing distances , angles and elevations
5. drawing the topographic map

5.2 Soil survey/ Soil mapping

This is the process of classifying soil types and their soil properties in a given area and the Geo-encoding such information. It applies the principles of soil science, and draws heavily from geomorphology, theories of soil information, physical geography and analysis of vegetation and land use patterns.

Primary data for the soil survey are acquired by field sampling, supported by remote sensing. This information about soil survey is used by farmers and ranchers to help determine whether a particular soil is suited for crops or livestock. An architect or engineer may use these soil properties for engineering purposes to determine whether or not the soil is suitable for certain type of construction.

Soil samples from the field are taken to the laboratories to analyze their chemo physical properties like; soil density, soil hydraulic properties, soil strength, soil texture, soil pH, soil structure and so many others.

The area having soil properties for safe design for earth dam construction will be chosen basing on topographic and soil map surveys.

5.3 Technique selection and Justification

The Karimojong move their cattle from place to place with the hope of finding pastures and water during the dry seasons. During such times crops have failed to mature and therefore increasing the situation of food insecurity in the district as much of the harvest is lost due to crop failure.

Water harvesting approach can contribute to the enhancement of water availability in this drought prone region for watering their livestock and as well as irrigating their crops at times when the rains are not reliable.

Then basing on the facts that, the district has seasonal rivers that flood during rainy seasons, water harvesting technique like small earth dams can be built across these rivers so as to trap flood waters for productive uses as mentioned.

With this technique (small earth dams) in place, the karimojong pastoral communities will remain on their land, with no need to move their animals from one place to the other in search for water and since small earth dams are able to store water for future uses like: irrigation, human consumption (drinking), watering of animals, and so many other uses, I therefore proposed small earth dams.

5.4 Small earth dams

Guidelines that must be followed, when implementing the small earth dams water harvesting techniques were discussed above.

An earth fill dam can provide a cost-effective method of storing larger volumes of water for livestock or irrigation. Successful dams require planning, proper site assessment, design, construction and maintenance. Without this attention to detail, dams are in danger of washing out. Dam construction is not a "do-it-yourself" type of project. It is essential to obtain the assistance of experienced water specialists and construction contractors for a dam project.

5.4.1 Planning

Before you start construction, develop a long-term water management plan for the proposed dam. To do this plan, one will need to have these thoughts in mind:

- The current water sources available
- The amount of water provided by these sources
- Additional water that will be required from the dam

5.4.2 Site Assessment

Site selection is a critical component to the success or failure of an earth fill dam. Consider the following points:

1. The dam must have the potential to fill with runoff (most years) or store sufficient water between runoff events that fill the reservoir. It is essential that the dam and reservoir have sufficient depth and volume to last through extended periods of drought.
2. Topographical features such as slope, width and height of dam, as well as reservoir capacity will influence construction costs. A topographical survey of the proposed dam site will be

required to estimate costs, prepare necessary information for licensing and provide construction details for the contractor. ***(Figure: 13)*** shows typical elevation view of a dam prepared from a survey.

3. Soil conditions **(*Figure: 15)*** must be suitable for both compaction and the prevention of seepage losses through the dam. It is highly recommended that some pre-construction soil testing be done at the proposed site or sites. This testing can be accomplished by digging five or six test holes or test pits where the dam and reservoir are to be located. Soils should be checked to depths three feet below that of any proposed excavation for the dam or reservoir.
4. An assessment of the hazard potential downstream should be done in case of dam failure.
5. A good location for a spillway that will effectively handle runoff and minimize erosion should be checked.
6. Watershed activities that can affect the water quality or quantity of runoff should be checked.

