KAMBITI FARM

Water in Capitalising Asals

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DEDICATION

All Kamba Women	Who nurture the people and the earth.
Wangari Mathai	Who insists on friendly environment
Joshua Mukusya	Who dreams subsurface dams
Harold Miller	Who loves epistemology of development
Harris Mule	Who conjures statistics
Mbatau wa Ngai	Who questions policies

GLOSSARY

Agro-ecological Zone	Classification of land in terms of agricultural potentials and climatic factors. Ministry of Agriculture follows a classification of seven zones ranging from high mountains as zone 1 to desert as zone 7. This classification is usually referred as the Jaetzold classification after the specialist who developed it in the Ministry of Agriculture.
ALDEV	African Land Development Board. This was a programme initiated by the colonial government after World War 11 for the resettlement of Africans in some of the dry areas of the country.
Aquifers	Water held within the soil or rock formations which can be tapped by wells.
ASAL	Arid and semi-arid lands. This short form is used when discussing agro-ecological zones four to seven.
Bench Terrace	A construction which reduces the slope of the land by either throwing the soil from a ditch upward of the slope - fanya juu terraces. When the slope is eliminated then the piece of land between the terraces is flat like a bench.
Bimodal Rainfall	Two seasons of rainfall in a calendar year separated by dry periods.
Biomass	The total mass of living organisms, including animal and plant life, expressed in terms of weight per unit area.

Catchment Basin	A physical catchment is defined as the area of natural drainage,bounded by a watershed and is therefore a basin collecting water falling on it. If it is drained by a stream or a river it is an open basin. Where it not drained it is a closed basin.
Contour Ridges	Ridges made on the contour line to stop erosion and to retain water. The area made by digging a ditch and throwing the soil down slope.
Cut-off Drains	Earth works made on top of a catchment basin or a farm to channel excess water away from farmland.
Dam	A structure for holding water created either by building a barrier across a stream or by scooping out soil in a depression. Most small dams in Kenya are built to supply water for human and animal use. A few are now constructed for irrigation. Very big dams are built for flood control and generation of electricity.
Sand	A dam built across a seasonal river to hold sand and water in the river bed. Water wells are then dug up in the river bed or near it.
Sub-surface	A dam constructed by building a barrier across the bed rock of a channel or a river to block the flow of sub-surface water. Over time, the water level on the upstream may accumulate and rise to the surface. As the stream deposits more coarse sand the dam can be raised to create more water storage,

forming a sand storage dam.

Surface — A dam without cover over the water. In the dry lands where temperatures are high a large amount of such water evaporates. That is why sand and subsurface dams are preferred in such areas.

Ecosystem — The community of plants and animals which are dependent on each other and co-exist within a given physical environment.

Evapotranspiration — The water loss from an area with vegetation through the process of evaporation and plant transpiration.

Friesian — A breed of dairy cattle with high milk yield.

Gabion — A structure which can be made with wood or wire to be used to stop soil and water in a gully or a river. Typically the structure is made and filled with stones to keep it from washing away.

Ground water — Water which has sunk from the surface into the soil and sub-soil and is held in soil storage. The top surface of the collected ground water is called the water table.

Katumani — The site of the dry lands research station to the south of Machakos town.

Maize — A variety of dry zone fast maturing maize produced at Katumani.

Kiinga — The traditional granary

for preserving grain constructed of thin sticks and grass. To ensure that vermin did not attack stored grain when very long storage was required it was plastered with a mixture of cow dung and soil to seal it completely. Grain was evacuated by means of a small stick stuck through the bottom wall.

Kutusya — Literary to house but usually meaning to allow someone to build his home and to use your land whilst looking for his own.

Kuvithya — Literary to hide. The concept was to loan friends or relatives livestock which were thereby hidden from the owners misfortunes.

Land Capitalisation — The basic means of production are land, labour and capital. Land is capitalised if it is improved in such a way as to be more productive. Although there are many ways of improving land so it can become more productive, it is the argument of this work that in the dry lands the most important method of improving, capitalising, land is to ensure that it retains the limited water which is available in those areas.

Log Granary — A granary introduced by the African Inland Mission missionaries at the turn of the century which borrowed its construction from North American log cabins where logs are stacked on top of each other and held together by either nailing or cutting to ensure they dovetail.

Micro-climate — The climate of a small area which differs from the climate of the adjacent area, usually caused by vegetation.

Mwilaso	A work group whose organisational principle is that work is done for each participant in turn or in rotation- kulasana. It usually involves small numbers to complete the rotation speedily.
Mwethya	A work group called for a specific task without the principal of rotating to each participant. Small numbers are involved. If large numbers are involved it is called vuli.
Ng'undu	Family land properly claimed by establishing proper boundaries and proper recognition of the claim by the local community.
Photosynthesis	The conversion of light energy into chemical energy in green plant cells. This process forms carbohydrates and oxygen from carbon dioxide and water.
Run-off	Water which runs on top of the ground.
Utui	Village.
Water Table	The upper surface of ground water.
Weu	The low land away from the hills which historically was not claimed by specific individuals and which was perceived as good for cattle keeping. Rangelands.

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FOREWORD

All flesh is modified organic plant material. Whether man eats the plants directly; as leaves, roots, seed or fruit, or indirectly; by eating the animals which feed on plants, he depends wholly on plants. Green plants convert simple chemicals and minerals into organic tissue of which all flesh is made.

The most important plants are the grasses. Of the grasses, the cereals; maize, wheat, rice, barley, millet and oats; make the bulk of staple foods for man. Grasses produce the bulk of the pasture on which animals are fed. They possess the power to grow again vigorously after being eaten down by animals. The basis of civilisation is the production of grass. The basis of development of ASALs, therefore, must be to produce grass. Grass needs water to grow. Therefore, the most important activity in developing the ASALs is to ensure water for production.

1. INTRODUCTION

Kambiti farm is located in Wamunyu Location of Mwala Division in Machakos District. The farm is in Agro-ecological zone 5 which is typically a livestock production zone. The climate is hot with short unreliable rains.

The farm is basically a dairy farm which raises Friesians successfully. All the grain food consumed in the farm is grown there with a substantial surplus for sale. The success of Kambiti Farm, in this harsh climate, is a model of realised production potential of the ASAL's. This success has been achieved through effective application of water conservation measures on the farm. The major technologies used in water conservation are: maintenance of ground cover by trees, shrubs and grass; bench terraces; and sub-surface dams. These measures aid water infiltration for ground water storage thereby increasing available water on the land for production. This effectively removes the major constraint in ASAL production which is the lack of available water.

This write-up traces the development of Kambiti Farm from its origins to the present (1991). Central in this is water conservation for production. The book is written with an eye to two different audiences. The first is, of course, current and future ASAL farmers. For the current ones, the objective is to reinforce their innovative pursuits. For the future ASAL farmers, who more often than not do not get relevant reading materials, the book points at what is possible. It comments on some of the key technologies and explains their theoretical basis.

The other major audience is ASAL policy makers. It is the sincere hope of the authors that this case study will contribute to the debate on ASAL development policies and strategies. The innovations found in Kambiti farm re-affirms the authors' conviction that ASALs' full potential has yet to be tapped. The ASALs can produce surpluses in grains and proteins. This case study documents what is possible and thus challenges conventional thought and policies on the ASALs.

2. THE ORIGINS

The story of Kambiti farm starts in the late 1910's. This was the time Ngula, father of Nthuku, the current proprietor, migrated from his ancestral lands at Kiteta to claim new land at Wamunyu. The land was uninhabited and in its natural state. Kambiti means the place of hyenas. For this land to have been so dominated by hyenas, so as to get the name, would indicate that it was rich in animal life. These animals would form the food for hyenas and other predators. It would also indicate the presence of water since a lot of kills, by all predators, occur at or near watering places. According to Ngula, land which supported large numbers of wild animals was ideal for the vocation of animal husbandry.

The farm, as is shown in Appendix 2: Figure VII, lies between two rivers, the Mumbuni and the Watuka. Kambiti is a small stream which starts on the land and forms a tributary of the Watuka river. The Watuka and Mumbuni rivers join a short distance from Kambiti farm to form the Kyambuthu river, a tributary of the Athi river, the major river in Machakos district.

To lay a claim on open land by forward migration from the main centres of population is known as "Kukwata", literally to catch or to hold, by the Akamba. A claim is established by marking a boundary by half felling perimeter trees into the land you claim. This form is called Nguuu. These were respected as the survey beacons of the parcel of land. Subsequent immigrants to the area would lay their claims outside the already beaconed and therefore traditionally surveyed land.

Ngula was a pioneer in the area. His driving force was to look for rangelands to use for grazing his animals. Kiteta, where he came from, was getting pressure from the Mbooni hills emigration. The Akamba had settled on the hills before exploding to the plains. The movement into the plains away from the hill massifs was common during the first two decades of this century both in Machakos and Kitui.

When Ngula migrated to Wamunyu, the Watuka river flowed permanently. Ngula's claim extended to the area east of the Mumbuni river. The Mumbuni river did not exist at this time. It cut its channel around 1934, when after the major drought, Yua ya Mavindi, it rained heavily. It is a very young river as compared to the Watuka. The land to the east of the Mumbuni river was ceded to his brother Musembi. It was to be contested up to 1991.

As a pioneer Ngula was followed by other people into the new lands. Some were relatives: uncles and in-laws. Some were just people from Kiteta. He was a generous man. So he allowed them to set up temporary homesteads (Kutusya) in his claim (Ng'undu). They should have been transient and used the hospitality to identify desirable land elsewhere and lay claim to it. However, taking advantage of Ngula's hospitality, some of them did not use the temporary stay as a springboard to claiming their own land. This would have given them an advantage over newcomers to the environs. They overstayed the hospitality. They were to present a major problem to Ngula's descendants after his death before they were finally evicted from the land. In 1991 the last of the 11 families is still laying claim to the land in the courts in spite of the fact that formal survey, adjudication and registration of land was completed in 1969. As a result, the land belonging to his descendants is held as parcel number seven in the land register. The male descendants do not have individual title yet.

According to the 1969 land survey, Ngula's claim, which is shown in Appendix 2: Figure 7, was an area of 796 acres. It will eventually be subdivided for the 5 sons: Muthama, Mwalimu, Mateli, Nthuku and Mbatha. This land is registered as plot No. 7. The division has not been formalised since there is still some claim on it by the people invited years ago to a temporary sojourn who had become squatters. In addition to the 159 acres, Nthuku Ngula, the proprietor of Kambiti farm, would inherit as a share of his father's land, acquired plot No. 346 with an area of

307 acres. Kambiti farm has 466 acres and its approximate boundaries are shown in Appendix 2: Figure VI.

Ngula initially selected his land for livestock rearing. The land had permanent running water. He owned land on both sides of the Watuka river. There was plenty of water for his animals, whereas animals from distant places had to come to the Watuka for their water. His animals were thus in a better condition than those of his neighbours.

Ngula saw water as the limiting factor in animal production. Having come from Kiteta, at the foothills of the Mbooni hills, where water is plentiful, must have influenced his convictions. His constant advice to his sons on acquisition of land was to ensure that one had plenty of water. He associated water with the production of grass which is basic for animal production.

Mental images helped Ngula visualise the reclamation of land near where there was water. His explanation of the sorry state of land near water was that it was due to overgrazing. Trampling of animals coming to water also caused degradation of the land. His solution to the problem of degraded land, which would help it recover, was keeping away the animals from the land during that portion of the year where temporary watering could be found in hollows in the ground. From modern range studies, we now know this leads to resting of grazing land. We further know that shifting animals to new areas gives them varied feed. Fencing of the degraded land, with thorny branches, would keep away animals allowing the land to heal itself. Ngula reiterated to his sons that though such land had the capacity to recover, one had to nurture it.

To preserve his land and prevent undue degeneration of the land, Ngula had cattle outposts, "syengo", at Athi River, about ten kilometres away and at the Yatta Plateau, near Mwita Syano River, about twenty kilometres away. The "syengo" would relieve the pressure on his land in dry years. He had two "syengo" which would mean he had between 100 and 200 animals.

The droughts of the 1930's were to deal a cruel blow to Ngula's operations. These extended droughts resulted in the destruction of most of the vegetation in Wamunyu, as in all zone 5 areas of Machakos. For the first time the river Watuka ceased to flow. Since then it has become a seasonal river. The Government had closed Yatta as crown land and it was out of bounds to native animals. It was to become the hunting ground for the colonialists as well as their grazing reserve in drought years like 1948 when Machakos settlers moved their animals there. With nowhere to take his animals, Ngula's carefully nurtured herd was decimated. By the time he died in 1946 there was only one cow in his homestead. That lineage exists up to today at Kambiti farm.

The loss of his herd was devastating to Ngula. He died a dispirited man. He had lost all he had lived for. In his last days he instructed his youngest twin sons, Nthuku and Mbatha, on how to recover their patrimony by defending his land and keeping livestock. It is befitting to his memory that Kambiti farm continues to fulfil his dream. All the sons and mature grand sons keep cattle and not just the traditional. They also keep Friesians.

During his time, it was not possible for Ngula to institute water conservation methods on his land. There was adequate vegetative cover on the land for most of his life. He further had a flowing river through his land until his old age. The need for conservation had never arisen for the population and livestock densities could allow regeneration of grass. The natural balance was tipped in the 1930, when human and livestock population density and repeated drought set land degradation on the way. As a result of the droughts of the 1930's, the rains which followed carved out the Mumbuni river which was a flood plain. The parched land was eroded and a deep channel developed. As this is a young river it is still developing and eating away on its sides.

The profound loss of their father and his wealth was to influence Ngula's sons profoundly. It would lead them to defending the family land against squatters and eventually to systematic land management, as they inherited interest in livestock production. The result of these concerns is the keeping of Friesians by Ngula's sons.

One of the sons, Nthuku has developed a prize herd of Friesians on his individual farm, Kambiti farm. Although the conventional wisdom would have discouraged the keeping of Friesians in this hot, dry area, the results achieved are staggering. The herd is being built to an ideal carrying capacity. This will be determined by the development of pasture which is dependent on water conservation.

3. LOCATION, CLIMATE AND SOIL

Kambiti farm is located in Wamunyu location of Machakos District. It is three kilometres from Wamunyu town. The area is in Eastern Machakos on the lee of the Yatta Plateau and abuts the Machakos Kitui road, about a kilometre past the Chief's Camp at Itunduimuni. The farm lies between 37^{0} 34' 57' E and 37^{0} 35' 51' E longitudes and 1^{0} 23' 20' S and 1^{0} 24' 17' S latitudes. The nearest weather station, in an area with almost same ecological factors, is at Makindu, close to a hundred kilometres as the crow flies to the South South east. It thus is not accurate to extrapolate data from so far away. The nearest rain gauge station is at the Chief's office at Itunduimuni. For this recording station the available rainfall data over a twelve year period is an annual average of 792 mm. No breakdown exists for first and second rains. Data on Mean Annual Temperature, Diurnal Variation, Annual Variation and Evapotranspiration is unavailable.

The rainfall at Wamunyu is bimodal. The first rains occur in March to May and the second rains occur in October to December. For Wamunyu, the second rains are the more significant. Cropping is undertaken in this period with marked success. These rains produce more food than the first rains.

The high temperatures experienced in Wamunyu area are conducive to high transpiration demand. With this high transpiration demand, plant survival is marked where the ground water storage is highest. Observation reveals that terraced cropland will produce a crop even in adverse years. Under more normal conditions such terraced land out yields unterraced land due to the higher water availability to crops.

Wamunyu lies in Agro-ecological Zone (AEZ) 5 according to the Jaetzhold classification. This is savanna land. It is suitable for livestock production and minimal cropping. The main vegetation is characterised by Acacias ad Commiphora. These are hardy trees which withstand the common droughts. These trees shed their leaves during the dry season and provide fodder for the animals. The grasses dry out to leave only coarse grass stems as forage for animals in the dry seasons. Only animals which can utilise this coarse forage survive.

