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RAINWATER CATCHMENT SYSTEMS

**Proceedings of the Second National Conference
on Rainwater Catchment Systems in Kenya
Nairobi. 30th August - 4th September, 1992**

Edited by:

S. K. Bambrani

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Proceedings of the Second National Conference
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PREFACE

When the United Nations designated the period from 1981 to 1990 as the International Drinking Water Supply and Sanitation Decade (IDWSSD), it was generally expected that increased efforts would help provide adequate and safe drinking water to all needing this vital life-sustaining commodity. Unfortunately, with each passing year throughout IDWSSD, we have only realised, how enormous the task of providing this essential service to all of mankind is. Hundreds of millions of people living in developing countries continue to lack reasonable access to adequate supplies of safe drinking water, and the human population in regions deficient in water resources is steadily increasing.

It is now clear that modern technologies involving exploitation of river systems and groundwater resources using large piped water supply schemes, or the scaled down version of urban installations serving small communities, are not necessarily viable technologies in all situations. In addition to the high costs involved, these technologies are fraught with operation and maintenance problems.

Even where these technologies are considered to be viable, the relationship between large scale water resources development and the destruction of ecosystems gives reason for concern.

Rainwater has been collected and stored for domestic and agricultural uses for thousands of years. It is an ancient art which is still practised in many parts of the world and this technology is increasingly being recognised as an affordable, environmentally sound and simple alternative as a water supply option. The utilisation of rainwater may be the ultimate solution for water supply for many people in rural and urban settings.

The International Rainwater Catchment Systems Association was formed in 1989, in response to the needs of the IDWSSD with the main objectives of:

- promoting and advancing rainwater catchment technologies
- attempting to link all those working in this field
- drawing up a set of international guidelines for use of rainwater harvesting technology
- supporting a series of International Rainwater Catchment Systems Conferences.

Five international conferences have been held by the association *between* 1982 and 1991. During the fifth international conference held in Taiwan in August, 1991, it was agreed that Kenya should host the sixth international conference. The theme of this sixth conference, to be held between 1-6 August, 1993, will be "Participation in rainwater collection for low income communities and for sustainable development".

Organisation of the sixth international conference is currently underway, and several regional and national workshops have already been held in preparation for this. The first of the national workshops was held in Nakuru in May, 1991 and the second, proceedings of which are presented in this report, was held in Nairobi between 30th August and 4th September, 1992.

We take this opportunity to acknowledge, the support provided by the Swedish International Development Authority, United Nations Childrens Fund and the German Volunteer Service for the second national rainwater catchment systems conference and the production of these proceedings.

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WELCOME ADDRESS

Mr Lostelius
Swedish International Development Authority

I am pleased to see Sweden as one of the supporters to this important conference. There are several reasons for that.

Having been supporting and following the water sector in Kenya and elsewhere for more than 20 years, SIDA has had ample opportunities to assess the sector development. The need for continuous, innovative technology and methodology development has been apparent.

The International Drinking Water and Sanitation Decade made steps forward in the supply of drinking water and sanitary facilities but fell far short of the bold global goal of reaching everybody. Despite much emphasis on increased finance both from governments and donors, community involvement and technology adaptation, the measures taken did not suffice to fulfil the needs. Recognising the importance of sanitation, health education and other related needs to reach the over all goals of life improvement, I will here only talk about the water component as that is the topic of the conference.

In the sixties and seventies the idea was that the government should give water free of charge to the consumers as water is a natural resource to which everybody had right of access. The only option of supply considered at that time was to provide water through piped supplies. There was also the concept of advantage of scale; the more consumers on a supply from one source the cheaper per capita cost. All these concepts proved later to have their limits. Though some of the pipelines worked well others fell into disrepair.

This brought about the need to develop appropriate technologies. Though that sounded simple the experience was that what was appropriate in one area was not in another. The need for diversity of technologies became apparent.

It also stood out clearly at this time that the governments could not, for financial reasons, supply water free of charge. Neither was it any longer feasible to put in the resources required to maintain all the supplies centrally. The concept of sustainability became the issue. Decentralisation of operations and search for technologies which could improve sustainability and design of schemes and equipment to minimise maintenance cost became important factors.

The role of the communities were revised. They would have to struggle on their own to solve their water problems or at least pay part of the cost. This again activated the technology discussions. Point sources of various kinds and handpumps were promoted. With involvement of consumers from the start they could be in a position to make their own choices and service levels tuned to their ability and willingness to pay, of course within the natural limits of the water resources available. Planning should therefore be adjusted to involve them already in the pre-planning phase.

In this country there has been a marked increase in the small scale and point source supplies over time, including Rain Water Harvesting

The Swedish assistance shifted during the decade from construction of piped water supplies at numbers of sites all over the country to concentration on integrated area programmes which, as far as water is concerned, have dealt with drilled wells, improvement of springs, hand pump supplies, piped supplies and indeed Rain Water Harvesting. I am thinking of the Tharaka and Kwale programmes.

Efforts have also been made on assisting the Ministry of Water Development to develop its financial management system and services in conjunction with strengthened community roles and increased participation.

It has been experienced that the smaller the communities the better the care of the systems have been. Hence the ownership of the supplies became important. In fact the best maintained supplies are those which are owned and cared for by the communities themselves.

Rain Water Harvesting is an additional technology which can contribute in this context either as meeting the total need or as a complement to other communal water supplies.

All experiences show that if facilities are brought within the control of individual families, care and up-keep improves. Again Rain Water Harvesting could provide an opportunity for that whether it is for drinking, irrigation or livestock purposes.

To supply such ideal water supplies at family level may not be possible in all areas but where it is possible it might be the best thing to support.

An increasing problem experienced everywhere is the pollution of the environment. Hence the need for protection of the water resources. One way of

by-passing the dilemma would be to catch the water before it touches the ground, at least in the developing countries where the air is still relatively clean

It is with pleasure I note that Kenya is one of the advanced countries on the continent with reference to Rain Water Harvesting. The number of participants gathered here to-day should thus be a strong forum for exchanging experiences and bringing knowledge about the role that Rain Water Harvesting can play, to the continued effort to bring clean water to the people and to improve utilisation of the vulnerable water sources so necessary to life.

With these remarks I would wish the conference vivid and successful discussions and I will be looking forward to reading the proceedings of this important conference as soon as available.

OPENING SPEECH

Professor F. J. Gichaga MBS, EBS, Ph.D, R.Eng, C.Eng, FIEK, MICE,
Vice Chancellor, University of Nairobi

MR. CHAIRMAN,
HEADS OR REPRESENTATIVES OF UN BODIES REPRESENTED HERE,
DISTINGUISHED GUESTS.
PARTICIPANTS, LADIES AND GENTLEMEN.

INTRODUCTION AND WELCOME

It is a great pleasure to be given this opportunity to address you and officially open the Second National Conference on Rainwater Harvesting systems. Let me take this opportunity to welcome all of you to this important National Conference. I am told that there are participants from all over Kenya and especially from remote rural areas. I hope that all of you will take this opportunity to share your experiences and learn from each other for the betterment of mankind.

IMPORTANCE OF WATER

Ladies and Gentlemen, I do not have to remind you of the importance of water in everyday life: - agricultural purposes, industrial needs and indeed for man's survival. More often than not, most of these are hampered by lack of adequate potable water. Countries that have adequate water resources often have a strong agricultural base upon which industrialization has been anchored. There are exceptions, of course, and I am not trying to blame all cases of under-development on lack of water.

Kenya has about 25 districts which are classified as Arid or Semi-arid. The lack of water in these districts creates severe problems for the inhabitants and can explain the current lack of industrial and agricultural activities in these districts. Indeed, these districts form about 88 per cent of Kenyan land and yet are inhabited by only 35 per cent of the population leaving the rest of Kenyans to use the 12 per cent as their homes.

Mr Chairman, rainwater if properly harvested and utilised can improve the living standards of most Kenyans, may be indirectly if not directly. For example an integrated water use system could have rainwater supplementing other more conventional sources thereby relieving pressure on the demand for water. Such use can and should be encouraged at all levels of National Planning.

NEED TO DEVELOP AN INTEGRATED WATER USE SYSTEM

Mr. Chairman, Ladies and Gentlemen, the effects of drought in Kenya in 1984 and the resulting food deficit have not yet been forgotten. This, coming soon after a wet year when so much water was lost as run-off and in fact in some cases causing deaths, is a clear manifestation of the need to harvest rainwater. In paved urban areas of Kenya, the quantity of run-off during wet periods is quite substantial. Research has also established that except for the initial flush of the surface, the quality of such run-off is reasonable for industrial, agricultural and even domestic use. It is therefore unfortunate that such an important resource has not been tapped, at this time of our development, when technology to facilitate this is available.

Ladies and Gentlemen, I note with appreciation that the purpose of the conference is to try and harness rainwater as a resource for use by both mankind and animals. Specifically, I understand that the objectives of the conference will be:-

- 1) sharing of experiences among engineers, scientists, farmers and community developers on the suitability of rainwater harvesting systems.
- 2) Reviewing the problems that hinder optimum utilization of rainwater harvesting systems for the betterment of mankind.
- 3) Identifying practical solutions for the maximum, beneficial, utilization of rainwater harvesting systems particularly in Arid and Semi-arid lands where the systems are most needed.

Ladies and Gentlemen, I am also reminded that the first National Conference on Rainwater Harvesting was held in 1991 in Nakuru, Kenya - whose proceedings are available at a nominal fee and a necessity for persons interested in this field.

I am also informed, Ladies and Gentlemen that this conference is a preparatory one ahead of the 6th International Conference on Rainwater Cistern systems to be held from August 1st to 6th 1993. This is the first time that the conference will be held in Africa. I would like to encourage many of those present today to do all that is within their means to make this conference a success.

RESEARCH IN RAINWATER HARVESTING

Ladies and Gentlemen, all the activities that I have referred to above show the determination and vigour with which researchers have pursued the issue of rainwater harvesting. Whilst I would not wish to pre-empt technical discussions that may arise, but being one of you, I can guess the multiplicity of parameters involved in rainwater harvesting. These include, but are not limited to:-

Hydrological aspects

- Impact of rainwater harvesting on the environment
- The role of women and children in rainwater harvesting
- Appropriate technology in rainwater harvesting
- Role of floods and run-off in rainwater harvesting
- Training for sustainability of rainwater harvesting

Adequate data and information are necessary for the assessment, development and effective utilization of rainwater. Ladies and Gentlemen, I remain hopeful that scientists and engineers from our institutions of higher learning and certainly mine, the University of Nairobi will play the leading role in this task. I am aware that the research in these areas continues in the Departments of Meteorology, Civil Engineering, Agriculture Engineering and Geography among others, within the University of Nairobi. I would like to encourage those involved in such research to intensify their efforts and share their findings with others outside the University.

Mr. Chairman, for the scientists and engineers to accomplish their research satisfactorily, it is necessary that funds are made available. It is in this respect that I would like to request Donors to come forward with the necessary funds to enable research to continue in the important area of rainwater harvesting.

However, Ladies and Gentlemen, I would like to warn against the dangers of uncoordinated research. It is important if efforts are not to be duplicated that all research be coordinated. There is, therefore need to set up a coordinating institution in rainwater harvesting matters. Such an institution could focus on but not be limited to:-

- 1) The development of databases for managing and conserving rainwater catchments.

- 2) The development of water harvesting technologies for crop, livestock and domestic use.
- 3) Assessment of soil erosion,
- 4) Land use planning and preparation of master plans relating to water harvesting,
- 5) Efficiency in water use, and planning of river basins, water control storage and flood control.

Institutions of this kind would generate vital information needed for long term planning for sustainable development. Indeed existing post graduate programmes at Universities like the one in Soil and Water Engineering at the Department of Agricultural Engineering, University of Nairobi should be expanded and strengthened accordingly to reflect the importance of rainwater harvesting in national development.

CHALLENGES

Ladies and Gentlemen, we all know that attending a conference and putting the conference recommendations to use are two different things. There is no doubt however that rainwater harvesting has great potential for this country. We must also remember that what our people need is clean water but they are expected to follow and necessarily understand the processes involved in making it clean. I would, therefore like to challenge you to do at least two things:-

- 1) Ensure that the discussions about rainwater harvesting systems are followed by actual practice;
- 2) Ensure that the development of these systems are compatible with environmental conservation.

Otherwise, any work without regard for these may lead to other environmental problems.

CONCLUSION

Mr. Chairman, Ladies and Gentlemen, before I come to the end of my address, it is my duty as your Chief Guest, and on behalf of other guests invited to this function to say a big thank you. Firstly, I wish to thank SIDA, and others who contributed financially to make this conference a success. I also recognise the

effort of the organizing committee who made all the necessary arrangements. To all participants, I say thank you for finding time to be here.

I am happy to note the cooperation between various Kenyan institutions in organizing this conference. In particular, I am grateful to the UNICEF Kenya Country Office Representative for making available these excellent facilities for the conference.

Mr. Chairman, Ladies and Gentlemen, it is now my great pleasure to declare the 2nd National Conference on Rainwater Harvesting Systems officially open.

Thank you.

PRICELESS GIFT

T. Rimbui
Kenyatta University

It was created in the beginning
This much used and misused
Precious gift that has sustained
Life systems and will maintain
Life in fauna and flora for many
Many years to come.

Countless generations and civilisations
In ages past have all been bathed
Replenished, purified and cleansed
And alas, created and sometimes
destroyed
by this mysterious life-giving gift
Known for its supreme greatness
In all corners of the earth

This powerful magic whose transparent
And colourless looks, alas conceals
The powerful germ-yes-the grain that
Drives man's many a myriad machine
Thus providing him with thermo
muscle
For all his developmental needs.

And yet its shapelessness
And its non-assuming pose
Have fooled many an individual
Who sees valleys and gulleys
Turned into huge rivers and causeways
Leaving a tale of destruction behind
After a brief but costly seasonal visit
That presents man with yet-another
challenge.

This grossly abused, polluted and
Soiled divine gift now here
And everywhere only to be
There and later nowhere thus
Overwhelming man with its
abundance
And scarcity-thus leaving him
Definitely puzzled.

Let man store, purify, harness
Utilise, conserve and manage
This constant friend for better results
In food production, industry, health
And in transport - oh yes
He must appreciate and co-operate
With his dear friend
If he wants to prosper

Who shall accept this gift
And recognise its splendour and
majesty
That stem from its naked simplicity
And humility -attributes which make
The fools and the wise, young and old
The small and the great, the poor and
the rich
Even take it for granted!

And yet-poor mortals
They do depend on it
And shall continue to depend on it
For their development - oh yes!
For their very survival non-assuming



1. STATE OF ART OF RAINWATER HARVESTING

KEY ISSUES IN RAINWATER HARVESTING SYSTEMS

S. K. Mutiso
University of Nairobi

Chairman
Guest of Honour, Vice Chancellor of the University of Nairobi
Principals of colleges
Deans of faculties
Directors
Donors
Distinguished guests
Members of the Organising Committee
Participants
Ladies and Gentlemen

I feel greatly honoured to have this opportunity to deliver a speech on the "Key issues on rainwater harvesting systems in Kenya" in this important forum. Rain is the most important component of the hydrologic cycle. However, if not properly managed, it can have adverse effects in the socio-economic development of any nation. These effects are associated with floods, soil erosion and river and reservoir siltation.

Mr Chairman, the adverse effects can be averted by controlling or harvesting the runoff and converting it into a resource for development. This could be achieved by, among others:

- Bench terracing and vegetation cover
- Construction of dams for water supply for domestic, agricultural and industrial purposes
- Silt trap construction to lengthen life span of reservoirs
- Roof and rock catchments
- Surface dams and underground reservoirs

I would like to provide a brief overview of the state of the art of rainwater harvesting in Kenya, with particular reference to the key issues which include the status, attendant problems and the course of action for sustainable resource development and management. These issues will be discussed within the framework of roof, rock catchments and sub-surface dams.

Mr Chairman, these catchments and sub-surface dams have been the major water supply systems in the arid and semi-arid lands which constitute eighty percent of Kenya. However, the technology for harvesting water from these catchments is not fully developed and thus the resources are underexploited.

Significant efforts by government, NGO's and the local communities have been made to harvest rainwater. However, full utilization of roof and rock catchments and sub-surface dams have not been achieved due to the following constraints:

- **Technical know-how**
- **Capital**
- **Coordination among the involved agencies**
- **Lack of baseline data**
- **Lack of monitoring of water quantity and quality**

The Kenyan Government has long recognised the need to reduce population pressure in the high potential areas by developing arid and semi-arid lands to make them attractive for settlement. Considering the fact that the conventional surface ground water resources are scarce in the ASALS, the roof and rock catchments and sub-surface dams will continue to play a major role in the socio-economic development of these areas.

Mr Chairman, in order to ensure sustainable development and management of the aforesaid rainwater systems in the ASALS, the following intervention areas have been identified:

- **Establishment of the inventory of existing systems**
- **Establishment of regular monitoring of quantity and quality with a view to acquiring sufficient data for planning purposes**
- **Coordination of research and development agencies**

Mr Chairman, you will appreciate that I have highlighted only the major issues and it will be the task of this conference to elaborate the details. I wish you success.

Thank you.

SOME BASIC PRINCIPLES IN THE PROVISION OF WATER

P. Morgan

Blair Research Institute, Harare, Zimbabwe

Touring around Kenya one sees ample evidence of the widespread use of rainwater harvesting catchment systems and I wish to compliment those who have performed this excellent work in Kenya. The state of the art of rainwater catchment has progressed significantly, not only in technical development, but also in its promotion, and in its use in the field of crop production. The success of the technique is obvious by the numbers which are in use, many of them in family settings. It is an obvious choice.

Whilst rainwater catchment systems exist in Southern Africa, they are less well known and less well used. The tendency has been to make greater use of ground water and lift it to the surface. The very long dry periods, which can amount to eight months every year also puts a damper on any development of rainwater catchment systems because the management throughout this period is more difficult. Villagers have tended to place more emphasis on digging their own wells to gain access to water and in Zimbabwe today there may be as many as one hundred thousand privately owned family wells in use. Some twenty thousand boreholes or deeper wells are equipped with handpumps and some thousands more are equipped with motorised pumps.

Wells in Southern Africa are an obvious choice for much of the country, just as rainwater catchment systems are an obvious choice for East Africa. As a result, the concept has become well established and is commonly used.

Family owned wells are very popular in countries like Zimbabwe, and large numbers are now being improved. This "upgrading" process involves the lining of the well chamber with mortared bricks and the improvement of the headworks in the form of a hygienic apron and water run-off. A windlass and tin lid also form part of the technology. Where financial arrangements have been made, each family with a fully equipped well is entitled to a subsidy of three bags of cement, a windlass and a tin lid. Upgraded wells provide far better water, both in bacteriological quality and clarity, compared to more traditional wells and water holes. The emphasis is based on providing a facility at the family level, and it has been shown in more recent implementation programmes that several thousand units can be upgraded every year if the financial backing is available. Remarkably, the cost per head of providing a subsidy to a family to assist in

the improvement of its own well is far less than the cost of providing a handpump supply.

We all know that the effective and sustainable maintenance of rural water supplies is a major issue on which the overall success of water decade activities depend. This is particularly the case for motorised and handpump supplies. When simpler means of providing water, like rainwater harvesting and improved simple wells are used, these problems are much reduced and put into manageable perspective, especially if the facilities are placed at the family level.

The quality of most water provided from roofs in rainwater catchment systems is good, and fit for human consumption. Even in wells, provided the headworks are properly made and the use of the well is hygienic, water quality can be acceptable, even without the use of a handpump.

Thus, I see some similarities in the concept of providing water in our two regions, whether by the use of rainwater catchment systems or simple improved wells.

They are both obvious choices, and each is considered to have been absorbed and accepted as a sound technical solution, especially by the users. They both have a simplicity of design and are durable. Both are easily managed and easily understood. Both are best placed in the family setting, and in such a place they are seen as good investments for the future.

As family investments there is a willingness to pay for the construction and maintenance of the system to get the best return from the investment. When placed in the homestead reliance on outside intervention for its operation is minimal.

These features are all important in an area which has already shown time and time again that maintenance is of prime importance and is the key to the success of all rural water projects.

SOME NOTES ABOUT RAINWATER HARVESTING

J. Colombani
ORSTOM Representative in East Africa

1. INTRODUCTION

Having worked as a scientist in hydrology for thirty two years in Africa I have been involved in many studies for water supply of cities and for agricultural use. Therefore it is with a great interest that I attend this conference and that I have listened to the relevant papers presented until now. I think there is nothing new that I can add, but perhaps I can point out some results or ideas.

2. TRENDS OF WATER AVAILABILITY IN THE WORLD AND IN AFRICA

If we point on a graph the availability of water per capita since the year 1750 to the year 2050, we see a tremendous trend (Fig 1). The estimation of the availability is made from estimated runoff and stable runoff. For many reasons such as seasonal and annual variability, environmental conditions and physical limitations (1) the amount of water really available for human use is only one part of the total runoff: it is what we call stable runoff.

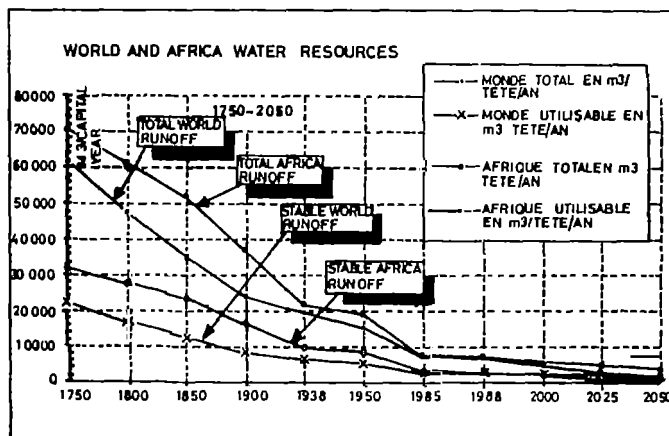


Fig. 1: World and Africa Water resources

These results are only evaluations which are not very precise for the beginning and the end of the period but indeed the trend is a reality.

The graph reflects only mean values, but the reality is far more worrying as some countries have far less availability. Although only five percent of the potential resources of Africa are actually used, it must be considered that five countries only own fifty percent of the resources; many others have a critical situation. Some of them already use one hundred percent of their runoff as Libya and perhaps in year 2000 Tunisia, or others have such climatic and geographic conditions that a part of their population do not have enough resources. This situation is currently endangered by the very fast increase of the population. For example if we consider the countries included in the region covered by the Sahara and Sahel Observatory the forecast of the increase of the population is as indicated in Table 1 hereafter. According to this forecast in the year 2025 the availability of water will be 500 cubic metres per capita per year in North Africa, 800 in East Africa and 3000 in West Africa. In North Africa the consumption is already 642 cubic metres per capita per year.

No doubt it is necessary to use every possibility to manage water.

TABLE 1: TREND OF THE POPULATION IN THE REGION OF SAHARA AND SAHEL

| COUNTRIES | NUMBER OF INHABITANTS (MILLIONS) | | |
|--|----------------------------------|-------|------|
| | 1988 | 2000 | 2025 |
| North Africa | | | |
| Algeria, Morocco Tunisia, Libya, Egypt | 111.2 | 147.6 | 221 |
| East Africa | | | |
| Djibouti, Ethiopia, Kenya, Uganda, Somalia, Sudan | 116.3 | 168.9 | 324 |
| West Africa | | | |
| 6 Sahel countries and Cape Verde, Gambia, Guinea-Bissau | 40.3 | 56.9 | 105 |

3. NECESSITY OF KNOWING WHAT HAS BEEN DONE IN OTHER COUNTRIES IN THE WORLD AND SPECIALLY IN AFRICA

Technical processes exist sometimes, since centuries ago, which have been proved to be efficient with no expensive imported materials or methods. For instance we can mention in arid south of Tunisia the "meskat" technique used on the hills near the town of Sousse (something like what is described in the paper of Mr S Burgess (contour bunds) of the "gessour" technique in Matmata (something like "sand-storage dams"; in Togo, the Kabre and the Somba use a very ancient technique to cultivate very steep slopes upto the top of the little mountains. In Cape Verde, some people use the mist which forms water when it gets into contact with trees or shrubs which are grown purposely for this. Many others could be quoted, but the scientific links between countries of the south are far less developed than those with countries of the North. As is said in the paper of Mr Erik Nissen-Petersen "Assistance to improve peoples' traditional water sources on their terms may be more successful than schemes involving high technology inputs".

4. NECESSITY TO REMEMBER THE HAZARDS

It is necessary to note that climate is subject to short, medium or long term variations. Rainwater harvesting is a necessity but is also necessary to anticipate the possibility of droughts more severe than ever seen. All the solutions which are at the limit of the possibilities are dangerous as there is no security margin. It is also necessary to understand that each region has physical limits to support a certain amount of population. It is dangerous to think that modern techniques can overtake these limits.

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DISCUSSION

Mr P Karinge asked how the system of rainwater harvesting from mist in Cape Verde operates and the speaker said that farmers plant about 20 sisal plants in a line and place plastic sheeting underneath to collect the water which

condences on the plants. By this method a farmer can collect 100 to 200 litres per day.

Dr Ndege asked the speaker whether he agreed there was plenty of water in Africa on a per capita basis and management was the main problem. The speaker agreed that overall the availability of water per capita was high but 95% of the available water is too far away to be of use in the arid areas and the cost of transporting it to those areas is too great. However, he agreed that management could improve the situation.

Mr Burgess asked the speaker to explain his comment that Libya uses a hundred percent of their runoff. Mr Colombani replied that in Libya there is very little possibility of increasing the availability of water through rainwater harvesting except for a very small fraction of the population and for this reason Libya is using groundwater which is a non-sustainable resource. Groundwater levels are going down and there will be serious consequences in fifty to a hundred years.

RAINWATER HARVESTING IN KENYA - THE STATE OF THE ART

M. M. Ndege
University of Nairobi

1. INTRODUCTION

Kenya has an area of 582 647 square kilometres out of which 2.3% is water, 30% is arable land and the remainder is land which falls within Semi-Arid and Arid lands.

About seventy percent of Kenya's population lives in high potential areas, which can already be considered as saturated. Through development of the water sector, the government aims at supporting the efforts of bringing about the rural-urban balance and opening up the arid and semi-arid areas for increased economic activity. Development activities in the arid and semi-arid areas, for the last three years, are steadily building up through the support of both the local and international development agencies. Top of the list of major barriers documented is lack of sufficient water, the development and management of any available resources.

In Sessional Paper Number one of 1986 on "Economic Management for Renewed Growth", the Kenya Government asserted a set of goals for the country's economic development towards the year 2000. With a renewed economic growth target rate of five percent for Gross Domestic Product (GDP) from 1984 to 2000, provision of basic needs where water for domestic, livestock, agriculture, watershed conservation, food security, improved rural-urban balance and gradual structural change were the major components.

This paper highlights the state of art of Rain Harvesting in Kenya. the harvesting processes are highlighted according to Kenya's classification.

2. CLASSIFICATION

There are a variety of ways of using rainwater and runoff. In Kenya, the state of the art will therefore be conveniently discussed from modes of collection and storage. The classification of rainwater harvesting systems is therefore given according to the following:

- catchment
- storage
- use

2.1. Catchment

Classification according to catchments is further sub-divided into two groups:

- Small catchments with sheet runoff typified by microcatchments. Roofs of all kinds and ground surfaces less than fifty to a hundred and fifty metres in length within field catchments belong to this group
- Large catchments with turbulent runoff and/or channel flow. Slopes longer than fifty to a hundred and fifty metres and minor gullies, flow in wadis, gullies, rivers and all natural drainage channels including wells are in this group.

2.2 Storage

In this system, the storage technique is the principle mode of classification:

- Tanks above ground found only in small catchment areas. The water is from roofs or ground surfaces less than fifty to a hundred and fifty metres in length. Water in this classification is used mainly for drinking and domestic purposes.
- Excavated tanks and cisterns found only in small catchment areas. Water in this classification is used for both drinking, domestic, livestock and agricultural purposes.
- Pans and small dams found both in small and large catchments of various sizes. Water in this group is used for drinking, domestic, field irrigation and livestock.
- Soil moisture; this can be further sub-divided into soil at field capacity and soil at saturation. Common for both sub-divisions is the fact that water is from ground surfaces within field catchments, external catchments and, flood water from streams, rivers and gullies.

2.3 Use

In this system, the harvested rainwater is used for the following purposes:

- Domestic
- Livestock
- Irrigation from cistem, tanks or dams
- Runoff water for farming with external catchments

3. COLLECTION AND STORAGE TECHNOLOGIES

3.1 General

There ought to be some rain before harvesting can be thought of. Kenya is lucky in that rainfall takes place all over the country. Different regions have harvested rain using some traditional technology in one way or the other. Probably, the earliest and most widely practised technology was tanks above the ground. These could be in the form of jars and pots. Small excavated pans, surface dams or sub-surface sand dams were generally used for livestock in areas where streams or rivers were far from homesteads or where rivers were seasonal. This paper, therefore, while addressing the issue of the state of the art, will be assuming that all of us have seen rain being harvested around our regions. What, therefore may be new, and hopefully to only a few of us, will be the current technological strides we are trying to make in rain harvesting.

Theoretically, the ninety percent probability annual rainfall should be regarded as the dependable rainfall for the purpose of rainwater harvesting for domestic use. According to this figure, almost the whole of Northern Kenya, the greater part of Machakos District, the greater part of Kitui District with the exception of areas around Kitui Town, Kajiado District, North Eastern Kenya, Coastal Region excluding Wundanyi, Taita and the forty kilometre coastal strip would be regarded as not dependable for rainfall harvesting purposes. This reflects, therefore, that almost sixty percent of Kenya should not depend solely on rainwater harvesting for domestic use.

3.2 Roof Catchment

The use of roofs for water collection is widely practised in different parts of Kenya (Fig 1 and 2). Such roofs are made of corrugated, galvanised iron sheets,

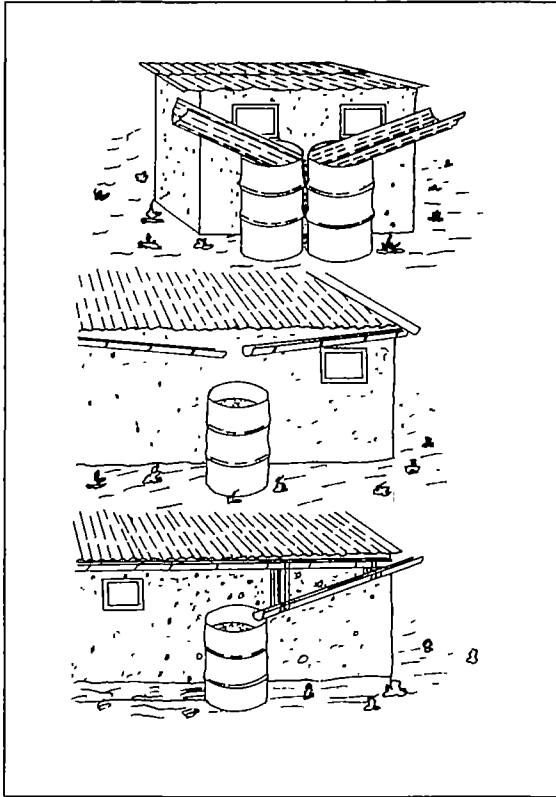


Fig. 1: Improved rainwater collection with 200l storage
(After Hofkes, 1981 and White at el 1972)

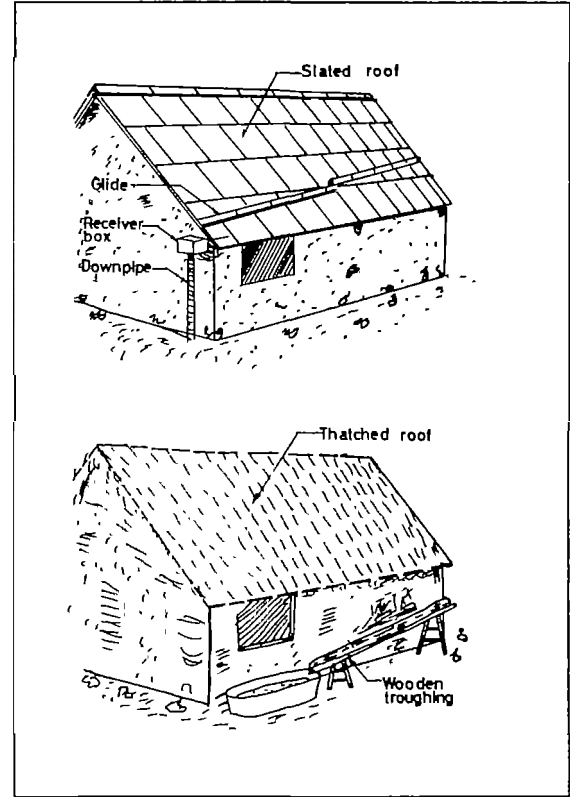


Fig 2 Alternatives to Guttering

tiles and thatch. Sometimes storage is by way of brick, galvanised or ferroce-ment tanks. Water may be collected by an open gutter which leads the water to the tanks.