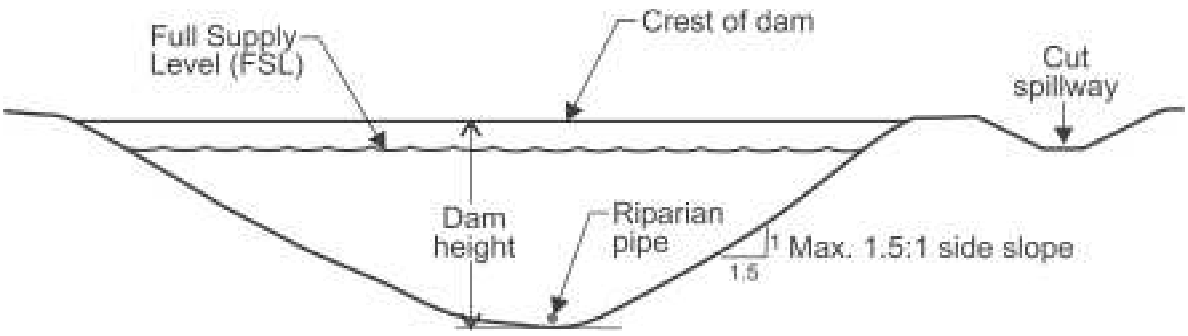

Figure 13: A typical elevation view of a dam

5.4.3 Dam capacity

The water storage capacity of a dam and reservoir (shown in ***Figure: 11)*** can be estimated as follows:

Dam capacity = [Reservoir Length x Reservoir Width (at the dam) x Depth of the Water (maximum)] / 3

This calculation provides a close estimate on steep sided V-shaped water channels, but the accuracy of the estimate is poor on flatter, U-shaped water channels.

Note: The reservoir must store enough water between runoff events for a secure supply and have good storage characteristics to prevent excessive evaporation losses.

These factors mean that an average reservoir requires a depth greater than six feet. The storage capacity versus flooded area should exceed a six to one ratio. In other words, more than six acre feet of water should be stored in a reservoir with one acre of flooded area.

5.4.4 Dam design

A typical design of a small earth-fill dam is shown (***Figure: 14)***. For stability, the upstream slope must be a minimum of 3:1. Erosion protection is required to protect the dam from wave action. This protection can be achieved with a combination of smaller and larger rocks (or other suitable material) and, with smaller projects, a floating log boom. The downstream slope requires a minimum 2:1 slope, seeded with native grasses to prevent surface erosion. The top or crest of the dam should be a minimum of 10 feet (preferably 15 feet) to accommodate road traffic and minimize the potential for erosion. The crest elevation should be a minimum of three feet above the Full Supply Level (FSL) of the reservoir.

The dam should be fenced to prevent livestock traffic, as this traffic can be a major cause of slope and crest degradation.

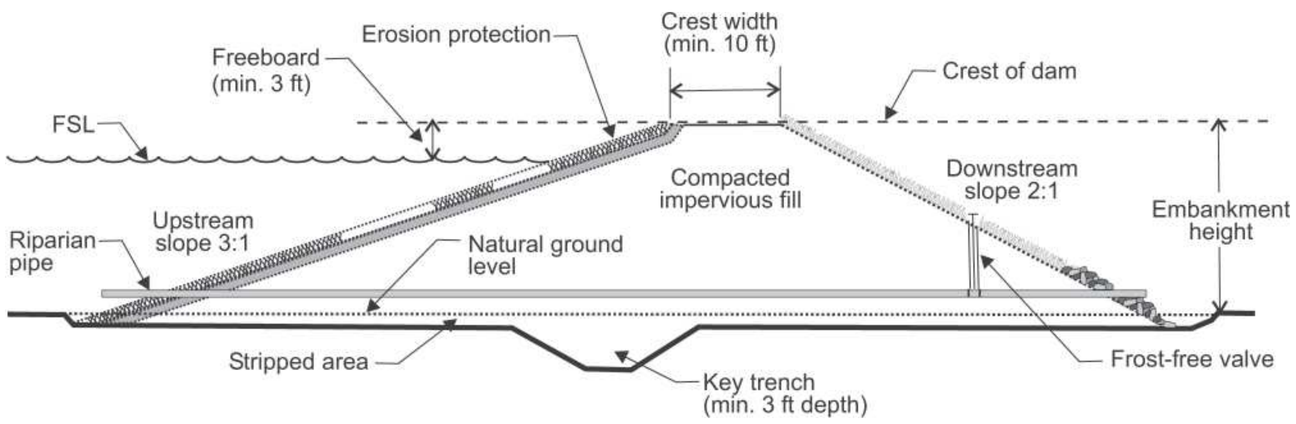

Figure 14: Cross section of dam

5.4.5 Spillway design

The spillway is a critical part of dam construction. An under-designed spillway will result in the dam overtopping or serious spillway erosion during peak runoff. These situations can cause major water losses, potential flooding and damage downstream, in addition to the costs to repair the dam.