The seasonality of the rains and their variability results in short wet periods. It is important in these conditions to develop large groundwater storages to increase the length of growth periods. An increased water availability in the soil will prolong the growing period through the stored water surpluses.

Rivers in Wamunyu, like the rain, are seasonal, flowing only during the short rainy periods. For long periods, water can only be obtained by digging shallow wells (Mivuko or Mivukuo) on the dry river sand beds. As the rivers are not very steep, they are amenable to the construction of subsurface dams. This type of dam is suitable in the climate type because it stores water below the surface of the sand in river beds. There is less evapotranspiration from these dams since they do not have a large exposed surface of water unlike surface dams.

The area of Kambiti farm has a "Kitune" loam soil. This is a preferred soil in Machakos. It is a soil which can hold a large capacity of stored water. In addition, a high proportion of the stored water is available for plant growth. The soils in Kambiti are quite deep. The soil depth is more than 3 metres.

4. RAINFALL AND WATER AVAILABILITY

Rainfall in Kenya is largely dependent on the activity of the Inter Tropical Convergence Zone (ITCZ); with the related phenomenon of the equatorial trough and the sub-tropical high pressure cells. Two major air streams are prominent. The South-Easterlies, predominant from May to October and the North-Easterlies from November to April. The wet seasons are associated with the period of change of the prevailing winds. The details of the interactions of the various air masses which are involved are highly complex and are beyond the scope of this text. Rainfall over most of Kenya is bimodal, peaking in March to May and October to December, according to the activity of the prevailing winds. For Eastern Kenya, the second rains from October to December are more significant. The wet seasons are unreliable, coming late often, or failing altogether.

The distribution of rainfall is a function of relief. The highlands of Central Kitui; Kangundo, Iveti, Mbooni and Kilungu Hills in Machakos; receive much more rainfall than the surrounding low areas. Eastern Machakos which lies between the Kitui Central hills and the Kangundo, Iveti, Mbooni hills receives an average annual rainfall of under 800 mm. The hills receive an annual average rainfall of 1000 mm. It is not possible to be more exact on rainfall since there is a shortage of records.

Rainfall, temperature and wind interact to define the ecological environment. In the environment, it is water availability for plant growth that is critical and not the total amount of rainfall. Evapotranspiration, which is influenced by climate, is a major player in the final effect of rainfall. Vegetative growth is dependant on the balance of rainfall and evapotranspiration demands. The evaporative demand is high in Kenya's ASALs, often equalling or even surpassing the total precipitation. With full water storage in the soil, it is possible to sustain transpiration for a longer time using the received rainfall than if only partial storage has been achieved due to excessive run-off. The ground vegetative cover is proportional to the level of ground water storage.

The seasonality of rainfall and the high evaporation demand emphasize the role of the soil in ground water storage. The physical condition of the soil has a significant influence in its water holding capacity. Compacted soil hinders infiltration and promotes run-off. Poor structure soil is liable to collapse and cap, preventing infiltration. Well structured soils have a large storage capacity and the water is available for plant growth. Poor soils, more so than good structure soils, must be nurtured, conditioned and built up to improve their structure, which would improve their water holding capacity.

The availability of water to plants is affected by soil texture, the relative amounts of clay, silt and sand; the level of organic matter in the soil; the soil structure; and the depth of the soil profile.

In general the water holding capacity of a soil, or its field capacity, increases from sandy soils through sandy loams, to silt loams, after which it levels off. Silt loams, clay loams and clays generally have identical field capacities. The wilting period however increases throughout the range of soils from light to heavy soils. This means that the soils which have highest values of available water are the loams, silt loams, and clay loams. Clay soils have less available water than these soils.

The level of organic matter in a soil influences the amount of available water in the soil through its effect on structure. The structure of a soil determines the balance between the micro and macropores in the soil. The drainage and retention of water by a soil is dependant on the ratio of these porosities. All other factors being equal, the deeper the soil profile, the greater the amount of water it will hold.

The story of Kambiti farm is then the struggle for increasing water availability for production. The farm enjoys structural advantages in this because of its location between two rivers and type of soil. However, recognition of this should not be used to minimise the management contribution, for in a basic sense this is the challenge for developing ASALs. Even when the locations and soils do not easily lend themselves to easy solutions in increasing water availability, improvements can be made. Kambiti farm has nurtured its soil by ensuring that there is always ground cover, significant parts are terraced, erosion is controlled and subsurface dams retain water in the rivers. Yet more can be done as we show later.

5. A CASE FOR WATER CONSERVATION IN ASALs.

The most important resource in ASALs is water. The water falling as rain in a particular area can either evaporate, penetrate into the ground or run off. Precipitation in an area depends on the topography, climatological factors, the soil and vegetation cover.

Naturally water flows from high to low levels. The lay of the land, the steepness and length of the slope would therefore determine the speed and force of the flow. Water running from steep hills cuts deep channels, whereas the same quantity of water meanders sluggishly and harmlessly on the plains. On bare land or thinly vegetated land, the bulk of the water runs over the land to be lost from the immediate area of precipitation. Compacted bare soils can have a run-off rate in excess of 70 % of the precipitation. This run-off carries with it soil from the land and results in soil erosion. The water, with its load of soil causes flooding in the plains.

Vegetation plays a role in retention of water at the area of precipitation in many ways. Among these are: protection of soil particle dislodgement by drop impact force and destruction of structure; absorption of water by decaying matter; modification of soil structure by humus; support of soil root associates which promote soil structure formation; action of roots which open up the soil for effective infiltration and creation of physical impediment to flow by vegetation detritus.

Areas with high ambient temperatures invariably experience high evapotranspiration rates. The warmer air will contain more moisture at saturation than colder air. Warm dry winds thus dry the soil and remove large quantities of water from surface water storages. Keeping a vegetative cover ameliorates these problems by creating favourable microclimates. To use precipitation in ASALs for production, it is important therefore to first keep the ground covered by vegetation. Beyond maintaining a ground cover, it is important to create structures which promote rain water retention at the locality. This involves increasing infiltration by creating barriers to flow. The water which is held back on the land has time to percolate into the ground water storages, recharging the water-table and deep aquifers.

Earth works can control run-off. Contour earth ridges are a form of control of water run-off. The earthwork prevents run-off and keeps water at the site of precipitation. Well laid out earthworks, like terraces, prevent soil erosion and loss of fertility. They prevent the formation of gullies and deep stream channels by gentle release of water through springs as opposed to run-off floods. Small dams constructed across shallow river beds effectively hold back water and soil. The water held back infiltrates into soil storages. A series of small dams along a shallow river provide an enormous infiltration area.

6. THE WATER BUDGET EQUATION

The amount of rainfall received in an area can be measured by a rain gauge. This gives us the income of the water budget. The expenditure side of the equation tells us what happens to the precipitation. The expenditure side has three key components: run-off, evapotranspiration and storage. This information can be expressed in the following form.

Precipitation = Run-off + Evapotranspiration + Storage

The precipitation received in an area is a function of the global hydrological cycle which is dependent on global climate. Man does not have the capacity to influence this cycle. In the cycle, solar energy changes the salt water in the oceans, which contain 97 % of the world's water, into water vapour. The water vapour rises and condenses into small droplets forming clouds. The clouds are moved by wind to the land where they lose their freshwater as rain. The total fresh water in the world makes about 1% of the worlds water. The remaining 2% of the world's fresh water is locked in the form of ice and is concentrated mainly at the earth's poles.

We are powerless to manipulate the world's water in the oceans and in the atmosphere. However, we can manipulate the water which is received as rain in the liquid form. This manipulation involves influencing the balance between run-off, evapotranspiration and storage. By minimising, and, at times, eliminating run-off, man can increase the potential for evapotranspiration and storage. This manipulation of precipitation can modify the hydrological cycle on a localised scale with improvement of local climate and thus improvement in production. Since there is not enough water in ASALs to waste in run-off, harvesting it, or pocketing it, is mandatory if ASAL production is to be improved.

7. CENTRALITY OF WATER IN ASAL PRODUCTION

Water is the principal production limiting factor in ASALs. Due to population increase, the pressure on land in high potential areas, is being relieved by migration into the ASALs. At the same time ASALs population is also increasing. Designing development strategies which preserve and improve dryland species and manage the ASALs for sustained production, is therefore an urgent task.

The ASALs are characterized by high evaporation rates which may equal or even exceed the rainfall. Furthermore, the rainfall is unreliable both in amount and extent. It is in the interest of ASALs to increase the water in ground-water storages, regulate stream flow, re-humidify the air by trees, shrubs and other vegetation, and protect the existing vegetation.

It should be the target in ASALs to capture a large proportion of the precipitation that either evaporates or is lost in run-off, during the rains. This water should be stored in the soil to prolong the growing period and to re-humidify the air through the evapotranspiration by trees and shrubs.

The extension of the growing period, coupled with the increased moisture content in the soil, results in increased biomass production. Hardy trees multiply and less drought resistant plants appear or re-appear. The range of plants increases creating a much more diversified vegetation. The modified ecosystem is then capable of carrying much more varied animal life. The re-humidification of the air may increase the incidence of rain and total precipitation per unit time. The increase in precipitation would be due to the moisture evaporated from the seas and oceans combined with the evapo-transpired moisture from the vegetation forming clouds and then rainfall. This is how the forest recycles its water, between the ground storages and the atmosphere.

The capture and water control in ASALs produces a modified ecosystem by diverting water from the natural hydrological cycle. This capture is at the run-off stage where water is forced to percolate into the ground-water storages rather than to run off. This can be achieved by systematic planning and management of watersheds and catchment areas.

8. CATCHMENT BASIN MANAGEMENT FOR PRODUCTION

A catchment basin is an area whose precipitation run-off is drained by a water channel. The catchment area is bounded by watersheds, or high grounds, dividing two neighbouring drainage channels. Water flows to either one or the other catchment basin depending on which side is downhill since water always flows from higher to lower ground.

Catchment areas vary in size from small areas, drained by shallow depressions, to large areas drained by rivers. Management of these areas, to control water flow, must begin near the watersheds. Near the watershed, the water is spread out over the land surface. As the water flows, further away from the watersheds, it starts to collect in small channels, as rills. These small channels combine together to form larger channels. They collect the water and increase its energy and destructive power. The bulked water is capable of forming gullies and ravines. In ASALs this leads to a tragic loss of productive capacity since the water, not only causes soil loss, but, is not available for production. Given the high evapotranspiration rates, this water should be conserved for production. The unreliability of rainfall in ASALs actually demands water conservation in ground-water storages for survival.

By systematic management of a series of small catchment areas or parts of catchments, the ecosystem, and the ecological and climatological modification of the area can be achieved. Ground water storage is recharged, springs appear where none existed and new types of vegetation can be established.

As the water table is recharged, the deep rooted plants draw water from the capillary fringe to survive the dry periods. They therefore recycle nutrients for shallow rooted plants, including most food crops. Cultivated crops take their moisture from the superficial layers of the soil and survive over a longer period. Percolating water moves slowly through the soil to feed springs and support high water demand crops along the streams.

9. INTERVENTION TO CONTROL RUN-OFF FLOW

The main aim of water flow management in ASAL is to control run-off and facilitate infiltration so as to maximise ground-water storage. This aim can be achieved through different pathways. Some of the methods used are very expensive and complicated. To be effective the methods adopted must be simple, affordable and easily instituted.

Earth structures are cheap because there are no external materials required to construct them. Heaping soil to act as a barrier to water run-off is the simplest step in the improvement of water infiltration. Earth contour ridges keep water at the precipitation site. To be effective, the ridges must be laid out properly, that is along the contours. Also the spacing between two ridges must be determined depending on the slope of the land. In general, the top of the ridge must be level with the base of the ridge above it. The ridges break the slope into short stretches in which water does not gain enough energy to become destructive. They facilitate infiltration by holding back the water and prevent it from flowing away.

Bench terraces offer a method of breaking a long slope into a series of steps which are more or less flat. The effective slope is completely eliminated by those steps. As there is no clear slope there is no run-off from terraced land. Bench terraces offer a very effective method of water retention on the land.

The terraces can be developed as wash stops in cultivated land, such as unploughed strips, grass strips or trash lines laid along the contour. The strips hold the soil which is washed down from the slope above building up the strip higher than the area below it and breaking up the slope. The water is slowed down at the strip and infiltrates into the soil. Eventually a bench terrace will be built up from the accumulating soil. To build up bench terraces this way is slow and could be affected in the ASALs by the dying back of grass in the dry season and the destruction of the vegetation in the strips by white ants. At the onset of rains after a drought, there is a time-lag before the grass re-establishes itself. This is the period of storms and the barrier could be breached resulting in an erosion channel. This would lead to a lost opportunity to maximise water infiltration. Therefore strips and trash lines are of limited value in the ASALs.

Bench terraces can be developed most effectively by the "Fanya Juu" method. In this method a ditch, 1/2 metre wide and 1/2 - 3/4 metre deep, is dug throwing the soil upslope. Grass, for example, Makarikariansis, is planted on the mound to stabilize it. The ditch can be used for planting fruit trees, bananas, or other high water demand crops. The ditch is eventually filled by cultivation thereby contributing to the levelling of the terrace.

When terraces start midslope, they need to be protected from storm water rushing down from upslope. They can be protected by cut-off drains which also act as infiltration ditches or other specialised channels which hold water back and ensure discharge of excess water into artificial or natural waterways for safe disposal. However, since there is not enough rainfall in the ASALs, a good strategy may be to start terraces as near the watershed as possible so as to keep all the water on the farm.

Small dams effectively control run-off and hold water back for infiltration in small shallow streams and facilitate ground-water storage. A series of small dams on a stream provide a large infiltration area.

Sub-surface dams are cheap to build and have the additional advantage in that they can be built up in stages. Their positions must be planned with care. Ideally, they should be on rock outcrops so as to guarantee good anchoring. The first subsurface dam should not be too far from the head of the stream or it will be destroyed by the force of storm water. During the first season, it should not be built up to more than one metre to facilitate filling with large grain sand, for maximum water holding and to avoid wash out. Subsequent subsurface dams, at full development, should be level with the base of the one upstream. This arrangement of subsurface dams is essentially making terraces along the course of a river. Sub-surface dams can be constructed using stones, gabions or cement works. Seasonal additions to the structure increase the height of the dams to predetermined levels. Again these should not be more than a metre to avoid wash out. The small dams fill up with water and sand eroded upstream. Excess water and sand overflows the dam to the dam below.

Taken together, a series of sub-surface dams hold back a vast amount of water. The water covers a large area which acts as its infiltration zone. Deep rooted trees and plants at the sides of the dams, help infiltration by opening up the soil.

In the ASALs, which are characterised by high evaporation rates, small sub-surface dams have an advantage over surface dams in that they have a much lower water loss through evaporation. The water is covered by sand and thus is not exposed to the elements. Water stored in a sub-surface dam can be obtained by digging shallow wells in the dam, piping or from wells downstream or on the sides.

10. ORIGINS OF A FARMING SYSTEM

Nthuku Ngula dates the beginning of development of Kambiti farm along sustainable agriculture lines from 1959. The very specific idea is traced to a discussion between Nthuku and Nyika Mutiso one weekend in August 1959. At this time, Nthuku, whose main vocation was wood carving, was based at Mombasa. He came home only occasionally. Therefore there was little investment on the farm which still had squatters.

In the fateful conversation, Nyika Mutiso urged Nthuku to invest some of his income from the carving business in the development of the land for it was mother. Carving trade did not feed people, Nyika argued. There were too many people in the land and if farmers did not capitalise their land, there would be repeated famines. Starvation was, and still is, central in Nyika's thinking for he has experienced all the famines of this century. To him famines are only broken by people growing food and not by buying food.