A rough estimate of the required minimum roof area can be made using the following formula

$$A = (450 * D)/R$$

where A = Minimum roof area in square metres

D = Total water demand in litres per day

R = the 90% probability annual rainfall in millimetres

The collection tank's capacity should be calculated using the available meteorological rainfall data of the area. A rough calculation of the capacity can be made using the following formula:

$$C = 0.03 * D(T + 2)$$

where C = Tank capacity in cubic metres

D = Total water demand in litres per day

T = Longest dry spell in months, average year

The dry spell is the period when the average monthly rainfall is less than fifty millimetres. The meteorological department has maps showing lengths of the dry spells in different areas of Kenya for reference.

In almost all the cases, people do not care about the capacity of the storage tank. It all depends on what her/his money can buy; nor do they care about the tank cover thus greatly reducing the volume stored during the warm and hot days. Birds, dust, leaves and dead animals also find their way to the tank thus polluting the water. In Kisii area, a galvanised wire mesh acts as a sieve for such tanks, raised to allow easy tapping.

Apart from usage in villages, this type of technology is getting very common in schools as the only source of water or as a source of water to enhance an existing but inadequate supply.

Treatment of roof water before use has not been documented.

3.3 Ground Catchments

Water harvested from ground catchments is used for crops , wildlife, livestock and domestic consumption where there is no better alternative source. In Baringo, ground water harvesting for crop production is fairly developed (Fig 3 and 4). The application of contour ridges is very popular (Fig 5). The runoff catchment area is planted with a drought tolerant legume in a low population density and therefore not impeding runoff. Ridges of fifteen centimetres height and intra-distance of 1.5 to 3 metres are commonly used with a soil profile of a least one metre deep. There are many options of laying contour barriers as shown in Fig 6. In some cases the use of bunds is practical as shown in Fig 7 and 8.

Ferrocement tanks are failing in Baringo which has, a very hot and dry climate, due to problems with curing and reinforced stone tanks have been found to be a good replacement.

Sub-surface cisterns for surface runoff are also in use.

When there is need for the sub-surface cisterns water to be used for drinking, at household level, simple treatment with aluminium sulphate to enhance coagulation is used before filtration using some pieces of white cloth.

There is some design guidance on small dams and pans by the Ministry of Water Development, quite handy for an engineer as a handbook.

It is not common to have a mobile water laboratory for testing and chlorinating water tanks as is the case in Nakuru. Depending on the volume to be chlorinated, Table 1 serves as a quick guidance to this process.

In areas where rivers are seasonal, shallow wells are dug manually in the river beds from where water for domestic consumption and livestock usage can be collected.. This type of technology is well practised in many parts of Machakos District No technical design formulae or criteria are used.

4. CONCLUSION

Currently there is a lot of disjointed and uncoordinated information on rainwater harvesting.

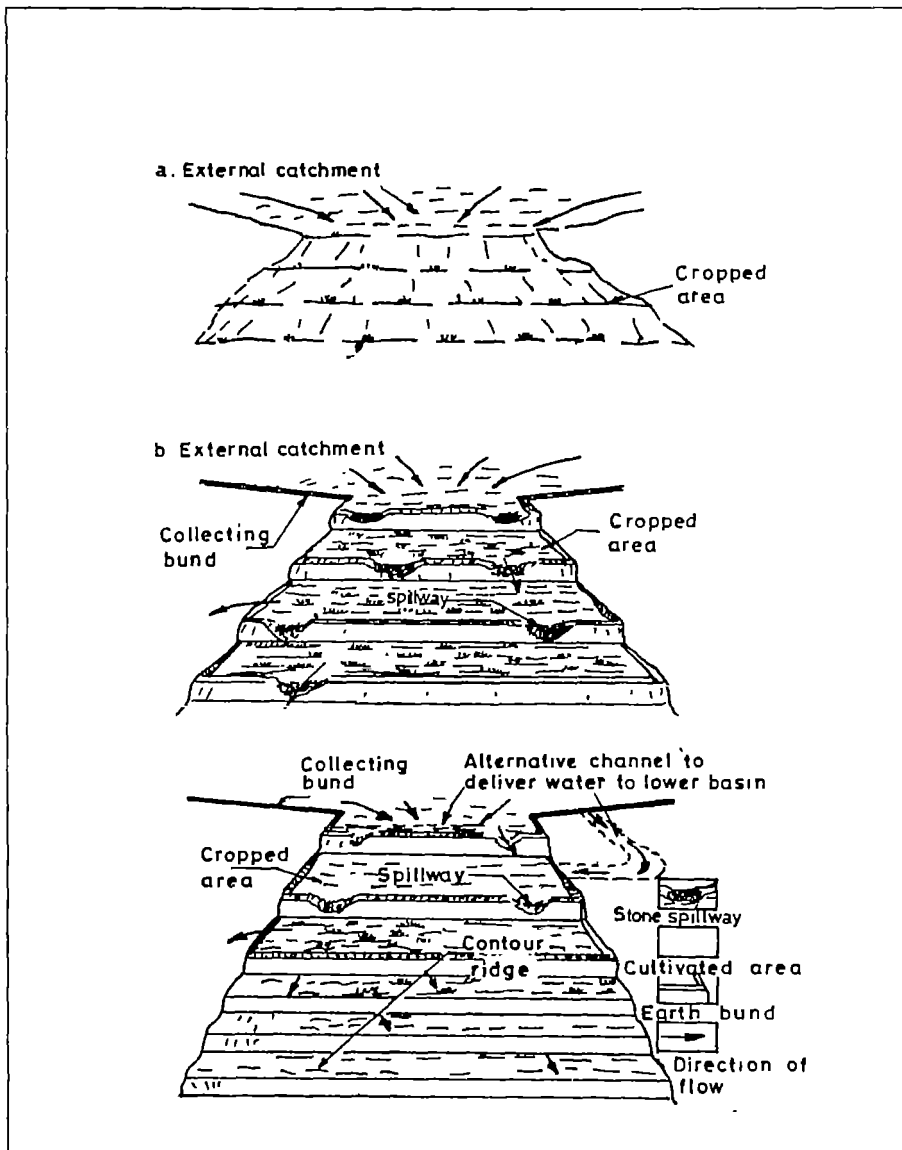


Fig 3 Run off farming using external catchments (Critchley 1984)

- a) 'Simple' run off farming
- b) Improved run-off farming using collecting bunds
- c) Improved runoff farming further modified with contour ridges

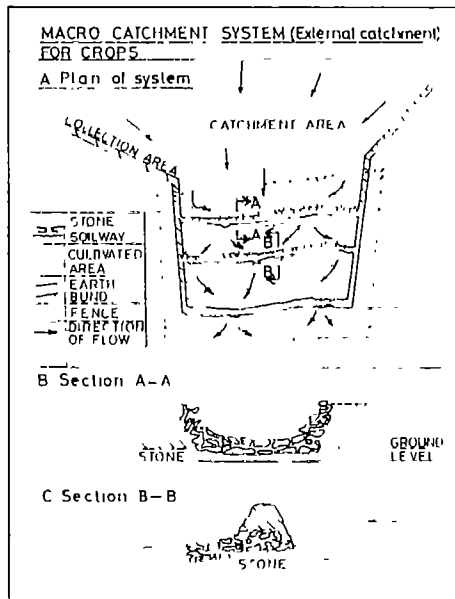


Fig 4 Macro-Catchment systems

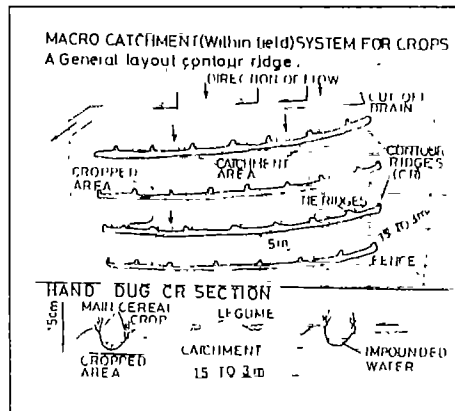


Fig 5 Contour Ridge

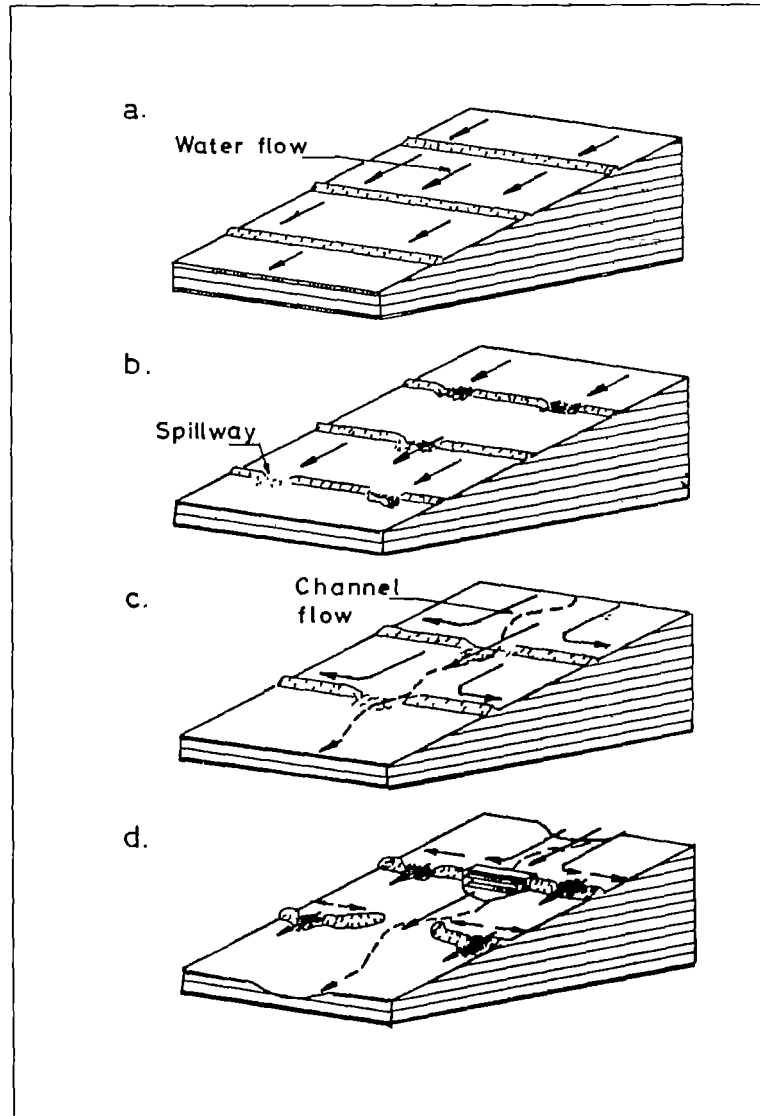


Fig. 6: Options for laying out contour barriers (after Wright 1984)

- a) Simple stone barriers
- b) barriers with spillways
- c) Small dams and spillways

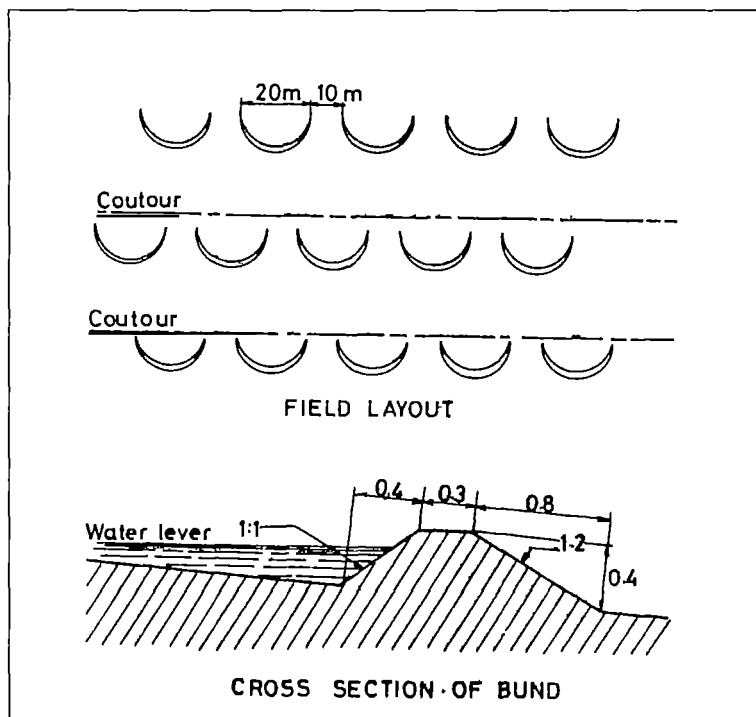


Fig 7 Semi-circular plots with curved bunds or 'hoops'

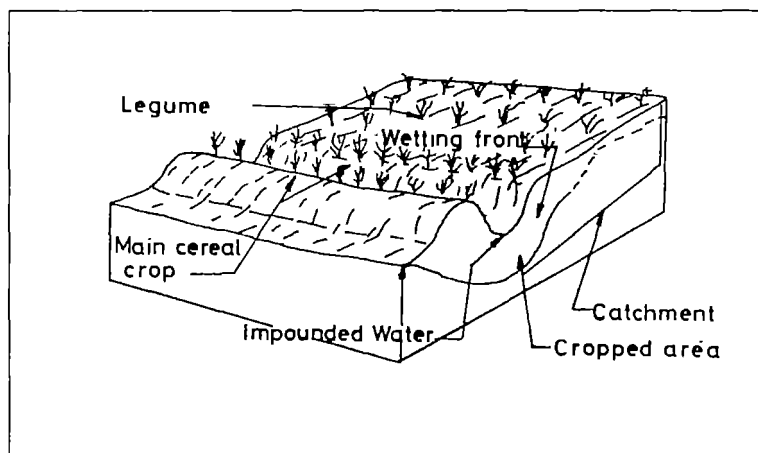


Fig 8 Contour Barrier

There is need for a co-ordinated research on rain harvesting leading to the type of appropriate technology, equipment and techniques that are relevant to local resources and needs, to feasible patterns of organisations and to local environment. The design of rainwater tanks or runoff farming systems for a specific area requires a much more detailed analysis. Information will, therefore, be needed about rainfall, existing water sources, availability of materials, housing and roof types and the people's means of livelihood. There are likely to be different points of view about local needs and how the project will affect them. Water supply experts, government officials and local residents will have varying views.

What is important is to collect information on all these different views and seek common ground between them. The development of an appropriate technology for rainwater harvesting is not achieved by the simple process of collecting information and using it to formulate an optimum design. It needs an "innovative dialogue" in which information, opinion and innovation come from the users of the system as well as the designers. The process can be called interactive research. Education and training of the users on water usage and conservation techniques, health and personal hygiene, small scale but effective agricultural methods etc. need to be stressed through various workshops and seminars. Leaders should encourage and assist in regional visits to different projects. This will not only educate the public but also instill in them competition which will enhance positive developments.

Proper documentation of rainwater harvesting techniques and practices should be welcomed.

The need for rainwater harvesting should be strongly stressed to the public by the officers from government, NGO's and interested parties.

With proper development of rain harvesting, Kenya will be striding quite ahead in trying to realise the views contained in Sessional Paper Number one of 1986 mentioned in the introduction to this paper.

TABLE 1: A CHLORINATION GUIDE

| Water Vol. /m ³ | Concentration in mg/l | | | | | | | |
|----------------------------|-----------------------|------|------|------|------|------|------|------|
| | 0.5 | 1.0 | 2.0 | 5.0 | 10 | 20 | 50 | 100 |
| 1 | 7 | 14 | 28 | 71 | 140 | 280 | 710 | 1420 |
| 2 | 14 | 29 | 57 | 140 | 290 | 570 | 1430 | 2860 |
| 3 | 21 | 43 | 86 | 210 | 430 | 860 | 2140 | 4300 |
| 4 | 29 | 57 | 110 | 290 | 570 | 1140 | 2860 | 5710 |
| 5 | 36 | 71 | 140 | 350 | 710 | 1430 | 3570 | 7140 |
| 6 | 43 | 86 | 170 | 430 | 860 | 1710 | 4300 | 8570 |
| 7 | 50 | 100 | 200 | 500 | 1000 | 2000 | 5000 | 10 |
| 8 | 57 | 110 | 230 | 570 | 1140 | 2290 | 5710 | 11.4 |
| 10 | 71 | 140 | 280 | 710 | 1420 | 2860 | 7140 | 14.3 |
| 12 | 86 | 170 | 340 | 860 | 1710 | 3430 | 8570 | 17.1 |
| 15 | 110 | 210 | 420 | 1070 | 2140 | 4290 | 10.7 | 21.4 |
| 20 | 140 | 290 | 570 | 1420 | 2860 | 5710 | 14.3 | 28.6 |
| 30 | 210 | 430 | 860 | 2140 | 4300 | 8570 | 21.4 | 42.9 |
| 40 | 290 | 570 | 1140 | 2850 | 5710 | 11.4 | 28.6 | 57.1 |
| 50 | 360 | 710 | 1430 | 3570 | 7140 | 14.3 | 35.7 | 71.4 |
| 100 | 710 | 1420 | 2860 | 7140 | 14.3 | 28.6 | 71.4 | 143 |
| 150 | 1070 | 2140 | 4290 | 10.7 | 21.4 | 42.9 | 107 | 214 |
| 200 | 1420 | 2860 | 5710 | 14.3 | 28.6 | 57.1 | 143 | 286 |

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DISCUSSION

Mr P Karinge queried the statement that eighty percent of the country does not have dependable rainfall for reliance on rainwater harvesting and commented that it is precisely these areas that have greatest need to harvest rainwater for domestic use.

Mr Kimuyu asked what was the best roofing material which has no health problems and was told that smooth surface corrugated iron sheets are so far the best available material.

Mr Owino asked what effort was being put into development of alternative or supplementary catchment areas and whether the speaker knew about windrows to provide additional catchment areas. Dr Ndege said that almost no effort is going into the subject and there was a need for research into various technologies.

Mr Ngao referred to the rapid loss from groundwater tanks due to evaporation and asked what measures could be taken to curb it. Dr Ndege agreed that evaporation takes a good percentage of what has been collected and that there is a need to carry out research on evaporation and seepage and produce guidelines for different situations.

THE ROLE OF WOMEN AS PARTICIPANTS AND BENEFICIARIES OF RAINFED WATER SYSTEMS IN RURAL KENYA

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1. INTRODUCTION

Women in rural and urban areas around Kenya understand the urgent need for improved and more accessible water for domestic consumption. This is well documented. In a study I carried out in Narok in 1986, I noted that all women covered in my study (about 87 households) spent 85 percent of their time drawing, carrying, managing and using water. In majority of the cases, the water was not safe for drinking and was too little. This is the case for most women in rural and urban Kenya.

Women themselves are well aware of the time and energy spent in obtaining this basic life resource and thus of the enormous amounts of time and energy lost which could otherwise be utilised for more productive tasks.

Women may not be aware of the germ theory of disease or may not be able to see a direct relationship between improved water supply and health but once water becomes accessible they quickly evaluate benefits in terms of improved health and reduced workload.

Women are well aware of additional time and energy savings, and the possibilities for additional productive activities. This new time may be used in different ways in income generating activities such as growing more food for the market, commercial activities, promoting their family health etc. The list may be endless but no matter what activity you add to this list, they contribute to improving the quality of life for their families and consequently their communities.

2. WORKING TOWARDS UNDERSTANDING OF WOMEN IN RURAL WATER SYSTEMS

It is good to discuss some of the important roles that women play in relation to improvement of rural water systems and to suggest ways of improving systems design and hopefully to try to diminish failures. The purpose of this paper is to explore five key factors and these are:

1. The change agent factor
2. The manager factor
3. The user factor
4. The acceptance factor
5. The primary health care factor

My paper tries to place women at the centre of any intervention that is water related and most especially interventions that relate to water for domestic usage. The paper also offers some recommendations for consideration when thinking of any water systems.

3. THE CHANGE AGENT FACTOR

Women are key change agents in water technology. That women diffuse improved water technology and are agents of behavioural change must be taken into account in evaluating project effects. This contention holds true whether one is concerned with household or community-wide effects and needs to be interpolated into both external and self evaluations.

- a) Household level effects.
To a large extent the achievement of household level benefits, both health and social, are dependent on the ability of women to diffuse information, attitudes and water related behaviour to other household members. As carriers of water in rural Kenya, women directly influence the volume consumed and thus the possibility of achieving health effects related to increased volumes of water. As people who select water sources (in areas that have choices) women determine the quality of water that they carry home based on their perceptions of what is good and acceptable.
- b) Community level effects.
In communities where a single water source serves from 40 to 250 or more persons, the achievement of health and socio-economic benefits and their evaluation also depends a great deal on the role of women. Women as drawers of water control to a great extent the possible contamination of the source through the manner in which they use the system - be it rainfed or piped.

4. THE USER FACTOR

A key issue that confronts any water technology at the onset is whether or not the new facility once installed would be more used by those whom it is targeted for. Any water technology, regardless of the excellence of construction and function, will not achieve its objectives if it is not used.

There is need to educate women as key users of water. That also the new knowledge that is imported must be related to local beliefs and behavioural systems. That the type of training/education should bear the following main strategies:

- increasing knowlwdge of the water-health relationship.
- promoting water handling, and food preparation practices that contribute to better health.
- Promotion of positive attitudes toward proper and hygienic use of the water supply and storage receptacles.
- promotion, where possible and acceptable the appropriate re-use of wastewater for uses that may not need clean water e.g kitchen gardens and family compound trees.

5. THE MANAGER FACTOR

Women are of course managers, of household water supply systems (roof water catchments, wells, hafirs, rivers, piped systems etc). Whether it is recognised or not, they also have a strong potential role as managers of community water systems. Women are the "heart" of the household while the men are the "heads" as they are called. It is the women who have to think of when, how, where and with what to get the water. They also have to "budget" for the available amount of water across the family or household. Women thus keep a centre stage as far as training in water systems and their maintenance is concerned.

That several tasks in the maintenance and repair of new water systems must be learnt by somebody in the community, is a fact. There has to be somebody who has to learn how to monitor leaks and other defects, doing routine maintenance and minor repairs, training other community members in repair and maintenance. My argument here is that this person has to be mostly the woman who knows the meaning of carrying a twenty litre jerrycan on her back for ten kilometres during the rainy season because the rainfed tank has burst.

Women can also be trainers of other women. The women also play a central role in socialisation and health education and health care networks as well as their performance within the household making them more suitable for managers and trainers for water systems handling, both at the community and household levels. The training should be task specific which includes information necessary for women to practice, teach and supervise others.

6. THE ACCEPTANCE FACTOR

Women are usually the first ones to use new water technology. Their role as household water budgeters makes them primary users and mediators between the water systems and the household. The choice of water for bathing, drinking, cooking, washing clothes etc is the result of a woman's careful organisation based on what she has learnt from her mother and on her observation of the costs and benefits of any change.

7. PRIMARY HEALTH CARE FACTOR

This is a strategy which has emerged as the leading approach for meeting health needs in developing countries and it includes among other elements community participation, universal coverage and appropriate technologies for improved water and sanitation.

The approach places heavy reliance on women and water for success. The women are placed as key change agents in this approach. Improved systems and water adequacy are closely linked to reducing the workload of women - a result with profound implications for reaching primary health care objectives

How do all these relate to rural rain water harvesting.

- That until women participate in systems design and implementation, including user education and management of such facilities, limited acceptance and impact can be anticipated
- That there is need to look beyond technology to the roles and attitudes of the potential beneficiaries, particularly women, who are the primary users of water and the educators of their children in matters of personal hygiene.
- That roof water catchments remain the simplest way of obtaining water outside the door, world over.

- That with simple, low cost tanks where there are roofs to use, much of the time during the wet season could be used in doing other duties around the home as there is water in the tank.

8. RECOMMENDATIONS FOR RAINWATER HARVESTING TECHNOLOGY PLANNING, IMPLEMENTATION AND EVALUATION

- i. That run-off and roof catchments be quantity, quality and accessibility based. There is need to gather information on womens perceptions on the above three variables.
- ii. Such information be used for sighting, and selecting the technology best suited to the people and area.
- iii. User education should target women as priority candidates.
- iv. That the content of such education should include specific behavioural objectives relevant to women such as changes in practices relating to water handling.
- v. That women be trained in the technical and managerial aspects of any new technological find in rural rain water harvesting systems.
- vi. That once such women are trained, they should become trainers of technologies that are community based.
- vii. Evaluations on any rural rain harvesting technologies should go out of their way to look at the role women have played in program and benefits that have accrued to women as a result of the new technology.

These recommendations considered along with others based on practical experience in working with communities , could be of great help in achieving a balance in the community.

WHO IS WHO IN RAINWATER HARVESTING IN KENYA: AN APPLICATION OF THE SYSTEMATIC AND STRATEGIC APPROACH TO DATA MANAGEMENT

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ABSTRACT

The systematic approach to information collection, processing and selection is described as a background to compilation of a who is who in rainwater harvesting in Kenya, in the introduction to this paper. This approach which incorporates strategic identification of information sources, has been developed by the author as part of her research on project planning. A detailed who is who in rainwater harvesting in Kenya forming the bulk of this paper follows a brief description of the systematic approach. An evaluation of the results obtained and suggestions on future work form the final section of the paper.

1. INTRODUCTION

When the author started compiling the who is who contained in appendix A in this paper, she faced the situation outlined below.

- although she knew about several, even numerous organisations which could be connected with rainwater harvesting, these were not all listed within any specific information source or database.
- she faced severe limitation on time available to compile the who is who
- The spatial spread of rainwater harvesting in Kenya was not available as inventoried information.
- she was not aware of any inventory of rainwater harvesting technologies or projects.

Forced to think in terms of creating something systematic out of the randomly available bits of information, a strategic approach to information collection was adopted to ensure maximum use of the limited time resource. The systematic approach described below was formulated in response to this call.

2. THE SYSTEMATIC APPROACH

2.1. General

The systematic approach, called for:

- definition of problem
- identification of problem components
- collection, processing and analysis of relevant information
- presentation of findings

2.2. Problem Definition

Use available information, in minimum possible time period, to develop a who is who in rainwater harvesting in Kenya.

2.3. Problem Components

The components of the who is who are as follows:

a. Inventory elements

- which institution is involved in rainwater harvesting
- who are the individuals involved
- how can these individuals be located (Address, telephone)
- what are these individuals doing (Projects, activities, designations)

b. Classification elements

- how are the individuals/organisations to be grouped

Spatial characteristics have been used to classify the individuals in this who is who. Based on spatial characteristics the following classification is adopted:

- global institutions
- multi and bilateral agencies

- National bodies
- Public institutions
- NGOs
- private agencies and individuals

2.4. Information Management

Adopting a strategic approach, the information contained in this who is who was obtained from seven sources including; the Ministry of Reclamation and Development of Arid and Semi-Arid areas and Wastelands, UNICEF, World Bank, GTZ, Church of Province of Kenya, an NGO and a consultant (also a representative of the IRWCSA). This strategy was based on the assumption that if one organisation could be identified in each spatial grouping, then this one source would have some information about other members within the same group, either through co-operation or through competition.

2.5. Presentation of Findings

The who is who compiled using the systematic approach is presented in Appendix A.

The list of people contained in the who is who compiled and presented below is very preliminary and basic and should not therefore be treated as being exhaustive.

3. RECOMMENDATIONS FOR FURTHER WORK

The Who's who compiled above can be refined and expanded in three ways:

- More names can be added to it
- More information can be added to it by increasing the elements in the inventory
- The accuracy of the information can be checked and evaluated periodically

To this end, if any seminar participant knows of persons whose names should be included in the above list or whose particulars as appearing above are incorrect, the author would be pleased to know this information. You are therefore invited to write this information and give it to the organisers before the end of this seminar.