In small stock watering dams, a drop inlet spillway structure is cost prohibitive. Cut or natural spillways are most common. The spillway should be designed with a wide base and a gentle slope, which will reduce water velocity and spillway soil erosion. The spillway base and sides should also be seeded to grass. To prevent spillway erosion, rip rap (a collection of loose stones) alone or in combination with geotextile material may be required if the base slope of the spillway is steep. Side slopes of the cut spillway should be no less than 2:1 (4:1 slopes are preferred).

The spillway should be located away from the dam fill, not through or directly adjacent to the fill. This placement will reduce the risk of the dam washing out. Culverts are often used in spillway design, and if undersized, they can restrict spillway flow and result in project failure.

5.5 Construction

- **stripping**

The area covered by the base of the dam must be stripped of all vegetation and organic soil. The organic soil can be stockpiled and used on the downstream slope of the fill. All slopes steeper than 1.5:1 on sides of draw should be flattened to minimum of 2:1.

- **Key trench**

A key trench (cutoff trench) is excavated below the base of the fill upstream of the centerline of the fill. The key trench is incorporated in the design for two reasons: to anchor the dam to the material and to prevent piping (seepage under the fill).

The key trench should be a minimum of three feet deep for a dam the height of 10 feet to12 feet. It should extend the full length of the dam and reach one third to one half of the way up the side slope of the draw.

- **Fill construction**

The dam must be constructed from an impervious (clay or clay-based) material. A simple field test to determine the suitability of the material for compaction requires adding a small amount of moisture to a handful of material and then mixing to the consistency of putty.

Next, try rolling the material between the palms of your hands. The material has good compaction characteristics if it can be rolled to the diameter of a pencil, approximately six inches long, then bent into a loop without separating the material. Several attempts may be required to obtain the proper moisture level to do the test.

Construction material taken from the surrounding hillsides or an excavation in the reservoir area must be placed close to horizontal in the fill in six inch layers and compacted. If the material is dry, moisture will have to be added, and suitable compaction equipment such as a sheep foot packer used to obtain the proper compaction.

A simple test to evaluate proper compaction is to place the edge of the heel of a hard-soled boot on the fill and push down hard with all your weight. If only a mark is left, compaction is satisfactory. If the heel sinks in, compaction is poor. No rocks over six inches in diameter should be placed in the fill.

5.6 Maintenance

Earth fill dams require regular inspection and maintenance. An inspection before spring runoff is critical to ensure the spillway is not blocked with snow or other material. All blockages must be removed to prevent over topping and the dam washing out. During runoff, additional inspections should be carried out to watch for signs of erosion, spillway blockages (ice or debris) or over topping.

After the dam is free of snow, a visual inspection can be completed to assess the slopes for erosion, rodent damage, seepage or slumping. Burrowing rodents such as beavers, muskrats and gophers should be removed from the dam immediately. All potential problems must be repaired as soon as possible to safeguard the dam. Side slopes should be cleared of tree growth on a regular basis.

5.7 Water quality and drought proofing considerations

There are a number of ways to improve the water quality in a dam. At the planning stage, avoid sites where watershed activities can allow poor quality or contaminated runoff to enter the reservoir of the dam. Examples of these sites include heavily cultivated fields or areas where a heavy concentration of livestock manure exists.

The design of the reservoir can also help to improve water quality. The deeper the excavated reservoir, the better the water quality and the more drought proof it will be from evaporation losses.

Stripping the topsoil from the flooded area of the reservoir will reduce the amount of nutrients available for plant and algae growth. The more plant and algae growth generated, the more rot and decay are generated and cause the water quality to deteriorate. Regular treatments to help control plant growth will help maintaining water quality.