According to Nyika Mutiso, Nthuku and his companion carvers were involved in a lucrative business. They were making money but they were not investing it. All they did was consume instead of saving and investing their money in land to guarantee feeding their families. They were involved in a vicious consumptive trap. Without investment, they were losing opportunities for improving their standard of living. This sentiment was largely true. Nthuku himself did not have a savings account or an investment scheme of any kind. Worse still, he was occasionally buying food. All his brothers and most other people he knew in Wamunyu, were also buying food.

Nyika Mutiso is a church elder who had been schooled by the AIM missionaries. He was, and still is, articulate on food for development issues. He saw the need for every family to be able to feed itself as was the case in the old days. He saw the forced labour schemes, which removed men from their lands to work for settlers, as a way of making the African dependant on settler grown food. In addition, the settlers were enriching themselves from the land. He understood that the wealth of the country lay in the development of the land. These were the sentiments he passed on to Nthuku on that momentous weekend.

Reflecting on these issues, Nthuku remembered how in earlier times, the Ngula family had never lacked food for their mother produced enough on the farm. Also he himself had produced food at their land at the Athi River Kyengo, before he was moved into wood carving. Further, he had also traded in food, which he travelled to acquire from Kikuyuland, for sale in Wamunyu, especially in the years after World War II, when famine was endemic in Wamunyu. He knew many people, who only survived the famines of the forties and the fifties by going to work for food, Kuthuua, in the Zone 3 areas of Machakos, Kiambu, Muranga, Nyeri and Meru. They never capitalised the land by improving its productive potential.

Nthuku also knew that Wamunyu was marginal land for food production and rains often failed. Many families were spending all their income on the purchase of food. They thus could not even invest in educating their families. To investment in growing one's own food was a sound idea. Although one could grow food, Wamunyu society saw this as a marginal occupation then for it was the tradition to keep cattle in Wamunyu. Society was not mindless. It had arrived at this conclusion out of experience with the variable rain. There was logic in emphasizing livestock at the then existing technology. Animals did very well in Wamunyu. One could develop a livestock industry which would be highly paying. To achieve this end, Nthuku remembered the lessons taught by his father.

However, Nyika's argument for self sufficiency for grains was good. Whereas in the past techniques of preparing land for cultivation did not exist, they were now available. What Nyika was arguing was that each farmer should use these new techniques and assure themselves food grain self sufficiency. Nthuku internalised this lesson. His first steps in conservation and water harvesting were to be directed towards food security, defined as grain food security. Protein food security, defined as milk, small stock and cattle, was initially not linked to conservation and water harvesting. It was to be so linked in 1978, when keeping Friesian dairy cattle was brought on stream. Vegetable food security, possibly the hardest component of food security to generate in the ASALs, was to be linked with conservation and water harvesting only as an output of a mature water harvesting and conservation system in 1991. During this year, a natural spring, made possible by the general conservation work on the land, made it possible to start growing vegetables all year.

In order to keep animals, one had to have a constant supply of water. One had also to grow enough fodder for the animals. By 1959 it was not possible to carve out cattle outposts in the wild. All the land had been inhabited and claimed by people. The only solution was to defend and develop the family land for animal production primarily. The decision to emphasise livestock was initially rationalised therefore in terms of traditional knowledge acquired from the father, availability of water on the farm and the natural regeneration of fodder grasses for which the area had an advantage. Nthuku Ngula intuitively and experientially knew he had to generate the grass only on his land for there were no possibilities of creating Syengo. Neither could he rely on the tradition of scattering cattle, Kuvithya, for friends and relatives were in the same predicament.

Nthuku Ngula realised that, in the long term, Kambiti farm had to evolve a modern farming system geared to development of livestock production. Food was to be produced in the farm primarily for on farm consumption and not for commercial purposes. Excess food would be sold only when the current crop was ready for harvest to remove it from the stores.

11. WATER HARVESTING AND CONSERVATION IN THE FARMING SYSTEM

SOURCES

Unlike his father Ngula, who was not in any position to do much about improving the water situation on the land, Nthuku had opportunities. First he started by taking advantage of technologies introduced by ALDEV in 1946 in the reclamation of devastated bare lands, "mang'alata", after the droughts of the thirties. There were a few people who had been involved in these programmes. They would be his technical sources. Nearby places, in Zone 3 areas, were quite advanced in farming techniques for they were the focus of the few agricultural staff in the district. He had to get practical knowledge directly from these farmers in Zone 3 somehow.

MANAGEMENT

To facilitate the development of the land, Nthuku transferred his carving business from Mombasa to Wamunyu in 1959. The translocation was to allow him to continue his carving business, ensuring a steady income, and, at the same time, allowing him to develop the land. This way he was spreading his risks.

Since he was creating a new farming system, he had to reorganise time and to invest in acquisition of farming knowledge. Nthuku Ngula allocated the first part of the week, Monday to Thursday to carving. The latter part of the week, Friday and Saturday was dedicated to the development of the farm. Sunday was for church. This time allocation would continue until 1979 when all the time, save God's time, would be spent on farm related activities. The farm was from then on to be a full fledged dairy farm.

COMMUNAL LABOUR

The ALDEV (African Land Development Board) Programme was instituted to deal with the problems of reclamation of devastated land in the "native reserves" after the 1930's - early 1940's droughts. The programme involved the blocking of gullies, digging of cut-off drains and urging people dig contour ridges or bench terraces for their farms. The first terraces in Wamunyu were dug under the auspices of ALDEV for the control of soil erosion.

The first formal conservation activities introduced in Wamunyu were the forced reclamation of Mang'alata, bare land. This involved chiefs and agricultural extension personnel from ALDEV. They would map out where land was denuded and eroding and force all the adults in a the sublocation or Utui to fence the area with thorn bush and then plant star grass. Conservation was thus introduced on forced communal labour basis. When these forced activities were initiated, soon after World War 11, many young men ran away to avoid communal labour. The "reclaimed" lands never lasted since the communities did not understand the purpose. Many thought it was a precursor to the taking of the land by the settlers. Nobody therefore kept livestock out. Since land was still used, note not owned, communally, nobody was responsible for maintenance. Thus the lands degraded more.

This rehabilitation programme was not to be very successful until much later because people were forced to undertake these measures. Forced labour was to result in the resistance to adopting conservation measures. A lot of time was to be lost, great damage done to the land and loss of soil, before people would take to conserving their land. Because of this faulty introduction to conservation, serious voluntary conservation measures did not start until the 1950's in Zone 3 areas. That Nthuku, based in Zone 5, was implementing some of the measures this early is remarkable.

Nthuku's attitude to communal labour was hostile. He went into trade and carving to avoid it throughout the fifties. When he reestablished in Wamunyu in 1959, he was to refuse to take part in the communal labour. By this time, the colonial government was under pressure by the Kenya nationalists to reduced forced labour in conservation. It had been agreed, within colonial government and not by the communities, that any farmer who was implementing conservation techniques on his land should be exempted from conservation communal labour. Nthuku argued against communal labour from the point of view of efficiency. He states that the Mwethya form, the organisation of many people on a sublocation or utui basis, to undertake conservation randomly, was inefficient. The Mwethya was too large and therefore sociologically diffuse. It was not geared to production. It reclaimed land randomly. It was task specific as it only fenced and replanted manag'alata. Thus people did not make linkages to benefits to themselves or assist them in solving immediate problems.

MWILASO (SMALL SCALE ORGANISED LABOUR) FOR TERRACING

In contradistinction to Mwethya, Kamba society had the institution of the Mwilaso. This was an organisation of a few people who agreed to work collectively in turn. They did whatever was requested by the person hosting the work party. Mwilaso groups tend to be sociologically integrated, activity diffuse and very stable over time. Nthuku was to use this institution, organised around the family, for instituting terracing of his and family land.

Nthuku, who refused to participate in communal forced labour was arrested and taken to the Chief in 1959. The chief had no choice but to release him since he was, with the help of his created family Mwilaso, terracing his land. Nthuku's refusal of communal labour was based on the fact that it was spurious treatment of "mang'alata" which were not taken care of by anybody subsequently. This is still a telling comment on ASAL programmes targeted to lands without secure titles.

In 1959, his first bench terraces were laid out, at Kambiti farm, by Mutisya Nzive. Mutisya Nzive had acquired the necessary skills as an ALDEV technician. Nzive retired from MoA recently. Nthuku was one of the earliest farmers in the area to systematically terrace his land. He would dig some of the terraces himself. The Mwilaso, where he participated, would dig some. Particularly problematic areas, or when there was urgency, would be contracted to Mutua Mawathe, who, to date, is a specialist terrace digger.

PLOUGHS IN TERRACING

By the time the first terraces were laid in 1959, Nthuku had neither oxen nor plough. Neither could he obtain oxen or plough from his immediate neighbours for they had none either. As he contemplated what to do, Muthama Katumo passed through Kambiti with his oxen and plough from a ploughing contract at Athi River. He asked Nthuku whether he could leave the oxen and plough at Kambiti, for they would be assured of fodder. The concept of leaving ones animals at another person's place was widespread in Ukambani and was known as "Kuvithya". Its basis was the spread of risk in the event of animal disease outbreak or to take advantage of availability of fodder. If there was an outbreak in one area, the animals at a different area would survive to enable the owner to rebuild his herd again. To be involved in ploughing contracts, Muthama Katumo must have owned other oxen and ploughs. Leaving some animals at different places would ensure the continuity of his business. He could leave the animals at Kambiti, because he was assured of fodder for them. The logic of Kuvithya was that when animals were left in one's homestead, he had to look after them carefully and could use them or their products. Nthuku used the oxen, and the plough, for ploughing and making terraces as the payback for taking care of them.

The acquisition of a plough and oxen lightens the labour of terrace making. The loosening of the soil in the ditch is done by plough rather than by hand hoe. This reduces the total labour and time inputs. The major chore in the terrace construction is then the scooping of the soil and putting it upslope. By building bench terraces on his land, Nthuku laid the foundation for a constant food supply for his family. The prevention of run-off and the containment and infiltration of water on the terraces keeps available precipitation on the land assuring a crop even in poor rainfall years.

This production security can be observed in a year such as 1991 in which the first rains were minimal. Although the neighbours are going to be buying food until the second rains, Kambiti farm is going to produce enough food for its own consumption. There is even going to be a surplus for sale. The difference between total crop failure and the crop produced by Kambiti farm is the availability of water for production. At the same time there is going to be a severe shortage of grass as fodder for cattle in the environs. This is not a problem at Kambiti farm which has plenty of grass in its pastures.

All the land which has been cropped in Kambiti farm has been terraced. After cropping for five years, the land is left fallow. Eventually this fallow land, "Iei", is managed through tree pruning and control of shrubs to become high yielding grassland.

MURANATHA OUT OF CONSERVATION

Recent research argues that the Katumani maize technology enabled populations to move into Zone 5 and to produce subsistence. This is seen as the major legacy of ALDEV derived research at Katumani to ASAL development. Nthuku's system is different. After making the first terraces in Kambiti farm in 1959, Nthuku harvested 86 bags of maize during the second rains starting in October. From that time on, no grain food has been bought in Kambiti farm to date. The food held in the farm stores is sold only when the new crop has matured and the stores have to be cleaned to receive the new crop.

In 1962 the farm produced 12 bags of beans and 120 bags of maize in 1963. In 1968 Nthuku bought additional land, Plot No. 346 which he proceeded to develop. That year he produced 170 bags of maize. The selling price of maize in 1968 was Ksh 21.10 per bag. In ten years, Kambiti farm was able to become a successful grain producing farm in ASALs! This can only be explained by terracing.

Kambiti farm has always planted "Muranatha" breed of maize rather than the recommended "Katumani" maize. This choice was as deliberate as it was significant. According to him, Katumani maize has a short growing period to take advantage of the short wet periods characteristic of ASALs. It also has a low yield unless all related technologies, like fertilisers, are adopted. Muranatha maize on the other hand has a slightly longer growing period but a much higher yield without the other technologies. The risks of crop failure are higher with Muranatha maize if no extra measures for water harvesting are instituted. The moisture retained in the terraces provides the stored surplus which extends the growing period, hence the production of Muranatha maize. It should also be noted that the Muranatha maize has been selected from the late forties so there is just about forty years of selection and adaptation. The type is adapted to the farm, it can be argued. The same strategy was adopted for selecting traditional pigeon pea, cowpea and bean seed. Since there is annual selection, the yields and drought escaping traits are reinforced. The Muranatha example shows Nthuku's key innovative trait of going for maximum returns by exerting an extra effort in managing risks. He was to repeat it in the livestock production sub system on the farm.

MIXED LIVESTOCK OUT OF CONSERVATION

By the time Muthama collected his oxen and plough, at the end of the crop season, in 1959, Nthuku had bought his own two oxen and a plough from sale of crops supplemented by carving income. He now could continue opening more land. He, in addition, acquired a few cows and started building up a herd of native cattle. He built up a herd of 27 head plus goats by 1963. The mixed livestock farming system was important for range use purposes over and above risk and income diversification. The goats were used in opening up thickets. They feed on species not used by livestock. Thicket opening also allows grass to reestablish. This allows cattle to benefit. This system of mixed livestock made clearing for crops easier.

After farming the land for five years, whilst fertilising it with livestock manure, it would be left fallow to grow grass for cattle. Nthuku argues he was doing this since traditionally it was done. He did not do it formalistically for rotational needs.

Interestingly, this traditional system was to enable him to improve his rangeland. As the Kambiti natural vegetation is wooded thicket, it made sense to clear the land for cultivation then rotate it as pastureland, in Nthuku's terms, after the crops paid for the clearing. Also at this time Nthuku had not built up a herd. Although he had grass in the open areas this could not carry a large herd. For the herd, he anticipated to hold, he needed more terraced land so that grass would grow. The land use problem was that between World War II and the late fifties, the land had not been farmed or grazed systematically and since burning was banned by ALDEV, bush had totally encroached.

Not all the land which is terraced in Kambiti farm has been cropped. Since 1978, some of the land which was bare, "mang'alata" has been terraced for the sole purpose of rehabilitation of the land for grass production. This terracing of uncultivated lands has been undertaken to speed up the opening up of the land without necessarily going through the cultivation cycle.

The maintenance of bench terraces on pasture lands is minimal. The experience on Kambiti farm, as well as other farms in the environs, has been that no maintenance work is necessary in a ten year period. One has to be careful however that the animals do not make permanent paths across the terrace. Such paths can be prevented easily by placing a thorny branch on paths frequented by animals forcing them to take another route.

CUT OFF DRAINS

Cut-off drains have been constructed in areas of Kambiti basically to channel storm water to areas where it is needed. Although they are a measure of soil conservation preventing the formation of gullies and increase water infiltration, they are not Nthuku's choice of technique. He has generally terraced from close to the watershed and thus has not needed many of them.

PRIMACY OF TERRACING

The amazing thing about Nthuku's land development is the choice of terracing rather than the simple construction of contour ridges right from 1959. To his thinking, which is very clear, terraces afford a large area of infiltration. Contour ridges on the other hand have a small infiltration area limited by the width of the ditch. Using contour ridges would thus result in streaks of grass whereas bench terraces offer larger areas of growth. He argues that he saw these differences as he travelled in Zone 3 as early as 1959. Consequently he plans to eventually terrace all the land for the development of its full potential. Current ASAL programming is now stuck on the notion that terracing is expensive and other techniques should be pushed to farmers. Nthuku disagrees. He argues that terraces last more than ten years even in pastureland with minimal maintenance. There is no reason therefore, as far as he can see, for instituting the other techniques which do not seem to him to retain as much water on the land. Appendix 1 shows calculations on the cost of terracing. It is clear that they are affordable.

PADDOCK TERRACES

Nthuku has come up with another novel idea about using terraces in pasturelands. He is currently planning to increase the height of some of the terraces to act as animal barriers for Friesians are not as nimble as native stock and they can be effectively contained in such terraced paddocks. The areas between two raised terraces would act as paddocks. This will save a lot of money for wire fencing. It will also save the vegetation needed for thorn bush paddocking. An alternative approach under consideration is to plant live hedges on selected bench terraces to create paddocks.