APPENDIX A

WHO'S WHO IN RAINWATER HARVESTING IN KENYA

| GROUP | ORGANISATION | NAME | CONTACT | INVOLVEMENT |
|-------------|------------------|---------------------------------|---------------------------------|--|
| 1 GLOBAL | WORLD BANK | 1. H Tabatabai | P O Box 30577 Tel 228477 NBI | ASAL team |
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| | | 3. J Cappon | | |
| | | 4. F Ahmed | | |
| | | 5. G Pathmanathan | | |
| | | 6. G Schulzberg | | Water and sanitation Resident Rep |
| | UNICEF | 1. V O'Reilly | P O Box 44145 Tel 520597 NBI | Chief, wss Proj Off |
| | | 2. C Hubert | Tel 521478 | Prog Off |
| | | 3. S Makondiege | Tel 521478 | Pastoralist Water Proj Consultant |
| | | 4. S Mwenda | Tel 521478 | |
| | | 5. P B Bigot | Tel 521478 | |
| | | 6. A Bonfiglioli | Tel 521335 | |
| | UNDP | 1. L Kallren | P O Box 30577 Tel 228477 NBI | WS Engineer |
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| UNSO | 1. K Muller | P O Box 30218 Nairobi | Pastoralist Water Proj | |
| WHO | 1. V Aalto | P O Box 45335 Tel 723069 Nbr | Sanitation Engineer | |
| UNWFP | 1. S Anderson | P O Box 30218 | Pastoralist | |
| | 2. G G Mwangi | Tel 217598 Nbr | Water Proj | |
| UNCHS | 1. G P Alabaster | P O Box 30030 Tel 230800 Nbr | HSO Research & Dev. | |
| IFSP | 1. U Saidi | P O Box 46719 Nairobi | Wamba Samburu | |
| 2 BILATERAL | SIDA | 1. R Winberg | P O Box 30600 Nairobi | Senior Regnl Ad Prog Co-ord Reg SCU |
| | | 2. G Settergren | | Tharaka WS |
| | | 3. A Lennartson | | Tharaka WS |
| | | 4. K Lundbert | Tel 0161-20423 | |
| | | 5. M Nyaga | Tel 0161-20423 | |
| | GTZ | 1. M Trojanow | P O Box 55784 Tel 729006 Nbr | Ger/Ken Water team |

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| | | 3. W J Kassen | P O Box 19512 Tel 222451 Nbi | WS Engineer |
| | JICA | 1. S Shibuya | P O Box 50572 Tel 716185 Nbi | MOWD/JICA |
| | | 2 M Fujita | | |
| | USAID | 1. L E Fallon (1963) | | Turkana |
| | DANIDA | 1 M Tinkel | | |
| | | 2 Henk | Tel 0141-22707 | with KIDP in Machakos |
| | FINIDA | 1. P Sarkknen | Tel 0331-30010 | Western WSP Kakamega |
| | | 2 J Kleijn | Tel 035-42240 | KRDWSSP II |
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| | ODA | 1 G Vernon | P O Box 1199 Tel 20676 Embu | Dryland Applied Research Proj |
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| 3 NATIONAL | MOWD | 1 B Bakker | P O Box 30521 Tel 729006 | WRAP Co- ordinator |
| | | 2 F J Edalia | P O Box 50284 Tel 729006 | WRAP Hydro- logist |
| | | 3 K Kimani | | |
| | | 4 J M Wangura | | |
| | | 5 D T Mogusu | | |
| | | 6 D N Karenga | | |
| | | 7 S Ngao | | |
| | | 8 J M Kinyanjua | | |
| | | 9 B Tronneler | P O Box 18 Kwale | WRAP |
| | | 10 F D Mwakamba | P O Box 18 Kwale | District Water Eng |
| | | 11 J M Mwambur | Water Insp | |
| | | 12 L L Njogholo | geologist | |
| | | 13 B Chimega | Eng Asst | |
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| | | Tel 2043 Iten | Water Eng |
| | 18 M M Bahir | P O Box 31 | Provincial |
| | | Tel 0161-2272 | Water Eng |
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| | | Hola | Officer |
| | 5 R S Bikatsi | P O Box 49 | SC Off |
| | | Kinango | |
| | 6 C M Mwangi | P O Box 2 | Agriculture |
| | | Kwale | Officer |
| | 7 F V Mutotia | | Asst A O |
| | 8 H Kutakasa | | AAO |
| | 9 M M Chombo | | AO |
| | 10 D Kirombo | | AO |
| | 11 V Oyleng | | AO |
| | 12 W Aludah | | AO |
| | 13 S Mwachoti | P O Box 23 | Div SWC Off |
| | | Madogo, Garissa | |
| | 14 F N Piko | P O Box 1 | SWC Off |
| | | Malindi | |
| | 15 J M Adongo | | Irri Off |
| | 16 J A Makodiah | | Irri Off |
| | 17 G Oriku | P O Box 65 | Agr. Asst |
| | | Marigat | |
| | 18 M Bakari | P O Box 153 | |
| | | Mwatate | |
| | 19 Z Japhe | P O Box 23 | |
| | | Mwatate | |
| | 20 B N Mwakileo | P O Box 23 | SC Off |
| | | Taveta | |
| | 21 J K Mutuma | P O Box 1035 | AO |
| | | Wundanyi | |
| | 22 J Mungere | | AAO |
| | 23 M Mulinge | | AAO |
| | 24 C S Chengo | P O Box 29 | WC Off |
| | | Mariakani | |
| | 25 J M Adongo | P O Box 1 | Irri Off |
| | | Malindi | |
| | 26 P Mukholi | P O Box 19 | District |
| | | Tel 0125-22646 | Irrigation |
| | | Kilifi | Officer |

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| | 31 D K Khaemba | | SCO |
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| | | Tel 45 Kibwezi | |
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| | | Kyeni | |
| | 4. S Mbisi | P O Box 92 | Water Eng |
| | | Kyuso | |
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| | | Webuye | |
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| | | Tel 0328 21006 | |
| | 3. J S Tinkoi | P O Box 463 | Maasai |
| | | Tel 2245 Narok | Peoples |
| | | | Proj |
| | 4. G Gitau | P O Box 50816 | Proj Co-ord |
| | | Tel 334080 Nbi | |
| | 5. T Wanjala | | Proj Co-ord |
| | 6. G Walhaupa | | Proj Co-ord |
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| SCC | 1. D N Njagi 2. M Mathenge | P O Box 1722 Tel 20442 Meru | Save the Children Canada Country Dir |
| KFH | 1. P M Kipsang | P O Box 3066 Nakuru | Water Insp Freedom from Hunger |
| CARE | 1 A Oluoch | P O Box 606 Siaya | Care Inter- national |
| CMM | 1 O Ryan | P O Box 6 Mangat | Catholic Mission |
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| PAP | 1. S McGovern | P O Box 91 Mangat | East Pokot Agn Proj |
| VSW | 1. E Sugule | P O Box 7 Wajir | Social Work Volunteer |
| KWTP | 1. S Mutua | P O Box 674 Meru | Kamutine Water Tank Proj |
| KWWP | 1. P Kimeu | P O Box 128 Kwale | Kwale water & Sanit Proj Eng Asst |
| MUTI- CON | 2. M Mbui 1. C M Mutiso | Water Insp P O Box 14333 Nairobi | Consultant |

DISCUSSION

Mr. P K Karimi asked that an explanation be provided as to why some District Water Engineers were included while others were not while their work is supposed to be the same. This he stated would also apply to other Ministries. The reason for this, it was explained was that only the names of those actively involved with projects in RWH, showed up in the strategic data collection.

In response to an enquiry regarding a follow up questionnaire to find out who is actively working in any form of RWH, it was explained that this would probably form part of the work to expand on this preliminary who is who.

Mr. S. Burgess stated that he had a copy of bibliography produced by ITDG on RWH both in Kenya and elsewhere which would be available for anyone who would like it.

RAINWATER HARVESTING FOR CROP PRODUCTION IN KENYA: RESEARCH NEEDS AND PRIORITIES

S. K. Mutiso, University of Nairobi

D. N. Mutisya, Kenyatta University

1. INTRODUCTION

Runoff harvesting (ROH) is a technique which has only recently received scientific recognition as a system which has much to offer in the hot dry areas of the world where irrigation is not feasible. In Kenya ROH is used for domestic water supplies (Omwenga 1984), crop production (Smith and Critchley 1983, Critchley 1989, Imbira 1989) and range improvement (Smith and Critchley 1983). The empirical principal of ROH is to collect and impound run-off, thus increasing the availability of water for plants in areas where rainfall limits production.

It is evident to us that most of the research work on rain water harvesting for crop production has concentrated on semi-arid areas where crop growth is limited by low total rainfall amounts, strong seasonal concentration and high variability from season to season and year to year. (Mutiso et al 1991)

Contrary to the contemporary view that rainwater harvesting is confined to the semi-arid areas, field observations (Mutiso and Mutisya 1991/92) show that the technique is also applied in humid areas where, for instance, runoff from roads, foot paths, and cattle tracks is diverted into banana pits and napier grass plots.

It is also important to note that runoff harvesting is ultimately dependent on rainfall which is the most limiting factor to crop production and animal rearing in semi arid areas. However, run-off is a conspicuous feature of many rainfall events particularly at the micro-catchment level, which has been the focus of several studies as opposed to the microcatchment level. (micro-catchment is within field while macro-catchment' involves an external catchment). Both approaches have their advantages and disadvantages in the rainwater harvesting technology. However, in both cases most of the work is confined to engineering designs, the impounding structures, agronomic practices and crop yields (Imbira, 1989, Kilewe, 1984, Critchley 1989, Smith and Critchley 1983, Pathak, 1985). None of these studies have addressed themselves to the issue of the effectiveness of rain water harvesting as determined by physical soil characteristics as they relate to soil moisture retention. For instance Critchley

(1989) confined his study to the structural soil properties for the construction of ridges and bunds to ensure that few breakages occur.

2. RAIN WATER HARVESTING FOR CROP PRODUCTION IN KENYA: A LITERATURE REVIEW

Kilewe and Ulsaker (1984) investigated the topographic modification of land to concentrate and redistribute run-off for crop production in the Katumani National Dryland Research Station (KNDRS), Machakos District. Their main objectives were:

- (i) to develop low-cost land management systems to concentrate and redistribute run-off for crop production and
- (ii) to determine their water-storage and crop production efficiency effectiveness in preventing run-off and controlling erosion.

In terms of materials and methods they used the following: (a) contour furrows (Fig.1) 0.75m planted with maize (b) wide furrows 0.75m with two rows of maize in each furrow (c) mini-bench with 0.75m wide maize rows and (d) flat beds (no furrows) with 0.7m wide maize rows.

Using a crop spacing of 0.30m the plants per hectares were 44,000 while the size of plots was 9x4m. Farm yard manure alone was used in all plots. Soil water content was measured on a weekly basis at 30,60 and 100cm depth in the middle of the plot.

The first three experimental plots retained all the run-off with the furrows and allowed adequate infiltration to take place in both short and long rains. Although there were no statistically significant differences noted in water storage capacities between the run-off retaining treatments, the wide furrows consistently resulted in a higher storage capacity. The mini-bench showed poor soil moisture distribution due high water accumulation in the lower parts while the flat plot lost all the run-off.

Secondly, there was adequate moisture in the soil profile in the first three plots during the short rains of 1982 and long rains of 1983. Moisture stored in the 100cm profile was above field capacity in all the plots except in the flat plot.

There were significant differences in the annual marketable yields between all the treatments. During the short season, maize yields were higher than those harvested in the short rains mainly because in the latter the available water

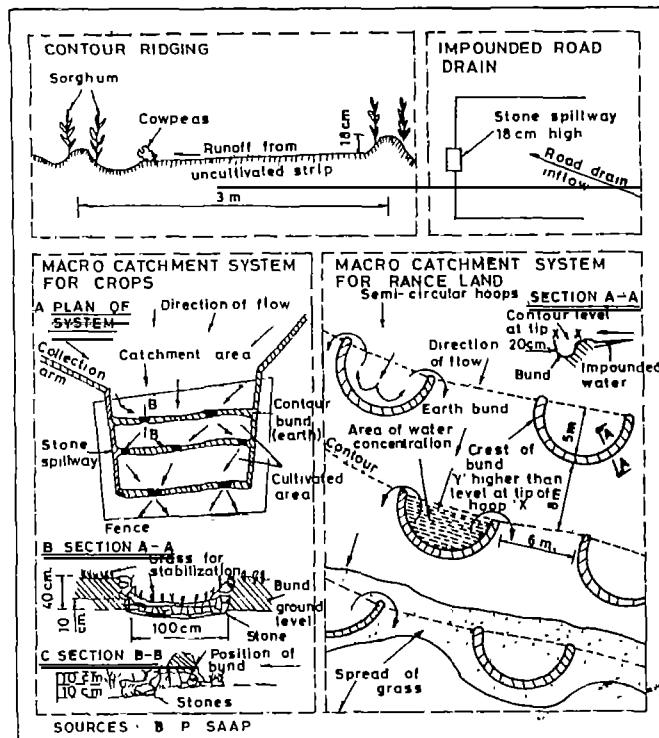


Fig. 1: Runoff harvesting methods compared in observation sites.

content in the surface layers approached permanent wilting point 30 days after germination

In conclusion, more emphasis was placed on annual rather than on seasonal water use efficiency since the benefits of run-off conservation are not often realised until the following season. Kilewe and Usaker recommended the use of the wide furrows as they can easily be maintained as a permanent land feature, and therefore provide conservation throughout the year

In another study, Smith and Critchley (1983) examined the potential of run-off harvesting for crop production and range rehabilitation in semi-arid Baringo. Their sole objective was to compare the initial performance of some different methods of water concentration for crop production and rangeland rehabilitation that have recently been tried in the semi-arid parts of Baringo as part of the Kenya Government Baringo Pilot semi-arid Area Project (BSAAP)

Four methods of run-off harvesting were compared with a control plot. Treatments included (a) contour ridges (b) semi-circular ridges (c) impounding of road run-off (d) impounding of road runoff with zero cultivation and (e) control plot (a deeply dug place with a cut off-drain above it to prevent inflow of water). Three varieties of crops which included Serena sorghum, pigeon peas (local Meru) and cowpeas (local red) were tried. Serena sorghum was planted in plots (b) to (d) while pigeon peas were planted in all five plots. Cowpeas were planted after regrowth of sorghum ratoon.

The results were as follows. Despite the good rainfall during the first four weeks, the height measurements did not correspond to the available moisture except for those plants in the semi-circular plots. However, by the eight weeks, and after more than one week without rain, plant height measurements showed increased advantage of the runoff harvesting method.

Methods (a), (b) and (c) produced good crops and the best, contour ridging, produced over seven times as much as the control plot which almost completely failed to produce the first harvest. Ratoon harvests were better than the first harvest because by the time the second rains commenced, the roots were partially developed and could utilise the rain for vegetative growth and subsequent grain fill rather than in extending the root system.

Method (a) had a lower ratoon harvest because it had a much higher crop density while methods (b) and (c) gave greater overall sorghum yields. All runoff harvesting methods produced a greater cowpea harvest than the control.

In sum, Smith and Critchley (1983) recommended the contour ridge method for incorporation into an extension programme because it produced the most even stand of sorghum and their construction is simple and less time consuming. They also recommended planting one each side of the furrow to planting on each side of the ridge. Finally, the use of a "cultivated absorption waterway" designed to absorb water by infiltration rather than simply leaving surplus water off the farm was encouraged.

Critchley (1989) investigated the viability of ROH systems and whether one or other system could be recommended as an alternative soil conservation measure to "fanya juu" terracing for the lower hotter LM5 of Kitui District. This is because "fanya juu" terracing is an effective soil conservation technique, but which does not adequately address the problem of moisture shortage in dry seasons.

Four sites were selected. The first site had a high clay content whereas the soils of other sites contained significant quantities of coarse sand. The basic design was to divide each site (of approximately 0.25 - 0.5 ha) into four treatments (a) contour ridges, (b) external catchment (c) a "fanya juu" terraced plot and (d) a control plot with no structures. The plots were intercropped as follows (a) maize and tepary (b) sorghum and cowpeas during the short rains of 1984 (c) millet and tepary (d) sorghum and cowpeas in the long rains of 1985 and (e) sorghum and cowpeas and maize and beans in the long rains of 1985.

The results of three seasons of trials show that there can be crop yield responses to ROH in seasons of below average rainfall.

3. RESEARCH NEEDS AND PRIORITIES

According to the survey of available literature on ROH for crop production there is need for further research on the following.

- (a) Rainwater harvesting potential for crop production not only in the low rainfall areas but also in the humid zones of Kenya.
- (b) The success in rain water harvesting depends not only on the engineering designs and structures, agronomic practices, and labour inputs, but also on such soil moisture release characteristics as water retention or water holding capacities and available water capacities. Hence, there is need to carry out research on the influence of soil physical characteristics of different soil types and their effectiveness under rain water harvesting systems.
- (c) It appears from Smith and Critchley (1983) that the following aspects of rainwater harvesting all require further investigation (a) the spacing on the contour ridges (b) the correct catchment area for the semi-circular bunds and (c) a better understanding of the runoff characteristics of the local soils.
- (d) There is need for research on socio-economic factors that will influence on-farm adoption of contour ridges which have proved most appropriate because of their simple design and wide applicability; and which cannot readily be constructed by the common oxen plough (Critchley, 1989).

4. CONCLUDING REMARKS

1. As we stated at the outset, most of the ROH for crop production has been confined to the efficiency of the engineering and impounding structures and mainly in Baringo and Kitui District.

2. The most successful of the ROH techniques have been identified as "the contour ridge" and the "external catchment" systems.
3. Lack of adequate research on rain water harvesting for crop production has been the major limiting factor to the breakthrough of this technology to the public.

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DISCUSSION

Mrs. M. Mukui said that she had observed that after about two weeks sunshine without rain, crops suffer a lot of water stress and start wilting. This occurs on volcanic soils in the Rift Valley where the soil is underlain at about a metre depth with pumicious material. She pointed out that it is important to know the soil type and its physical characteristics in areas where water harvesting is to be practised

Dr. Mutiso agreed that the effectiveness of water harvesting does depend on soil water retention and release characteristics.

Mrs. D. Mutisya asked what was the effect of land slope on rainwater harvesting especially when using semi-circular bunds.

Dr. Mutiso replied that steeper slopes will lead to greater runoff and bunds will therefore collect more runoff, depending on rainfall characteristics.

Mr. Stephen Burgess commented that there is a need to document who is doing what and what has been done on rainwater harvesting for crop production. The speaker agreed

Mr. J. M. Wanyonyi asked why a ratoon harvest could give a better yield than the first harvest and whether problems of water logging are responsible for poor yields

Dr. Mutiso replied that the ratoon harvests were better than the first harvest because the time the second rains commenced, the roots were partially developed and could utilise the rain for vegetation growth.

He agreed that waterlogging can cause problems but it can be avoided either by using spillways so that excess water can be discharged or by planting on ridges.

2. RAINWATER HARVESTING TECHNOLOGIES

APPROPRIATE TECHNIQUES IN RAINWATER HARVESTING

J. M. Wanyonyi

Kenya Polytechnic, Building and Civil Engineering Department

1. INTRODUCTION

The possible range of techniques and their combination increases when various options and uses for rainwater are considered. Thus rainwater harvesting systems may be classified according to the catchment from which water is being harvested, the type and size of storage used and ultimately the use for the harvested rainwater

In tropical developing countries, these classes may be grouped as follows -

- (i) Natural distribution of floodwater to support crops
- (ii) Intentional use of runoff from microcatchments within the fields to support specific crops e.g fodder, fruits etc.
- (iii) Field irrigation from a storage tank e.g for horticultural crops
- (iv) Kitchen garden irrigation from cisterns
- (v) Livestock watering
- (vi) Water for domestic uses e.g drinking, washing, cooking etc

It is thus for such varied uses of rainwater that appropriate technology is needed for maximum utilization and economical adaptability based on our dynamic environment in the developing countries. It is quite evident that rainwater can be collected from any type of roof and ground surface. Tiled or iron sheet roofs are best as from these the "cleanest water" can be harvested. But considering the very poor regions in our developing countries such roofing materials are rarely affordable hence the need to collect rainwater from thatched roofs or cow dung plastered roofs like the manyattas in parts of Kajiado, Kakamega and many other such parts of Africa and Asia. Whereas tiled roofs are very strong and durable, some roofing materials which are painted with lead based products and asbestos materials are quite a health hazard for harvesting water. Therefore in appropriate technology there is need to identify suitable, available

affordable roofing materials and ground surfaces from which rainwater can be harvested (see Fig.1 below).

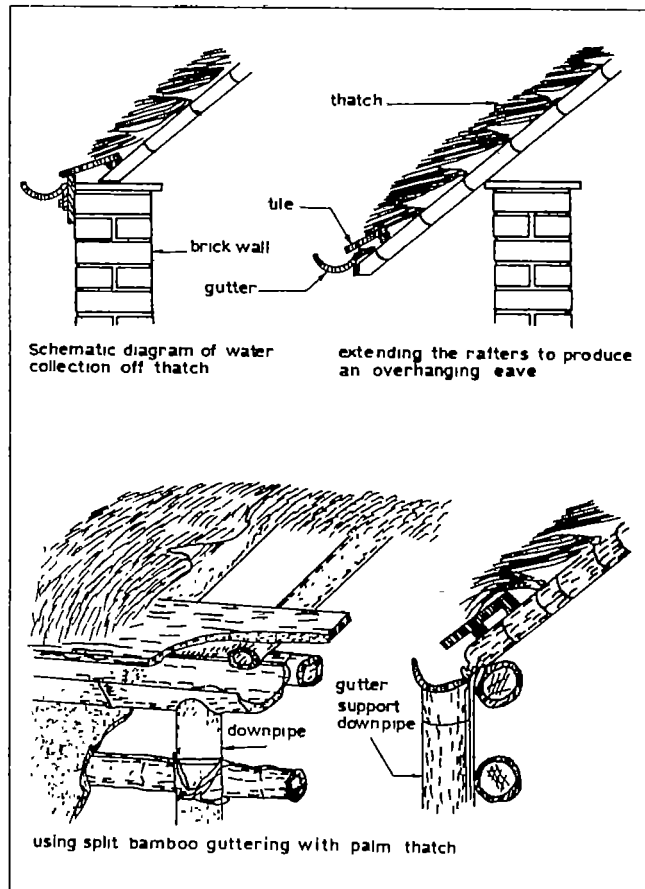


Fig. 1: Gutters for rainwater collection from thatch (Hall 1982)

The roof of a house is designed primarily to provide shelter, privacy and in some cases as a symbol of status. Flat roofs in some places/countries are used for storage and drying clothes and food, and thus when it is used to collect rainwater it becomes a multipurpose structure whose rainwater harvesting requirements in regard to quality must be considered at the earliest onset.

The collection of rainwater from ground-level catchments is considered possible and viable using a surface created for some other purposes such as playing grounds, thrashing floors and tarmacked roads here referred to as "road

catchments". Though most of these catchments have been used for agricultural application only, it is practically possible that the harvest from such ground surfaces can with appropriate techniques be used for any purpose as its collection also encourages soil conservation and improves environment. Examples can be seen along Kimende - Naivasha and Magadi roads.

It is however, necessary to emphasize here that how catchments are used and how rainwater is applied make it clear that rainwater harvesting cannot just be analysed in a purely technical manner as its relevance in any situation depends critically on whether:-

- (1) It is compatible with other economic and domestic activities
- (2) People have the organizational structure necessary to build and maintain the system.
- (3) They have adequate housing units.
- (4) They regard rainwater harvesting as a high priority.
- (5) They have appropriate low cost technology to fit in with their financial budgets.

2. DESIGN CRITERIA: - TECHNICAL AND SOCIAL ASSESSMENT

The essence of appropriate technology is that the equipment and techniques used should be:-

- (1) Relevant to local resources and needs
- (2) Appropriate to patterns of organizational structure and the local environment.

Much of the research done on rainwater collection has been purely of a technical kind but very little if any investigation has been made of the processes by which a successful rainwater harvesting project might be extended, spreading from one village to another over wide areas. It is here argued that such processes not only involve the spread of information, but also depend on village organization, and political will, on the organization of the support services and technical assistance, the availability of manpower and skills, money and material resources etc. If also considered, given the culture of Western tech-

nology which is sometimes hard to recognise and face upto, that our enthusiasm for the ingenuity of a technical device, or its performance under test, can often mislead us into believing that it is more relevant than is really the case. There is a distinct danger that we begin to interpret peoples needs or to study environmental circumstances very selectively, examining only those facets of a problem which the favoured technique might remedy and neglecting other aspects which ought to rule it out For example in semi-arid areas of Africa where pastoralism is the chief means of livelihood, ways of using rainwater are by means of excavated underground tanks (cistern), small dams and natural water holes. But in Western Sudan, parts of Ethiopia and Kenya the cisterns are used for collecting rain water for all purposes. In small dams, e.g in Turkana and Kajiado districts livestock usually gains access to the water by walking in at the inflow side, leading to erosion and rapid silting and it is here recommended that animals be watered via suitable drinking troughs (see Fig.2.1 and 2 2)

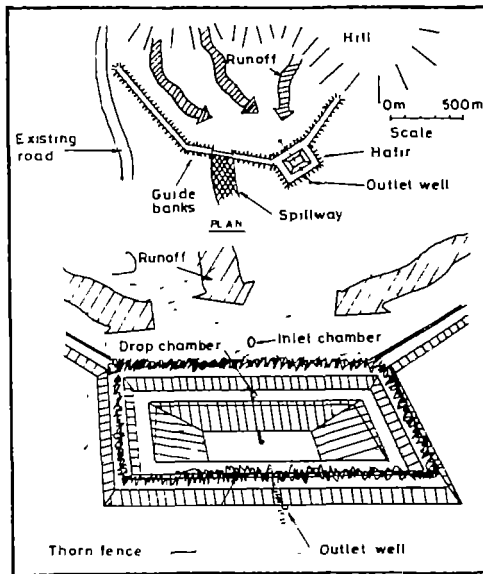


Fig 2.1. Perspective view of a Somali hafir

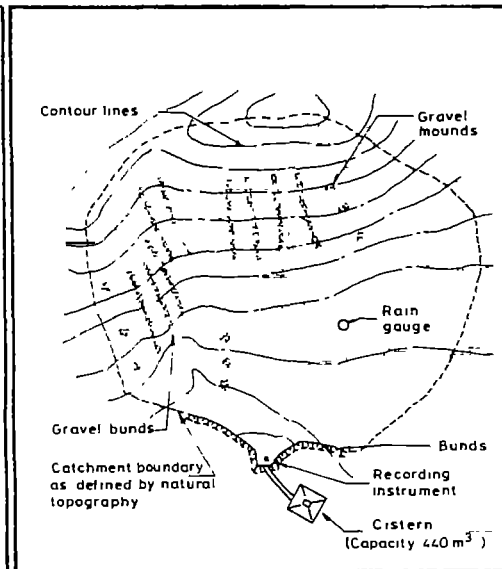


Fig. 2.2: Plan showing the location of an excavated cistern in relation to its catchment area

Technical assessment begins by seeking formal rainfall records from weather stations near the project area, though frequently the figures obtained are unreliable or will come from places that seem unrepresentative of the project

site. Besides this, the technical assistance methodologies of many agencies tend to be deficient in some of the following ways.

- fully comprehensive packages of help with information, skills, materials and money are rarely developed.
- there is lack of commercial involvement, e.g with builders interested in constructing rainwater systems such as gutters and tanks as a business venture.
- there is inflexibility and lack of dialogue with potential users of rainwater because of over-commitment to one specific technique.
- there may not be sufficient attention to local organization, especially, in relation to maintenance.
- follow-up and monitoring of the completed projects may be neglected

It is in view of this, that in appropriate technology there should be an inventory of local materials, tools, skills, and resources as summarised in Fig 3; "decision tree"

But by contrast the social assessment is concerned with collecting information on the following:-

- existing rainwater catchment practices.
- opinions of local people about the usefulness and quality of water collected from roofs and its priority usage.
- options as to whether shared or individually owned rainwater tanks/dams would be best.
- Views of people interested in acquiring rainwater cisterns as to how much time and money they would wish to spend.

The importance of social assessment is that one can devise rainwater collection equipment based on materials which people know how to use, and that are easier and cheaper to build and maintain.

For the design of microcatchments or runoff farming systems, a considerable amount of hydrological data is needed. However there has been no serious investigation of the potential of runoff farming in many of the developing

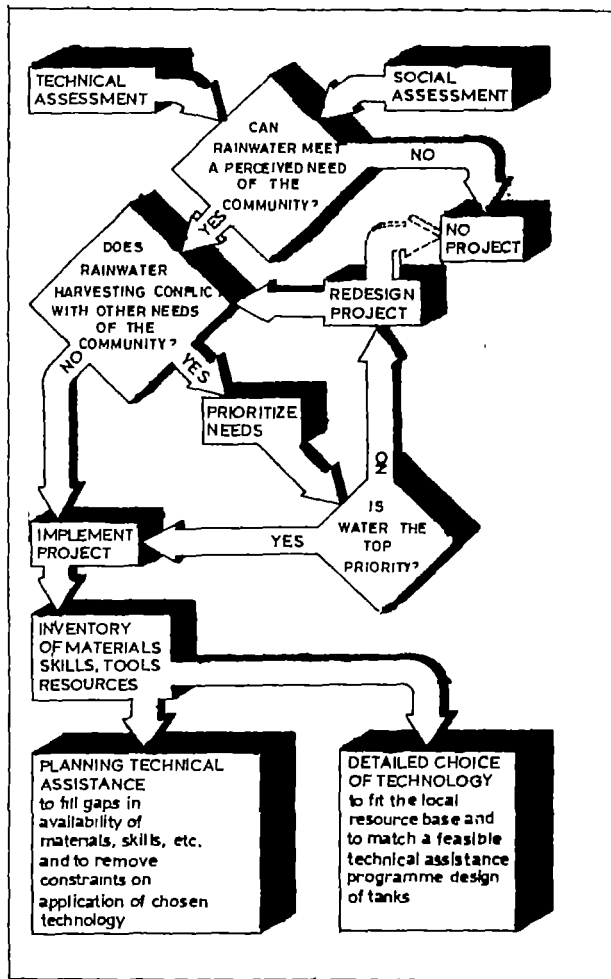


Fig. 3: Decision tree representing successive phases in the planning of a village rainwater collection project.

countries as evident in "Weakness of Agricultural Research" World Bank Report. Runoff farming is but one of the approaches to land and water management which together contribute to a slow recovery of pastoralism, crop production and forestry in drought prone areas, with potential varying with local climates, soil patterns and social organization.

By contrast, when rainwater is to be collected from house roofs, much more approximate data is usually sufficient. However the main question hydrologists

need to ask is HOW BIG SHOULD THE STORAGE TANK OR CISTERN BE?
This leads to three problems namely:

- choosing a tank size that is appropriate in terms of cost, available resources and construction methods
- matching the capacity of the tank to the roof area
- matching the volume of the tank or cistern to the quantities of water required (or consumption rates)

It is appropriate that in poor and developing countries greater weight has to be placed on cost, as it only makes sense to take account of what resources are available i.e existing roofs, local materials and labour. Then one can work out plans for expanding these resources in a way that approximates targeted consumption.

Therefore a simplified calculation to give an estimate of the potential for rainwater collection involves average monthly rainfall records in millimetres and measurement of the roof from which rain is to be collected (plan area).

The volume of water in litres collected monthly = plan area x mean monthly rainfall x runoff coefficients which depend on the type of catchment. (See Table 1). Technically the planning, design and construction of storage tanks is the most interesting and difficult aspect of a rainwater collection system as the constraints affecting its replication include high cost, inadequate guttering, unsuitability of local roofing materials etc. In practice, most rainwater programmes do not tackle major problems of repair and construction of roofs, but install tanks only where roofs are judged as adequate catchment surfaces. In appropriate technology, the criteria influencing the planning and design of tanks for collecting rainwater should include cost; availability of materials; employment opportunities, teachability and the organization of technical assistance; adequate curing of cement mortar and procedures for operation and maintenance schedule of the system.

Table 1 Components of technical assistance programmes for runoff farming. Compare examples cited. Refer to the Yatenga programmes in Burkina Faso (and occasionally to the Gram Gourav Pratisthan or Pani Panchayat programme in Maharashtra, India)

| COMPONENTS | EXAMPLES |
|--|---|
| TECHNOLOGICAL OPTIONS | |
| - options selected by professional fieldworkers and agency staff | e.g microcatchments |
| - options based on local techniques and skills | e.g stone barriers, including their construction and spacing |
| - options for complementary developments | e.g livestock projects or grain banks |
| PRACTICAL ASSISTANCE PACKAGES | |
| - training, including training for women farmers where they exist | e.g training farmers to survey contours (one group of women farmers, the 'widows') |
| - materials and equipment | e.g water tube level supplied (in GGP, India, grants from government and foreign sources negotiated by parent body) |
| - follow-up work | e.g agricultural extension, continued advocacy of tree-planting |
| ORGANIZATION AND INSTITUTIONAL DEVELOPMENT | |
| - village-level institutions and organization | e.g potential for mutual help, co-ops. development of female versus male roles (in GGP, India, 30-40 family groups of irrigators) |
| - parent organizations giving support to village-level groups, making contact with banks, government, etc. | e.g local voluntary agencies (in GGP, Pani Panchayat meetings linking local groups) |
| - government institutions and development agencies | e.g agriculture extension services, government irrigation departments |

Biggs et al 1984

Procedure for building a 9 cubic metres tank of the type developed at the Friends' Training Centre, Hlekweni, Zimbabwe

1. **The formwork** needed to build this tank can be used repeatedly for construction of many tanks. It is made from sheets of corrugated iron curved to a radius of 1.25m and is in four sections, each quarter of a circle in plan, and equal to the full height of the tank. Each section has angle iron riveted to the vertical edges. When the formwork is assembled, the angle iron flanges face up to one another and have holes which allow them to be bolted together through a wooden wedge (Diagram 1).