If water is being removed with a pump system for year round farm use, a floating intake system is recommended to help improve the quality of the water removed from the dam. Both natural wind aeration and the addition of compressed air with a windmill or electric compressor will greatly enhance water quality.

For more information on improving water quality, refer to the *Quality Farm Dugouts* manual as the same principles for improving water quality apply for both dams and dugouts.

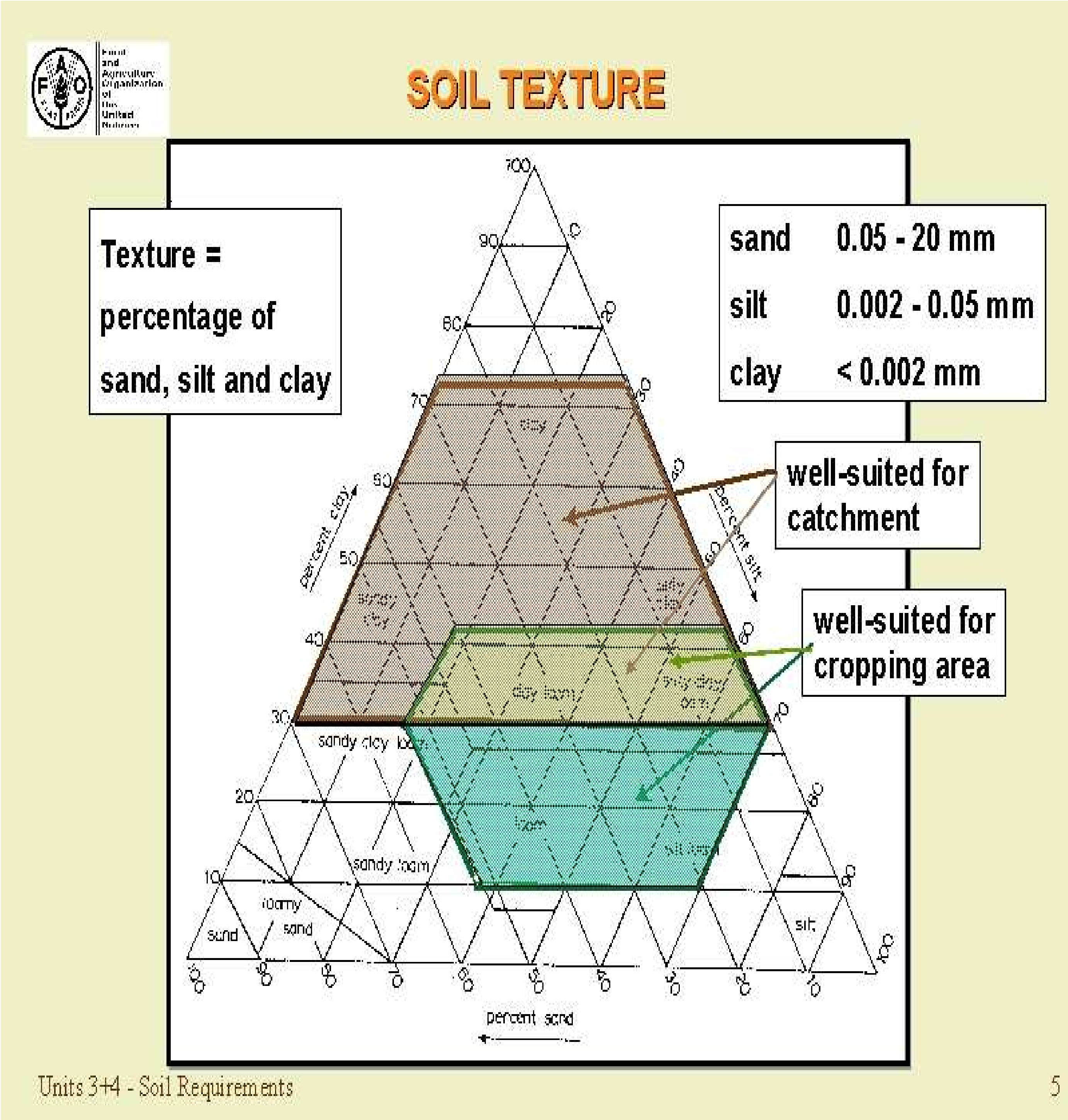

Figure 15: Soil requirements for rainwater harvesting

Conclusions and Recommendations

Conclusions

Micro catchment rain water harvesting techniques that are used to conserve water and soil moisture have been found to be effective in improving crop production.