SUB SURFACE DAMS

There are six dams in and around Kambiti farm, on extended family land. Five of these are subsurface dams and one is a surface dam. In addition there is a gabion/stone and cement structure, constructed to block a gully in the middle of the farm, which could be classified as an additional subsurface dam. More subsurface dams are planned to increase the amount of water which is held back in the extended family land. This is a large concentration of dams which has already influenced the ecology of the area. The proposed increase of dams will modify the ecology further and increase the potential production for the extended family farms enormously.

Two of the subsurface dams were constructed by ALDEV in 1946. One of the dams was constructed on the Mumbuni river almost at its confluence with the Watuka river. This dam has no water since the

Mumbuni is a young river and has a lot of silt which chokes the dam. The other dam was constructed on the Watuka some distance up from the confluence of the two rivers. This dam, although not very well sited, holds a substantial amount of water.

The ALDEV subsurface dam of 1946 on the Watuka was improved and built up by Nthuku and the Kambiti Development Association (which emerged out of the family Mwilaso) with help from Machakos Integrated Development Programme (MIDP) in 1981. The final phase, in the development of this dam, will be undertaken when other subsurface dams have been developed on the Watuka. Of these, two have already been constructed, both upstream to the MIDP dam. The first one was constructed in 1978 and the second in 1987. The earlier one always had sweet water. The second one had slightly saline water initially but is now palatable. It is to be raised more. Three more subsurface sand dams are planned by Nthuku on the Watuka.

No further development of subsurface dams is feasible on the Mumbuni river due to its high load of silt. However, it might be possible to institute measures which would hold back this load raising the level of the river and preventing the deepening of the channel with the associated eating away of the banks. This would increase infiltration but is not recommended on the basis of water supply alone. It can only be justified as an area of producing fodder all year round.

The fifth subsurface dam on the farm was built on a small stream which runs just above Nthuku's homestead. This dam was constructed in 1968. Above this dam, on the stream called Kyandani kwa Ee Ndavi, had been constructed earlier a gabion to check the deep gully which had formed on this stream. This can be regarded as an additional subsurface dam.

The people around Kambiti farm get their household water from the sub-surface dams on the Watuka. The first two dams on the Watuka have fresh water. Water in the lower dam is salty. Seepage from the dams forms pools of water below the dams especially from dams two and three.

Nthuku has submitted the plans for development of the subsurface dams on the Watuka to the Locational, Divisional and Machakos DDC. It is improbable that there are many requests to the DDC for subsurface dam development. The chances of getting assistance for their construction, when public funds are available, is therefore high. Even if this help does not come, there are contingency plans for the building of these dams from family Mwilaso resources.

SURFACE DAM

Above the two small sub-surface dams, on the Kyandani kwa Ee Ndavi, is the surface dam constructed in 1981 to provide drinking water for the animals. The objectives were to minimise the labour of digging watering holes in the subsurface dams and also to keep the Friesian cattle from mixing with other cattle at the watering holes for disease reasons. The capacity of this surface dam is being increased by creating a barrier on the spillway. Although the construction was by the Soil and Water Conservation Dam Construction unit, this additional work is done by Ngula and some hired labour. This is the only surface dam on the farm. A few check dams will be developed above this dam to prevent its silting. The area around the dam, which is only protected by a cut off drain, will have soil conservation measures, among them terracing and fencing, instituted.

THE SPRING

One of the greatest achievements of the water conservation system at Kambiti farm was the start of the spring, at Kyandani kwa Ee Ndavi, below the subsurface dam, in 1990. This spring is still flowing. This is the only water which has flowed permanently anywhere in Wamunyu since the 1930's. To see water from the ground in the dry season is therefore a minor miracle. Ground water storage recharge has been effected here. A preliminary hydrological study shows that the major sources of the recharge are from the terraces and the subsurface dam on the Kyandani kwa Ee Ndavi.

ROOF CATCHMENTS

The best water, used at Kambiti farm for drinking and domestic applications, is harvested from the living house roof. A large tank of stone and mortar is used for this purpose. Due to the increase of outhouses for the farm, for example the dairy house, which was built early this year, the potential for water harvesting from roof catchment has increased enormously. Nthuku plans to build a tank to store water which would be used in the dairy and to supply drinking water to the animals in the dairy area. The construction of this tank is the major project for the farm for 1992. After this construction all the water from the farm house roofs will be stored and effectively used. The waste water used in the dairy will be channelled to irrigate supplementary fodder of lucerne and bana grass. This water will flow by gravity to the fodder fields.

11. ACQUISITION OF FARMING KNOWLEDGE

TRAVEL

The only time Nthuku had for his farm in the 1960's and 1970's was Fridays and Saturdays. All the farm oriented activities had to fit into this time schedule. He had to acquire farming knowledge which was not available in the locality. He was a pioneer. The local farming advisory staff did not seem capable of satisfying his quest for knowledge. He probably was ahead of the extension staff in knowledge of what to do.

His solution to acquiring farming knowledge was as simple as it was original. He decided to travel to seek knowledge every Saturday. In his travels, he would observe what other farmers were doing. His interaction with them, through conversations, would explain why they did what they did. The technique was to be used for the acquisition of dairying knowledge later. He maintains this method of observation and interaction with other farmers to this day.

The Kangundo, Matungulu, Mitaboni, Iveti and Mbooni, all in better zones than Wamunyu (Zone 3 primarily), were more advanced in farming techniques. These were his first targets. The travelling cut down the time spent on the farm. However, this was time very profitably spent.

As it is very difficult to travel alone, Nthuku found a colleague, Katema Kitonga, to accompany him on his trips. Together they would take a bus to Machakos, then ride their bicycles through a chosen route back to Wamunyu. This system spared them riding uphill and saved time. They would take different routes to see different farms and meet different people for discussions. In the event of being asked where they were, the reply was: "We were looking for knowledge". This quest for knowledge has led to the making of Kambiti farm a model for farm production in ASAL. It is travel and contact with other farmers which led Nthuku to take water conservation measures on his farm. He could clearly observe the advantages of terracing and internalise and process the knowledge on a practical rather than theoretical basis.

An example of this process of observation, internalising and putting into practise the knowledge acquired, was the building of the earth dam. On a visit to Kyalo's farm at Machakos, Nthuku observed that Kyalo had four dams on the farm. Kyalo thus had plenty of water for his animals but little grass. Kambiti had a lot of grass but the animals had to walk relatively long distances for water. Nthuku concluded that Kambiti farm had to build a dam to remove this constraint and solve the problem of water for the animals.

Another area where travel and observation has helped him is in pasture development. Kambiti farm has moved from total clearing of pasture lands, through severe thinning of trees to pruning and selective thinning of trees.

Currently Nthuku travels widely in the country to visit farmers in the dairy industry. He is familiar with farms in the Central Province, for example Mary Nevill's farm at Limuru, Rift Valley Province; Major General Cheruiyot's farm and many others. Closer to home, he works in liaison with Kyalo who has a long experience in dairy farming, as a worker in the Machakos settler farms. Kyalo's long experience of dairy farming has led to his breeding the champion milk producer in Kenya in 1990. Kyalo also holds the national butterfat cup for the same year. Mary Nevill has produced the champion milkers for the previous 9 years. Major General Cheruiyot has produced the national Champion Friesian bull. This year, 1991, Nthuku will travel to Zimbabwe for the country's Agricultural Show. He is making the trip as a member of the Kenya Holstein Friesian Cattle Breeders Society. He also travels with the Machakos Dairy Farmers Association to all parts of the republic.

RADIO BROADCASTS

Another source of information, which has been useful to Nthuku, is radio broadcasts. One radio broadcast in 1980 has left a lasting impact on him. This broadcast dwelt on the anticipated global climatological changes. It reiterated that there was going to be an increase in temperature and increased incidence of droughts. If he were to continue his dairy farming, he saw water supply and grass production as his major constraints. He had to secure a constant supply of water for his animals. He also had to have surplus grass in case of an extended drought. To grow enough grass it had to be watered by holding as much water on the land as possible. He had to manage his land for maximum biomass production to feed his animals throughout the year.

To grow enough biomass as fodder for his animals, Nthuku decided to enhance water conservation on his land by terracing rangelands without going through the cycle of croplands. He built a small dam and carried out some sub-surface dam work. The tree pruning technique was extended over most of the land to create a micro-climate which allows grass to stay green for longer periods.

It is interesting to note that though Nthuku has little formal schooling, he is thoroughly knowledgeable in his subject of interest. His actions are deliberate and the results are visible. He is clear as to the direction he wants to take and patiently considers the most viable alternatives. He has the ability to devise practical methods to solve his production problems, problems which perplex most, including development experts. As a result of his pioneering work, which is slowly being copied by other farmers, the landscape and economy of Wamunyu is going to change to everyone's benefit.

FARMER TO FARMER EXTENSION

Nthuku is a member of the Machakos Dairy Farmers Association, Wamunyu Farmers Cooperative Society, Kenya Holstein Friesian Cattle Breeders Society among others. Through these associations, Nthuku has visited most of the areas where Friesians are kept in the country. The members of the Machakos Dairy Farmers Association hold their meetings at different farms. In this way, they can assess the state of the farm and help each other to solve problems. They tutor each other on animal production.

Nthuku has acquired a large wealth of knowledge on the management of a dairy farm and has become one of the main sources of knowledge for his fellow farmers not just in Wamunyu but through the whole district. Through the District wide association, the dairy farmers are able to lobby for better service from the public sector. For example, they established tick resistance to acaricide in public dips before the authorities knew the problem. They were able to force changing of the acaricide type for the District, even though the public officials were not in support. They are able to go to the large manufacturers of chemicals and feed and argue for better prices than is possible normally. The dairy farmers have also taken leadership of the general farmers cooperative in Wamunyu, and introduced better management and marketing of milk and other products. Within all this Nthuku carries a major share of the thinking and innovating necessary.

Apart from the knowledge gained from the membership of the association, members benefit by maintaining shared facilities. For example, Kambiti farm has no cooling facilities, it cannot therefore maintain its AI service. Mr. W. Kyalo, at Machakos, has access to electricity and acts as a central point for storage of semen. Kambiti farm can pick the semen and the animal can be serviced within six hours. Due to the shortage of veterinary technicians, Nthuku had to learn to give drugs to his animals, assist in calving and also perform the AI service. This knowledge is shared to others in the region. Walking with him in the environs, one sees other farmers thanking him for having treated their animals. The skills he has mastered are not only used for the farmers with Friesians but with all livestock. He has become a community resource to be used for collective self reliance.

12. DAIRY FARMING

Approaching Kambiti farm, from Wamunyu, one travels eastward for three kilometres to a turn-off onto the extended family farm. It is marked, for those who know, by two young acacia tortilis trees. There is no flamboyancy of the now common massive farm gates here. The impression one gets is that you have missed your way. This area surely could not possibly carry a prize Friesian herd. One travels for half a kilometre on plot No. 7 to the Watuka river. Then the scenery changes. Next to the road crossing, one can see the wall of sub-surface dam II on the Watuka river. Across the river one sees the managed pastures of Kambiti farm. On the left side of the road across the river one can see the cattle dip.

Once across the Watuka, one climbs up to the Kambiti farm houses on a farm road constructed over shaved terraces with a terminalia brownii standing guard in the middle of the road. One goes past the houses and approaches them from the top. The nearest building, going to the top, is the brand new dairy, for fourteen cows. If one is lucky, the animals will be either in the enclosure next to the dairy, on your right as you enter the compound, the house area in front or in a paddock to the left. Again there is no dead wall of a farm gate to welcome you.

Irrespective of where you find the animals, they never fail to impress. Amid all the neighbouring relatively unproductive scrubland stands this choice herd. You stop and wonder what stroke of fate has placed these animals here. What kind of genius has managed to keep these animals in these surroundings, you muse. One wonders how the farm manages to maintain these animals in such prime condition and how it produces champions here. The awe inspiring spectacle is the success story of Kambiti farm. It is a creativity of production which should serve as a model of what should be achieved in the ASALs. It is the result of the determination of Nthuku to try the unconventional. It primarily is a result of pocketing all the water for production.

Against all the advise of the professionals, Nthuku chose to keep Friesians since they produce more milk than the recommended Guernseys and Jerseys. To succeed in this venture, he had to have enough water and feed. He has achieved both these aims by employing both vegetation and water conservation measures. All activities in Kambiti farm are geared towards a successful animal production. The basis of the operation is water conservation for grass (fodder) production.

Dairy operations were introduced in the farm in 1978. The first animals were one grown cow, Kyatu, and a calf, Kavoo. The breed chosen was Friesian because it is the top of the range in milk production. Since Kambiti farm is in Agro-ecological zone 5, the most suitable choices, according to public literature and extension messages, were either Guernseys or Jerseys. However, Nthuku knew that Kyalo was successful in rearing Friesians in a similar zone with poorer soils. In fact, Kyalo has become so successful that he holds the 1990 Kenya record on milk production. Kyatu and Kavoo and their offspring form the backbone of the herd which today stands at 28 animals. At the time of introduction of dairy operations at Kambiti farm, Nthuku still maintained his business activities in Wamunyu. In 1979, he resigned his business activities in Wamunyu and elsewhere to concentrate on dairy farming.

The animal production milestones at Kambiti farm to date:

1978: Introduction of the first Friesian animals.

Construction of cattle banda and crush.

Introduction of drastic thinning of trees on grazing land.

Introduction of terracing grazing land.

1979: Nthuku's resignation from all non-farm business commitments to concentrate on dairy farming.

1979 Introduction of tree pruning as opposed to tree thinning.

1981: Construction of a surface dam to provide water for the animals.

1988: Construction of a cattle dip at Kambiti farm.

1990: Construction of a dairy/milking house.

1991 Introduction of fire in management of pests and vegetation.

1992: Projected construction of a water tank for irrigating lucerne and bana grass in the farm with waste water.

Projected development of silage.

In 1978, to provide the dairy animals with enough fodder, Nthuku started opening the original vegetation for grass growth. The technique used was to uproot most trees while clearing the thicket and leaving only sparsely distributed trees. This severe thinning of the existing vegetation resulted in an open canopy grassland. Such an open grassland offers little protection of the grass from the hot sun, and the drying effect of the wind.

The thinning techniques was changed in 1979 to a tree pruning technique after Nthuku visited Makau Mutiso's farm, ten kilometres away. This technique is advantageous as it results in extensive shade for the grasslands and high infiltration resulting form the effects of tree/shrub roots. In this technique the opening of native vegetation, for grass growth, involves severe pruning of the trees with selective thinning and clearing of the shrubs. It offers a high cover for the grasslands. High ground cover from pruned trees results in more vigorous grass growth which remains greener for longer periods than in the case of highly thinned trees. The difference maybe due to, the higher water infiltration of rain, coupled with the modified microclimate, and nutrient circulation. This difference can be observed in adjacent paddocks in Kambiti where the different management techniques have been applied. In areas where the trees have been severely thinned, young trees are being nurtured to increase the tree populations. Trees are important for producing pods which are used as livestock feed. Their leaves are also used by livestock as feed.

Areas which have been farmed and left fallow, "maei", have re-established the natural vegetation. This has been made easier by reseeding through mature preferred trees which had been left in the cultivated fields. Specimens of A. tortilis, A. seyal, Sesbania sesban, Terminalia brownii, Balanites eagyptica, A. polyacantha and so on, are now not felled during clearing for cultivation. The young trees attain a height of about 4 m in eight years in fallow lands. It is almost certain that this fast regrowth rate is the result of terracing which has reduced the period of water stress on the trees due to superior water infiltration. Managing this tree regrowth by pruning and clearing the undergrowth has promoted grass production. At Kambiti farm, there are very few exotic trees. The ones which are found are either ornamental or fruit trees.