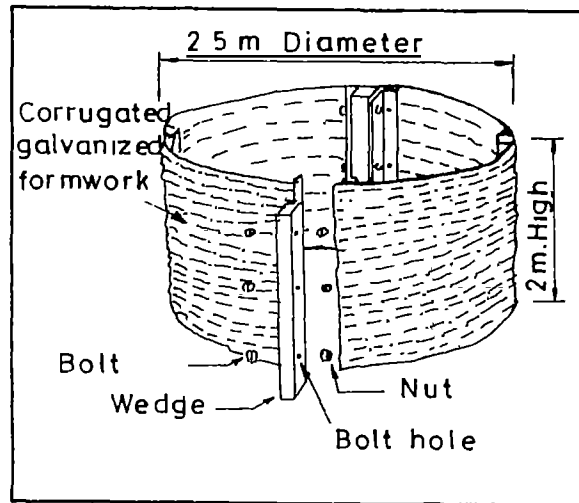


Diagram 1

2. **A circular foundation** 2.8m in diameter is dug out on site and a concrete floor 80mm thick is laid. A 20mm bore pipe bent to a U-curve is concreted into the floor in such a position that one end will project upwards in the finished tank 80mm above the floor and the other end will be outside and can be fitted with a tap.

3. **Erection of the formwork** follows when the floor slab has hardened. After oiling the formwork, wire netting of 50mm mesh is wrapped round it and tucked

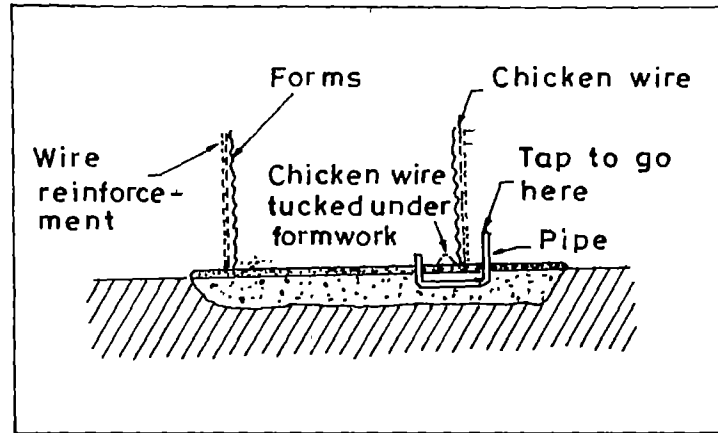


DIAGRAM 2

under it at the bottom (Diagram 2). Then a length of 2.5mm plain wire is pulled round each corrugation and the ends are twisted together until the wire is taut. (Two wires are used in the four bottom corrugations and in the topmost one.)

4. Plastering of the outside then begins. first with a thin layer of 1:3 cement/sand, then two hours later with a second layer to a depth of 15mm. This should be finished smooth with a float, entirely hiding the corrugations.

5. The formwork is unbolted some 48 hours after the second plastering. Ladders used for climbing into the tank are leaned against the house, not against the incomplete tank. An overflow pipe with mosquito screen on its inner end is built into the top of the tank wall. Then a 50mm layer of concrete is laid on the floor.

6. The inside walls are plastered once the floor has set. Two layers of 1:3 cement/sand are applied to fill up the corrugations. The inside walls and floor are finished off with a thick cement slurry to render the tank water-tight.

7. Curing. Water to a depth of 50mm is poured in and the walls are periodically moistened or otherwise kept wet for seven days.

A SCHEDULE OF OPERATION AND MAINTENANCE TASKS FOR CONCRETE AND FERROCEMENT RAINWATER TANKS AND ASSOCIATED ROOFS AND GUTTERS. (IWACO, 1982 - CONSIDERABLY MODIFIED.)

TASKS NEEDING FREQUENT ATTENTION FROM HOUSEHOLDERS

1. Roof surfaces and gutters to be kept free of Bird droppings. Gutters and inflow filters must be regularly cleared of leaves and other rubbish.
2. The mosquito net on the overflow pipe should be checked regularly, and renewed if necessary.
3. Unless there is some automatic means of diverting the first flush of water in a storm away from the tank, the inflow pipe should be disconnected from the tank during dry periods. Then 15-20 minutes after the rain begins, it can be moved back into position so that water flows into the tank.
4. The water level in the tank may be measured once a week using a graduated stick (which should be kept in a clean place and not used for any other purpose). During dry periods, the drop in water level should correspond approximately with consumption. If this is not the case, the tank is leaking, and wet spots on its walls should be carefully looked for.

ANNUAL OR INFREQUENT TASKS FOR WHICH TECHNICAL ASSISTANCE MAY BE REQUIRED

1. At the end of the dry season when the tank is empty, any leaks that have been noticed should be repaired. Where there have been wet spots on the walls, a cement/water mixture is applied on the inside and finished off with a layer of plaster. If there has been evidence of leakage but no wet spots have been discovered on the walls, the floor should be treated with a cement/water mixture and then finished off with a layer of plaster.
2. The roof surface, gutters, supporting brackets and inflow pipes need to be checked and repaired if necessary.
3. If a sand filter is incorporated, the filter sand should be washed with clean water or renewed. Other types of strainer, filter or screen must be checked and repaired as necessary.

4. The mosquito net on the overflow pipe should be checked and if necessary renewed.

5. Removal of deposits from the bottom of the tank is periodically necessary. Depending on local conditions, this may be desirable annually (IWACO 1982) or only once in 3-5 years.

6. After repairs have been carried out inside the tank, after deposits have been cleaned out and after the new tank has been completed, the interior should be scrubbed down with a solution of one of the following: 3 parts vinegar to one part of water, or 1 kg baking powder to 9 litres of water or a quarter cup (75ml) of 5% chlorine bleach to 45 litres of water. After scrubbing, the tank should be left for 36 hours and finally washed down with clean water.

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DISCUSSION

Mrs. Dorothy Mutisya asked whether there were trained people at village level to train rural people on rainwater harvesting methods. Mr. Wanyonyi replied that there are no qualified people to do the training and that is why project components should include the training of the target group or end users on the techniques being introduced. However this should be through dialogue and discussion and not through a forced programme which might involve conflict with local culture or existing principles.

Prof. Thomas asked about the feasibility of collecting rainwater from thatched roofs and was told that thatched roofs are suitable catchments because they have low initial cost, can easily be repaired and maintained and require only locally available material. The quality of water harvesting is acceptable since

the owners know how "clean" it is and it is particularly valuable where the alternative water supply may be 10-20km away and of similar or poorer quality. Vernon Gibberd confirmed that, having used water from a thatched roof for many years, he encountered no problems apart from a slight difference in taste and colour.

Mr. G. Mailu suggested that the quality of water should be considered when trying to improve supplies in rural areas. Mr. Wanyonyi said that the quality of water harvested depends on the surfaces from which it is collected and the uses to which it is put. In an appropriate system the quality should be acceptable and affordable since the prime objective of rainwater harvesting is to save life but not to harm the users whether people, livestock or crops. The first step is to know to what use the water will be put and then to consider the quality requirements rather than the other way round.

Mr. Vernon Gibberd asked the speaker if he had any ideas on how to line hafirs when they are excavated in pervious soils. Mr. Wanyonyi said that seepage can be reduced or avoided by a) applying internal "tanking" using bituminous paints, b) by using Vandex or water proof cement or an ordinary sand cement mortar of 1:1.5 or 1:2 or c) use of a well compacted cavity wall of clay soils plus suitable plaster of water proof cement.

Mr. S. Burgess suggested that water from asbestos cement roofs should not be rejected. In the first place it has uses besides drinking; second, the danger from asbestos is supposed to arise from inhaling the fibres rather than drinking them and thirdly, it should be possible to filter the water. He thought that clear recommendations are needed in view of the extensive use of asbestos cement roofs in urban areas and the need for rainwater collection. Mr. Wanyonyi agreed that the danger from asbestos cement is primarily from inhaling it and that the Factory Act which seeks to protect people from asbestos cement dust recommends the use of asbestos cement for water pipes and storage tanks. He agreed that, if necessary, rainwater can be filtered with sand or metal-filters.

Mrs. Jedidah Ndegwa asked about the role of women in rainwater harvesting and whether they were being given any training. Mr. Wanyonyi replied that women form the most versatile and dynamic target group for the extension of information on rainwater harvesting. As they form over 50% of the population and play the biggest role in water collection, they should be trained and involved in planning, implementation, operation and management of rainwater harvesting systems. There are other target groups such as parent/teachers associations; student bodies, cooperatives, church groups etc but women's groups which are already organised are particularly important.

LOW-COST APPROACH TO RAINWATER HARVESTING: WATER TANK CONSTRUCTION

V. Gibberd
Overseas Development Administration

1. INTRODUCTION

Everyone needs water and on the whole, the more water they have - the better their living standard e.g the water which is free for fruit or vegetable production can improve health and vigour, especially of children.

To make water available to everyone, in the first instance, store it where it falls - next to the homestead. Water is stored more cheaply underground in what is called a HAFIR in the Sudan.

2. CATCHMENTS

Roofs are an obvious source - even water from thatch is useful. It is potable even if it is the colour of weak black tea and tastes organic.

Compounds are a good source if kept fairly clean, especially of human and dog excrement.

Thrashing floors are ideal, though they may be too small.

Roads are a good source but beware of excessive run-off having destructive force when it enters the Hafir; it can damage the lining. In places where the soil is structureless sand, the catchment area may need to be sealed with a cement mortar screed, asphalt or black polythene sheeting to generate run-off.

3. HAFIR LINING

Soils are almost always too porous to permit storage of water for long periods in an unlined Hafir. Vertisols (Black Cotton Soils) are sufficiently impervious.

The lining constitutes perhaps 95% of the total bought-in costs and so, if water for all is to be our goal, it must be very cheap and easy (i.e not requiring a paid worker) to install as the majority of water-less people are very poor and becoming POORER. The otherwise excellent ferro-cement linings are not affordable by such poor people.

Promising lines in the low-cost hafir linings are likely to be based on synthetic membranes (PVC, Polythene, Butyl) and clay. A multiple sandwich of 150 micron (0.15 mm) clear polythene sheet and thin layers of black clay are the most promising combination for reliability, ease of installation and cheapness, but they are laborious and susceptible to problems (see below) PVC and butyl may be used by themselves but the former degrades and should therefore be protected, as should the mud-polythene sandwich, by a revetment of stonework or low-cost ferro-cement. A successful example of the latter is 60 cm long, 8 cm diameter polythene tubes filled with a 1:14 mix of cement and ungraded sand, laid in a simple bond and skewered together with short lengths of 3 mm wire.

4. COVER

Covering is necessary because annual evaporation rates commonly reach 2 metres while 2 metres is the maximum convenient depth for manual excavation. But, uncovered water exposed to direct sunlight breeds fewer mosquitoes and becomes safer to drink through the sterilising effect of the sunlight. A cheap method consists of crude matting made from sisal string and sorghum or millet stalks tied down on strands of plain wire strained across the hafir. A better one would be a simple wood and plastic, or wood and iron, floating structure

5. SAFETY

Children (and drunkards) can fall into hafirs and drown. Also farm livestock Hafirs must be fenced securely, e.g with a dense bush fence and secure gate.

6. TERMITES

Termites can eat polythene and PVC. They can be effectively deterred by an application of say, dieldrin on the sides and floor of the excavation before the lining is done. Because seepage will be outward, there should be no risk of contamination of the water. However, Dieldrin is likely to be phased out as a noxious chemical for replacement by a more environmentally friendly product. This is not yet available; does KIOF have a suggestion? Could salt be used?

7. RODENTS

These can badly damage PVC and Butyl linings. Keep cats and encourage owls.

8. ROOTS

Roots can penetrate the mud-polythene sandwich lining. Either remove all trees and shrubs in 100 m radius (ruining the homestead) or try applying a liberal coating of old engine oil to the sides and floor of the excavation before lining

9. QUALITY OF WATER

See above regarding the value of cover and sunlight. The pathogen load of water gradually reduces over time, even in shade, so water may be safe within six weeks of the last inflow. Water can further be improved by either using a sand filter or a charcoal filter.

10. SILT

The last ten metres of run-in should be level and wide and grassed if possible to encourage deposition of most of the silt load. Add a small transverse trench if necessary.

11. MOSQUITOES

Breeding of mosquitoes can be prevented by weekly application of a few drops of paraffin or diesel to the water surface.

DISCUSSION

Mr John Karingi asked how surface contamination and algal growth is controlled in the ground water storage tanks especially if the water is going to be used for drinking. Mr Vernon Gibberd replied that it was necessary to teach people not to defaecate in the catchment as human faecal matter is the main contaminant. Hence the construction of toilets should be encouraged. His experience with large butyl lined tanks was that algal growth did not occur though he could not say what inhibits it.

Mr J Tinkoi asked how siltation of hafirs is controlled and how silt is removed once it has been deposited. Mr Gibberd replied that the slope area at the entrance to the hafir should be less than 1%; the more level it is the better, because water spreads out and slows down and has a chance to drop its silt load. In addition, a small transverse trench will act as a suitable trap. If the area is grassed the effect is better still. Fruit trees can be established in the area to use the water that soaks in but make sure their roots do not interfere with the hafir lining.

Eric Nissen-Petersen asked how one should choose the appropriate technology for a particular place. Mr Gibberd said that experience combined with intuition could help in 'short-listing' the options. Experience of living in the area is an advantage. Peter Morgan commented that a new technology should be tried as a demonstration for a year or two and then evaluated for acceptability.

Mr Kungu Kimani asked whether a hafir development had led to an increase in mosquitoes and how this could be controlled. Mr Gibberd replied that adding a few drops of kerosene or diesel every ten days or so was successful in preventing mosquitoes from breeding. Mr Kimani also asked whether the low cost linings described had been used for livestock water supply and what type of draw-off facilities were used. The speaker answered in the affirmative and said that hand pumps can be used to deliver the water to a trough a few metres away.

Mrs H Mukui asked what was the adoption rate of the low cost tank technique and whether it had been taken up by communities in Botswana. Mr Gibberd replied that the designs illustrated were not really ready for introduction as part of a major extension effort especially as labour requirements might be unacceptably high for a traditionally pastoral people. As Botswana became more prosperous money went into higher cost solutions such as ferrocement tanks but a few individuals had successfully constructed such hafirs and the Ministry of Agriculture promoted them with some success.

In answer to a question about how to stop siltation of underground tanks, John Mbugua commented that grassing the approach channel proved very effective and, if in addition there is a series of two or three silt traps, the silt can be removed and used for a small vegetable garden near the tank.

Mr G Mailu raised the question of water quality and Mr Gibberd said that the first priority is to get a dependable supply of water and the second priority is to clean it. In answer to a question from Mr Olouch about rusty roofs affecting water quality, Mr Gibberd replied that the problem is not serious as iron is an essential nutrient. However, rusty water can dye white clothes orange.

THE WATER TANK THAT OUTLASTS ALL OTHERS

P. K. Mani
Livewell Industries

1. INTRODUCTION:

Whether it is a hotel, a hospital, factory, private home, school or any other institution, no building is complete without a permanent water storage tank. Because of the importance of water to people, animals and plants, the water tank for any building should be as permanent as the building constructed with stone on strong foundation.

Livewell Industries use no corrodable materials while constructing the water tank. Our water tank should therefore outlast steel or steel reinforced structures by many years.

The semi sheet and paving product described here-in are made of the same concrete and technology and like water tanks are made to stay.

Livewell Industries produces special interlocking blocks for the construction of water storage tanks.

Stocks are held at the Company's Kikuyu yard for the immediate construction of the water tanks to whoever needs them. The company trained personnel construct tanks within the shortest time possible, sometimes within a week after order confirmation.

2. BENEFITS OF INSTALLING LIVEWELL WATER STORAGE TANKS:

2.1 Materials Used on Walls

The interlocking concrete blocks produced by Livewell Industries are made of locally available materials like cement, sand and aggregate. Most of them do not require steel reinforcement and therefore the finished products are cheap compared with tanks made of other materials like plastic and steel.

For the different sizes of water storage tanks, blocks are made with correct curvature for say 2, 3, 4 and 5 metres internal diameters all of which incorporate dove-tail tongue and groove interlocking ends which provide an effective interlocking bond.

The bigger tank of say 6 metres internal diameter and over will require steel reinforcement and cost a little bit more

2.2 The Roof

The roof is made of specially vibrated panels which weigh less than 130 kgs per square metre. By comparison a solid slab system weighs two to three times as much.

It contains no degradable material such as wood or exposed ironwork, and is designed for permanence and protecting water.

There are no gaps to let in insects or dust. The entry points can be locked to prevent illegal access. The roof excludes sunlight so as to prevent growth of algae

2.3 Clean Water Container

Whilst many tanks contaminate water after a period of storage, this non-reinforced concrete design will not pollute drinking water.

Location can be either above or below ground. If below ground they are capable of utilising low pressure in the supply main.

Where the water pressure is high, tanks are raised up to say one metre and over above ground level. Water coming from these tanks flows freely and can even be used for irrigation purposes.

POPULAR SIZES FOR PRIVATE HOMES, WAREHOUSES AND OTHER INSTITUTIONS

| NO OF COURSES | INTERNAL DIA. IN 'M' | HEIGHT | GALLONS | LITRES | PRICE GUIDE IN KShs. |
|---------------|----------------------|--------|---------|--------|----------------------|
| 8 | 2 | 2 | 1,517 | 6,888 | 23,000 |
| 10 | 2 | 2.4 | 1,863 | 8,459 | 26,000 |
| 12 | 2 | 2.9 | 2,209 | 10,029 | 28,000 |
| 14 | 2 | 3.4 | 2,555 | 11,600 | 32,000 |
| 8 | 3 | 2 | 3,563 | 16,178 | 34,000 |
| 10 | 3 | 2.4 | 4,342 | 19,712 | 37,000 |
| 8 | 4 | 2 | 6,601 | 29,970 | 48,000 |

Larger sizes are produced on request. Prices are subject to change if cement cost goes up

3. RAIN WATER HARVESTING THROUGH FOOT PATHS AND PATIOS

A patio is the natural link between a home and a garden. If it is paved with slabs it becomes an ideal place to collect water, relax and entertain. It also becomes an excellent play area for the children. Paved paths, patios and other paved areas look stylish and special. The value of paved property is high.

Water collected from paved land can be directed into an underground Livewell water storage tank for domestic use and farming.

Livewell Industries produce Non-slip paving slabs for use in garden and over all improvement of the home (Fig 1).

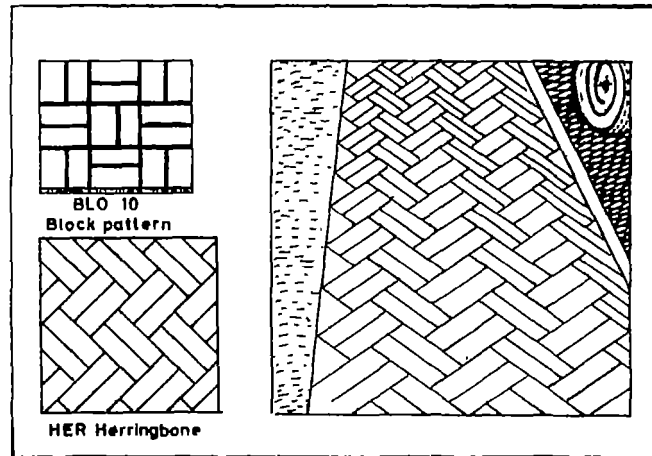


Fig. 1: Slabs for foot paths and patios

4 LIVEWELL SEMI-SHEETS

Livewell semi-sheets fill the gap between ordinary roof tiles and steel sheets. They are larger than tiles but smaller than corrugated sheets. One semi-sheet is easily handled by one man. Four (4) semi-sheets will cover one (1) square metre of roof surface.

Semi-sheets are most comfortable to live under. No health risk and collected water is safe to drink. Semi-sheets can maintain cooler temperatures than corrugated iron sheets and are quiet during rainstorms.

The semi-sheet costs much less compared to asbestos and steel and lasts much longer (just like tiles).

The semi-sheets can be used for all roofing situations and are excellent for large buildings like churches, warehouses and schools.

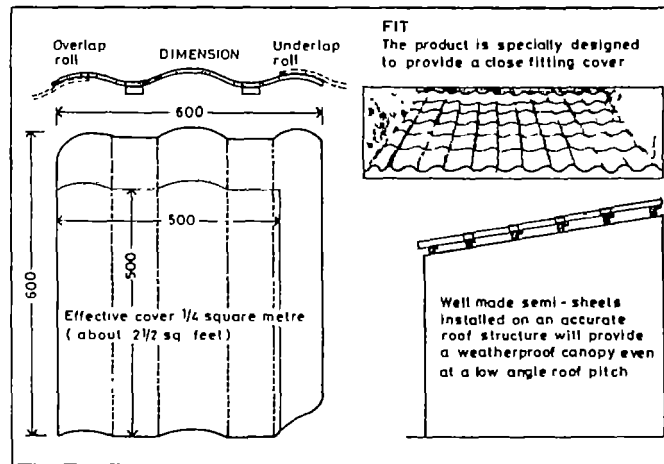


Fig. 2: The semi-sheet for roofs

DISCUSSION

Prof. Thomas asked whether the interlocking blocks can be fabricated anywhere or whether they have to be fabricated at Kikuyu and transported to the site. Mr. Mani replied that they can be fabricated anywhere if there is a sufficient market.

Jane Gachogo asked about the training of artisans and was told that this can be done at the Kikuyu yard at a cost of Shs.6,000 for two weeks which includes accommodation and meals.

Mr. Oluoch asked about extraction of water from ground water tanks and was told that a booster pump, hand pump or bucket and rope could be used.

Mr. Chepkole asked if any special sand was used and was told that suitable sand could be obtained from Machakos, Kajiado or Naivasha.

Mr. Badloe commented that the method of construction appears to leave out community participation.

Mr. J. Tinkoi asked about the strength of the blocks and whether they could support a concrete roof instead of concrete panels. He was told that mechanical vibration used in the fabrication of the blocks makes them very strong.

Mr. Karingi asked whether such tanks could be afforded in rural areas and was told that they were durable and the cost is minimal if spread over the life of the tank.

FERROCEMENT TANKS FOR ROOF WATER CATCHMENT

L. A. Vijselaar
Kilifi Water and Sanitation project, MOWD/GTZ

ABSTRACT

The introduction of ferro-cement construction to be used as water containers for the rain water harvesting from roofs in the Hinterland of Bamba, Kilifi District. Rain water roof catchments are constructed at schools as demonstration to show the people that clean water can be collected from roofs. There is resistance to the acceptance of the system. Their main efforts are in collection of water and food as the area is marginal. Therefore pans are constructed in various areas to alleviate the immediate water collection problem.

1. INTRODUCTION

Kilifi Water and Sanitation Project (KIWASAP) is a community based project implemented under the Ministry of Water Development with funding from the German Government, the said funds are administered through GTZ (German Technical Cooperation). KIWASAP was initiated in 1985 and its first phase took off in 1988 with the intention of extending to a larger part of Kilifi District. The Hinterland of Kilifi District, namely Bamba is a main target area (see Fig.1). Water is an entry point into the communities and is part of a Hygiene and Sanitation programme. The hygiene education is important to ensure the understanding of water and sanitation. Water is the main problem in the area, especially in the dry season when women have to spend a lot of time on collecting water.

A Sample Survey to Establish Basic Parameters in the project area was done for KIWASAP by Sam Sekyembe of Crossland Management Consultants the results being as presented in Tables 1, 2, and 3 shows the percentage of the population involved in water collection and gives the average age. Table 1 indicates that the able bodied women are mostly occupied with water collection as it is a heavy job. Table 2 indicates the distances involved. Time was more difficult to check but distances were checked on the ground. Table 3 shows from which sources the water is mainly collected. In Table 1, 2 and 3 is included an area called Kapecha which is a target area of the project located 12km south of Kilifi town.

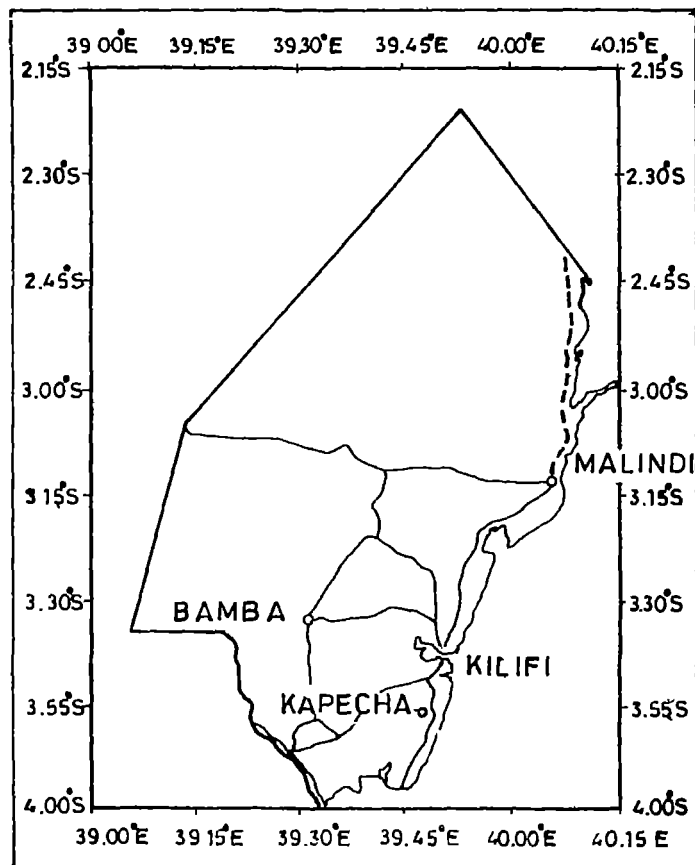


Fig 1. Map of Kilifi District. Location of Bamba and Kapecha

Table 1 Percentage of population involved in water fetching activities

| Project Area | Percentage of Population | Average age |
|--------------|--------------------------|-------------|
| Kapecha 1 | 30.0 % | 24.5 |
| Kapecha 2 | 30.0 % | 26.6 |
| Bamba | 25.5 % | 23.6 |

Table 2 Distances travelled per day by each water fetcher during the longest dry season

| Project area | Mean distance to & fro (km) | Turns (trips) per day | Probable distance travelled (km) |
|--------------|-----------------------------|-----------------------|----------------------------------|
| Kapecha 1 | 4.2 | 2 | 8.4 |
| Kapecha 2 | 7.9 | 2 | 15.8 |
| Bamba | 13.5 | 2 | 27.0 |

Table 3 Types of sources of water available in the Project Area

| Type of water source | Bamba | |
|----------------------|-----------------|-----------------|
| | Dry Season in % | Wet Season in % |
| Shallow well | 20.5 | 12.2 |
| Puddle | 18.2 | 41.5 |
| Pan/dam | 29.5 | 41.5 |
| Tap | 2.3 | 0.0 |
| Stream | 29.5 | 4.9 |

The tables show how important water is and how much time is likely to be spent on water fetching, if one looks at the distances travelled, from unsafe water sources. Roof catchments could improve the water collection to a certain extent. Men do not feel the problem as the women do but by making them aware they might wish to make changes in the future. By minimizing the walking distance more time can be used on other activities.

As part of the programme to alleviate water problem more pans are being constructed with a certain input from the community. The roof catchment is being done to show the possibility of getting clean and relatively safe water with the help of a roof which every person has, even if the roof is thatched. Ferro-cement tanks cannot help the population much as they cannot afford them. The use of the roofs as a source of water could augment the water collected from pans during the rainy season and other water containers could be used. By using the roof one way or the other they could make improvement in their circumstances. As part of the training of teachers (who in their turn will teach their pupils) two toilets are built on each school compound of the targeted schools. A roof water catchment is provided in case a suitable roof is found.

2. RAINFALL FIGURES & SIZE OF TANK

The summary of rainfall figures for Bamba town are presented in Table 4, if one goes into the plains beyond Bamba then the rainfall could be lower but no reliable figures are available.

Table 4 Summary of Rainfall Data

| Month | J | F | M | A | M | J | J | A | S | O | N | D | |
|-------|-------|-------|-------|-------|-------|------|------|-------|------|-------|-------|-------|-------|
| Mean | 25.3 | 12.9 | 68.3 | 77.0 | 91.2 | 38.7 | 27.5 | 31.7 | 25.8 | 39.9 | 81.8 | 72.9 | 592.9 |
| Min | 0.0 | 0.0 | 0.0 | 7.7 | 14.8 | 3.6 | 2.3 | 3.9 | 2.1 | 1.4 | 23.6 | 21.2 | 354.8 |
| Max | 121.3 | 100.4 | 290.5 | 140.4 | 266.9 | 94.9 | 63.8 | 119.2 | 69.3 | 208.7 | 175.2 | 129.1 | 968.5 |

The sizing of the tank was based on the plan of a standard size workshop built for all the schools, which measure approximately 7x20 metres; with a roof collection factor of 0.8 and with the mean rainfall figures of Table 4 gives the cumulative result in Fig 2. (The system used is explained in detail in Rainwater harvesting by Pacey and Cullis, 1986.) and gives the size of the tank of approximately 12000 litres for a constant consumption. We took as a standard,

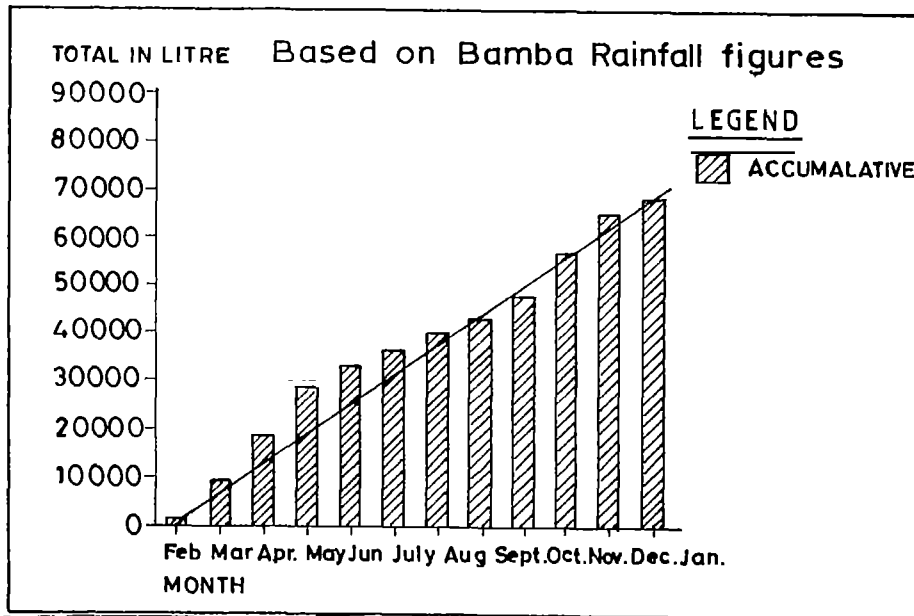


Fig. 2: Sizing of Tank on 7 x 20m. roof

a 15000 litre tank as it is easy to build and gives extra storage. From the consumption point of view there are more consumers than collection possibilities.

3. TRAINING AND COMMUNITY INVOLVEMENT (SUSTAINABILITY)

The training in making ferro-cement tanks was formerly done as an on-the-job-training by previously trained artisans from Lamu District. The present approach is to get several artisans from the target area; train them theoretically in making ferro-cement tanks and guttering before constructing a tank of 15000 litre. The sizes used in training are 1200 and 5000 litre to get them used to various sizes of tanks. If one introduces them to one size they tend to believe that is how it should always be. Therefore it is essential to give them experience in different tank sizes. To be able to teach the artisans effectively one has to approach all work in great detail.

The training gives the artisans extra skills that they might use locally or they might relocate to better positions in Kilifi District. This is a problem we had before when training male members in pipeline maintenance. Based on a one week course for 10 people they all found jobs elsewhere and are not in that specific area anymore. They earn money to support their families who are still in the area. Economically it is all right but counter productive for the project. As a result of that experience we are now training women in the communities to repair their pipeline, with success. We might use this system as well for the ferro-cement tank construction if required.

Simplicity of design and construction is important so that it can be replicated easily and reliably. The dissemination of the information is done through training, on-the-job training and introduction to the system by making demonstrations at schools, chief's offices and other public buildings. A pamphlet in Kiswahili was made for the community to introduce ferro-cement tank technology and especially roof catchments in Kilifi District.