The overall results have been improving food security and farm income resulting from improved yields or production.

According to this study, I have found out that Macro-catchment techniques like small earth dams can be built across seasonal rivers to store water for the Karimojong people. This will enable them have water during the drought periods for watering their animals , irrigating crops and other uses so they will remain on their land with no need to move from place to place in search of water.

Recommendations

Considering socio-economic factors like land tenure, the basic technical data like soils, topography, amount and distribution of the rainfall, the crops which are mainly annual and the availability of labour, I recommend the implementation of the following rainwater harvesting techniques, because they may play important roles in soil conservation. These are:

- Tie – ridging: This techinque involves tying ridges with animal traction. This is an advantage bearing in mind that the Karimojong people are agro-pastroalists, therefore cheap and available labour is provided by draught animal manpower in pulling the ridger as well as land preparations.
- Negarim micro-catchment: this is mainly used for tree planting in arid and semi arid areas. The advantage is that tree planting would help rehabilitate the degraded land of Moroto through soil nutrient recycling by the trees roots and leaf fall which have positve impact on achiving improved crop yields (under agro-forestry), and also this technique limits mechanization making it cheap for the people to be maintained.
- Small earth dams: they are constructed from materials found on-site or nearby, they are very cost-effective in regions where the cost of producing or bringing in concrete would be prohibitive. Moroto district recieves very intense rains, poor and unevenly distributed for a short time, but causes floodings and seasonal rivers to occur. These dams can be built across these rivers trapping runoff water in reservoirs for use in months when the rains are little.The waters can be used for watering their livestocks since they are agro-pastoralists .

During the design stage, considerations on gender and equity should be addressed so as to improve the lot of farmers in poorer, drier areas. There is little point in providing assistance which only benefits the relatively wealthier groups.

For new techniques there is often a need for demonstration before people will understand and appreciate their effectiveness. Motivation and promotion of awareness among the people with regard to the project objectives and how to achieve them are important issues that project authorities need to bear in mind. This therefore calls for government's investment in training activities that will promote awareness within the Moroto population to better understand the benefits of the technology.

Government should contribute in funding the construction works, for water harvesting techniques.

Bibliography

Critchley, W R S and Reij, C., 1989. Water harvesting for plant production: Part 2. Case studies and Conclusions from Sub Sahara Africa. (Draft)

DWD (1995) Directorate of Water Development," Uganda Water Action Plan: Rapid Water Resources Assessment."

Evanari, M., Shanan, L. and Tadmor, N.H., 1971. The Challenge of a Desert. Harvard University Press, Cambridge, Massachusetts.

FAO/AGL, 2002. Water Harvesting;http://www.fao.org/ag/agL/aglw/wharv.htm

FAO, 1986. Irrigation Water Management Training Manual no.3/Rome (Italy)

NEMA (2001) State of Environment Report 2000 National Environment Management Agency Kampala Uganda

Pacey A. and Cullis A., (1986)"Rainwater Harvesting. The collection of Rainfall and Runoff in Rural Areas." Intermediate Technology Publication, London.

Prinz, D., 2001. Water Harvesting for Afforestation in Dry Areas. Proceedings, 10th International Conference on Rainwater Catchment Systems, Mannheim, 10-14 Sept. 2001, p.195-198.

Uganda: OCHA, 2008 Situation Report No.1- Focus on Karamoja

Wayland, E.J., Brasnett, N.V., and Bisset, C.B., 1938. Soil Erosion and Water Supplies in Uganda'Entebbe: Government Printer