Starting with one cow, "Kyatu" and a calf, "Kavoo", the farm has built a herd of 28 animals by 1991. Others were sold because Nthuku did not like their line. With further development, the farm expects to keep up to 50 animals. This figure might be revised later as the potential of the land and ongoing improvements are evaluated. The limiting factors in future maybe labour and power availability rather than water and fodder.

Although the farm is in AEZ 5, characterised by high temperatures, unreliable seasonal rainfall, and long dry spells, it has developed a champion herd of Friesians. The farm has won many prizes and trophies in animal exhibitions at several Agricultural shows. The competition in many cases comes from animals grown in more ideal conditions for the breed. Among the top prizes and trophies won by the farm are the following:-

1988

Embu Show		Kilundo 1st Prize
	Katuva	Reserve Champ(18 mon)
Machakos Show		Lancia 1st Prize

1989

Machakos Show	Lancia 1st Prize

1990

Machakos Show	Lancia 1st Prize

Nairobi International Show

Kyatu B2	2nd Prize(18 months)
Kitheka	2nd Prize(18 months)

Nthuku's family is totally involved in dairy farming. However, two sons impress one with their particular love affair with the herd. One 11 year old son is involved in the preparation and presentation of animals at the shows. He is involved in all aspects of the business and has a keen interest and a strong insight in handling of animals. Another very young member of the family, who shows a highly developed aptitude towards the animals is a nursery school boy. He is the youngest of Nthuku's sons. He spends all of his time with the animals and if no one prevents him, he is apt to miss nursery school. It is clear the family will regenerate future managers.

Nthuku is a member of the Machakos Dairy Farmers Association which is affiliated to the Kenya Holstein Friesian Cattle Breeders Society. The breeding priorities at Kambiti farm in order of importance are to: 1. Increase of milk production 2. Build up of heat tolerance 3. Improve body structure.

The bulls chosen for breeding are pedigree Friesian bulls which are strong in these lines. A list of preferred lines of bulls is held in the farm. This list is compiled by the Kenya Holstein Friesian Cattle Breeders Association as well as the National AI Service at Kabete. An example of bulls, which have been used in the farm, from the records of the Central Artificial Insemination records, is Lancia, Bull No. 293, whose lineage from the British bull, Bilslow Lancia is as follows:

Sire	Bilslow Lancia
Dam	Grove Sensation
Breeder	Grove Lavender
Reg. No.	10654 XLIII
Country of Origin	U.K.

This line of bulls have a high milk production and a strong well proportioned body frame. It also has good temperament. The Lancia line is the major bull line on the farm currently, as shown below. Other bulls are Bull No. 240, which laid the breeding foundation, and Nyara Mikado, registered as Bull No. 287. The latter is half brother of Nyara Oberon, registered as Bull No.

286 and was produced by the British bull Brynhfryd Emperor. The Nyara Mikado line has a good milk production as well as heat tolerance. It was expected to replace the Lancia line, but it had to be discontinued for it became too aggressive. Bull No. 305 is being introduced. It is expected that other bulls will be selected from other farms to increase milk production. Milk production of more than 10,000 litres per lactation have been achieved at Kambiti farm. This is a respectable production according to records maintained at many places in the world.

The breeding line from dam Kyatu, the main line in the farm is as follows:

A. d.Kyatu

s.Kavisi

s. ?

d.Katuva

d.KyatuB

s. Bull No. 240 s.Bull No.240

d.Kakeni

d.Katuva2

s.Nyara Mikado.s.Lancia s.Lancia s.Nyara Mikado
s.Lotaela

d.Kalekye d.Kamoli d.Kamwaka

d.Katumbi

d.Kakuvi

s.Lancia

d.Matiasi

B.   d. KyatuB

s.305   s.Lancia

d.Kavete d.KyatuB2

13. ENERGY, BIOMASS AND PRODUCTIVITY

Essentially all the energy in an ecosystem originates from the sun. Each living organism is dependent on photosynthesis by green plants. Also, all organisms are controlled by the existing climates that arise from solar radiation received on the earth's surface. Rainfall and the ambient temperature are determined by the incident solar radiation. Other energy inputs which contribute to production, for example fossil fuels and food imports also have their origins from solar energy.

The net primary production of an ecosystem is the mass of all photosynthates produced in an ecosystem per area per unit time. This value is less than the gross primary production since some products of photosynthesis are used in the maintenance and growth of plants. Some others are used in respiration.

The biomass of an ecosystem is the dry mass of all organisms in the ecosystem at any given time. In ASALs generally, the energy for production is plentiful. Other factors of production, such as soil, are adequate. The productivity of ASAls is generally limited by availability of water.

Therefore the strategy for increasing productivity of ASALs should focus on how to increase available water for production. The controlling of run-off and recharging of ground water storages is the only way to increase the productivity of the ASALs, through greater plant growth leading to increased photosynthesis.

14. FARM DEVELOPMENT TECHNOLOGIES

TILLAGE FOR FOOD PRODUCTION

Kambiti farm produces the bulk of the food grains and milk consumed on the farm. The food is grown in fields which are used for a period of 5 years and then allowed to revert to pastureland. Crop rotation and mixed cropping techniques are employed on the farm.

Originally the land was ploughed using an ox-drawn plough. Currently ploughing is by tractor. All ploughing and planting is done before the onset of rains. Weeding between rows is mainly by ox-drawn plough although limited cultivation by hand hoe is undertaken.

CROP VARIETIES AND SELECTION

The farm plants "Muranatha" maize rather than the recommended "Katumani" maize. It always has a substantial yield. Terracing allows for the growth of the longer period maturing maize because of the stored surplus water. The preferred maize has a higher yield than the quicker growing variety.

Cow peas are interplanted with maize for use in the farm as a leaf vegetable and for their seeds. They are used to supplement maize protein in the diet. Pigeon peas are also interplanted for seed which is a source of protein. The pigeon pea plant is used as an agroforestry tree. It is a soil improver due to its nitrogen fixation. Beans are also grown as a protein source.

Bananas, lemons, oranges, pumpkins are grown in the farm for their fruit. Young succulent pumpkin leaves are an important leafy vegetable. These are cooked together with maize and peas to prepare well balanced and nutritious meals.

Since the start of the spring, below the subsurface dam at Kyandani kwa Ee Ndavi, vegetables such as kale, cabbage, arrow root and tomato have been introduced. Other plants such as sugar-cane and arrow-roots, which are found in areas of high water availability, have been introduced.

The food grown on the farm is for home consumption not for commercial purposes. Food grain sales occur at the time of the ensuing harvest to clear the stores for the new crop.

FOOD STORAGE

The use of traditional and modern technology is also found in

Kambiti farm storage. The log granary, Ikumbi, which some argue was introduced by the African Inland Mission and thus became the dominant storage system in Machakos as early as 1930's, is found. The construction is square leaving small gaps in the logs to facilitate drying. Initially harvested crops are sun dried. In case of a rainy period, they are taken from the farm to the store. This type of store dries grain, especially maize on the cob, effectively. However, if storage is for long term, or for fool proof protection from rats, and to ensure that weevils do not attack maize, or other grains, Kambiti farm uses the traditional Kiinga, which is placed inside the Ikumbi.

A kiinga is constructed of grass. Once grain is dry, it is put inside and the top sealed. Storage in Kiinga eliminates vermin attack especially if ashes are added to eliminate air before sealing it. Historically, for long term storage of survival food, a kiinga is plastered with either mud or cow dung to seal grain inside. To evacuate the grain, a hole is made near the bottom and plugged with a durable stick. Needed grain is drained out creating a vacuum inside and therefore limiting the growth of vermin inside. Grain has been known to stay in sealed Kiinga for more than twenty years.

Kambiti farm has a complex storage system which integrates the Ikumbi and kiinga storage systems. It is able to reduce storage losses, estimated to be about 32% nationally, almost completely. The key to this is the kiinga. Most farmers do not have any kiinga for they do not have the grass species from which it is made! The kiinga system is probably a more efficient system than the introduced storage systems.

WATER FLOW CONTAINMENT

Bench terraces are the major run-off control measures on the farm. Extensive bench terracing has been undertaken and eventually all farm land will be terraced. A few strategic contour ridges have been constructed at selected sites to act as additional infiltration zones, channels or as cut-offs.

On the streams which traverse the farm, an earth dam and several cement work subsurface dams have been constructed. The earth dam was constructed using tractors. Roof catchment has been used to harvest water which is stored in a storage tank. The water in this tank is used as drinking water on the farm.

TRANSPORT

The milk produced on the farm is transported by bicycle to a collection point at Wamunyu market, three kilometres from the farm house. There is a dairy belonging to the cooperative in Wamunyu. It has a milk cooler. Milk is sold to the dairy and at home. In the near future, when the pedigree crop of heifers start to lactate, a pick-up truck for the farm, especially for transporting milk and collecting feed, will become mandatory.

Bulk loads, such as removal of produce from the croplands, is accomplished by a tractor trailer. The tractor is hired from a company of extended family members and others, another spinoff of the Mwilaso.

A major road from Kitui to Machakos fronts the farm on the southern side. Access to the outside world is thus guaranteed on this increasingly busy transport and trade channel.

MILKING

All the milking on the farm is manual. The farm is not served by electric power yet.

PADDOCKS

Grazing on the farm is on rotational basis. The grasslands are divided into paddocks using "Mathanzu", the branches of thorny trees obtained in the farm through tree pruning. One large branch at the entrance to the paddock is taken aside to let in or let out the animals.

A novel method of making paddocks using bench terraces is planned. This will involve increasing the height of the terraces to act as animal barriers thereby cutting down the use of thorn tree branches for paddocking.

CONCENTRATES

The farm harvests A. tortilis pods and other tree pods to use as feed concentrates. Tree pods have been used in the country by herdsmen for survival of their animals. During the 1984 drought, a bag of A. tortilis pods cost Ksh. 250 in Wamunyu. Usually the trees shed their pods during the dry periods. The deliberate systematic harvest of this source of animal feed is however a new idea. The farm pays hired labour Ksh. 10.00 for collection of a bag of the pods. The pods are used to feed the animals during milking. Clearly, tree planting programmes should pay attention to the uses of some of the key traditional trees for pod production.

Other concentrates are purchased from commercial animal feed producers. Bulk buying is undertaken by the Wamunyu Farmers Cooperative Society. Supplementary minerals are also obtained from the feed producers.

RANGE MANAGEMENT

The preferred vegetation management technique, in Kambiti farm grazing lands, is that of severe pruning of trees with clearing of the underbrush. This technique, coupled with terraced land, produces a lush grass growth which remains succulent for a long time. Presently the underbrush is cleared with a hand hoe and a panga. The possibility of using controlled burning to clear the underbrush and old coarse grass is being investigated. An experimental plot was burned during the kathano, in 1991. The results were a very good growth of Mbeetua, the preferred grass. It is anticipated that burning will drastically cut down the labour required to maintain the grasslands without damaging the trees.

EXOTIC FODDER

Exotic fodder crops at the farm include boma rhodes, bana grass, cana lily and lucerne. These crops are cut and fed while fresh to animals either during milking or in the evening as supplementary feed.

The farm is planning to start of hay and silage making. It would thus have reserve fodder for the animals in the event of a severe drought which would curtail fodder production. This will be a superb method of feed risk management and will also contribute to improved milk output.

Kambiti farm already grows one legume for fodder. Lucerne at Kambiti is grown for feeding during milking as a supplement.

Other legumes which are going to be introduced in the farm for improvement of the pasturelands include Siratro, Centro, Crotolaria, lupines and sesbania sesban, Munyonyo. Sesbania sesban grows in the region traditionally. Seed for the others are hard to come by. Government should make them available to farmers who are ready to use them. Whichever of the selected leguminous plants will be successful will help the production of grass in the farm due to their nitrogen fixing capabilities. Sesbania Sesban is to be rapidly introduced in all parts of the land for its nitrogen fixing properties. Knowledge on the utility of this tree was gleaned from Baraka farm in Molo, Rift Valley, in 1991.

15. VEGETATION

One of the key problems in all ASALs is the loss of vegetative cover and thus loss of vegetation diversity. This limits production in the long term. A related problem is the failure to transmit the knowledge to the young generation. At Kambiti farm, the knowledge is being transmitted to the young generation. The following list was compiled by Nthuku's son in standard 8. He included all the trees, shrubs and grasses except five exotic trees on the farm which were included by Nthuku himself. He had a working knowledged of all the trees on the farm.

The climatic climax vegetation of the area surrounding Kambiti is that of dense woodlands. The dominant tree species include the Acacias, Commiphora and Combretums. Other abundant trees are the Terminalias, Balanites and Delonix. Shrubs rather than grass dominate the undergrowth with Ngondu, Wuti and Muvila being by far the most abundant. Mutavisi/Mukiti (Lantana) which is a recent introduction, has colonised large areas and will be significant is not controlled effectively. The commonest trees are Muaa, Muswiiswii and Mung'ole. Grass growth is only significant where the undergrowth has been cleared and the canopy density is reduced.

Trees and Shrubs in Kambiti Farmland

1. Muthiia	Acacia mellifera
2. Mung'ole	Acacia senegal
3. Muswiiswii	Acacia eliator
4. Muuku	Terminalia brownii
5. Mukuu (Ikuu)	
6. Muaa	Acacia tortilis
7. Muvingo	Delbargia melanoxylon
8. Mutheu	Rhyus natalensis
9. Muvila	
10. Munina	
11. Muamba	Adansonia digitata
12. Muasi	Lennea schwenfurthii
13. Mulong'oyo	
14. Mulului	Balanites aegyptica
15. Mukengeka	
16. Munyonyo	Sesbania sesban
17. Mukomoa	
18. Mutuva	
19. Mukakaa	
20. Mukiti (Mutavisi)	Lantana
21. Musemei	
22. Kyowa	
23. Musewa	Acacia polyacantha
24. Mukiliuli	
25. Mutithi	Combretum zeytasi
26. Matitiu	
27. King'uuthe	
28. Kyuwi (Kiui)	
29. Mutongu	
30. Kiunanii	
31. Muvou	
32. Wuti	
33. Muthekethe	
34. Mwelanganga	
35. Kilawa	
36. Kitungu	
37. Kithalwa	
38. Mukulwa	
39. Mwisya	
40. Kyatha	
41. Mukuswi	

42. Mulyambila	
43. Muthika	
44. Mutei	
45. Mutaa	
46. Kitimu	Rough lemon
47.	Ficus Benjamina
48.	Cassia siamea
49.	Umbrella tree
50.	Nandi flame
51. Kiembe	Mango
52.	Persian lilac
53. Kisungwa	Orange (Washington navel)
54. Mukulu	
55. Muema Nzou	
56. Kyaa kya usi	
57. Musaa	
58. Muatine	Kigelia aethiopsum
59. Mukame	
60. Mukau	Melia volkensii
61. Mukenea	
62. Muthi (Kithi)	A. gerradii
63. Kisovasovi	
64. Mukenya	

Grasses and Herbs in Kambiti Farm.

1. Mbwea Ntheke	
2. Mbeetua	
3. Kinanunga	
4. Misyi ya mbiti	
5. Ikoka	
6. Nthata Kivumbu	
7. Kimooi	
8. Watima	
9. Kitothya	Bana grass
10.	Boma Rhodes
11. Yotwii	
12. Ndande	
13. Lamuyu	
14. Kithuku	
15. Mbwea ya Nzou (nene)	
16. Ithea utuku	
17. Uthui	
18.	Cana lily

19. Lucerne

Constant clearing of the undergrowth and management of the woody species by thinning and pruning is important in maintaining prominent grass undergrowth. High level pruning with greater density of trees had been observed to provide a richer grass harvest than more exposed land with fewer trees.