Training includes: materials to be used, construction techniques, how to deal with leaks and the operation and maintenance of the tanks to its smallest component. Even the use of the tap needs to be explained.

During construction at schools we try to involve the parents (members of the community) as much as possible and they are expected to do the unskilled work. The mobilisation is not difficult but to explain to them what the use of the tank is and the advantages present a bigger problem.

The trainers and employees need to be trained in community skills. The skill of talking to the community cannot be acquired over night and needs to be done over a considerable period to get the required effect.

4. COMPONENTS AND CONSTRUCTION OF THE FERRO-CEMENT TANK

Roof - Corrugated iron roof sheets or fibre-cement roof tiles

Gutters - Aluminium to minimise rusting problems and therefore minimise replacement; they are V-shaped and are fixed by wire on the roof so that no fascia boards need to be used.

Tank inlet - Fixed only with mosquito wire as strainer, in future settling boxes with strainers will be built.

Base - Required so as to be able to get the water out of the tank by gravity and to be able to get all the water out without placing the tap below ground level.

Tank outlet - No washout provided to minimise leakage, cleaning will have to take place via a manhole on top. Pipe out of tank, gate valve and then tap. Gate valve is required as the locally available taps break fast. The place for water collection is such that one is able to collect water with the help of a 10 litre bucket. The use of 20 litre containers is discouraged, to minimise water misuse.

Drainage - Soakaway, so that the area around the tank does not become messy and therefore a place from which diseases can be transmitted from. The users are trained in water use and that is not easy as a school. Carelessness is difficult to deal with. Also collection of the water by individuals of the community or teachers is difficult to curb. The positive side is that the persons using the water recognise that clean water is an advantage.

TANK ITSELF

Table 5 Materials required for the tanks:

| | 5000 litre | 15000 litre |
|------------------------------|------------|-------------|
| Weld Mesh, 7' x 14', 8 gauge | 4 | 7 |
| Chicken wire 1/2" per roll | 2 | 3 |
| Binding wire in kg | 10 | 20 |
| Sand - well graded-in tons | 1 | 2 |
| Cement | 10 | 21 |
| Labour in W/Days | 20 | 22 |

Piece of threaded G1-pipe with gate valve and tap, and a piece of metal welded on the place where it fits in the tank to minimise leakage. A 2" or 3" pipe is needed as overflow.

Tools required: The normal tools of trade one can expect a brick layer to have. Cutting of the weld mesh could be done with the use of chisel and hammer or hacksaw blade; diameter of tank is then set out on ground, bottom part and top part is cut; full height 7' of weld mesh to be used for side. Depending on roof height one could shorten the weld mesh if needed, but it is not recommended.

A cage is then produced that can be worked on easily. In the top a manhole is made through which one can enter the tank.

First chicken wire is placed inside, then the outside is wired. It is important that the chicken wire is tightly connected to the weld mesh.

We used to place two layers of chicken wire in and outside. Nowadays we only place one layer of chicken wire inside and outside to minimise the costs, the whole tank could be transported (after being plastered and cured) but we found that transportation of 15000 litre tanks is never done. Normally the tanks are made in situ.

The overflow must be made before the plastering starts. The overflow needs to be made in such a way that no foreign matter can be introduced through the inlet. Witchcraft is still practised in the area and people fear possible misuse of the tanks.

Once the cage is ready and the foundation is finished the cage can be placed on top before the concrete is settled and therefore incorporated with the base. The next day the sides can be plastered. The water pipe is nowadays made through the foundation, formerly it was done through the wall. The 1200 litre and the 5000 litre tanks still have the pipe through the wall.

Plastering - One artisan stands inside and a second one on the outside who pushes the mortar through. The inside artisan spreads it and adds mortar on his side as well so that a layer of 5cm is placed. One makes a smooth finish as according to the artisans' abilities.

The breeding of mosquitoes in the tanks needs to be avoided by placing mosquito wire at inlet and outlets as required.

The roof of the tank is made the day after the walls are finished.



Photograph 1: 5000 Litre Tank being Plastered

5. PROBLEMS AND POSSIBLE SOLUTIONS

Batches of mortar: it is difficult to make the artisans understand the requirement that the sand-cement mix needs to be used within 45 minutes.

Curling - during a water shortage it is difficult to make the community to understand that it is vital to keep the tank wet. Even if there is no water shortage, to make them keep the tank wet is difficult enough and needs close supervision.

Maintenance - training of the correct persons involved is essential and follow up from time to time is required.

Community - to inform them about rain water catchment and to induce them to participate is a challenging job and one should take time to inform them. For technicians to take the time to talk to the community needs training over a period of time. It is easier to train technicians in simple community approach than to teach a community worker technical work.

Sand - to get well graded sand in the Bamba area was initially difficult and it took a few months to locate a source. Another problem is that no transport is available in the area and that makes it difficult for the community to get the required items on site.

Taps and gutters - the materials for the gutters etc are not available in Bamba and have to be collected either from Kilifi or Mombasa. The transport creates extra expense for the interested persons to make tanks.

6. ALTERNATIVES AND COSTS

To make the construction cheaper we are experimenting with stabilised soil blocks with chicken wire and mortar on the inside for 5000 litre tanks.

Costing - the price of even a small tank is presently out of range for most of the Bamba community. We will have to formulate alternatives. We are going to introduce the tank also along the coastal strip where the technology of rain water harvesting is not unknown and the communities are better off financially.

7. CONCLUSION

The project will disseminate the techniques of roof catchment, gutter making and ferro-cement tank construction further within the targeted areas of Kilifi District. Based on the experience gained, a training manual for the area is under preparation with handouts in English/Kiswahili for the participants.

Further approach to rain water harvesting will have to be determined and added to the project budget for the next phase from 1994 - 1996. The present phase being an introduction of possibilities to the public and to train the employees to become able trainers who can work with the community.

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DISCUSSION

Dr. F. N. Gichuki commented that community expectations and government policies seem to be major constraints to the adoption of low cost technology. The ambitious programme of the Ministry of Water Development to supply water to the community by the year 2000 and the heavy reliance on donor supported water supply projects are prime examples. What the MOWD, donor agencies and rural development agencies doing to alleviate these constraints by promoting self reliance.

Mr. Vijselaar replied that Government and donors have to become more aware of what the communities would like and can afford. This is a time consuming dialogue between the givers and possible recipients without making prior assumptions about what is needed or what is sustainable. Government and donors do not like to give money if there is no Goal Orientated Project Planning and/or Workplan. Because of the question of sustainability, Government and donors have started reformulating projects. Even the Ministry of Manpower Development is planning to train their technicians in community participation so that the peoples' voice is heard. So the short time frame of pre-feasibility studies for community projects will have to be changed. Introducing greater flexibility and transparency will depend on Government/donor agreement but the persons involved will have to ensure that the various participants are aware of the issues.

Mr. Kung'u Kimani queried how the cost of water from roof tanks compared with that from other sources such as streams or shallow wells. Mr. Vijselaar pointed out that roofs provide clean water whereas the water from many other sources is not safe. Mr. Kimani questioned the adequacy of the water from roof catchments. Mr. Vijselaar agreed that the water collected would not be sufficient for all the pupils throughout the year but it would be beneficial.

Mrs. Omuodo asked why only artisans were trained and was told that artisans were trained in the initial stages but other community members, including women, could be trained later. She also asked the cost of 5,000 and 15,000 litre tanks and was told that the cost (August 1992) for a 5,000 litre tank was KSh.8,400 and the cost of a 15,000 litre tank was 19,390. These figures exclude the cost of transporting the reinforcing and are for a tank without base.

Dr. F. N. Gichuki asked what the demand was for roof catchment tanks, what the community could afford and whether loans could be provided. Mr. Vijselaar said that it was too early to assess demand as the system adopted is still new. The tanks are beyond the means of most of the inhabitants but there are a few individuals such as teachers and traders who may be able to afford them. The possibility of loans needs to be explored.

Mr. Oluoch asked how the form work was done and was told that there was no need for form work. He also asked how long mortar would be held before it sets and was told that it is applied immediately and that the weld mesh and chicken wire hold it while setting. The important factor is the ratio of water to cement which should be 0.4.

Mr. John Mbugua asked if the school programme was the ultimate goal or whether this was just a way of entry into the community. He was told that efforts

are being made to make the community aware of the value of rainwater harvesting.

Mrs. Hilda Mukui asked about the durability of the tanks and was told that these were to last 30 - 50 years depending on the quality of workmanship which depends greatly on maintaining the correct water content of the mortar.

Jane Gathogo asked about the curing of the tanks and was told that polythene was better than guny bags as it was necessary to prevent rain and drying winds. Construction of a 5,000 litre tank takes 16 working days and construction of a 15,000 litre tank takes 20 working days. Normally two artisans are required or one experienced artisan with a helper but plastering is best done with two experienced artisans. After construction, the surfaces should be kept wetted for 1 - 2 weeks.

Mr. Wanyonyi asked why some trained artisans leave the programme and was told that they use the skills they acquire to get better paid work elsewhere. He also asked how the schools were selected and was told that the intention was to provide water tanks for all the schools as part of a programme on hygiene education which includes the construction of VIP latrines.

Mr. Vijselaar was asked about the lack of awareness among the local people and how it could be tackled by social workers and development agents. He said that it was essential to try and inform as many people as possible including councillors, teachers and community leaders. Various subjects should be discussed at the same time and repeated on several occasions.

Mr. Nzainga asked whether the speaker had any experience with uPVC gutters made from splitting sewer pipes into two thus getting two gutters for each pipe. He commented that they can be glued and therefore avoid the problems of leaking joints associated with metal gutters. The bends and tees can also be split and if the pipes are painted they will resist sunlight.

Mr. Vijselaar commented that this had not yet been tried but the type of paint to be used would be important. He said that the use of V-shaped gutters with baffle plates should be recommended.

GHALA CEMENT TANKS

J. W. Njoroge
Kenya Institute of Organic Farming (KIOF)

1. INTRODUCTION

Rain water harvesting is a very important and real need for smallholder farmers who do not have the necessary capital to construct large water tanks and purchase and maintain an engine to pump river or deep well water to the tank.

One of the most practical methods of getting a reasonable container for the harvested rainwater is construction of a Ghala Cement Tank.

There are several methods of making the Ghala tank. Kenya Institute of Organic Farming (KIOF) has adopted the following method. Farmers who construct this type of tank find it durable and economical.

2. MATERIALS:

- i. Long sticks which are easy to intertwine
- ii. Rope for bending the sticks to take shape (ring at top)
- iii. Barbed wire to strengthen. 100 metres
- iv. Hard core for the foundation
- v. Ballast for making the slab/sand 1 load 12 w/barrows
- vi. Old barbed wire or mesh wire for the slab
- vii. Tap and wash out pipe
- viii. 6 supporting posts (wooden)
- ix. 5 ropes for positioning and levelling
- x. Nails for making ladders and scaffolding
- xi. 2 pieces of timber 4" x 2" x 15" each
- xii. 10 bags of cement
- xiii. 4 packets of waterproof cement
- xiv. Red oxide for colouring (or paint) for beauty

3. The semi-sheets can be used for all roofing situations and are excellent for large buildings like churches, warehouses and schools. MAKING THE BASKET: STEP BY STEP

- i. Make a circle on the ground - diameter 7 feet (2.5m)
- ii. Erect stronger sticks at an interval of 18 inches (4.5cm) in slanting manner
- iii. At the base, let the erected sticks be in a circle

- iv. Start intertwining upto 3 feet (1m) put a rope round and pull the upright sticks inwards to make the basket take the shape of a barrel or pot.
- v. The height of the basket is 7 feet (2.5m) and the top ring has a diameter of 3 feet (1m) for the lid.
- vi. Strips of barbed wire are then placed upwards all the way round and others run across round the basket over the sticks to make the sticks firm, ready for plastering.
- vii. Make the foundation pit diameter 8 feet (2.75m) depth 1 foot (30cm) and fill with hard core.
- viii. Hammer in the hardcore and mix concrete with cement to make the bottom slab.
- ix. When the slab is still wet, bring the basket and place it and set it properly.
- x. Plant supporting posts all round and tie the basket firmly with the ropes when it is firm and upright put concrete along the base.
- xi. Put two strong posts for the top ladder and hammer in the 4" x 2" timber above the basket.
- xii. Make a connection ladder and portable ladder and wait for the second day.
- xiii. Dress the basket with secateurs or hand saw, then plaster internally and externally, put tap and wash out pipe about 6 inches (15cm) from the bottom.
- xiv. On the third day put a coat of sand and cement + water proof cement.
- xv. Fourth day put cement and water proof only ('nilo') internally and smoothen the outside.
- xvi. Fifth day do final touches and put red oxide only on the outside to give the completed tank colour.
- xvii. Keep it wet by watering for 10 days (to cure the cement) and after drying wash the tank thoroughly and put in water which is good for use by the family and livestock and for watering crops.

4. ADVANTAGES

- i. Roofing materials are minimal. The neck has a diameter of 3ft (1m)
- ii. Constructed mostly with locally available materials
- iii. Cheap in cost compared to a galvanised iron tank
- iv. Takes a longer time serving the owner before repair

5. DISADVANTAGES

- i. Not movable
- ii. Limited quantity of water harvested - maximum capacity 8000 - 10000 l

EFFECTIVENESS OF A SAND BURIED MEMBRANE FOR RAINWATER HARVESTING

R. K. Muni and G.E. Onyulloh
University of Nairobi

1. INTRODUCTION

Rainwater harvesting systems are among the oldest water systems still in use in many areas of the world. For many isolated areas and especially islands they are still the major source of water supply. These systems are usually for single houses, although in some areas it is common to have collective storage systems for villages, small towns, manufacturing plants and agricultural purposes.

Depending upon the water use, the collecting surface can be a natural one with some improvements or an artificially developed surface. Several methods have been studied to determine the effectiveness of the collecting surfaces. Six factors control the effectiveness of the systems:

- the amount and time distribution of rainfall
- the runoff coefficient of the collecting surfaces
- the amount and time distribution of the demand
- the size of the collecting surface
- the reservoir storage provided
- evaporation and other losses from the reservoir

Thus for a given demand and a given historical rainfall data, the designer can determine the size and characteristics of the collecting surfaces as well as the size and characteristics of the reservoir.

2. RAINWATER HARVESTING TECHNIQUES

Water harvesting techniques can be divided into five basic methods:

- Vegetation management converting woodland to grass cover

- Natural and manmade impervious surfaces, rock outcrops, roofs and highways and roads.
- Land alterations, smoothing and soil compaction
- Chemical treatment of the soil, making it water repellent
- Ground covers; soil is covered with some form of impervious membrane

These methods have a wide range of costs, performance and durability which can limit the potential applicability of a treatment. Knowledge of the advantages and disadvantages of each method of treatment is needed to select the treatment best suited to a given site.

In many parts of the world, domestic water for both human and livestock use has been supplied by a method called water harvesting using structures or catchments to collect and store precipitation runoff. Properly designed water harvesting systems are potentially capable of supplying domestic water in any area where there is sufficient precipitation to grow forage. Water harvesting is less costly in many places than alternative means such as hauling or piping.

The water harvesting efficiencies of different treatments range from as low as seven percent on natural cover to a hundred percent with butyl rubber and sheet metal surface.

Water harvesting systems depend on precipitation which is, at best, a highly variable and non-uniform supply. The potential impact of any water harvesting system depends on the end product resulting from the use of the harvested water. The possible end products include livestock, crop production, wildlife watering and water for domestic purposes.

While the above rain water harvesting techniques have depended on the capability of the structures and catchments to harness runoff, the sand buried membrane would rely on the subsurface drainage of the sand cover over the membrane to determine the water yield. These drainage characteristics of the sand would be a function of the following

- moisture conditions at the time of the rainfall
- hydraulic conductivity
- rate of evaporation during and after the storm

- the infiltration characteristics of the soil
- the moisture release characteristics

The theoretical and practical considerations underlying an interflow collector of this type would therefore be more complicated than those of the overland or surface flow systems. Water yield would, however, be sensitive to rainfall and climate.

The effectiveness of the sand buried membrane system was tested using plastic sheet and this paper summarises the preliminary results of the field trials at Kabete Campus, University of Nairobi, Kenya

3. EXPERIMENTAL LAYOUT

As the drainage characteristics of the sand cover would depend on its water retention characteristics; porosity, air entry pressure value and hydraulic conductivity, two types of collector configurations were tested as shown in Fig 1. Different sand materials from Machakos, Magadi and Longonot were used to back fill the excavation over a plastic sheet lining. The drained water was collected through prefabricated plastic pipes and conveyed to corrugated galvanised iron tanks.

4. RESULTS AND DISCUSSIONS

4.1 Sand Characteristics

The particle size distribution of Machakos, Magadi and Longonot sands are presented in Fig 2. The Machakos and Magadi sands were similar in silt and clay content (less than 0.063mm) ranging between 0.52 to 0.32 percent while the Longonot sand had about 2.16 percent of silt and clay.

The saturated hydraulic conductivity of the sands as determined with a standard constant head permeameter was; Machakos sand 0.46. Magadi black sand 0.0027, Magadi red sand 0.0011 and Longonot sand 0.0018 cm/s.

4.2 Water Yield

The water obtained from the different sand catchments was collected in separate two thousand litre capacity corrugated tanks. The effectiveness of the rain water harvesting units was then worked out on basis of the total seasonal rainfall and the results are shown in Table 1.

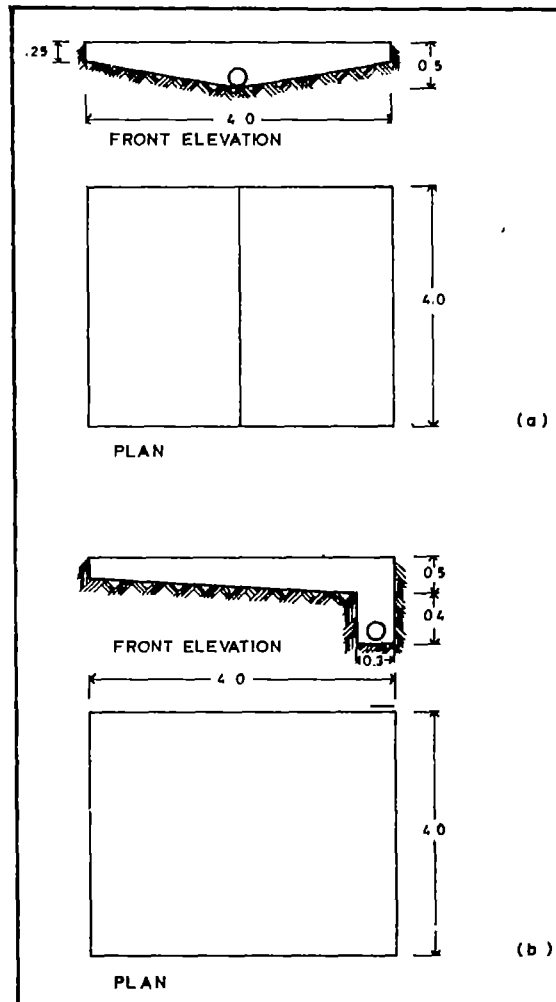


Fig. 1: Test collector configurations
(All dimensions are in metres)

TABLE 1: EFFECTIVENESS OF WATER HARVESTING SYSTEMS

| YEAR | 1989 | | 1990 | | | | 1991 | |
|-------------------------------|-----------|-----|-----------|-----|-----------|-----|-----------|-----|
| | SR= 387mm | | LR= 808mm | | SR= 183mm | | LR= 531mm | |
| SAND SOURCE AND CONFIGURATION | RWH | EFF | RWP | EFF | RWH | EFF | RWH | EFF |
| MKS-C1 | 167 | 43 | 480 | 59 | 127 | 69 | 329 | 62 |
| MKS-C2 | 273 | 71 | 505 | 63 | 141 | 77 | 390 | 73 |
| MGDR-C2 | 200 | 52 | 497 | 62 | 147 | 80 | 335 | 63 |
| MGDB-C2 | 186 | 48 | 569 | 70 | 160 | 87 | 368 | 69 |
| LGT-C1 | 133 | 34 | 365 | 48 | 102 | 56 | 257 | 48 |
| LGT-C2 | 236 | 61 | 497 | 61 | 124 | 68 | 236 | 44 |

From the efficiency characteristics, it is found that the configuration of the treatment has some effect on the final yield with configuration type-b giving a bit more yield than configuration type-a. The efficiency of the treatments vary from 34 percent to 87 percent. However, the low collection efficiencies were later detected to have been caused by leakage in the tanks, thus indicating the need to continue the research with better means of storage in order to reach better conclusions on the effectiveness of the systems. It is, however, worth noting that the system could be as good as any of the systems already commonly used elsewhere.

ACKNOWLEDGEMENTS

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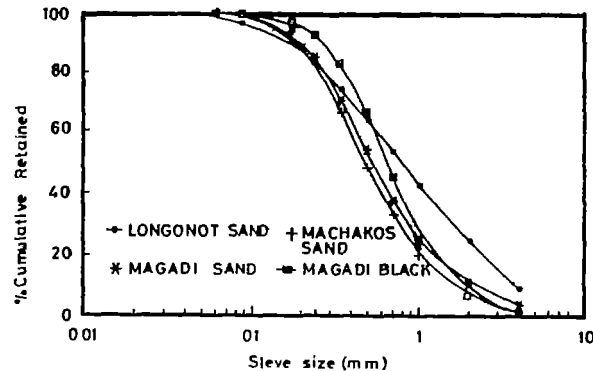


Fig. 2: The sandy soils particle size distribution

RAINWATER CISTERN CAPACITY: AN ASSESSMENT OF THE USE OF AVERAGE MONTHLY RAINFALL RATES

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1. INTRODUCTION

Several considerations are made in the choice of the capacity of a rainwater cistern. These include;

- the financial resources available
- the demand
- the materials available
- ease of construction
- the need to standardise the capacities
- the available catchment area and its characteristics and
- the hydrology (rainfall, evaporation etc)

This paper deals with the hydrological considerations. i.e The determination of the required size of a cistern on the basis of;

- the rainfall
- the water demand
- the available catchment area
- other parameters (eg. evaporation, seepage)

Often, simple formulae or procedures are adopted to compute the capacity. An example of a formula that is common is given in equation 1.

Capacity = periodic demand x number of dry periods -----(1)

(The period could be a day, a week or a month)

A procedure in common use applies the mass inflow curve of the average monthly inflows computed from the product of catchment area, the runoff coefficient of the surface and the average monthly rainfalls. The procedure is illustrated in Fig.1.

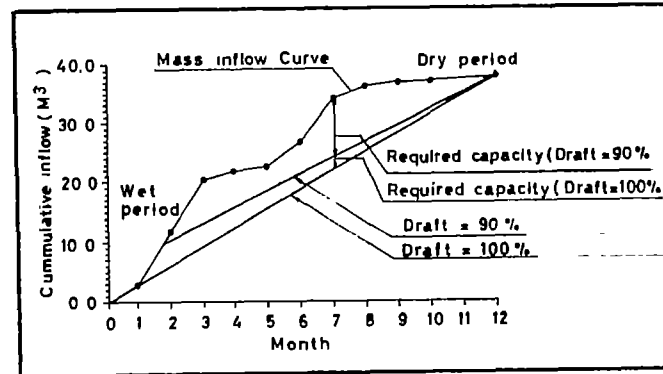


Fig. 1: Storage determination by mass curve of average monthly inflows.

Such formulae or procedures assume the averages represent adequately, the complete rainfall sequence and thereby ignore the annual variability of rainfall. This variability is often high and ignoring it could have a significant effect on the determined capacity. Fig.2 illustrates the variability of annual flows for two rainfall sequences. Garissa exhibits a much higher variability than Kericho.

The effect can be evaluated by comparing capacities determined by using the averages with those determined by procedure that applies to the complete sequence but is otherwise not fundamentally different in principle. Furthermore, by determining the reliability levels of the capacities determined using the averages, the suitability of using the same can be assessed. This paper presents the results of a study on the effect of using average rainfall rates by an assessment of the procedure described in Fig.1 hereafter referred to as the MAV method.

2. STUDY METHODOLOGY AND RESULTS

The main study was carried out in two stages viz;

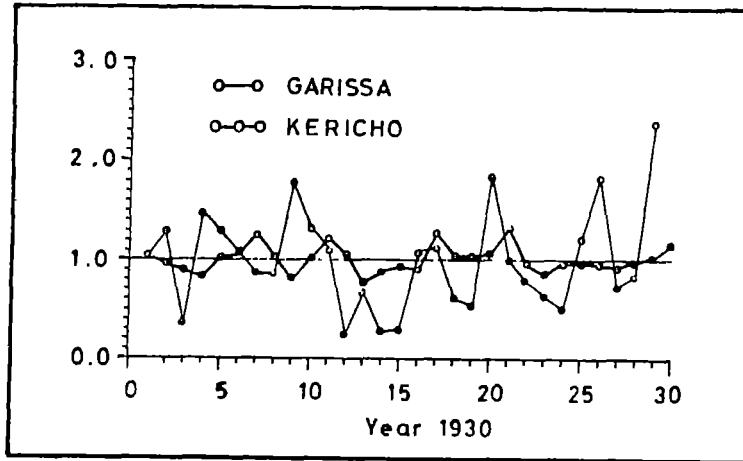


Fig. 2: Deviation of annual flows from the long term average.

(i) A comparison of capacities determined by the MAV with those determined by the Sequent Peak Algorithm (SPA) method. The SPA method applies the complete historical sequence and is described in appendix A.

(ii) The determination of the reliability levels of the MAV capacities using the Behaviour Analysis (BA) and the modified Gould's Probability Matrix (MGPM) method. The BA and MGPM method have been recommended for the final determination of the capacity of water supply reservoirs in some comparative studies (see McMohan et al 1978, Carty et al 1990). More information on the two and their application in this study is given in appendix B.

A further analysis consisting of the determination of the reliability levels of the capacities determined by the SPA method was also undertaken.

Five monthly rainfall sequences within Kenya were used. Table 1 presents some pertinent information on them.

Table 1 : Monthly rainfall sequences used in study.

| Site | Length (years) | MAR (mm) | CV |
|---------|----------------|----------|------|
| Subukia | 43 | 900 | .255 |
| Garissa | 29 | 282 | .518 |
| Kajiado | 30 | 465 | .349 |
| Ramisi | 30 | 1487 | .207 |
| Kericho | 30 | 1837 | .137 |

MAR: Mean annual rainfall

CV : Coefficient of variation of annual falls (see appendix C)

Draft levels of 50, 90 and 100% of the average inflow were applied in the study.

A: COMPARISON OF THE MAV AND SPA METHOD

For the five sequences and three draft levels, capacities were determined by the MAV and the SPA method. The ratios of the capacities by the MAV to those by the SPA (referred to as MAV/SPA in Table 2) were computed.

It was observed that;

- some very small values of MAV/SPA were obtained (a least value of 0.096)
- the mean MAV/SPA were less than 0.5 at all the draft levels
- MAV/SPA decreased as the demand and CV increased. Fig.3 presents the relationship between CV and MAV/SPA.

These results indicate that the effect of using monthly averages instead of the complete sequence is highly significant.

Table 2 : Table of Results

| Site | MAV/SPA | DRAFT = 50% | | | |
|-------------|---------|------------------|-------|------------------|------|
| | | % PROBFS FOR MAV | | % PROBFS FOR SPA | |
| | | BA | MGPM | BA | MGPM |
| Subukia | 384 | 10.21 | 9.74 | .19 | .18 |
| Garissa | 146 | 15.52 | 15.57 | .00 | .19 |
| Kajiado | .777 | 4.44 | 4.44 | .28 | .50 |
| Ramisi | .645 | 3.61 | 3.74 | .28 | .33 |
| Kericho | .411 | 5.28 | 4.96 | .00 | .09 |
| Mean Values | .473 | 7.82 | 7.69 | .15 | .26 |

Table 2 Cont

| DRAFT = 90% | | | | | |
|-------------|---------|------------------|-------|------------------|------|
| Site | MAV/SPA | % PROBFS FOR MAV | | % PROBFS FOR SPA | |
| | | BA | MGPM | BA | MGPM |
| Subukia | .277 | 12.79 | 12.49 | .00 | .86 |
| Garissa | .125 | 29.60 | 34.18 | .29 | 6.47 |
| Kajiado | .319 | 13.89 | 16.23 | .00 | 1.46 |
| Ramisi | .485 | 8.06 | 9.02 | 2.28 | 1.19 |
| Kericho | .375 | 8.06 | 5.88 | .28 | .03 |
| Mean Values | .316 | 14.48 | 15.56 | .57 | 2.00 |

| DRAFT = 100% | | | | | |
|--------------|---------|------------------|-------|------------------|------|
| Site | MAV/SPA | % PROBFS FOR MAV | | % PROBFS FOR SPA | |
| | | BA | MGPM | BA | MGPM |
| Subukia | .144 | 17.44 | 17.62 | 2.71 | 2.28 |
| Garissa | .096 | 31.61 | 30.95 | 1.44 | 5.29 |
| Kajiado | .265 | 20.56 | 22.26 | .83 | 5.05 |
| Ramisi | .340 | 11.39 | 13.48 | .00 | 3.63 |
| Kericho | .271 | 12.22 | 10.75 | .56 | 2.99 |
| Mean Values | .223 | 18.64 | 19.01 | 1.11 | 3.85 |

B: RELIABILITY LEVELS OF CAPACITIES DETERMINED BY THE MAV METHOD

The probabilities of failure (%PROBFS) determined as a percent by the BA and the MGPM method are given in Table 2. Equation 2 could be used to determine the reliabilities.

$$\text{Reliability} = 1 - (\%PROBF/100) \text{ ----- (2)}$$

It was observed that:

the values of PROBF determined by the BA and the MGPM method compared reasonable well

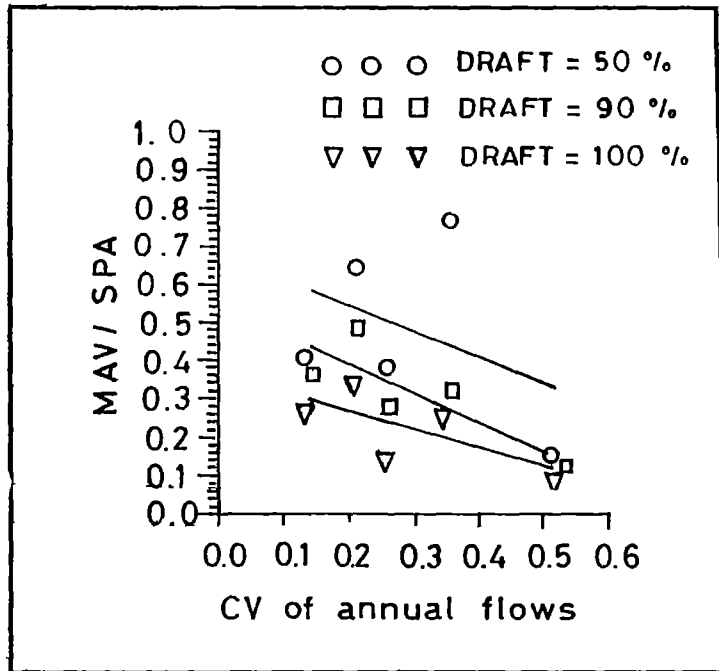


Fig. 3: Relationship between CV and MAV/SPA

- the PROBFs varied highly with the sequences
- some very high values of PROBF (about 30%) were obtained with one sequence (Garissa) at the 90 and 100% draft levels
- the PROBFs obtained with two of the sequences, Ramisi and Kericho were not high.
- PROBF increased as the applied draft and CV of the rainfall sequences increased.