The colonisation of land by grasses on land cleared of underbrush follows the following sequence:

1. Kinanunga (the colonising grass)
2. Ikoka (Star grass)
3. Nthata Kivumbu
4. Mbeetua

The same sequence of grass succession occurs on bare land "mang'alata" during the process of recovery. However, in land which has been cultivated, the grass succession is significantly different. The following two major grasses succeed:

1. Ikoka
2. Mbeetua

The explanation for this different succession sequence must be related to soil fertility. Where animal manure has been used on the fields, Ikoka recolonises quickly and almost exclusively. The two grasses however co-exist without eliminating each other.

Ikoka and Mbeetua are the preferred grasses for animals in this area and eventually end up as the dominant grasses. The two eliminate the other grasses. Ikoka (star grass) has great recovery powers. According to Nthuku, it is often eaten down to the roots by animals but it recovers quickly, producing a vigorous regrowth. In addition, Ikoka is reseeded by the animals through their droppings. There is a deliberate policy of extending ikoka coverage by planting when labour is available or by penning animals in different parts of the land.

Woody species, which recolonise cleared areas in this region, are predominantly the Acacias and Combretums. The dominant colonising shrubs are Mutongu, Muthekethe, Muvila, Wuti and Mutavisi/Mukiti. Muvila and Mutavisi are pioneer shrubs in degraded lands. The spatial distribution of the woody trees is determined by some innate mechanism in the trees themselves. In the case of Muthiia (A. Mellifera) for example, the growth of the young trees of the same species is suppressed. If the mature tree is removed, however, many young trees grow until a dominant one suppresses the growth of the others which are stunted and eventually die off.

To help the recovery of bare land the steps taken on Kambiti farm, to increase infiltration and create microcatchments, are pitting, terracing, rough ploughing (chiselling) and planting of Ikoka. The rhizomes of Ikoka provide an easy method of propagation and give a quick ground cover. Some herbs, which are found in land which is recovering, are Muthangila and Mukuutu. Mukuutu is a preferred cattle fodder.

16. CAPITALIZATION OF LAND

CHANGES IN TRADITIONAL LAND OWNERSHIP

Up to the turn of the century, land in Ukambani, belonged to the clan essentially. All clan land was communally owned and used. However, certain areas of prime land were delineated and belonged to specific households. These were passed down and inherited in the family. Such lands included valley bottoms which had a survival value. These were the last lands to parch in case of a drought and crop failure. Each family guarded its valley bottom plots jealously.

Land pressure, due to the increasing population and introduction of the monetary economy, in the first and second decades of this century, led to the disintegration of the traditional land tenure system. With this break down came the exploitation and the mining of the land.

During the operation of the old system of land tenure, the council of elders arbitrated on land issues. They selected and supervised the preparation of areas to be burned for grass regeneration, and control of thicket and animal disease. In the case of disputes over the privately held land, such as gardens and valley bottoms, the council of elders settled the matters. For the sake of animal survival, the council of elders designed and managed the reserve rotational grazing system significant in drought years.

INSECURE TENURE

After the breakdown of tradition, no one in the clan was responsible for the clan lands. The lands were overgrazed since there was no control. They degraded. Where once were managed grazing areas, was now bare land. There was no reserve grazing for collective self reliance, assuring survival of community breeding stock.

A factor which aggravated the situation was the acquisition of land for the formation of the White Highlands and creation of crown lands. Significant areas of Machakos, in the west, were deeded White Highlands and the people grazing there evicted between 1908 and 1910. They were forced back to the hills. This resulted in extensive struggles over land. It resulted in degradation all over the district as significant numbers were pushed back to the so called native reserves. The Yatta Plateau, which had been seasonal grazing land for the Kamba, was closed to them and left only for European ranchers during periods of drought in their concessions. Historians estimate that as many as 40,000 cattle were moved back to the settled areas of Machakos from Yatta in 1924. Withdrawing these lands from the use of the people created land pressure, land struggles and degradation. There was no new land **(WEU)** to be colonised.

By the third decade of this century, there was no stability and formalised legitimacy in land ownership. Claims and counter claims were made by clans, families and individuals on specific pieces of land. Extensive resources were spent on litigation within the clans and in the nascent colonial court system. Within society extra legal activities, like resorting to medicine men and intimidation were common. There was a gradient of these problems. They intensified earlier in the high potential lands, Zone 3 and 4 and trickled to the dry lands of Zone 5. By 1920s, all administration in Kangundo, Matungulu, Mbooni, Iveti, Kilungu and Kalama was tied up in land cases. Those who lost out migrated to the more dry areas. Earlier, we commented that Ngula moved out of Kiteta to Wamunyu in the 1910s. It is not clear what reasons pushed his parents from Mbooni, over and above general crowding. In his case, the movement from Kiteta was driven by both lack of land for his livestock, the related degradation and land cases.

With the deepening of the degradation and crowding, it was impossible to develop land effectively. One might expend a great deal of effort just to lose the land to the next strongman who came around. Insecurity was rampant. Many families did not know whether or when they would be dislodged from their homesteads and lose their land.

DEGRADING ENVIRONMENT

As the major droughts of the 1930s hit, the land was already degraded. The livestock were weak. The people were spending almost all their savings on land litigation. The strong were preying on the weak in this unstable society in a degrading environment.

Under the circumstance, and as a means of self preservation, families and individuals started laying claims on the land and privatising it by fencing and keeping all and sundry out of its utilisation unless it was for a fee. In the fluid society which existed then, the father would give a portion of his claim to each of his sons. This resulted in the inheritance of land. However there was a problem of the division of the extended family lands. Wrangles arose with the result that some of the members of the family were ejected from the land.

It was in this situation that the colonial government misread the causes of degradation. It did not see the socio- demographic changes and the imposition of a colonial economy driving it. Rather, it defined the problem of degradation of land in Machakos as overstocking. By 1936 proposals were made to forcefully cull the herds. Kenya Meat Commission (then known as Liebigs) was created to implement the forced sales at prices which were often only a quarter of what European farmers were getting for their native livestock. This led to the Muindi Mbingu political protests in 1938. The unifying principle for this movement was forced cattle sales. The enemies were the native colonial officials who were using the culling programmes to accumulate both cattle and land and of course the European settlers.

The jailing of Muindi Mbingu and World War 11 slowed the forced sales partly because of the distraction of the state by war and also since livestock prices moved up dramatically. After the War, the colonial government changed strategy and rather than force sales, ALDEV was created to force conservation of land. The change in strategy came about since there really were not many cattle. The 1941 drought had decimated the herds. The few animals remaining were sold at premium prices to the military during the rest of the war years.

The coming of ALDEV and the forced labour in soil conservation in the 1940's and 50's can be viewed against this background. People were being forced to work on conserving the land. They understood that this was a precursor to the lands being turned into White Highlands.

INABILITY TO COPE WITH STRUCTURAL CHANGES

Ngula had lived through all these tribulations on degrading land. In the twenties, he had sent some of his cattle to the Yatta Plateau and the Athi River from his Kambiti base. He was one of the stock owners kicked out of the Yatta Plateau in 1924. This forced him to concentrate his cattle at the Athi River Kyengo and Kambiti farm. This not only limited his capital accumulation but no doubt contributed to degradation of his land and the environs for it was not just him who collapsed back to Wamunyu. Other stock owners brought their vast herds back with equally disastrous impacts on the ecology of Wamunyu.

During the early thirties, he build up his herd although land was relatively scarce. He protected his land for he was a fierce fighter. Stories are told of how he personally beat anybody who grazed on his land or in any way interfered with his cattle. He sociologically was a pressurised man. Among the key lessons his youngest sons remember are his admonitions to fight to ensure nobody illegally grazed their land or interfered with their cattle. For him, as for Wole Soyinka, only the strong breed survive. He had personally claimed the land, invested in building livestock capital and he was not about to let others take advantage of his land which had been capitalised.

Ngula's adaptation to the evolving circumstances did not match the structural changes acting on his production system. He had already lost his Kyengo in Yatta. When branding and forced sales were implemented between 1936 and 1940, he had to sell his mature animals. The drought of 1939 to 1941 decimated his remaining animals for there were no Kyengos to take animals to escape the droughts. When the drought broke in 1942, Ngula had five head of cattle. Even the Athi River Kyengo had succumbed to the population pressure and it had been claimed by other families.

The institution of Kuvithya was not possible for the general environs had become so degraded that there was not many people with spare grass. They could thus not help. Consequently, by the time he died in 1946, he had only one dam.

SECURING NGULA'S KAMBITI LAND IN LAW

A gigantic struggle to secure Ngula's land claim for the family started in 1947 soon after his death. As long as Ngula was alive, there was no dispute on the land as he was the one who had laid the claim on open lands. He was a pioneer. He did not however, have a council of elders to protect his interest for his family after he died. There was no set mechanism for arbitration of disputes for the immigrants. The social structure had collapsed.

When Ngula died, he left people on his land who had failed to lay their own claims. Most of the surrounding land had by this time been claimed by other people. These relatives of Ngula had no open land to lay claims. They tried to partition Ngula's land for their ownership. It was the beginning of a long, bitter struggle for Ngula's family before the illegal settlers were finally evicted from the land.

Ngula had instructed his sons on the limits of their land. He had battled to lay a claim to this land and to protect its degradation. It was now up to the family to protect their legacy. Special responsibility was to be borne by Nthuku who though the youngest in the family, was Ngula's choice to head the family. A very strong and able supporter was his twin brother, Mbatha. These claims on their land aroused their father's warrior traits in the last borns. They are twins.

In 1947, Kilonzo Mbithi's family claimed a quarter of the land. Nthuku and Mbatha went on the warpath and beat them back to their homestead. Kilonzo reported the matter to the headman. The headman ruled in favour of Kilonzo after the hearing. As a reward Kilonzo slaughtered a bull for the headman that night. The demarcating line was to be established the next day by planting sisal plants. At dawn, the headman Maingi Kaleli accompanied by Kilonzo Mbithi and his family came to establish the boundary. He was dared by the Ngula family to place a marker. He declined the challenge and left.

Next Kilonzo went to the sub-chief for an appeal. The sub-chief ruled that he could get the land he claimed excluding the "maanzo" i.e. Ngula's former homestead. Ngula's family did not accede to the judgement. Kilonzo then went to the chief who sent Muathe, the Assistant Chief to establish the boundary. However, there was no agreement between the two groups so no boundary could be established.

Ngula's family then decided to start court proceedings against Kilonzo Mbithi's family and all other people on the land. The whole family was to be involved in this exercise. To maintain clear heads throughout this important undertaking they swore to keep away from alcohol! If anyone got drunk, the could talk in drunken stupor and reveal the family strategy on reclaiming their inheritance. If a family male member was caught drunk, they were fined a goat! Family women were never told anything about the land cases!

The court cases were to start in 1954 at the rate of one case a year. There were 11 families against which cases were filed. It took 11 years to clear these pretenders to Ngula's land. The chronology of the cases is:

1954 - Kilonzo Mbithi
1955 - Mutiso Mulalya
1956 - Kyengo Ndiku Nalika
1957 - Ndukaa wa Mwania
1958 - Musyoni wa Nzomo
1959 - Nzuki Mbole
1960 - Kilinga Mutwetumo
1961 - Mutundu wa Syomuaa
1962 - Muta Kasoka
1963 - Kimondi Muinde Nzioka
1964 - Masika Ndunda

All these were relatives of Ngula to whom he had given refuge in his land at the frontier. All of them lost all the cases, most of which went all the way to the highest court in the land. A fortune was spent on these cases.

In 1969 the land at Wamunyu was surveyed. This was the final opportunity for the land claimants' last efforts. Mutunga Kiilu was the Chairman of the Adjudication committee which established boundaries. He was induced to rule against the Ngula family, Kibwea Ngui and Makau Nzau in all land cases against them. The last two were Ngula's contemporaries and neighbours when he got the land. Four people stated claims against the Ngula family, Musyoka Ntheketha, Muia Kasoka, Nzuki Mbole, and Ndothya Kilinga Mutwetumo.

Nthuku and the family appealed to the Land Board with the copies of the appeal to the Minister of Lands. The Land Board ruled in favour of Ngula's family. This basically removed all pretenders to the land. Due to these claims and counter claims to the land, the whole of Ngula's claim was surveyed as one unit, Plot No. 7. This land has yet to be divided into individual plots for each of the brothers.

Ngula had ceded the land east of the Mumbuni river to his brother Musembi, out of his generosity. Nothing in Kamba traditions specifies that a brother has to give land to his brother. This land was surveyed in Musembi's family name as Plot No. 8. However, the Musembi family felt that they were entitled to a bigger share of the original Ngula claim. There has been an ongoing case for a long time. Malonza, Musembi's descendant, instituted a case in 1981 which was finally ruled in 1986 for the Ngula family together with a payment of Ksh. 46,000 for costs. An appeal was launched and a ruling was made in June 1991, again for the Ngula family. Costs are yet to be determined. However, Ngula family hopes that they have now seen the last of the land cases. They intend to follow the dictates of their father's generosity in giving the land across Mumbuni river to the uncles, Musembi, family though as a matter of land case tactics they had caused Plot No. 8 to be merged in Plot No.. 7 during adjudication. After costs are settled, they still will have to come up with a lot of money to facilitate the survey and demarcation of the remainder of Ngula's land among his sons.

As is quite obvious from this protracted struggle, the role of the status of land is highly relevant to its development. Surely investment on the land and its capitalization can only follow the establishment of secure title.

CREATING INDIVIDUAL SECURE TITLE

Land adjudication and registration regime for Africans, was developed as part and parcel of controlling the nationalist movement, Mau Mau. It was started in the mid - fifties in Kikuyu land as an effort to create a land owning middle class, which, the colonialists hoped, would negate African nationalism. The only lands, which had been registered, up to that time, belonged to Europeans and Asians. Africans were not supposed to own any registered land. For Africans, security of tenure was supposed to be controlled by tribal traditions. We have shown above how colonial economics and demographics had made this assumption a myth.

By 1961, when internal self government was achieved, there was pressure to spread land adjudication and registration all over the country. However, it was not until the mid-sixties that land adjudication and registration was started over large areas of the country. In general all ASALs lag behind in adjudication for public policies still favour adjudication of the high potential areas. Wamunyu location was able to get adjudicated in the late sixties not because it was high potential but because the then current chief forcefully organised to get the service there. He used his office to settle many land cases before the adjudication system was started. This was so attractive to the adjudication officials since they had myriad land cases in most high potential locations of Machakos district that they gave the location priority. By 1969, the whole location was completely adjudicated and registered. Other ASAL locations of Machakos District did not have leaders who pushed for the service. By 1991, they are yet to be adjudicated.

The key problem in registration is mainly establishing of boundaries. Most people would take advantage and maximise their claims at this juncture. For legal purposes, an elders committee is constituted to help the government personnel establish ownership and boundaries. Cases have been known where these elders have been corrupted through influence and monetary gain.

Completion of adjudication and registration of land gives legal ownership to the individual claimant of the land. The land becomes a legal entity. It attains a value which is related to the size of the land, improvements on it and its current estimated potential. Land is a basic resource. The base potential of land is largely determined by climate, topography, and location in relation to existing infrastructure and current use. Altering any of the factors would alter the current potential of the land.

In case the point on how security of tenure operates over time, is misinterpreted, it is worth recapping that the Ngula family had secure traditional tenure based on Kukwata by Ngula. This was threatened by the social collapse and the economic and demographic changes of the past sixty or so years. When land registration came by, the problem of secure tenure was solved at the family level formalistically for the land was adjudicated as one plot, belonging to Ngula, although he had died twenty two years before, in 1946. This enabled the various sons to start developing their portions, which had been informally demarcated by themselves and clan leaders. This division of family land among the sons is yet to be formalised under the dictates of Chapter 300 of Kenya laws, the primary basis for land adjudication and registration in rural areas. At the point this is competed, then individual tenure will be secure for Ngula's sons. Security of tenure is a continuum over time. It is increased by land adjudication and registration under independent Kenya laws. Without it land capitalization is extremely problematic.

VALUE CHANGES TOWARDS CONSERVATION

During the 1960's there was a dramatic change in terms of attitudes towards capitalization of land. People knew that there would be no takeover to of their land by European settlers as a result of independence. They also knew that there was no WEU to go and colonise. The only choice therefore was to capitalise the land by intensifying. The pathway to that was through getting secure title.

Societal values do not change automatically. There are individuals in society who analyze problems and create ideas for solving those problems. In the case of Kambiti farm, Nyika Mutiso clearly was the source of the ideas which led to Kambiti farm being capitalised. Recall that he urged Nthuku to invest in the land to assure food security for his family. If Nthuku did not follow through on the ideas given by Nyika, no change would have taken place on Kambiti farm. Societal value changes therefore need individuals who will take on ideas and solutions perceived by some and implement them by solving the current problem and developing subsequent ideas. This allows society to continuously evolve. It evolves faster if many people take ideas and work with them. This is still a problem in ASALs for few make innovations within the ASALs.

Nthuku developed ideas of how to bring about what Nyika Mutiso suggested. Recall that Nthuku made several key decisions. First, he relocated his carving business from Mombasa to Wamunyu. This would give him time to farm. Further, Nthuku decided to spend two days purely on farm activities. He sought knowledge on what to do to improve the productive capacity of Kambiti farm. In sequence, he terraced, selected appropriate crops, extended the breeding line from the one cow left by the father and brought new tillage techniques (ox and tractor ploughing) to bear on the farming. On the grazing lands, he began to clear bush, to plant grass, to prune trees, to leave agricultural land so it can grow better grass and so on and ultimately to introduce Friesians. The total sum of all these activities is that Nthuku began to innovate and to manage the farm in ways which improve the potential and are therefore sustainable. By so doing he was capitalising the land. This had not been central in the management practices of his father, Ngula. Ngula had exploited the existing land potential with minimal capitalising of the land.

CAPITALIZATION FOR SUSTAINABLE PRODUCTION

Manipulation of the factors affecting land potential is possible if there are improvements on infrastructure and changes in land use. The other factors of topography and climate can be modified only with difficulty and on a localised scale only.

Land is a capital item whose capital value can be increased by labour. Where water is a limiting factor, as it is in most of ASALs, the value of land is increased enormously by making water available. Availability of water makes land inhabitable and improves its production in ecological and agricultural terms. Consider the following two examples. All great cities and civilisations of the past were developed in areas of constant water supply. If a river died, due to change of course or drying out, the city died. Modern man can deliver water to a city in a system divorced from river systems. In this manner, he can change the current use of the land by building a city where it was not possible before. In a similar manner, agricultural land can greatly benefit from making irrigation water available. This can be obtained from many miles away and can be delivered through channels or pipelines. If the basis of providing the water are not sustainable, the cities and irrigation systems would collapse and the lands would loose their value for the production system is not sustainable.

To always maintain and, indeed, increase the value of ASALs, there must be techniques for increasing the utilisation of water found there primarily. Any work on the land must be for the promotion of water retention on the land. Building dams and other structures which restrict flow of water from the land, forces the water to percolate into deeper layers of the soil. This water is available to the growing plants. The land acquires a new and higher current and future potential. Other actions which increase the value of the land include tree planting; which improves the soil, manuring and effective soil conservation measures.

Land can be greatly devalued by insensitively mining it. Among the key land mining activities found in the ASALs cutting forests for timber and other purposes without replacement; indiscriminate burning of vegetation; clearing of steep slopes for farming without adequate conservation; overgrazing, and so on. These actions result in soil erosion, flooding and lack of available water in the soil. One then gets poor un-productive land. Such land is not only undercapitalised but is continually loosing its value.

17. WATER CONSERVATION IN MAXIMISING KAMBITI FARM PRODUCTION

INTRODUCTION

Man's need for water, to sustain life and grow food crops, has always been well appreciated wherever civilisation developed. Rain water is the greatest source of fresh water. The ground aquifers are recharged by rain water while other water bodies get theirs from surface run-off. Rain water should be harvested properly by all means. Proper harvesting of rain water leads to more input into ground water and surface water bodies, better vegetation growth, good catchment management and hence higher production potential.

As a farmer gathers his yield from the farm and puts it in store, so should he gather all the available water in the different phases of the hydrological cycle and store it for profitable use to enhance production.

KAMBITI FARM AND ENVIRONS

Kambiti farm is within the Kyambuthu river catchment. Kyambuthu river joins Syuuni (Kambiti) river which later joins the Athi river downstream of the Machakos-Kitui road bridge. The catchment has several valleys with seasonal streams characterised by gentle slopes within the sub-catchments. The track and road network tends to follow the water divide with a few traversing foot paths.

The major streams within the catchment are the Mumbuni and Watuka as shown in Figure I. The average rainfall in this area is about 650 mm per year with an annual potential evaporation of about 2000 mm. But, according to some sources based on records of the Chief's Camp Weather Station, the average rainfall for the last twelve (12) years is 792 mm per year.

The farm lies between 37^0 34' 57' E and 37^0 35' 51' E longitudes and 1^0 23' 20' S and 1^0 24' 17'S latitudes. The farm is upstream of the confluence of Mumbuni and Watuka streams with Watuka dissecting the farm as shown in Figure II. The streams within the farm flow during wet seasons but the sandy river beds act as storage reservoirs during dry seasons.

CONSERVATION MEASURES

The farm needs to maximise proper conservation of water to achieve the environmental and economic goals. The basic strategy therefore should be to improve the vegetation cover and increase the water availability and potential. This would improve the carrying capacity of the farm and the dairy farming currently being practised. At the same time, the environment must be maintained at reasonable conditions.

So far a lot has been done in the conservation of water. Appendix 2: Figure V shows the areas of the farm which are already terraced.

Additional measures should be taken in the three areas which are:

a. Within the sub-catchments (mavaa)
b. Along the river channel
c. Water harvesting

The above will be discussed bearing in mind the concepts of water conservation. Water conservation is the physical control, protection, management and use of water resources to maintain vegetation growth and animal habitat for maximum sustainable benefits to man's socio-economic goals within sound environmental conditions.

1. The Sub-catchments ("Mavaa")

The sub-catchments are the areas whose water will collect at a certain point along a certain section. This can be likened to a roof catchment (mavaa). A traditional house with a round roof will have only one catchment (ivaa). A square house will have four (4) roof sub-catchments. Each roof sub-catchment (Ivaa) will have its water collected separately or connected to the rest and directed to a tank. The same should happen in the case of Kambiti farm.

On the farm, there are about seven sub-catchments whose water must be conserved separately and integrated for maximum productivity of the farm. The individual sub-catchments, marked A-G, are as shown in Figure II. The basic conservation idea is to reduce the surface run-off, increase infiltration and retain water first within the sub-catchment and then within the catchment. When this is systematically done, the flow in the river regime will change as shown in Figure III. When the ecosystem is stabilised after conservation, the total volume of water is more evenly distributed over time. This is so because water travels for a longer time underground than on the surface. Therefore the flow peak during the rainy seasons flattens and the depression during the dry season is raised.

The conservation strategy is to promote factors which enhance more infiltration. These factors include reducing slope, increasing vegetation cover and increasing retention time.

Slope

When rain starts, the rate of the incoming water is less than the rate of infiltration. However, as it continues, the reverse takes place and water starts accumulating on the surface. With some gradient (slope) the water starts flowing as surface run-off. If the slope is reduced, then the accumulated water on the surface will be retained for a longer time to give enough time for infiltration and percolation. The slope can be reduced greatly by terracing.

Vegetative Cover

In maintaining vegetative cover, the following three things happen:

a. Reduction of the intensity of water reaching the ground surface by reducing the sizes of the drops as they splash on the leaves.

b. The vegetation cover residue left on the ground acts as small terraces to reduce the slope and increase the retention time for better infiltration.

c. The root network holds the soil firm and through the penetration of roots into the soil gives way to better and faster infiltration.

Generating a vegetative cover is relatively cheap and is therefore always recommended as a first strategy.

Retention Time

The longer the water is kept on the surface, the more the infiltration process takes place to ensure that most of the water percolates into the ground. Usually one controls directly what is under direct ownership. The surface run-off from the area above one's farm can be controlled by using an appropriate cutoff drains which should retain the water for infiltration if possible or drain into a nearby water channel or area which can accommodate the run-off.

All in all, the objective therefore is to increase the volumes in the ground water reservoirs within the catchment which will assure a higher water table, resulting in extra water to recharge the river system. With more water in the ground, vegetation cover will increase due to abundance of water within the root zone for growth. The carrying capacity of the farm will increase.

Therefore, each sub-catchment (A-G) should be improved as a unit bearing in mind that it is a part of a functioning ecosystem within the catchment. The proposed water conservation measures are shown in Table I below. Some of the techniques are already undertaken. Though the water conservation is seen in terms of sub-catchments, the whole flow network underground is complex and integrated, hence, all the sub-catchments are interconnected. The ground water will flow at a low speed depending on the type of soil slope, permeability, and how much infiltration and percolation is coming from above. In fact, if incoming water is more than water being taken out, water accumulates in the aquifer and the water table rises leading to the water table cutting the surface which leads to several springs emerging as seen in Figure IV. If all the proposed measures are well done, the ultimate goal is to generate springs as is shown in Figure IV.

2. The River Channels

In general, within a river channel, there is water from the sub-catchments (mavaa), in form of surface run-off and groundwater from the water table which reaches the surface above or in the river bed. However, the river flow regime and its sources of water should be analyzed in terms of flows during the wet, intermittent and dry seasons (mbuani na thano).

During the wet season (mbuani) the river is supposed to get its water from the surface run-off within the catchment. As the water infiltrates and percolates, it might flow out into the river before reaching the water table. This is the subsurface flow. The third source is the recharge from the groundwater where the water table is higher than the river bed as groundwater recharge.

To conserve water from all these sources, check dams, subsurface dams and surface dams can be constructed at suitable sites. It has to be born in mind that water exposed to the elements will evaporate. In this case, subsurface dams are encouraged. Where there is a surface dam, then check dams are encouraged to reduce sedimentation of the reservoir.

In the Kambiti farm, a lot has been done and there is a lot more which can be done in water conservation. There are already several subsurface dams whose details are in Table II below. However, other proposed sub-surface dams can constructed and their details are as in Table III. The proposed dams can be done in phases when funds are available. According to the remarks in Table III, the order of magnitude can be established. Figure II, shows the relative positions of the proposed and existing sub-surface dams.

3. Water Harvesting

The water which man can control and use when need arises is the harvested and stored water. It is a saving just like money in the bank or at hand. Water can be stored in tanks, sub-surface dams, surface dams and aquifers. When harvesting water, the area of high surface run-off must be considered first to avoid the damage expected if the water is set free.

These areas include roof and rock catchments, roads, and tracks. Therefore, harvesting of water in these areas can be considered individually.

a. Roof and Rock Catchments

The water can be harvested and stored in tanks by collecting and directing the run-off from the roof catchment by using gutters into storage tanks. This provides very good water and avoid serious erosion by such water in the surrounding areas. The rocks can provide water into dams below or the water can be directed to a water tank for storage. Also this water from both the roof and the rock catchments can be stored in an aquifer by having the water into a suitable cut-off which gives the water time to infiltrate and percolate into the aquifer. However, direct use of water from aquifers is not as easy as when the water is in storage tanks. Therefore, all the roof catchments in Kambiti farm should have all the water harvested and stored. In fact, the dip's roof catchment should be enough to provide the required water for the dip in a year. There is no sizeable rock catchment for economical water harvesting in the farm.

b. Roads and Tracks

The roads on the extended family lands tend to follow catchment divides with tracks traversing the sub-catchments. The run-off from these roads should be harvested by directing the water into an accommodating cutoff or a well terraced area for onward infiltration and percolation into the aquifers. The same water can be collected in water troughs. These troughs, if well designed, and with provision for a settling basin, can provide good water for irrigation or other economic uses. When vegetation cover is well developed the run-off from roads and tracks can be channelled to such open areas since vegetation and its residues on the ground can act as mini-terraces to check the speed of water, giving more time for percolation.

INVENTORY AND FUTURE ACTION PROPOSALS

Table I: Water Conservation in the Sub-catchments

1. Sub-catchment A: Proposals

a. Terrace to reduce the slope.
b. Prune the trees to improve grass cover.
c. Harvest run-off from tracks and roads by diverting into cutoff drains or terraced areas.

Remarks A lot of what is proposed has already been started.

Sub-catchments B and C: Proposals

a. Terrace to reduce the slope.
b. Build cutoff drain at the upper end.
c. Institute economic control of vegetation cover.

Remarks The cutoff drains are very important in controlling run-off from above the farm.

Sub-catchment D: Proposals

a. Terrace and maintain cutoff drain to take in the run-off from the road along the divide.

Remarks Some of this area, especially the cultivated portions, is generally well terraced. More terracing is needed in the grazing areas.

Sub-catchments E and F: Proposals

a. Serious terracing is necessary.
b. Several check dams should be built upstream of the surface dam.
c. A main cutoff drain at the border upstream is required.
d. Vegetation cover is to be maintained as a priority.

Remarks This area is special in that it is used for harvesting surface run-off, therefore it requires special attention. Soil erosion should be checked because sedimentation can reduce the life of the surface dam. Good vegetation cover should be maintained. The spring downstream of the surface dam will have more water if this conservation is achieved.

Sub-catchment G: Proposals

a. Terraces to reduce the slope and increase infiltration.
b. A cutoff at the upper edge can be implemented.
c. Serious river bank reclamation should be done by planting fodder trees and grasses (bana and napier) along the river banks.

Remarks

The Mumbuni river is in its young stage. It developed in the 1930's. Consequently it has no current potential for sub-surface dams because of too much silt and an unstable river channel. The channel can be rehabilitated to produce fodder.

Table II: Existing Sub-surface Dams

Name of Stream	Watuka
Dam No.	I
Height	1.5m
Length	12m
Width	1.2m
Recommendations	Raise it by 0.5m, make it more firm, and have an outlet. Local material (rocks) should be used for walling.
Remarks	Length of sand reservoir is about 120m and will be more when raised. Water is not salty. The foundation is firm. However, raising it might bring an overflow hence it might not be necessary.
Name of Stream	Watuka
Dam No.	II

Height	3m
Length	14m
Width	1.2m
Recommendations	Raise dam by 2m in three stages. Create an outlet. Fill the gap between the two walls. Monitor and check the seepage. Fill downstream with rocks.
Remarks	This site can give a very big reservoir. The water is not salty. It has a very firm foundation and stable banks.

Name of Stream	Watuka
Dam No.	III
Height	5m
Length	20m
Width	0.7m
Recommendations	No immediate proposals.
Remarks	This dam was constructed by M.I.D.P and local participation. It has good foundation as well as extensive leaking. There is a shallow well whose pump is not working. The water is salty. No outlet.

Name of Stream	Mumbuni
Dam No.	
Height	1.5m
Length	8m
Width	1.2m
Recommendations	No immediate proposals
Remarks	The river is in its young stage. The reservoir has no water and is filled with more silt than sand.

Table III: Proposed Sub-Surface Dams

Proposed stream for all dams	Watuka
Dam No.	i
Height	1m
Length	15m
Width	0.5m

Recommendations	Do the dam in one stage. Use local material. Have an outlet.
Remarks	Due to firm foundation, the dam is a good upstream one, and will be big due to fair features for sand accumulation.
Dam No.	ii
Height	1.5m
Length	15m
Width	0.5m
Recommendations	Build the dam in two stages. Use the local material. Build an outlet.
Remarks	Site is 120m below Dam No. II with good rock foundation. The reservoir can be 50m long.
Dam No.	iii
Height	2.0m
Length	20m
Width	0.6m
Recommendations	Build in two stages Use local material. Create an outlet.
Remarks	Good dam site with firm rock foundation. Size of reservoir could be 200m long. Site is 300m upstream of dam III.
Dam No.	iv
Height	2.0m
Length	20m
Width	0.5m
Recommendations	Build in two stages. Use local material. Should have 2 outlets. Maintain minimum seepage.
Remarks	The site is about 100m upstream of the Watuka/ Mumbuni confluence. This is a

main dam in the sub-catchment and it is bound to be big.