These results indicate that;

- using the MAV method could at times lead to a serious underdesign especially if the variability of the annual rainfalls is high.
- The MAV method at times gives reasonable capacities. This is more likely to be the case if the variability of annual flows is low.

C: RELIABILITY LEVELS OF CAPACITIES DETERMINED BY THE SPA METHOD

The %PROBFs of the SPA capacities as determined by the BA and the MGPM methods are also given in Table 2. In most cases, very high reliability levels were obtained. This indicates that the SPA is a safe method but could at times lead to an overdesign.

3. RECOMMENDATIONS AND CONCLUSIONS

A) Caution needs to be taken in applying a mass inflow curve of inflows computed using the average monthly rainfalls (MAV) to determine cistern capacity especially in cases where annual rainfalls are highly variable. In such cases, it may be advisable to apply large factors of safety.

B) If high levels of reliability are required, the Sequent Peak Algorithm (SPA) method would be better to apply than the MAV method.

C) Methods that estimate the reliability of the capacity realistically (such as the Behaviour Analysis (BA) and the modified Gould's Probability Matrix (MGPM)) are the most suitable. Such procedures can be used to;

- determine the capacity for a specified reliability
- estimate realistically the reliability of the selected capacity if other considerations override the hydrological one.

Some notable attributes of the BA and the MGPM are:

- their ability to easily handle variable demands and
- their ability to easily handle operation schedules

With the availability of a computer and appropriately designed software, the BA and MGPM are easy to apply and could even take less time than the MAV method.

D) Catchment area-capacity-demand-reliability charts (appendix D) based on the BA, the MGPM and other suitable methods should be developed for the various areas of interest in Kenya. Such charts could assist in making well informed decisions on the required capacities of raintwater cisterns.

1 A %PROBF of 30% means the cistern will be empty during 30% of its lifespan.

2 The SPA method can also handle easily variable drafts not as associated with storage level.

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APPENDICES

APPENDIX A: THE SEQUENT PEAK ALGORITHM METHOD

-Compute the net inflow into the reservoir $X_t - D_t = 1$ to $24N$

where t is the inflow during month i

D_t is the demand during month i

N is the number of years of the record (note: the historical sequence is applied twice)

-Compute the cumulative sum of the net inflows

$$\sum (X_t - D_t) \text{ for } t = 1 \text{ to } 24N$$

-Locate the first and sequent peaks and troughs of the curve of cumulative net inflows with time and compute the ranges C between adjacent peaks and troughs. This is illustrated in Fig A1.

-The highest value of C_i gives the required capacity.

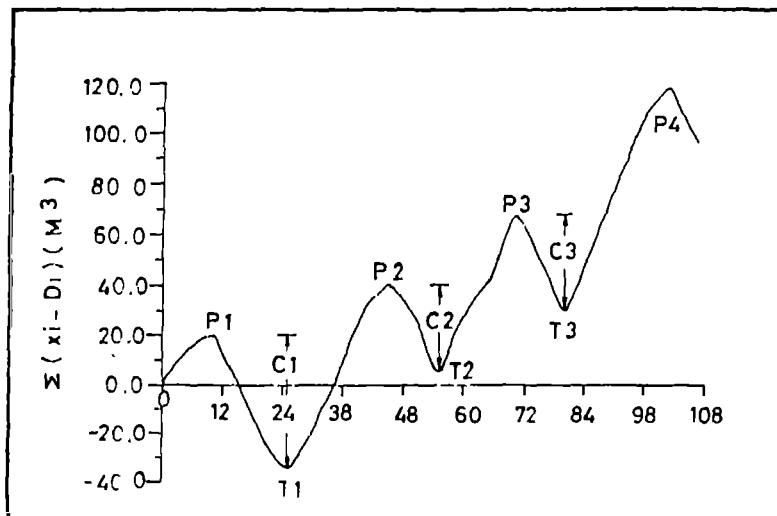


Fig. A1: The sequent peak algorithm method

APPENDIX B: THE BEHAVIOUR ANALYSIS AND MODIFIED GOULD'S METHOD

The Behaviour Analysis (BA) method closely simulates the expected behaviour of a reservoir but assumes an initial storage state. The MGPM method simulates the reservoir behaviour as the BA year by year (assuming several initial storage levels between the empty and the full state) and considers the yearly variation of the storage as a markov chain. This method has the weakness of assuming that annual inflows are independent but is more precise than the BA, does not assume an initial storage state and makes better use of the hydrological information in the sequence than the BA. Studies indicate that most annual rainfalls, unlike streamflows are independent. Some procedures to eliminate the effect of the assumption have been suggested (Ndiritu 1992b) and could be useful in case annual rainfalls are not independent. The BA method is described below. For a description of the MGPM method McMahon et al 1978 could be consulted. The two were applied in this study to check weaknesses inherent in each. An initial storage state of 50% of the capacity was adopted in applying the BA. The MGPM method was carried out using January as the starting month of analysis throughout. Trial runs indicated that annual serial correlations were not significant.

THE BEHAVIOUR ANALYSIS METHOD

- Determine the storage state behaviour of the reservoir over the period of the available data (say N years) on a monthly basis using equation A1 and constraint A2 assuming an initial storage state Z.

$$Z_{t+1} = Z_t + X_t - D_t - E_t \quad \text{-----A1}$$

$$0 \leq Z_{t+1} \leq C \quad \text{-----A2}$$

where

Z is the storage state at the beginning of period t

D is the demand in period t

E represents other losses (eg evaporation) in period t

C is the capacity of the reservoir

- Record the number of months in the analysis that the reservoir fails (empties) say N_f .
- Compute the probability of failure PROBF as given in equation A3

$$\text{PROBF} = N_f / 12N \quad \text{or} \quad \% \text{PROBF} = 100N_f / 12N \quad \text{-----A3}$$

- If a capacity giving a specified PROBF is required, interactively select other values of C until the required PROBF or one close enough is obtained.
- Fig. A2 shows a Behaviour diagram of a cistern.

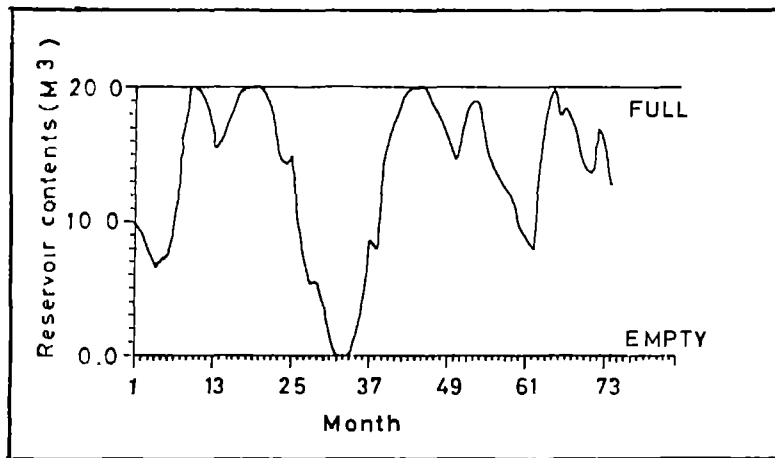


Fig. A2: Behavior diagram of a cistern

APPENDIX C: COEFFICIENT OF VARIATION OF ANNUAL FLOWS

The coefficient of variation of annual flows as determined by equation A3 measures is a measure of their variability

$$CV = \frac{\sqrt{\sum_{I=1}^N (X_I - \bar{X})^2 / (N-1)}}{\bar{X}} \text{----- (A3)}$$

Where

N is the number of years of the sequence

X_I is the annual rainfall for year I

\bar{X} is the mean flow

APPENDIX D: CATCHMENT AREA-CAPACITY-DEMAND-RELIABILITY CHARTS (AN ILLUSTRATION)

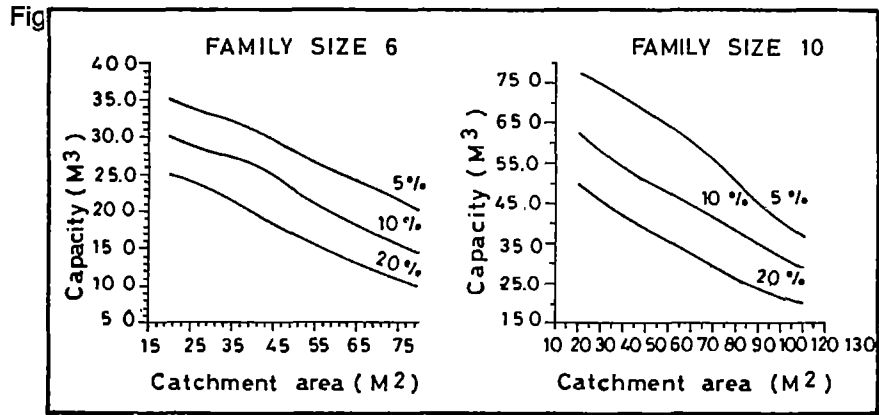


Fig. 3: Capacity - catchment area - demand reliability charts

NOTE: Fig.1, A1, A2 and A3 are hypothetical and not based on real problems.

3. PLANNING AND MANAGEMENT

PRACTICAL APPROACH TO RAINWATER HARVESTING

Eric Nissen-Petersen
Asal Consultants Ltd

A practical approach to rain water harvesting has been applied for creating water supplies in many parts of the world for thousands of years.

The oldest and best documented rain water harvesting systems are found in the Negev Desert of Israel. Some of these water systems, which are about 4000 years old, have been rehabilitated by the Desert Farm Unit of the Hebrew University of Jerusalem.

In Eastern Africa one of the few possible ways of getting water is to harvest rain water because this region has no other surface water except a few perennial rivers. Ground water is another solution but can only be reached by



Photograph 1: A Rock Catchment dam and an earth dam from Kyuso, Kitui.

drilling very deep boreholes with sophisticated machinery that requires a high amount of back-up once operational

As advanced technology was introduced to East Africa less than a century ago, the only possible ways to ensure a water supply during the dry seasons were to use a practical approach to harvest and store rain water. Rain water harvesting has therefore been practised in East Africa for an unknown number of centuries

By trial and error over the years, practical approaches have become so developed that most of the modern techniques for rain water harvesting are identical to the ancient methods. The use of cement, reinforcement and occasionally computer programming are the only modern inputs.

A practical approach to rain water harvesting involves using traditional knowledge and simple equipment for:

1. Location of catchment areas where rain water run-off can be collected e.g seasonal water-courses, exposed rock surfaces, hill-sides, land with sparse vegetation, roads and roofs on buildings.



Photograph 2 Roof as a Water Source.

2. Location of natural surface reservoirs where water can be stored with a minimum of input of labour and cost, e.g natural depressions in rocks or on land with clayish soils which can be used for the building of;

- a) earth pans and dams
- b) rock catchment dams



Photograph 3: A Rock Pool.

3. Location of natural underground reservoirs such as;

- a) underground dykes in seasonal water-courses which can be used for ground water dams
- b) pockets of sandy soil situated on impermeable layers of rock or murrum which can be used for the sinking of shallow wells
- c) springs from where water can be tapped and gravitated to a storage tank.



Photograph 4: An Unlined Shallow Well.

4. Location of man-made reservoirs and catchment areas such as;

- a) murrum pits excavated for road construction that can be converted into small earth pans, these can be fed by run-off from the roads.
- b) school compounds which can deliver run-off water to ground tanks for school gardens
- c) roof catchments that fill up water tanks

5. Identification of locally available skills and materials When deciding on which type of structure to build the local skills and materials available in that specific place must be identified because of the following factors:

- a) peoples' acceptance, understanding and participation
- b) peoples' capability of participating as much as possible in the construction and maintenance of their water project
- c) cost efficiency



Photograph 5: Murram Pit along Road.



Photograph 6: Making Ballast for Aggregate.

6. Structural design of water projects A design of a water project for rain water harvesting should always be based on low-technology as far as possible. This can be achieved by relying on gravity flow rather than lifting devices, pipelines without break-pressure stations and an absolute minimum of gate valves and water taps, for the purposes of;

- a) reducing peoples' burden and cost of maintenance
- b) improve peoples' understanding of the project's functioning
- c) cost efficiency.



Photograph 7: A Sand-Storage Dam.

RAINWATER HARVESTING TOWARDS CHILD CENTRED COMMUNITY DEVELOPMENT

J M. Mathenge
Save the Children - Canada

1. AN OVERVIEW

In the rural areas, large number of homesteads do not have access to safe drinking water or are far from water points. According to UNICEF only 31 percent of the rural Kenyans have access to safe drinking water.

In the dry, low potential areas this is as low as 20 percent. Thus 69 percent of the rural population in Kenya has no access to safe drinking water and is as high as 80 percent in dry low potential areas. It is estimated that only 26 percent of Kenya's total population is urban while 74 percent is rural based. With the current Kenyan population of 24 million about 17.8 million of the population is rural based.

Under the convention on the rights of the child and Kenya's "Age of the Majority Act" every human being below the age of 18 years is considered a child. This category comprises 60 percent of Kenya's population with about 10.6 million found in rural Kenya. Though this paper will focus on rural based strategy of water harvesting, it is pointed out that this problem is not only limited to rural areas. Indeed, 31 percent of the urban population do not have access to safe water and can also be direct beneficiaries of strategies being adopted to address the problem in this paper.

2. CASE EXPERIENCE

2.1 Background

Tharaka division was the largest of the nine divisions of the previously "greater" Meru district. Since the formation recently of Niithi-Tharaka district cut out of the previous Meru district, Tharaka division now falls under this new district which comprises of only two divisions. It has a land area of 1496 square metres and a population estimated at eighty thousand persons.

The division lies in the southern western dry plains and experiences erratic and unreliable rainfall. The scanty rainfall, low altitudes and high temperatures render the division unsuitable for intensive farming, except for a small area where irrigation is practised. In view of this most people in this area practice

sedentary pastoralism where they keep local breeds of animals and grow drought resistant crops like sorghum, millet and pigeon peas.

The division is served by four perennial rivers mainly originating from the slopes of Mount Kenya which drain into River Tana on the boundary with Kitui district. Though these rivers are perennial, they are far apart and cut through very deep ravines. Thus their waters cannot be readily utilised.

Inequitable distribution of district development resources has most adverse effects on the development of Tharaka. There is very limited infrastructure, basic services and amenities in this region as compared to other divisions.

In Tharaka a large number of homesteads are far from water sources. During the dry season these distances are even longer being up to seven kilometres for some areas. Most of the women spend up to a whole day collecting water during this season. As most of these rivers originate from the high potential slopes of Mount Kenya, the water is highly polluted as it gets to the lower Tharaka plains. The pollution is mainly as a result of agricultural activities upstream in the form of silt, herbicides, fertiliser, pest spray chemicals, sanitation wastes and coffee factory wastes. For example, Kathita river is polluted by sewerage and industrial wastes from Meru Municipality yet it is the largest and most utilised river by communities in Tharaka. Its waters are crystal clear at the vicinity of Meru Town while at Tharaka, the river is greenish as a result of algae and other microbial growth due to high organic pollutants.

2.2 Domestic Problems Associated with Water in Tharaka

- i. Long distances women have to walk daily in search of water
- ii. Diseases - incidences of cholera are prevalent in this area especially in the dry season; the last major outbreak was in 1984. Amoebic infections are also quite prevalent leading to frequent incidences of absenteeism from school for infected children and low productivity for adults.
- iii. General human hygiene is threatened by poor sanitation and improper methods of waste disposal in this area mainly as a result of scarcity or lack of access to safe water.

2.3 SCC Approach to Rain Water Harvesting

During the 1984 drought SCC was involved in the provision of relief food and services to the famine stricken communities in Tharaka and Garba Tulla. Though SCC policy since 1983 has been to promote child centred community development as opposed to relief or individual child sponsorship. In Tharaka, this was undertaken as an emergency activity by SCC and prompted a long term community development action. During the same period an outbreak of cholera in the area added pointers to the need for clean water and sanitation.

It is difficult to initiate child centred community development without considering this need in terms of the whole household unit and especially focusing the child and the mother. So SCC approach is both 'child targeted' and 'gender sensitive'.

2.4 Strategies Adopted

- i) **Mobilisation** : In 1985 a community organisation department was initiated to try and organise mothers in this area to developmental social groups. SCC assisted these to receive development, leadership, health and adult education through existing institutions.
- ii) **Institutional capacity development**: To be able to implement water and sanitation programmes SCC acquired an appropriate technologist and field assistants. These field assistants are trainable local youth to whom skills are imparted. They are on (a day to day basis) in contact with the groups in their operational areas and are also involved in monitoring, training, supervision and reporting.
- iii) **Identification of appropriate rain water technology**. Consideration here was in relation to:
 - cost: i.e can the community or households afford it. The ratio of SCC to group is 1:1. So cost becomes a very important parameter.
 - Can the local people learn to do it after they are trained without undue supervision - sustainability
 - Most houses are still thatch roofed in Tharaka and some families have to purchase corrugated iron sheets prior to establishing the tank and added cost.

With the above plus other considerations water jars were identified as viable technologies in this area.

- iv) Community training: Initial training was done for leaders from various groups, on water harvesting, management, sanitation, basic child health care and public health care in collaboration with other agencies and the government.

Hands on training is constantly done for group members as they put up tanks. These practical demonstrations were initially done by SCC. Interested groups are also attached to on-going group activities where they learn the skills and take them back to their members. Due to this approach there are more groups constructing jars apart from the five SCC nucleus groups. It is important also to note that offshoot groups are doing without SCC material or technical support. When they request SCC assistance we only facilitate contact and arrange where they can be attached to be trained by their peers through "peer training". This also changes their attitude and builds their confidence i.e "we can do it for we have seen mothers do it".

This approach applies for VIP latrines which groups put up along with constructing water jars.

3. ACHIEVEMENTS

Since 1990 the SCC has been working with five women groups with a membership of two hundred. They have managed to put up sixty three water jars to date. These water jars have a capacity of five thousand litres and cost about two thousand and five hundred Kenyan shillings each.

The confidence this process is building among women in this locality is encouraging. Initially the people of Tharaka used to consider themselves as condemned to problems. It has been a common saying among Tharakans that "Mungu ana jua shida zetu" so leave us alone. Today this process is empowering them to think differently and may lead to the process of their solving even other major and unrelated problems in future.

Families with this kind of water jar are able to manage and use this rain water for up to four to six months mainly for drinking and limited cooking. This is a direct benefit to children who make up the majority in the households.

The water jar is also becoming a symbol and a sign of prestige and families are proud of it. Families with thatched homes are buying five or six iron sheets to

roof the granary or a shed just to harvest water as they cannot afford to roof the whole house. So it is also having a positive impact on shelter.

4. FUTURE SCENARIO

SCC aims to intensify rain water harvesting techniques with the local communities. We have just initiated runoff harvesting techniques using underground water tanks. In situ rain water harvesting techniques are also being considered e.g runoff farming, conservation tillage to increase infiltration etc. Together with these will be nutrition programmes utilising this water and the added benefits to the child.

5. CONCLUSIONS AND RECOMMENDATIONS

Community involvement and capacity building at local level is an important pre-requisite to a successful rural based rain water harvesting strategy. The notion that experts have to be involved and locals are only recipients of the ensuing benefits is wrong. They should implement the technology, harvest water on their farms, manage the water, enjoy its utilisation and sit back with pride for their achievement. A rain water harvesting project is more successful if it is a process to address an identified and felt need in the local community i.e the harvested water is not the end but only a means while peoples livelihood improvement is the end result. This calls for public education in health, sanitation etc prior to implementation.

There are various options available but the lowest cost affordable option which can be sustained by the local communities especially women should be sought.

The government of Kenya had by 1980 subscribed fully to providing clean water and adequate sanitation as close to homesteads as possible (1 Km) by the year 2000. I still believe this can be achieved through greater involvement by all interested parties i.e local communities, development agencies and the government agencies and by all initiating, appreciating and supporting technologies and innovations focussing on rain water harvesting.

DISCUSSION

Mr Mani asked how long tanks which are plastered freehand by women remain in use. Mr Mathenge said that similar tanks constructed elsewhere are still in use after ten years. The technology is scientific even though done by people at the grassroots. For example the mixing ratio varies from stage to stage.

Mr J Tinkoi asked what role the agency played in the formation and skills training of the individuals and groups in the community and whether they are able to take over the work with minimum supervision. Mr Mathenge replied that Save the Children - Canada organises and finances community training and leadership seminars in the area. Thereafter groups have to contribute fifty percent of the cost and in the long run it is expected that they will contribute a hundred percent of the cost. The aim is to ensure that low cost technologies are used.

Mr G Mailu asked whether water quality tests had been carried out and was told that this had not yet been done but it was hoped to carry quality tests with the help of the department of environment. There is evidence that the rivers which provide an alternative source of water are polluted as they come from the high potential areas of Meru.

RAIN WATER HARVESTING IN SEMI-ARID AREAS: ROOF AND TANK APPROACH

Sirwan O. Said.
Netherland Development Organisation

1. INTRODUCTION

The Diocese of Kitui's water section applies different methods in harvesting rain water. Most of them are classical types (projects like dams, rock catchment, wells, tanks, etc.). However a new project was initiated by this programme called "Roof And Tank programme". This programme is from the very beginning supported by UNICEF. As a part of a pilot scheme UNICEF has donated 100 units to the people of Kitui.

The "Roof and Tank" programme is an interesting new approach in the community based rain water harvesting scheme and will therefore be the core of this paper.

2. BRIEF HISTORY OF THE WATER PROGRAMME OF THE DIOCESE OF KITUI.

Since the 1970's, the Diocese of Kitui, through a development programme has been involved in community animation programme. The animation was effectively conducted through organised:-

1. Women groups
2. Literacy classes
3. Self-help groups
4. Parish leadership group

The main approach includes:

- Training group leaders on related problems like group organisation, accountability of leaders to groups etc.
- Technical advice and supervision
- Group finance coordination and payment of any required local contributions

- Training and education to link health and water projects
- Follow up to individual families and groups
- Setting up a maintenance sector to serve the group with maintaining their projects
- Training local staff to stabilise the water programme

In the workshops conducted over several years water was given priority as a development need. The Diocese then started setting up a small scale community based water development programme. Over the years the programme has responded to water needs through these organised groups.

A variety of approaches have been used in rain water harvesting within the water programme of the Diocese of Kitui including:

Rock catchment
 Sub-surface (or sand-storage) dams
 Earth dams
 Shallow wells
 Roof catchments-Ferrocement tanks (different volumes 10 cubic metres to 50 cubic metres)

These projects are implemented with the collaboration of organised groups mentioned in this report.

The condition for the groups to get in the programme are:

1. Groups should have 10-30 members together over a period of six months.
2. The group should participate in organised training which analyses community themes and ways group action responds to these needs.
3. They should be able to show concrete evidence of their groups project work.
4. The group must be prepared to participate in committee decisions at grassroots or Diocese council.
5. The group must have a viable method of finance or labour contribution toward the project they are putting forward.

6. The group must contribute 10 percent or 20 percent towards cement cost needed for the project, and open a bank account with KShs.850.00 deposit for maintenance of the project.
7. All locally available material needed for the construction of the project such as sand, stone, aggregates etc. must be provided by the group.
8. Other relevant conditions to be worked out as project implementation gathers momentum.

3. ROOF AND TANK

Kitui District has 700,000 inhabitants distributed in a disperse style over 31,099 square kilometres. Realisation of rainwater harvesting projects near the communities is not always an easy task, as in many areas the underground water table is too low to be reached manually, there are no sizeable rocks for rock catchment, and no suitable stream or rivers for sub-surface dams. Finally most of the people in this area are poor and they live in huts made of clay without corrugated iron sheet roofs (or comparable roofing), hence there is no possibility of harvesting rainwater through roof catchment methods. As a result of the above mentioned restrictions for harvesting rainwater, the water section of the Diocese of Kitui reached the conclusion of providing a simple roof with an adjacent tank to the group members.

The programme became popularly known as "Roof and Tank programme".

The roof which consists of a wooden truss, covered with galvanised corrugated iron sheets (gauge 32), has a surface area of 35 square metres, rests on six reinforced concrete pillars 10cm x 10cm of length 3m, of which 0.55m will be under the ground. The roof has gutters made of galvanised iron sheets on both sides to lead the runoff from the roof top to a 10 cubic metres ferrocement tank. (For construction details see drawing numbers 1 to 4). Methods used for construction of the tank originated from the designing method of S.B. Watt. For construction sketch look at the drawing number 5, for workplan look at Appendix 1.

In Kitui District the average annual rainfall can vary from 600mm to 1000mm. In designing the roof (surface area) and the tank (volume) we assumed 100 dry days in one season, and an average annual rainfall of 800mm. It was further assumed that the tank can be filled in one rainy season thus 50 percent of the 800mm which is 400mm is considered for the calculation purposes.

The area of the roof 35 square metres x 400mm x 90% = 12.6 cubic metres. Therefore the roof area is enough to fill 10 cubic metre tank in one rain season.

Total volume of the tank is 10000 litres = family of 10 members x 10 litres per member x 100 dry days.

Thus family of 10 members can have an average of 100 litres of clean water per day next to their house.

This programme has a special focus on rural families. The family is challenged to save 50% of the unit cost which is KSh.8,500 (for the total unit cost. See Appendix 2, for water section's criteria see Appendix 3 and for application form see Appendix 4). A house of 2 small bedrooms and one sitting room can be constructed by the group members. Once the roof and tank are completed, the community with a direct request from the family helps to fill in the walls.

Most of the other programmes of small scale water points serve the communities while the Roof & Tank are directed at the family. The focus is on shelter for children to prevent them from getting sick through cold and unhealthy living. The clean rain water from the tank guarantees that the children do not become sick through contaminated water. Lot of child sickness in this area is through unsafe drinking water.

Final comments here relate to the dignity the family has by having a firm building apart from the time the mother saves to stay with the children instead of going to fetch water. The mother is given a longer life span because she does not have to walk long distances with heavy loads of containers of water. It has been observed that most of the husbands who have these Roof & Tank structures spend a good bit of time with their families due to dignity they get from the permanent house and clean water they enjoy from the project. The project remains very popular with women and rural development groups.

APPENDIX 1

WORKPLAN: HOUSE ROOF AND TANK PROJECT

- DAY 1 Transfer to site, inform owner of work procedure, measuring, cutting iron bars for pole reinforcement
- DAY 2 Casting concrete poles
- DAY 3 Tank construction in 8 days
- DAY 11 Placing poles and concrete filling
- DAY 12 Construction of trusses and purlins
- DAY 13 Placing trusses and purlins
- DAY 14 Roofing, placing corrugated iron sheets (mabati)
- DAY 15 Guttering, removing mould and brushig nil

INPUT BY THE BENEFICIARY

- Providing following quantities of local materials
 - i) 3 tons sand
 - ii) 2 tons aggregate
 - iii) 1.5 tons harcore
- Giving enough casual labour (2 casuals) to:
 - i) Excavate foundation for tank
 - ii) Excavate holes for poles
 - iii) Assist fundi in construction of the hole unit
- Transport mould (tank mould and poles mould)
- Providing accommodation and food for the skilled labour
- Walls, doors, windows should be made by the beneficiary after construction of the roof and tank has been completed.

APPENDIX 2

A. ESTIMATE OF ROOF BUILDING COSTS (AS AT AUGUST 1992)

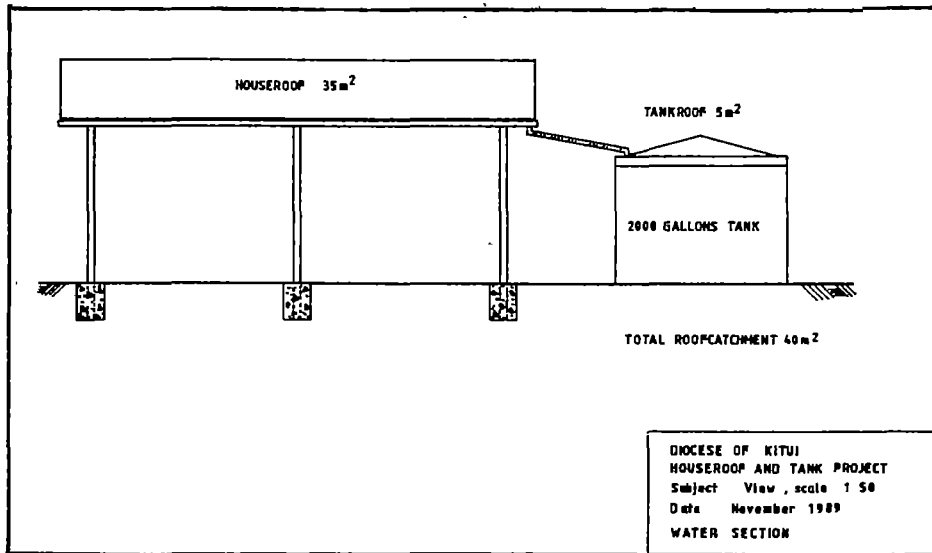
| ITEM | UNIT | QUANT. | UNIT COST | COST |
|--|-----------|--------|-----------|-----------|
| TIMBER 3"x2" | ft | 215 | 2.80 | 602.00 |
| TIMBER 4"x2" | ft | 55 | 3.50 | 192.50 |
| NAILS 4" | kg | 3 | 30.00 | 75.00 |
| NAILS CEILING | kg | 0 | 40.00 | 4.00 |
| NAILS ROOFING | kg | 2 | 40.00 | 80.00 |
| MABATI 2.5m 32g | pc | 18 | 145.00 | 2610.00 |
| KOFIA 6ft | pc | 4 | 34.50 | 138.00 |
| GUTTER PLAIN | pc | 4 | 80.00 | 320.00 |
| GUTTER END | pc | 2 | 90.00 | 180.00 |
| GUTTER END DOWN | pc | 2 | 90.00 | 180.00 |
| DOWNPIPE | pc | 6 | 40.00 | 240.00 |
| PIPE ELBOW | pc | 2 | 30.00 | 60.00 |
| PIPE T | pc | 1 | 35.00 | 35.00 |
| BRACKET | pc | 18 | 8.00 | 144.00 |
| BAR 1/4" 40ft | pc | 6 | 48.00 | 288.00 |
| REINF.SQUARWIRE | pc | 36 | 2.00 | 72.00 |
| CEMENT | bag 50kg | 3 | 200.00 | 600.00 |
| SKILLED LABOUR | man-day | 7 | 80.00 | 560.00 |
| | | | | 6380.50 |
| CONTINGENCIES : | 10 % | | | 638.05 |
| OVERHEAD COST : | 50 % | | | 3509.28 |
| GRAND TOTAL : | | | Kshs | 10,527.83 |
| ===== | | | | |
| B: ESTIMATE TANK CONSTRUCTION COST | | | | |
| ITEM | UNIT | QUANT. | UNIT COST | COST |
| CEMENT | bag(50kg) | 14 | 200.00 | 2800.00 |
| CHICKEN WIRE | rol 3ft | 1 | 550.00 | 550.00 |
| BINDING WIRE | kg | 8 | 30.00 | 240.00 |
| OUTLET/TAP | pc | 1 | 150.00 | 150.00 |
| OVERFLOW | pc | 1 | 16.00 | 16.00 |
| SKILLED LABOUR | contract | 1 | 640.00 | 640.00 |
| TOTAL : | | | | 4396.00 |
| CONTINGENCIES : | 10 % | | | 439.60 |
| OVERHEAD COST : | 50 % | | | 2417.80 |
| GRAND TOTAL : | | | Kshs | 7,253.40 |
| ===== | | | | |
| TOTAL HOUSEROOF & TANK: | | | | 10776.50 |
| TOTAL CONTINGENCIES : | 10 % | | | 1077.65 |
| TOTAL OVERHEAD : | 50 % | | | 5927.08 |
| GRANDTOTAL HOUSEROOF & TANK CONSTR. COST : | | | Kshs | 17,781.23 |

APPENDIX 3

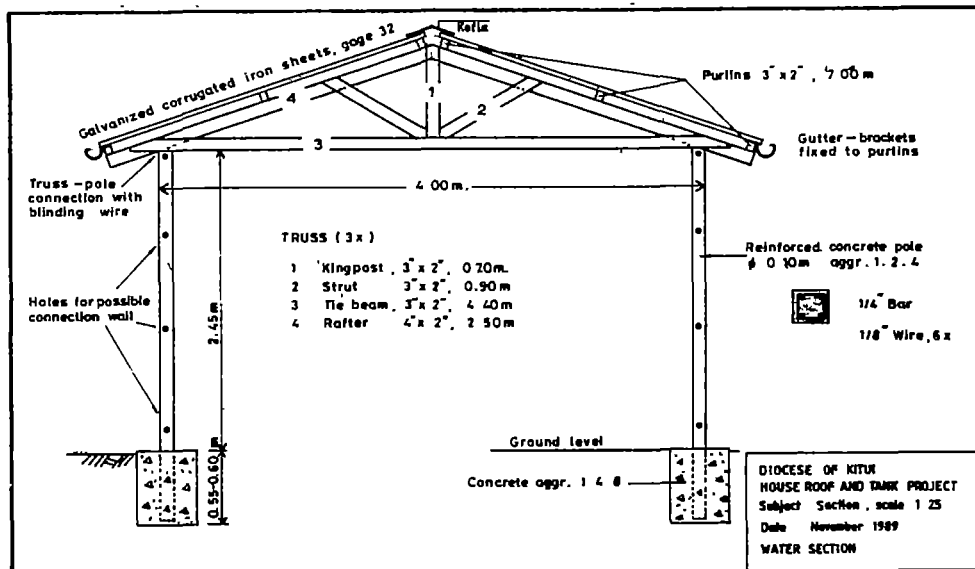
WATER OFFICE CRITERIA: HOUSE ROOF AND TANK PROJECT

1. The beneficiary should not have more than ten goats or five cows
2. The salary should not be more than one thousand Kenya shillings
3. In cases where a member has more than indicated above, but has children in secondary school, the office will consider each case on its merit
4. The owner has no mbati roof on the compound
5. The total cost of the structure of roof and tank is Kenya shillings seventeen thousand but the beneficiary pays fifty percent.
6. The recommendations for the construction will be made through the parish structure.
7. The minimum amount to start paying after approval of the D.O.K is one thousand Kenyan shillings
8. Only after having paid the total amount of eight thousand and five hundred (fifty percent of the total cost) will the structure be built.
9. All members who will benefit from the project will have to pay the fifty percent sum of eight thousand and five hundred shillings within the project period. In case of failure, their money will be refunded and the project will cease.