CONCLUSION

The water conservation in a given area can not be done in a day nor its effect felt in a week. Water conservation is a continuous exercise and within a given time, usually decades, a reasonable response is realised. Conservation measures in Kambiti farm have been undertaken since 1959. The results are clearly visible. However, to capitalise the land more, certain areas in Kambiti farm require immediate conservation action. These include:

a. Conservation of water in the sub-catchments E and F above the sub-surface dam.
b. Cutoff drains in upper edges of the sub-catchments.
c. General harvesting of the water.

After increasing water conservation activities, it is likely water will flow in the rivers, (Watuka etc.) most of the time. New springs can be expected over and above flow increase in the one downstream of the surface dam. Some things are important and they should be remembered when expanding water conservation activities. Among them are:

a. The water man can control well is that which is harvested and stored.

b. Water left to move freely destroys freely and disappears freely.

c. Measures to conserve water are useless without controlled grazing and establishing vegetation (grass, shrubs and trees) cover on the ground, especially around gullies.

d. Conservation of water and proper land management reduces flood destruction and erosion and makes more water available, increases flow into water bodies, creates a shallow water table, and ensures better vegetation cover.

e. Indigenous vegetation cover is more resistant to adverse climatic and pest conditions which might occur. Therefore the natural dominant vegetation cover should be maintained.

A journey of a thousand miles begins with one step. The courage to take the first stride was shown by Ngula. What has been done at Kambiti farm is worthy of praise. Most of the improvements discussed have already been implemented and on certain sub-catchments only the final touches remain. Kambiti provides a model for what should be done in an ASAL farm.

18. POLICY IMPLICATIONS

WATER HARVESTING

The story of the development of Kambiti farm is synonymous with the exercise of water harvesting on the farm. To count and pocket every drop and to prevent loss of water is the secret of production in the ASALs. On parched land, it may take a few years or decades before the ground water reservoirs are recharged. With every year the situation improves, albeit slowly. It may take many years before the first spring appears since water moves slowly in the soil. When water resurfaces on the land, then the land is on its way to realising its productive potential.

At Kambiti the water was pocketed through establishment of ground cover, creation of sub-surface dams, building of a surface dam, and extensive terracing. These measures act as water stoppage and allow soakage into the ground. The present complement of dams hold back a large volume of water. With the construction of the planned sub-surface dams, the water held back will double. These will supply an enormous area for water infiltration into the water table of Kambiti farm and its environs.

The people around Kambiti farm obtain their water from shallow wells dug in the sand dams. The advantage created for the local population is enormous since very little time is spent fetching water. If these dams were not there, they would travel up to six kilometres away to fetch their water in the dry season. Their labour would not be available for other productive activities. Of course other water extraction methods exist. The people of Kambiti know them but they are not in use currently because of problems of maintenance and cost.

The domestic water for Kambiti farm is obtained from the farm roofs. Clean, safe water is thus available for the family. At Kambiti farm along a stream where a spring developed in 1990, the farm has been able to grow vegetables, arrow-roots and sugar cane. These plants are not typical in AEZ 5. They are typical in AEZs 2 and 3. This is an example of ecological modification by the presence of water which has arisen through the recharge of underground storages. Due to the starting of a spring, the family will satisfy its supply of vegetables and other exotic foods from the farm.

Kambiti farm animals have enough water to drink to their fill. All their energy can then be concentrated on milk production rather than being shared for transport to and from watering holes.

The intensive land management, as seen in Kambiti farm, results over time in the overall improvement of water availability. The water table lifts and the growing season is extended for shallow rooted plants. As the soil holds more and more water, springs appear on the surface and water is discharged all year round. At the areas where springs exist, high water demand crops can grow where non existed before. A new localised ecology develops.

The policy implications are obvious. First, it should be clear that there are few alternatives to terracing in terms of all crop and grazing land. Second, in terms of provision of water, there must be a mixed strategy of subsurface dams, surface dams, and roof catchments. Some consultants are beginning to argue against roof catchments on cost grounds. Given the superior quality of roof water and the populations interest in improving their quality of life, this seem to be misplaced concreteness.

MILK PRODUCTION

Milk yields at Kambiti are high and are comparable to other farms in the country and other countries as well. That this production can be achieved in Wamunyu should prompt the national planners to re-assess their ideas about the milk potential of the ASALs.

In addition to the high milk production at Kambiti, the survival rate of the animals is very good. There has been no undue loss of animals on the farm. Animals, especially calf bulls from the farm, have been acquired by farmers from all corners of the country. Their survival rate should put to rest the myth that the suitable animals for ASALs are second and third grade animals. The breeding programme at Kambiti is geared to improving the tolerance of these animals to the hot, dry climate. However, we should note that animals in Israel and the prairies in America already have these traits. We should not therefore confine the first grade animals in this country to the cool areas. In fact, future breeding semen for heat tolerance will originate from Israel, USA, and Zimbabwe and for the imaginative, the Kambiti farms.

The milk production at Kambiti and the quality of animals kept on the farm should be a challenge to all livestock production and veterinary personnel working in ASALs. It should serve as an example of the potential of animal and dairy production in ASALs. This potential has not been tapped so far.

Before the beginning of Kambiti farm and allied farms in Wamunyu, Kitui town used to obtain its supply of milk from KCC Nairobi depot. Currently, the bulk of Kitui town milk originates from Wamunyu. Kambiti farm is the nucleus of this supply and is the forerunner of dairy production at Wamunyu. Not only does milk have to be transported for only a short distance from Wamunyu to Kitui, but also the economy of Wamunyu is bound to improve due to the milk trade. All the milk produced at Wamunyu is sold as fresh milk because there is a large ready market locally. The market for other dairy products has yet to be explored.

If the production of milk in large areas of the ASALs in Kenya were to be realised, the supply of milk in the country would be greatly expanded. The net result would be the reduction of the cost of milk, as one of the largest components of the price of milk, is the cost of distribution. As the production of milk in ASALs is expanded, the marginal benefits of dairy production in high potential areas would be minimised. These areas would than have to revert to those products for which they would have advantage over the ASALs. The high potential areas which are producing milk currently would revert to production of food. Overall food production in the country would improve.

To achieve these radical changes, the infrastructure in the ASALs has to be improved. The ASALs are characterised by high temperatures which are conducive to milk spoilage. Strategic cooling plants, collection roads and distribution centres will have to be designed and constructed at appropriate points.

The implications of Kambiti farm on national milk policy are stark. All national milk production programmes, including all zero grazing extension activities, concentrate on high potential land. The planners do not recognise that farmers, like Kyalo and Nthuku, have already bred Friesians for the low potential areas, which are suited to the heat and fodder found there. Since their milk yields are equivalent to the animals in the good areas, what is the case for not extending milk production to the ASALs? Second, why is high potential land suited to other production activities locked into milk production?

LIVESTOCK VERSUS GRAIN PRODUCTION

At Kambiti farm the production potential of the land has been realised through animal production. The Kambas of old originally had two homesteads, not homes. They lived on the hills where the food was produced and they had cattle outposts "syengo" in the plains "weu". The "weu" in Machakos and Kitui have always received less rainfall than the hills. The "weu" constitute the ASALs. "Weu" was always for animals. Attempts to contradict the conventional wisdom and trials to cultivate the ASALs without adequate management invariably leads to land degradation. This land maybe completely lost to production. A much more sensible route is the development of the land for animal production with integration of crop production for food.

The production of "weu" is dependant on the management of the land and its vegetation for grass production. The most productive grasses in the ASALs are those which are fed to the animals. Those grasses which provide grains for man are not as hardy and do not regenerate after harvest. In ASALs these grasses would be successful only after a marked improvement and capitalization of the land. However the production of these grasses can only take an inferior place to the production of grasses for animal feed in the ASALs.

At the policy levels, it is recognised that livestock is the major activity of the ASALs. However, there is deviance in this since by livestock, the planners, policy makers and consultants, mean pastoralism practiced in a communal land regime. Above we have documented how insecurity of title and land shrinkage negated pastoralism, in all variations, and its attendant land degradation. The policy implications are that land must be quickly moved to a secure title system by adjudication and registration. The hiatus of the Group Ranches is not good enough for it is trapped in pastoralism. Land is only secure if adjudicated to individual title. Only then will individuals begin to capitalise land, settle and produce surpluses above the needs of subsistence.

BIODIVERSITY

Local genetic resources have been raped through wholesale destruction of native vegetation by the use of inappropriate farming techniques in ASALs especially. This destruction of native genetic resources has no place in the farming system at Kambiti.

The farming techniques employed at Kambiti promote the re-seeding and management of native grasses shrubs and trees. In general then, the system provides vegetative forms which are suited to existing ecological conditions through natural selection for survival. Wholesale clearance and planting of exotic and often inappropriate vegetation is consciously avoided.

Kambiti farm promotes novel uses of the available resources such as the use of acacia tortilis pods as a feed supplement. This innovation could be extended to other products like Melia volkensii, Sesbania sesban and other Acacia pods and leaves which can be incorporated in feed concentrates and supplements.

Wherever possible new plant varieties have been introduced to supplement the available fodder. Lucerne, Cana lily and Bana grass which are not found locally are now grown in Kambiti farm. In future, other species will be introduced to improve the pasture and for further fodder supplement. Some of the suggested plants for introduction are Siratro, Centro, Crotolaria (Marejea) and lupines.

As the land improves, new varieties of plants will appear at Kambiti through natural seed distribution agents. While favoured plants should be nurtured, other plants should be destroyed.

As a consequence of land improvement, biomass production of the system will increase and more humus will be produced in the soil. Increased humus in the soil supports as higher population of diversified soil fauna. This soil fauna has a marked influence on the productivity of the soil through its soil conditioning activities. The improved soil is capable of supporting a more varied and vigorous vegetative growth.

Kambiti farm is basically focused on keeping dairy cattle. In addition there are a few cattle of the native breed. Using the available pedigree bulls it is possible to develop improved native cattle breeds. Already a system of improving local goats by crossing with Gala/Boran billies has yielded positive growth and size results on Kambiti farm. Kambiti farm in addition keeps chickens for home consumption and egg production. Due to the large variety of trees growing at different periods of the year, it is possible to set up a successful aviary business. However, the placement of the aviary should be away from the grazing paddocks for the safety of the cattle.

The obvious policy conclusion is that ASAL development strategies should favour improvement of the plants and animals found in ASALS for they are environmentally adapted. The subsidiary conclusion is that even when exotic plants and animals are introduced, their production is assisted by the native fauna and flora.

LAND CAPITALIZATION

Land is capitalised when labour is expended to improve its productive potential. Possible directions for the future of ASALs can be gleaned from the Kambiti experience. The myth that land terracing is expensive has to be viewed no longer from a soil conservation point of view alone. A more important standpoint of calculating the cost of terracing is that of water containments. This is **ZERO SUM**, that is, nothing or achieved production scenario. Without terracing the land would be almost worthless. Terraced land, which retains a very large portion of the received precipitation, has a much higher water availability for plant production. These plants, due to the limitations of ASALs, are likely to be the hardy grasses rather than those used for feeding people.

A preferable method of approach to production in ASALs is the catchment or extensive conservation area approach. In this method, an integrated development of a catchment area is undertaken rather than small isolated areas. Small catchments can yield spectacular results as those achieved in Kambiti farm. Larger catchment areas conserved give even more profound results. However, those large catchments must be divided into smaller more manageable catchments and developed systematically.

Areas which have been developed to improve water availability will also have a widened range of products. These introduced or colonising products will also need marketing outlets and strategies have to be developed. This can be done by the farmers themselves and need not be the concern of the state as is being argued by donor driven strategies.

The clear policy issue is the need to use the catchment approach. This is government policy. However, on the ground, there is little work done on implementation on catchment basis. The issue is really the failure of fit between how the public bureaucracy is currently organised and the sociological and physical dictates of catchment approach.

To educate and involve the population in planning on operable catchment development programme is a challenge to the technocrats knowledge of what innovations farmers have generated on their own and ability to communicate these innovations to others in similar situations. Effective technocrat extensionists must translate highly technical matters into a people language. They need not only be able to talk the language of the people. To use a people's language one has to establish empathy for the people's innovations, priorities, aspirations, expectations, securities and fears. The success of the catchment approach policy depends largely on whose priorities it serves.

The catchment approach policy seeks to promote and improve rain-fed production through run-off collection, concentration and the control of storm flow and floods. It aims at achieving food security for the populace at minimum cost, using biodiversity and modernisation of traditional methods of production. In contrast the development industry aims are to push for export crops and the development of markets for services and goods they are geared to sell. Herein lies the conflict which will be central in the implementation of the policy for the bureaucrats. The welfare of the rural population is not a basic objective of the development industry.

We are pessimistic on the possibility of the public bureaucracy implementing the catchment approach unless there is drastic reorganisation of ministerial procedures for extension and the delinking of extension thought from the international donor driven frameworks. A first step towards delinking is generating local knowledge on farmer driven innovations. That is why this book was written. We hope it is of use to the Ngulas of Africa and not just Kenya.

APPENDIX 1: COST OF TERRACES

Calculations by Carl G. Wenner 1981 for slope of 30%, vertical interval 1.8m and horizontal interval 6.1m derived bench terraces cost Ksh. 2461.00 per hectare. The base wage for a worker used was 10.25 per day. The current cost of a worker per day in 1991 is Ksh 40.00 per day.

The cost of terracing per hectare = $\dfrac{40.00 \times 2461}{10.25}$

= 9604.00

Assuming 3 ha/LU in ASAL

The cost of terracing a LU = 9604.00 x 3

= 28812.00 /LU

Assuming 10 years without maintenance, the cost can be calculated per year:

The cost of terracing = $\dfrac{28812.00}{10}$

= 2881.00/ LU /yr

After 10 years, the terraces can be repaired at half the cost of establishing new ones.

Supposing a calf is born at the beginning of the 10 years. It would produce its first calf in 2 1/2 years. In 10 years it would therefore have 7 lactation periods. If we assume 30 L per day for a lactation period of 300 days:

The total milk production in a year = 300 x 30 = 9,000 L

The total milk production in 10 years (7 lactation periods)

= 63,000 Litres

Assuming a price of Ksh. 6.00 per litre:

The total production = 6.00 x 63,000.00

= 378,000

$\dfrac{\text{The cost of terracing}}{\text{Total production}} = \dfrac{28812 \times 100}{378{,}000}$

= 7.6%

The 7.6 % forms the bulk of the feed for the cow.

Also to be considered against this figure is the opportunity cost. As we can observe, this is an all or nothing scenario. The use of an ox-drawn plough to excavate the soil so that the worker will only scoop the soil for piling up-grade would greatly reduce the cost. The figures by C.G. Wenner "Soil Conservation in Kenya" 1981 are based on the use of hand tools only.

APPENDIX 2: FIGURE 1: KYAMBUTHU SUB-CATCHMENT AT WAMUNYU

APPENDIX 2: FIGURE 2: PART OF WATUKA AND MUMBUNI SUB-CATCHMENTS WITHIN KYAMBUTHU CATCHMENT

APPENDIX 2: FIGURE 3: HYDROGRAPHS BEFORE AND AFTER CONSERVATION

APPENDIX 2: FIGURE 4: CATCHMENTS BEFORE AND AFTER CONSERVATION

APPENDIX 2: FIGURE 5: TERRACING ON KAMBITI FARM

APPENDIX 2: FIGURE 6: KAMBITI FARM: APPROXIMATE BOUNDARIES

APPENDIX 2: FIGURE 7: NGULA'S LAND

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