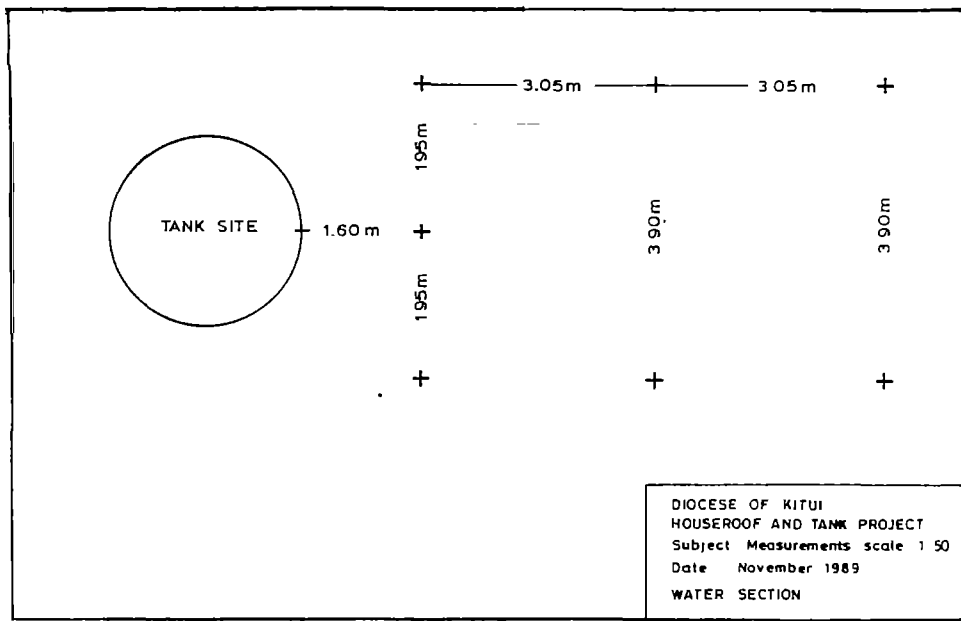
| ROOF and TANK PROGRAMME GROUPS INFORMATION FORM | | - WATER OFFICE - | | | | | | PARISH : | REMARKS CRITERIA/ADVICE |
|--|-----------------|------------------|-------------------------------|-----------------------------|-------------|--------------|---------------------------|----------------|-------------------------|
| GROUP NAME : | | | | | | | | LOCATION | |
| NO. of MEMBERS : | | | | | | | | SUBLOCATION : | |
| DISTANCE WATER SOURCE + TYPE : | | | | | | | | REQUEST DATE : | |
| | | | | | | | | SURVEY DATE : | |
| NAME INDIVIDUAL | WORK HUSBAND | WORK WIFE | NO. CHILD. -SEC- CHILD. | NO. WORK -PRM- CHILD. | NO. COWS | NO. GOATS | TYP ¹ HOUSE | | |
| 1. | | | | | | | | | |
| 2. | | | | | | | | | |
| 3. | | | | | | | | | |
| 4. | | | | | | | | | |
| 5. | | | | | | | | | |
| 6. | | | | | | | | | |
| 7. | | | | | | | | | |
| CONCLUSION WATER OFFICE : | | | | | | | COMPILED by : | | |
| | | | | | | | sign. : | | |



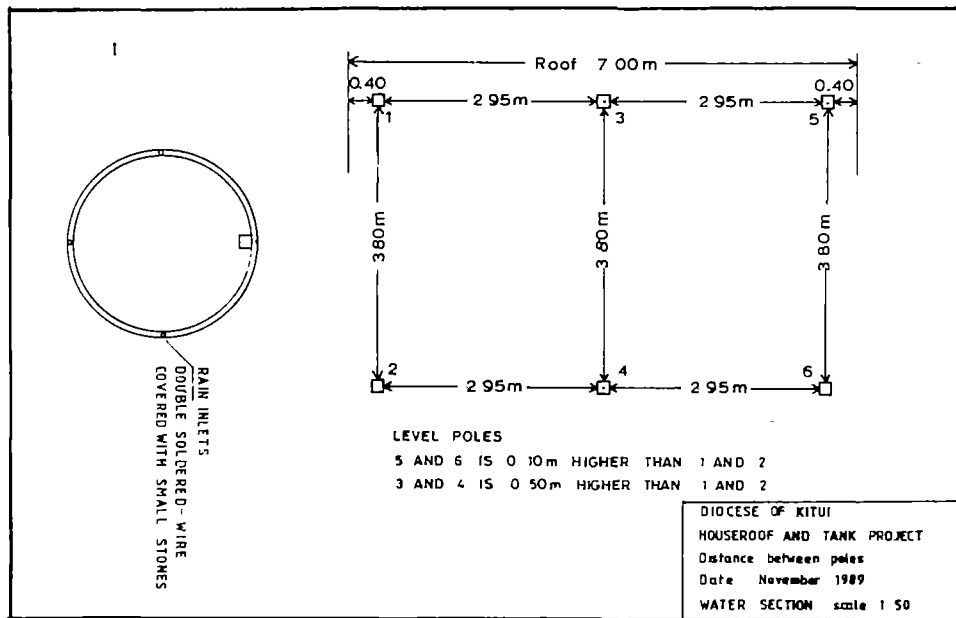
Appendix 5



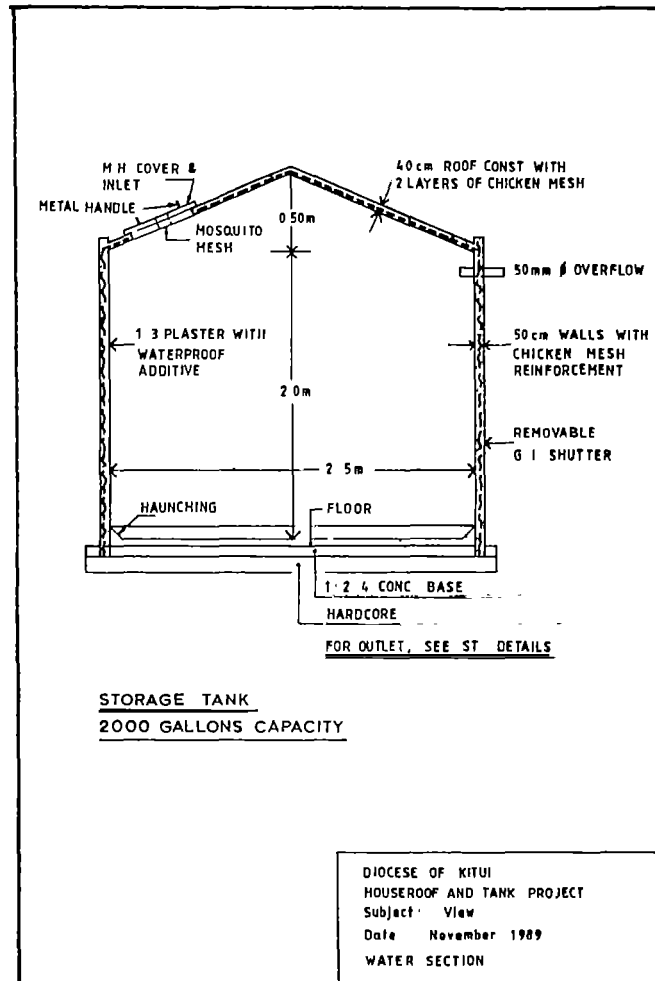
Appendix 6



Appendix 7



Appendix 8



Appendix 9

DISCUSSION

Mr. J. G. Ndiritu asked on what basis was size of the tank and the surface area of the roof decided.

Mr. Sirwan Said replied that the size of the tank and the surface area of the roof is based on an assumption of 10 family members requiring 10 litres per person per day for 100 dry days in each season i.e 10,000 litres.

Prof. Thomas asked how replicable the roof and tank approach is and whether it could continue without outside support.

Mr. Sirwan Said replied that the community is able to do the construction without outside assistance and should be able to fund the work as the structures are simple and the cost nominal.

Mr. P. Karinge asked what the achievements were and what was the response of the community.

Mr. Sirwan Said replied that within two and a half years of the three year project they had completed 120 shallow wells, 60 sub-surface dams and 13 rock catchments with a storage volume of 1 million litres. The response from the community had been quite good.

Mr. P. K. Karimi asked what provision is made for utilising the roof structure other than for water harvesting.

Mr. Sirwan Said replied that the roof is suitable for the construction of a house with two bedrooms and one living room.

SUSTAINABLE WATER DEVELOPMENT IN KENYA'S ARID AND SEMI-ARID LANDS

John Fox
Ministry of Arid and Semi Arid lands

1. INTRODUCTION

The "Pastoralist Water Project" was initiated as a result of an ongoing dialogue between the Government of Kenya and the donor community on future development programming for arid and semi arid lands (ASAL).

It was realised that the development of water resources was fundamental to sustainable ASAL development but there was no clear strategy concerning what sort of investments should be supported.

It was decided to establish the pastoralist water project in order to formulate basic strategies. The project is being implemented by the Ministry of Arid and Semi-Arid Lands.

Essentially the project has three tasks:

1. Investigative
2. Demonstration
3. Training

During the investigative phase the project team has visited many different ASAL districts and had an opportunity to identify on-going activities by the Government of Kenya and Non Governmental organisations (NGO's), some of which have strong community based orientations.

2. REPORT ON FINDINGS TO DATE

1. The first point to make is that the ASAL areas of Kenya are very large and extremely varied in terms of environmental conditions and the socio-economic lifestyle of its people.

In other parts of the world perhaps the best known example of ASAL development of water resources is Israel. However, if we consider the scale of the Israeli

operation and the level of investments made compared with Kenya, the Israeli case could easily be lost in many of Kenya's ASAL districts.

There is increasing pressure on the Zone V areas of Kenya through population movements from the high potential zones to the drier parts of the country. There is also an increasing movement of formerly nomadic peoples who are leaving zones VI and VII to settle in Zone V.

This movement is illustrated in Fig 1

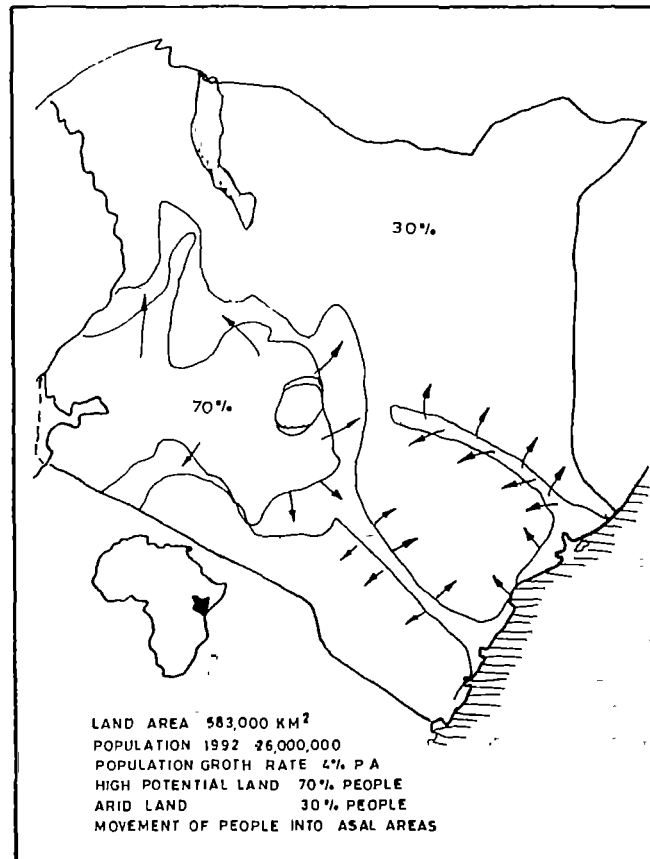


Fig. 1: Population movements from high potential areas to drier parts of Kenya

2. The task is very large. Too large for any one institution to succeed alone. It is therefore imperative that all institutions, whether governmental, NGO or donor should work together to maximise their strengths and to minimise individual weaknesses.

3. In order to facilitate such working together there is a need to evolve a collaborative coordinating structure.

4. Water resource development is very much divided between different sectoral groups which concentrate on "human", "livestock" or "agricultural" resources. In ASAL areas it is absolutely essential that these components are seen as the integrated use of one common resource.

5. Similarly it is important to make optimal use of the technologies available to us

In this respect it is possible to divide ASAL areas into three distinct strategy groups:

- Zone VI and VII strategies
- Zone IV and V strategies
- Urban Centre strategies (settlements with more than 2000 people)

It is not envisaged that the Zone VI and VII areas can develop effective water strategies without the use of boreholes and runoff catchment pans. These techniques play a very strategic role. However it is envisaged that shallow wells, rock catchments, sand storage dams and roof catchments can play a very important role in providing additional water whilst minimising the need for the more complex borehole/pan technology.

In Zones IV and V it is increasingly evident that the availability of perennial water sources is simply not enough to provide centralised schemes which make heavy use of the pumps and piping systems. The combined use of roof catchment tanks for human consumption, ground tanks for collecting run-off for livestock and intensive food production as well as run-off farming techniques can be developed as decentralised family/community based water supplies which are cheaper and more sustainable. This kind of approach is also more replicable and manageable for communities to play a leading role in their construction.

Many of the existing conventional water supplies in urban centres in ASAL are not operational, break down frequently or simply do not meet the present demand. There needs to be considerable effort put into developing appropriate design, development and management of such centres.

The Pastoralist Water Project has established a number of "Demonstration" activities in which the Ministry of ASAL is working in partnership with existing programmes to illustrate the kind of technical approaches which will be needed in the future to encourage sustainable water development in ASAL.

The areas of operation are illustrated in Fig 2.

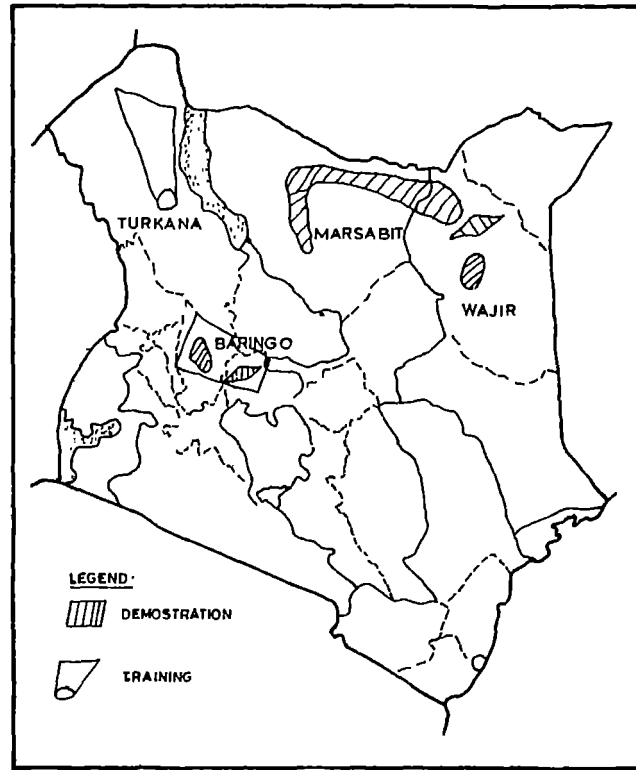


Fig. 2: Pastoralist water project - areas of operation

6. The most fundamental aspects of water development lie not only with the technical aspects but in the ownership and management of water facilities. In high population density areas (towns) it is more appropriate to have centrally managed water systems. In this respect all external support programmes of water development should have effective management training elements to assist in developing sustainable systems.

7. One of the major problems of encouraging more widespread water development programmes is low levels of implementation capacity in the districts. Capacity building would have to play a key part in the promotion of accelerated water programmes.

8. Some of the existing water programmes have evolved effective programming formats for assisting communities to improve their own water supplies. The most effective programmes tend to be NGO operated but not all NGO's have learned these approaches. Bigger programmes tend to be less efficient and more costly in achieving the same objectives but some of the bigger programmes are learning to be more effective.

9. The promotion and development of effective and appropriate technologies are fundamental to achieving wider water coverage. Community involvement is also essential for increased success rates. However these two elements alone will not achieve the objectives of providing water for all. Increased operating capacity and more appropriate programme management systems are equally important. Each of these elements must be dealt with in an integrated way as illustrated in Fig 3. Perhaps the most important stimulus to growth in the use of appropriate water related approaches in ASAL is a strong lead by Kenya Government in promoting and popularising these approaches. Equally within the framework of inter-agency collaborating structures there is a need to establish effective "role" clarification - "who does what?". Different agencies have different strengths and weaknesses. No organisation is strong in all sectors of activity. If respective organisations were able to agree on optimising their comparative advantages it would have remarkable effects in terms of improved field performance.

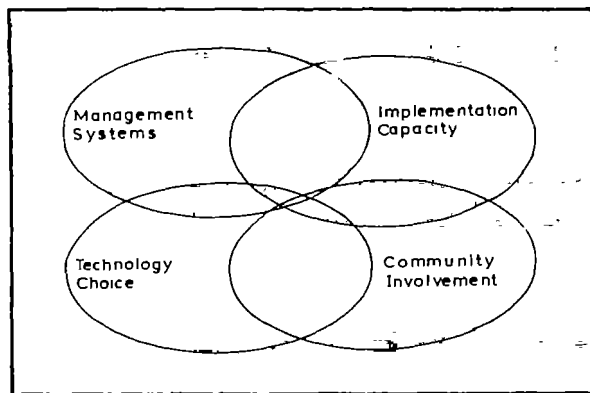


Fig. 3: Structural framework for wider water coverage

This is briefly illustrated in Fig 4.

| | LOCAL KNOWLEDGE | RESEARCH | PLANNING | FUNDING | IMPLEMENTING | SUSTAINING | MONITORING | EVALUATING |
|---------------------|-----------------|----------|----------|---------|--------------|------------|------------|------------|
| COMMUNITIES | x | | x | x | x | x | | |
| DISTRICT GOVERNMENT | x | | x | x | x | x | x | |
| NGO'S | x | x | x | x | x | | x | |
| NATIONAL GOVERNMENT | | x | | x | | | x | x |
| DONOR COMMUNITY | | x | | x | | | | x |

Fig. 4: Areas of comparative advantage for different organisations

DISCUSSION

Prof Thomas asked what is the experience with the use of windmills for pumping groundwater in ASAL. Is this technology sustainable? Mr Fox replied that the experience is mixed. From a technology perspective, the use of windpumps has a high capital input but low maintenance cost. In communities which depend on the windpump, the experiences are good and quite sustainable. In areas where the management element is not taken care of the pump unit breaks down with unacceptable frequency.

Mr G Mailu commented that the development of urban centres in ASAL areas is causing land degradation and asked what measures can be taken to develop settlements which are friendly to the environment. Mr Fox replied that it is the existence of permanent water supplies which generate new urban centres. In order to manage degradation around these centres we must assess the capacity of a particular site to cope with new settlements before establishing the water. With existing centres there needs to be some attempt to develop environmental management practices which seek to reverse and stabilise degradation.

Mr Vijselaar referred to the need for coordination and collaboration and asked who should be responsible for this on a nation wide basis as the need was urgent. Mr Fox agreed that there is a need for formal institutional coordination structures and that the Government of Kenya had established the Ministry of Reclamation and Development of Arid, Semi-Arid and Wastelands for this purpose. However people cannot be forced to collaborate. They have to want to collaborate. At the community level, the willingness and capacity to collaborate is quite high. At the district level this is less so but is still feasible. At the National level the ease with which coordination and collaboration takes place is the most difficult and requires much more formal structures.

4. ENVIRONMENTAL CONSIDERATIONS

QUALITY OF URBAN RUNOFF IN NAIROBI

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ABSTRACT

The volume of runoff from highly impervious areas of Nairobi is quite substantial and should be harnessed as a resource instead of being left to runoff as floods, in some instances being a nuisance to mankind and even causing deaths.

The paper looks at typical characteristics of water from various sources in terms of quality and compares these with the quality of runoff from selected points on streets of Nairobi to see if runoff has quality acceptable for use as a supplement to conventional sources of domestic if not industrial water.

The results of this work clearly demonstrate that in terms of Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Suspended Solids (SS), Nitrates as NO₃ and pH, runoff from the studied points in Nairobi in most cases, and certainly some 30 minutes after the commencement of rainfall, is of such quality that it is acceptable as a supplement for conventional water sources for both industrial and domestic uses, once it has been subjected to normal conventional treatment.

1. INTRODUCTION

Water is probably the most important natural resource in the world, since without it, life cannot exist. Unlike many other raw materials, there is no substitute for its many uses. Runoff from rainfall is a form of water which currently is not adequately utilised and is a hazard when it is allowed to runoff in large quantities resulting in floods, and on many occasions killing people. Runoff water must be considered as a natural resource that has to be managed carefully especially in urban areas of Third World Countries where the population increase is high and yet sources of water remain constant and in some cases diminishing.

Urban runoff if not controlled adequately can be responsible for some of the pollution of water courses. Indeed, it is acceptable that only by continual and and costly attention to water quality control is it possible to eradicate waterborne diseases which are responsible for many deaths in urban areas of developing countries. Indeed, it has been estimated that about 23% of the urban population had no reasonable access to a safe water supply in 1975 (Tebbutt, 1983). This figure is bound to have increased especially for urban areas of Third World

Countries where there are high birth rates and pronounced rural to urban migration.

Runoff, especially in urban areas that are highly impervious produce a volume of water which if properly harnessed can be used to supplement other conventional sources of water. This practice should be encouraged given that one of the most widespread and directly accessible sources of water is rainfall. One reason why runoff water has not been harvested and used to supplement conventional sources of water especially in Kenya may have to do with the uncertainty of its quality. This paper examines the quality parameters of urban runoff in Nairobi and its possible use for industrial and possibly domestic needs.

2. CHARACTERISTICS OF WATER

All natural water contains varying amounts of other materials in concentrations ranging from a few milligrams per litre in rainwater to about 35,000 mg/l in seawater. A simple measure of the total solid content of a sample is insufficient to specify the characteristics of water since for example, a clear sparkling ground water might have some total solids content as raw sewage. Therefore, to gain a true picture of the nature of particular sample, it is necessary to measure several different properties by carrying out physical chemical and biological analysis. Indeed, it must be pointed out that not all characteristics need to be investigated for any one sample. However, Table 1 gives a list of some important characteristics of water.

3. TYPICAL CHARACTERISTICS OF WATER

Since waters vary widely in their characteristics, it is not really possible to give details of what might be termed as normal characteristics. As a guide, Table 2 is presented to give typical characteristics for various sources of water.

In the case of water used for potable supply, it is common practice to assess its quality in relation to specified guidelines or standards. The formulation of such guide values requires critical assessment of the properties of the various constituents and it is often useful to classify constituents into five groups, namely:- organoleptic, natural physicochemical, substances undesirable in excessive amounts, toxic substances and microbiological parameters. Briefly these are :-

(a) Organoleptic Parameters: These are readily observable by the consumer but have little health significance. eg. colour, turbidity, taste and odour.

(b) Natural Physico-Chemical Parameters : Some of these may have health significance but in general when setting standards excessive amounts should be avoided, e.g. pH, conductivity, total solids, alkalinity, dissolved oxygen.

(c) Substances Undesirable in Excessive Amounts : These include a wide variety of substances, some of which may be directly harmful in high concentrations, others which may produce taste and odour problems, and others may not be directly troublesome in themselves but are indicators of pollution, e.g. nitrates, fluorides, phenol, iron, manganese, chloride.

TABLE 1 : Important Characteristics of Water

| Characteristic | River Water | Rainwater (Runoff) | Drinking Water |
|------------------------|-------------|-----------------------|----------------|
| pH | x | x | x |
| Temperature | x | x | x |
| Colour | x | x | x |
| Turbidity | x | x | x |
| Taste | | x | x |
| Odour | x | | x |
| Total Solids | x | x | x |
| Settleable Solids | | x | |
| Suspended Solids | | x | |
| Conductivity | x | | x |
| Radioactivity | x | | x |
| Alkalinity | x | x | x |
| Acidity | x | x | x |
| Hardness | x | | x |
| DO | x | x | x |
| BOD5 | x | x | |
| Ammonia Nitrogen | x | x | |
| Chlorides | x | x | x |
| Phosphates | x | | |
| Synthetic Detergents | x | | |
| Bacteriological Counts | x | x | x |
| Heavy Metals | x | x | |

Source : Tebbutt, 1983

(d) **Toxic Substances** : A wide range of inorganic and organic chemicals have toxic effects on man, the severity of the effects depending for a particular material on the dose received, period of exposure and other environmental factors, e.g arsenic, cyanide, lead, mercury.

(e) **Microbiological Parameters** : these are by far the most significant in determining water quality for portable supply. Standards for microbiological quality are essentially based on the need to ensure that bacteria indicative of pollution by human wastes are absent. Having examined the characteristics of the various sources of water, the study area will now be introduced with the view to seeing the quality of the resultant runoff.

TABLE 2 : Characteristics of Various Water Sources

| Characteristic in mg/l Except where noted | Source | | |
|---|---------------------|------------------|---------------|
| | Upland Catchment | Lowland River | Chalk Aquifer |
| pH (Units) | 6.0 | 7.5 | 7.2 |
| Total Solids | 50 | 400 | 300 |
| Conductivity (us/cm) | 45 | 700 | 600 |
| Chlorides | 10 | 50 | 25 |
| Alkalinity (total) | 20 | 175 | 110 |
| Hardness (total) | 10 | 200 | 200 |
| Colour (oH) | 70 | 40 | 5 |
| Turbidity | 5 | 50 | 5 |
| Ammonia Nitrogen | 0.05 | 0.5 | 0.05 |
| Nitrate (NO ₃ M) | 0.1 | 2.0 | 0.5 |
| DO (percent Saturation) | 100 | 75 | 2 |
| BOD ₅ | 2 | 4 | 2 |
| Coliform MPN/100ml | 20 | 20000 | 5 |

Source : Tebbutt, 1983

4. THE STUDY AREA - NAIROBI

Nairobi is the capital City of Kenya currently having a population of about 1.5 million, having doubled between 1976 and 1986, the increase being due to natural as well as migration of rural people in search of waged employment. With such a high increase, pressure has been put on the provision of public services including health, transport, water supply and also on the maintenance of these infrastructures.

The size of the built up area of Nairobi has also increased three fold from 1976 to 1986, the resulting impervious area being increased even more. Furthermore, most Nairobians think that it is trendy to pave their backyards and as a result, it is estimated that as high as 60 percent of the surface of the land area in Nairobi is impervious, thereby presenting a suitable surface for runoff.

5. RAINFALL PATTERN IN NAIROBI

The weather in Nairobi influenced by the south west Trade winds and the North East trade winds. The north east trade winds laden with little moisture from the Indian subcontinent prevail between December and March. The subsiding airmass being usually dry. The south east trade winds on the other hand obtain their maximum intensity between April and May.

Major storms occur between November and May. The long rains begin in mid March to the end of May, while the short rains occur between October and December, although some storms have been recorded in the dry months of January and February.

6. RUNOFF QUANTITY IN NAIROBI

The volume of runoff from intense storms that occur in Nairobi can be computed scientifically. The magnitude of this depends on basin factors such as the percentage of impervious area, slope of the surface, soil characteristics, the antecedent conditions, and also, on the characteristics of the rainfall among others.

Most studies examining the relationship between urbanization and runoff suggest that urbanisation potentially has a major effect of increasing the magnitude of the runoff, but that this varies widely with local conditions. In urban areas like Nairobi, infiltration can range from zero for paved areas to rates exceeding rainfall intensities for areas not subject to traffic by vehicles or people. Generally, lawns have low infiltration rates, with overload flows depending very much on the proportion of area that is impervious.

Soil moisture storage capacity is low in Nairobi. For paved parts, the storage is made up of surface retention and depression storage. Indeed, relative to forests, the soil moisture storage capacity of lawns is low and average moisture deficits are decreased through the application of imported water.

On the other hand, Evapotranspiration from impervious areas is very low, but where there are irrigated lawns, gardens and parks, it is higher than the natural situation. In garden conscious areas like Muthaiga and Loresho, it is probable that the higher soil moistures resulting from imported water more than offset the loss of potential evapotranspiring surfaces.

According to Krhoda 1991, in the high cost single house residential areas in Nairobi, the total runoff ranges from 26 to 42 percent because of the large gardens and sometimes non lined channels, the paved surface being less than 5 percent. The deep weathered volcanic soils found in Nairobi have high infiltration rates that absorb most of the rainwater, thereby reducing the runoff volume. Therefore, these areas behave in a similar way to rural catchments. For areas with more than 28 percent pavement, the total runoff ranges from 31 to 95 percent, especially in the city centre, Industrial Area and the Pangani area, while in the dense low cost residential areas, the percentage paved area is about 18 percent and the total runoff from single storms range from 26 to 84 percent.

Unfortunately, the relationship between rainfall for individual storms and runoff does not yield satisfactory correlation, partly because such a relationship does not distinguish between rainfall intensity and duration and partly because catchments have long lag periods, in which case the effectiveness of rainfall intensity becomes minimal. Therefore, with a good knowledge of the type of catchments in Nairobi and using standard known formula, it is possible to accurately calculate the volume of runoff from the paved areas of Nairobi.

7. QUALITY OF RUNOFF IN NAIROBI

To assess the quality of runoff from the streets of Nairobi for its suitability as a source of water for industrial and possibly domestic use, several samples were collected from various selected parts of the streets of Nairobi. To investigate the effect of the initial flush on the quality of the runoff, it was decided that where possible, samples be taken every 10 minutes for the first 30 minutes and then at 30 minutes interval for the duration of the storm or for two hours, whichever was the longer. The results are presented in Table 3.

8. DISCUSSION OF RESULTS OF QUALITY OF RUNOFF

It is recognised that data provided in this report is limited and therefore conclusions drawn from their interpretation cannot and should not be used alone to justify policy changes. However, the results as they stand form a sound basis upon which further work should be carried out with a view to major policy changes in the harnessing of runoff water as a source of water. These results clearly indicate that for most of the monitored parameters, the results are decreasing with time of runoff measurement, an indication that the initial flush clears most of the contaminants from the surface, leaving the rest of the runoff fairly clear and of comparable quality with lowland river water.

TABLE 3 : Results of Runoff Quality In Nairobi

| (All Values in mg/l except pH) | | | | | | |
|--------------------------------|-------------|-----|-----|------|-----|-----------------|
| Station | Time (Mins) | pH | COD | BOD5 | SS | Nitrates as NO3 |
| Uhuru Highway 1 | 10 | 5.0 | 90 | 30 | 240 | 60 |
| | 20 | 5.8 | 60 | 20 | 210 | 40 |
| | 30 | 7.1 | 40 | 13 | 120 | 20 |
| | 60 | 7.2 | 20 | 7 | 100 | 10 |
| | 90 | 7.0 | 10 | 3 | 60 | 10 |
| | 120 | 7.0 | 5 | 2 | 38 | 5 |
| Uhuru Highway 2 | 10 | 4.8 | 82 | 29 | 200 | 50 |
| | 20 | 5.7 | 61 | 22 | 210 | 40 |
| | 30 | 6.8 | 34 | 12 | 200 | 20 |
| | 60 | 6.9 | 30 | 11 | 80 | 10 |
| | 90 | 7.0 | 32 | 11 | 40 | 5 |
| | 120 | 7.0 | 5 | 2 | 30 | 5 |
| Kijabe Street 1 | 10 | 6.0 | 60 | 21 | 140 | 20 |
| | 20 | 6.4 | 50 | 18 | 120 | 20 |
| | 30 | 6.8 | 31 | 11 | 100 | 10 |
| | 60 | 7.0 | 30 | 11 | 60 | 10 |
| | 90 | 7.0 | 10 | 4 | 30 | 5 |
| | 120 | 7.0 | 10 | 4 | 30 | 5 |
| Kijabe Street 2 | 10 | 5.8 | 60 | 18 | 120 | 30 |
| | 20 | 6.1 | 40 | 12 | 80 | 25 |
| | 30 | 6.6 | 30 | 9 | 40 | 20 |
| | 60 | 6.9 | 10 | 3 | 30 | 20 |
| | 90 | 7.2 | 5 | 2 | 30 | 10 |
| | 120 | 7.1 | 5 | 2 | 20 | 5 |
| University Way 1 | 10 | 5.8 | 50 | 16 | 130 | 40 |
| | 20 | 6.4 | 40 | 13 | 120 | 40 |
| | 30 | 6.6 | 30 | 10 | 100 | 30 |
| | 60 | 6.9 | 10 | 3 | 70 | 20 |
| | 90 | 7.0 | 5 | 2 | 60 | 20 |
| | 120 | 7.2 | 5 | 2 | 30 | 5 |
| University Way 2 | 10 | 5.8 | 48 | 12 | 140 | 38 |
| | 20 | 6.3 | 42 | 10 | 130 | 40 |
| | 30 | 6.8 | 30 | 7 | 100 | 30 |
| | 60 | 6.8 | 30 | 7 | 60 | 20 |
| | 90 | 7.1 | 10 | 3 | 40 | 10 |
| | 120 | 7.2 | 5 | 1 | 30 | 10 |
| Koinange Street 1 | 10 | 6.2 | 40 | 16 | 80 | 30 |
| | 20 | 6.8 | 10 | 4 | 88 | 10 |
| | 30 | 6.8 | 10 | 4 | 60 | 10 |
| | 60 | 7.2 | 5 | 2 | 30 | 10 |
| | 90 | 7.2 | 5 | 2 | 30 | 5 |
| | 120 | 7.1 | 5 | 2 | 30 | 5 |
| Koinange Street 2 | 10 | 6.2 | 30 | 10 | 90 | 30 |
| | 20 | 6.3 | 10 | 3 | 90 | 30 |
| | 30 | 6.8 | 10 | 3 | 60 | 20 |
| | 60 | 6.9 | 5 | 2 | 30 | 5 |
| | 90 | 7.2 | 5 | 2 | 30 | 5 |
| | 120 | 7.2 | 5 | 2 | 20 | 5 |

Studies by Mein 1983 indicated that substantial BOD5 pollution occurs from urban runoff from heavily developed areas, especially industrial areas. The results of this ongoing study indicate that this is true as there is a higher BOD5 on samples taken from Uhuru Highway and Kijabe Street compared to samples taken from other streets. This could be attributed to the rather busy state of these roads, thereby giving them the industrial touch. Runoff quality is also considerably impaired because of increased erosion possibly as a result of construction activities, again this being more pronounced in samples taken from Uhuru Highway, where there is a fair amount of construction activity going on.

Comparing these results with what is generalised effluent standards for discharge into water sources namely BOD5 20 mg/l; COD 50 mg/l; SS 30 mg/l, Nitrates 30 mg/l; Sulphides 2 mg/l; and pH 6.5 - 8.5; (Ndiritu and Otieno, 1991), it is clear that except for a few samples along Uhuru Highway which gave a BOD5 of 30 mg/l, 29 mg/l and 22 mg/l, the runoff would be of better quality in terms of BOD5 than what is permissible. In terms of COD, again except for a few samples, the initial samples on Uhuru Highway and the first sample taken along Kijabe Street, the rest of the samples are of better quality than the recommended effluent standards for discharge. The same would be true for Nitrates as NO₃ and pH.

9. CONCLUSION

Finally, it is observed that in most cases, after 30 minutes of rainfall, all samples of runoff as tested meet the stated criteria for effluent discharge into water courses and therefore it can be argued that if 30 or more minutes of the initial flush of runoff water was allowed to pass unharvested, the rest of the water resulting from prolonged rainfall is of such quality that it should be tapped or harnessed to supplement more conventional sources of water as a water source, especially in urban areas like Nairobi. This case is even more acute given the volume of water under consideration.

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DISCUSSION

Mr. H. A. Adams, commented that although much research still needed to be done on the possibility of using urban run-off and supplement conventional water supplies, the paper by Dr. Otieno was very encouraging and could be a new school of thought for planners on upcoming middle class urban centres, similar to Nairobi.

The author agreed with this.

Mr. Gibberd asked whether the PH of rain had been checked as it fell in view of the surprisingly low PH of the initial street run-off. Dr. Otieno answered that this had not been done, but that he attributed this low PH to contamination of the soil lying around the surface of the study area. It was also possible that particles of sulphuric acid suspended in the air could have been responsible for this low PH during the initial rainfall.

An enquiry was raised by J. Wanyonyi regarding the practicality of harnessing urban run-off, and the bearing of the findings on policy on water. Who would certify the acceptability of the quality of run-off? To this, Dr. Otieno responded that the quality of run-off was acceptable to the local authorities who are charged with provision of clean water to Nairobi. He further stated that though it was not easy to harness urban run-off, this would certainly be a practical alternative for water supply. Dr. Otieno agreed that the findings should have a bearing on policy.

To a question by Dr. Ndege about how floodwater could be harnessed in Nairobi, Dr. Otieno responded that the exact nature of how and where the floodwater could be harnessed was a matter for further research, and the findings of in his paper was only a start to what can and should be considered.

Mr. Settergen stated that he was surprised to hear that rainwater harvested in the sheets of Nairobi had such a good quality in view of the fact that in other parts of the world, the discussion was whether the run-off should not be treated in sewage treatment plants before discharge into rivers etc. Dr. Otieno said that the quality of urban run-off was not of drinking water standards and would need to be treated before its quality is satisfactory for drinking purposes.

THE RISKS OF WATER POLLUTION FROM URBAN REFUSE

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ABSTRACT

The paper explores the risks of water contamination from urban refuse in Nairobi.

As the city grows at the rate of about 10 percent per annum, more urban gases are emitted into the atmosphere, as tons of solid waste are dumped recklessly in all sites without any regard to environmental consequences.

This paper intends to expose the risks of water pollution from the urban waste and to explore possibilities of curbing the looming ecological catastrophe which might result from these practices.

1. INTRODUCTION

One of the most remarkable spatial features of this century is the emergence and expansion of urban centres in the developing world. After the second world war, and especially in the post-independent Africa, the continent has recorded an average urban growth rate of 5 percent, the highest in the world. This has been caused by the mass movement of people from the rural areas to urban settlements. Some urban centres have several million people (Khinshasa, Nairobi, Cairo) while many are still under one million population mark. The projections to the end of the century and the first half of the next century are scarily high.

Numerous problems related to urbanisation have become amplified such as housing, traffic congestion, spatial organisation, unemployment and most relevant, environmental pollution.

Towns have become centres of pollution due to human, economic and social activities in search of livelihood. The available resources have become strained by the high population densities.

Looking at an urban set-up as an open system, it has imports as well as exports. The imports constitute all the materials which come from outside the town boundaries in the form of energy, food, industrial raw materials, "inter alia", while

the towns exports are what is generated. The internal activities of an urban system generates a lot of refuse/waste which when carelessly disposed are harmful to man and the natural environment. They are in gaseous, liquid and solid forms.

One of the natural resources that continues to be adversely affected by urban refuse is water, which is the focus of this paper. The various forms of wastes have contaminating effect on atmospheric water, surface water and sub-teranean aquifers.

2. WATER POLLUTION: CAUSES AND SOURCES.

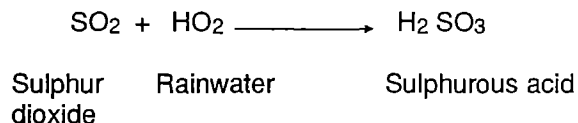
The gaseous emissions from the industrial set up and automobiles are posing a big danger to the water in the atmosphere. Amongst the notable gases include, carbon monoxide, hydrocarbons, nitrogen oxides sulfur dioxide, particulate matter and black smoke. The list is inexhaustable with the resultant consequences on environment and man's health. Obnoxious odours and various respiratory and psychological diseases are on increase in Nairobi as a result of atmospheric pollution (AMREF).

To give an insight to atmospheric water pollution in Nairobi, an illustration was taken from diesel vehicles in the city.

While the estimated number of diesel vehicles in Kenyas is 100,000, Nairobi itself could contain up to 50% of the total Kenya vehicle population at any time. By the year 2000, the number of vehicles in Nairobi is likely to be over 75,000. (Kenya Motor Institute).

The amount of pollutants emitted will increase in proportion as will the effects due to continuous exposure and accumulation in the atmosphere. Total levels of diesel pollutants in Nairobi will continue to rise. This trend has been allowed to continue unchecked or questioned. The effect and consequences are not being adequately monitored or assessed in Nairobi.

With the increase of polluted gases in the atmosphere we risk contaminating rainwater. A possible chemical combination from sulphur dioxide and rainwater to produce sulphurous acid is demonstrated here below.



Other gases in excess levels have their peculiar effects on rainwater. The possible consequences to rainwater should be of concern to all of us.

As soon as rainwater falls on the surface, the surface drainage in Nairobi has proved a disaster. Within a short spell of one hour rainfall in Nairobi, majority of areas get flooded. The Nairobi City Commission drainage system is mostly blocked or does not exist at all in some places.

The automatic route for the floods is obeying the gravitational pull, where water flows freely as surface run-off, collecting all the waste which includes oils, greases, decomposing organic materials, chemicals and whatever else is on its path. All these end up in the rivers such as Nairobi river, Mathare river, and all the other streams in Nairobi area.

These hazardous runoff pollutes the surface water system. They change the chemical composition of water, turbidity and above all kills the aquatic ecosystem. This is already evident in the Nairobi river which has become unfit for human consumption and industrial use.

With the population increase in the city the pressure on the sewer system is mounting. As a result incidences of burst sewers are on the increase. This sludge ends up in our rivers.

The adverse effects on surface water pollution are all over in Nairobi rivers ranging from changed water colours, eutrophication and dead aquatic systems. The trend continues unabated. Urgent remedial measures are called for, to arrest this trend and rehabilitate our water resources.

The provision of clean water in Nairobi is far below the expectation. It is estimated that about two-thirds of the population of Nairobi does not have access to clean water. This is mostly in the slums and squatter settlements which are expanding at an alarming rate. The low-income areas are inadequately served with clean water, as general water scarcity grips the entire city. Most of the water consumed in Nairobi is trapped from the rivers flowing east to the Aberdare Mountains.

As a response to often dry taps in the city, many institutions and individuals have resorted to tapping the underground aquifers as a supplement. Water drilling has become a common feature in the commercial, industrial and residential areas. These underground aquifers are threatened with pollution from surface water and urban refuse.

In the hydrological cycle, part of the surface runoff filters through the soil to join rivers while in other waters, "the through-flow" passes through the porous rocks to be stored in the geological formation known as aquifers. Further, part of the waters in the rivers infiltrate the underlying rocks as "through-flow" and join the subterranean water resources as well.

Both sources of water are already contaminated as explained earlier. The surface runoff gets polluted by the various chemicals found on the surface, and this does not eliminate all the dangerous compounds, especially the man-made chemicals. Also, as the already polluted river waters sink to the underground water, it carries all the pollutants with it.

3. SOLID WASTE POLLUTION

The menace of solid waste in towns and especially in Nairobi has reached alarming levels. A survey by the Foundation for Sustainable Development in Africa (FSDA) has estimated garbage generation in Nairobi to be in the tune of up to 3,000 tonnes of garbage per day. Solid wastes are generated from many different sources and hence comprise an almost infinite variety of materials and chemical composition ranging in size from a speck of dust to a discarded automobile and a density from foam, plastic to lead. They include organic waste, metal, glass, paper, plastics, leather, pulp, textiles, wood, yard wastes and other miscellaneous wastes. All these have adverse effects on aesthetics, odour, space occupation and environmental health as they react with one another and as the biodegradation takes its toll.

One of the widely used methods of disposing solid waste is the use of a sanitary landfill. There has been an increased concern with respect to the pollution potential of improperly operated landfills. The polluted effluent emanating from solid waste landfills is called leachate, and when leachates seep into underground aquifers, the threat of water pollution becomes real for areas outside the immediate vicinity of the fill site.

A large number of factors interact to produce a variable quantity and quality of leachate from landfills. Though some leachate is produced by organic solid waste decomposition and compaction of wet refuse, the main factor causing leachate generation is the inflow of water. Annual rainfall, runoff and infiltration typically results in leachates generation and possible water pollution. Leachate may contain dissolved and suspended materials of all sorts.

As the estimated two million population of Nairobi continues to grow at a rate of approximately 10 percent per annum the projected number by the year 2000

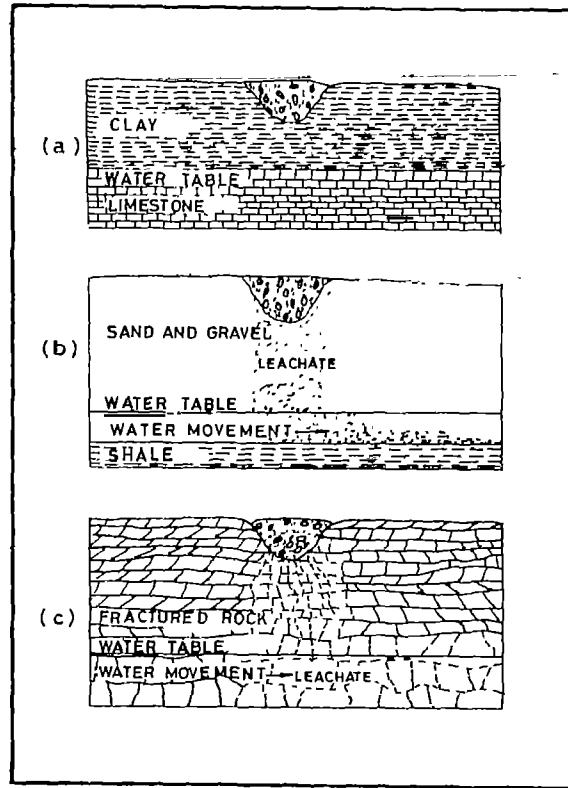


Fig. 1: Leachate flow in different rocks

will be over 4 million residents. This will tally in proportion with generation of enormous urban refuse with consequent impacts on the utilisation of natural resources, human health and environmental degradation. A big task lies ahead for resource planners and urban managers.

4. CONTROL MEASURES

Some possible measures to curb this trend are suggested below for policy consideration in water harvesting in urban areas.

(1) Ensuring efficient machine operation. Compliance with the *manufacturer* and maintenance instructions is essential in order to optimise machine performance, and to ensure that environmental and fuel economy design characteristics are met. Machine operation, and maintenance should adhere to the recommended specifications and control of the undesired emissions should be targeted to the polluted areas.

(2) Requirements of anti-pollution gadgets in the automobile and industrial exhaust systems. They should conform to environmentally acceptable standards.

(3) Encouragement of the establishment of "environmental friendly" industries as a policy for now and the future. Various incentives should be adapted.

(4) Monitoring and assessment. Constant monitoring and assessment of industrial, commercial, residential and automobile by-products should be enhanced. The following local departments and institutions should become involved in monitoring and assessing all implications; universities, environmental health departments, Kenya Environmental Secretariat, United Nations Environmental Programme, Kenya Medical Research Institute, Kenya Motor Institute and Kenya Bureau of Standards among others.

(5) Alternative ways of handling solid waste should be sought. These should include incineration, recycling, selective dumping in less porous geological set up to avoid leachate pollution threat.

(6) Legislation and enforcement. Adequate legislation should be introduced for control of environmental pollution and should be enforced. Political support should be given for this.

(7) Public awareness and participation. The public should be made fully aware of all the implications related to pollution. They should be an integral part of handling the problem. Existing media channels should be used and education programme should be delivered through formal and informal forums.

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5. PRACTICAL EXPERIENCES AND CASE STUDIES

WATER HARVESTING EXPERIENCE IN TURKANA

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ABSTRACT

The paper is about the accumulated experience of the author in two respects Firstly for having worked in this field for a period of six years and secondly, for being a co-author of a recent review of Water Harvesting Activities in Lokitaung Division, Turkana District (Critchley with Erukudi, 1992).

The Physical Environment of Turkana is briefly outlined, including location, area, climate, topography and soil. This section is immediately followed with a statement on the rural economy of Turkana, which is of diverse in nature.

Next, the Water Harvesting situation, history and techniques that have been implemented follow. This section is supported with diagram illustrations.

The approaches that have been used by the main implementers of water harvesting agencies lead to an interesting section on impact of water harvesting activities The physical achievements, economic impact, and social impact are indicated.

The final part on "Lessons Learnt" is the most important. The lessons are summarised in terms of conclusions and recommendations for future Water harvesting activities in Turkana District. It is emphasized that a water harvesting Programme should be implemented in phases, involving the beneficiaries, and the techniques promoted should not be labour intensive and expensive. A suitable co-operation between the different actors is also essential

1. BACKGROUND

1.1 The Physical Environment

1.1.1 Location

Turkana District occupies the arid north west of Kenya. It has a total area of approximately 77,000 square kilometres, which include Lake Turkana which forms the eastern boundary. It is bordered by Ethiopia to the North East, by Sudan to the North and by Uganda to the West (see Fig. 1.1).

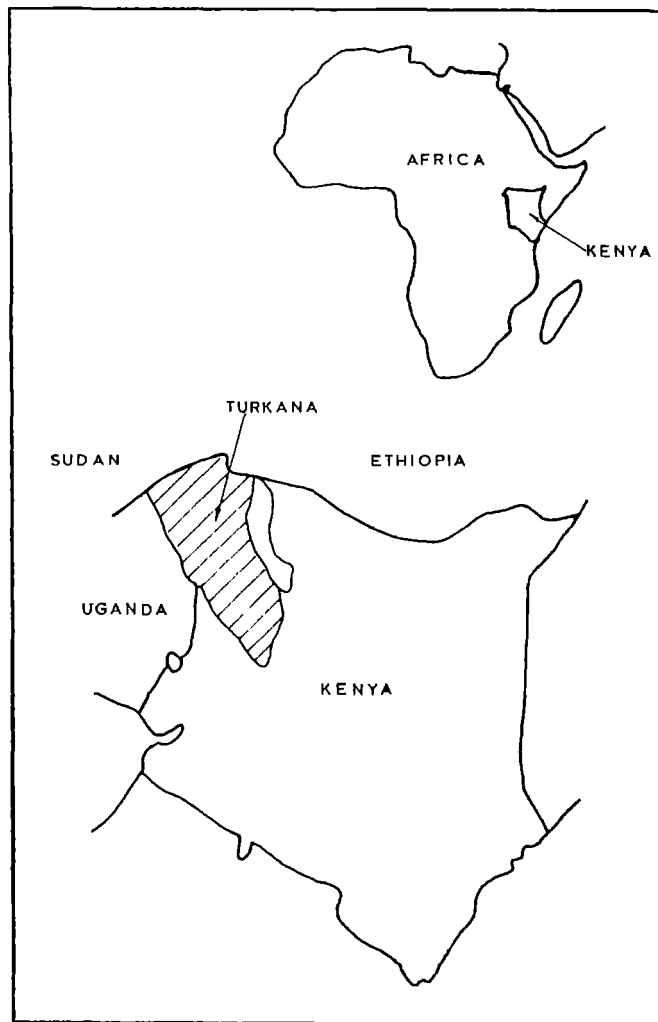


Fig. 1.1: Location of Kenya and Turkana District

1.1.2 Climate

Most of Turkana District is classified as arid under the "Lowland 6; Ranching Zone" or perarid (very arid) under the "Lowland 7; Nomadic Zone" Turkana District is subject to low and erratic rainfall with great variations both within and between seasons. The variability becomes greater as the mean annual rainfall decreases. Characteristic are also high intensity storms (over 40mm per day)

which produce considerable runoff in the absence of adequate tree or bush cover.

Rainfall ranges mainly between an annual average of 200 mm and 450 mm. Even in seasons of good rainfall, there are prolonged droughts, which make crop production a risky enterprise.

Potential evapotranspiration is generally above 2000 mm in Lodwar. This is a direct function of the prevailing temperatures which are also related to the altitudes. The temperatures are high and fairly uniform throughout the year with an average daily level of about 24 degrees Centigrade around Lodwar. Relative humidity registered in Lodwar is rarely above 60% and always above 30%.

Strong winds are frequent, usually coming from the east to south-east and sweeping across the district.

1.1.3 Agro-Climatic Zones

According to the Agro-Climatic Zones of Kenya, the district can generally be divided into five main zones on the basis of average annual rainfall and average annual potential evapotranspiration. About 53% of the district falls under the driest zone VII which represents the land with low and moderate elevation in the eastern and northern parts of the district. 17% lies in Zone VI, 26% in Zone IV and zone V. The remaining 4% is zone III found in the southern western and extreme north of the district (Fig 1.2).

1.1.4 Topography

The district consists predominantly of a vast low-lying plain, housing an altitude between 370 and 900 metres above sea level from which protrude isolated mountains and ranges of hills. The high elevations lie in a north-south direction following the general structure of the eastern rift valley.

1.1.5 Soils

The soils are generally classified as sandy loams to loamy sands, and are of high to medium texture. Some soil tests (Kenya Soil Survey 1987) show that the soils are subject to compaction and capping and suffer from phosphorus and nitrogen deficiency. They have also problems of salinity and sodicity of varying degree.

1.1.6 Water Resources

The two main river systems are the Turkwel and Kerio, both of which originate from the Kenya Highlands from the south of the district.

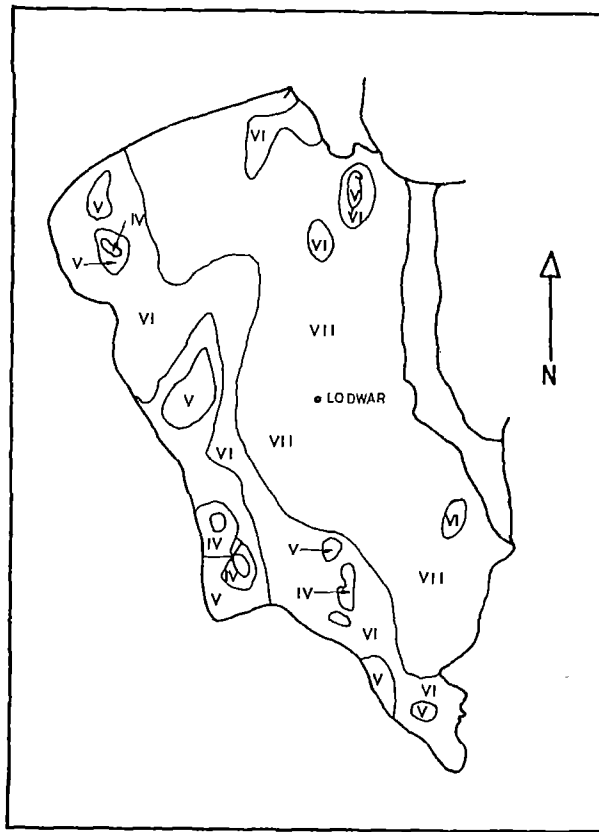


Fig. 1.2: Turkana District: Agro-climatic zones

Other water sources can be found both in numerous stream beds and from springs and wells dug in the sand rivers. These rivers are subject to dramatic variations in discharge. At times of high water, the silt load is often considerable. Ground water, boreholes and wells are increasingly becoming the most sought after source of fresh water especially for the settled population.

1.1.7 Vegetation

The vegetation is sparse in the central areas but moderately dense on the higher mountain slopes. The areas of forest woodland are confined to the major drainage channels and river course because there is a tendency of bushlands increasing in density along the moisture sources with elevation. The vegetation cover provides pastoralists with forage for livestock shade, fruits, building materials and fuelwood among others.

1.2 The Rural Economy

1.2.1 Population

No accurate data exist to give the actual population of the district. Aerial surveys give a figure of between 200,000 to 300,000 people, while population censuses give very low figures. It is claimed that the district is having an intercensal negative growth rate. The main reason is that the method used in conducting a census exercise is inappropriate and is not adapted to the nomadic pastoral situation prevalent in Turkana district.

1.2.2. Production Strategies

In common with other pastoralists, the Turkana have a relatively diversified economy as Odegi - Awoundo (1991), and quoted by Critchley with Erukudi (1992), discussing the Turkana says:

"History does not lend evidence to the popular myth that pastoral nomads know only one big thing; subsistence livestock rearing. Pastoralists combine livestock husbandry with hunting, gathering, cultivation, trade and metallurgy".

The Turkana are involved in a diversity of economic activities.

1.2.2.1 Livestock

As a result of the natural environment, pastoralism remains the main economic activity. Livestock include cattle, camels, donkeys, goats and sheep. The basic strategies of mobility, dispersion and mixed herds are applied as a rule of thumb. Unfortunately this sector is vulnerable to disease, drought and raids.

1.2.2.2 Crop Production

There is a history of cropping of sorghum which supplements pastoralism for some families (Erukudi, 1992).

Sorghum is the predominant crop. Local Turkana sorghum is very early maturing - some crops are harvested after only 60 days. Sorghum is planted in depressions where rainfall accumulates, on plains by water courses which seasonally flood, and also within river beds after ephemeral (or seasonal) flow has ceased.

Irrigation development has also a command area of about 1000 hectares and some people earn a living there.

1.2.3 Other Stategles

The Turkana along the lake practise fishing. In trading centres some people get involved in minor trading and handicraft activities. Quite recently, small and handicraft dispersed traces of minerals have been spotted whose potential is not yet known. Employment is also a source of earning for a few families.

The next section reviews the water harvesting situation, which forms the basis of this paper.

2. REVIEW OF WATER HARVESTING SITUATION IN TURKANA

2.1 History of Water Harvesting In Turkana

2.1.1 Early Initiatives

Water harvesting has been on the Turkana agenda from as long ago as the 1950s. The first attempts at water spreading for the irrigation of sorghum were implemented in 1951/52 in Nakuutan and Lodwar.

The Range Management Division implemented a number of experimental schemes in the 1960s and early 1970s. The "Impala Pilot Water Spreading Scheme" established at Lorengekippi was heralded as "a hope for impoverished people" after initial promise, by one of the instigators of the scheme.

Other range rehabilitation efforts, principally at Lobei in 1971 and Narongole in 1977, utilised "pitting" associated in the case of Narongole, with water spreading from a "lugga".

In all the above attempts, the projects failed for one or more of the following reasons:-

- Construction was carried out by forced labour (prison)
- Poor control of the flood waters
- River changes course
- A total disregard on the part of the planners for achieving social acceptance of the techniques used

- Technical problems and abandonment
- Poor maintenance
- Over ambition and unnecessary over design in size

2.1.2 Recent Development

After the disasters of late 1970s and early 1980s, water harvesting became one of the activities designated for food for work by the Turkana Rehabilitation Project (TRP) and other Governmental and Non Governmental Organisations. At the same time water harvesting was being talked about as a possible remedy to the problems of semi-arid zones in much of Africa.

TRP picked up the challenge and began to implement water harvesting on a very large scale, supported, at one stage, by up to three quarters of its enormous food-for work budget.

Water harvesting work had also been begun in Lokitaung Division on an experimental basis in 1978 under the Salvation Army village polytechnic, and later changed into Turkana Water Harvesting Project supported by Oxfam/ITDG with food for work also provided for by TRP.

The success of even the recent development have been limited because of a variety of reasons:

- Heavy rainfall events washed out the massive bunds
- Work was hurriedly implemented for the sake of distributing food, and making work
- Large scale operations
- Lack of technical guidance or training
- The largest portion of the work was directed to rangeland improvement, which was not a local priority
- The structures were overdesigned, hence labour intensive
- Not heeding lessons of previous experience, for example change from micro-catchments to spate diversions in 1985

- Forcing food for work recipients to move to isolated sites *where there was not even a perennial supply of drinking water*
- Inadequate technical designs
- Large maintenance requirements
- Poor identification of suitable sites, planning and implementation

2.2 Water Harvesting Techniques tried in Turkana

Turkana district has been a laboratory for experimentation with water harvesting techniques. A series of technicians - almost all expatriate - have brought their own particular design concepts, and implemented these, usually before testing the technology adequately first (Critchley and Erukudi, 1992).

However, there is no tradition of constructing water harvesting bunds in Turkana. But there are two evidences that the Turkana know a water harvesting concept. Firstly, Turkana gardens are located in low flood plains where water naturally concentrates. Secondly, a garden is fenced with a heavy thorn bush at the lower end as if it is intended to stop soil and water runoff. It is rare to see gardens on rocky hills, other than on flat areas. Various systems have been implemented including the following:

- i) **Micro-catchments** - make use of runoff on a small-scale, that is, within the catchment area. The prime use of microcatchments is to aid in the critical stage of tree establishment from the time of planting to proper root establishment. (Fig 2)
- ii) **Contour Ridges** - this technique consists of small earth bunds with heights upto 40cm, which are built on the contour.
- iii) **Semi-circular bunds** - the method is intended for increasing pasture and browse production by impounding local runoff. (Fig 4)
- iv) **Trapezoidal bunds** - the system is similar in principle to semi-circular bunds, but is used for enclosing larger areas and impounding larger amounts of water. This system is suitable for crop production thus potentially improving the traditional gardens. The slope of land for bunding should not be steeper than 2%. (Fig 3)

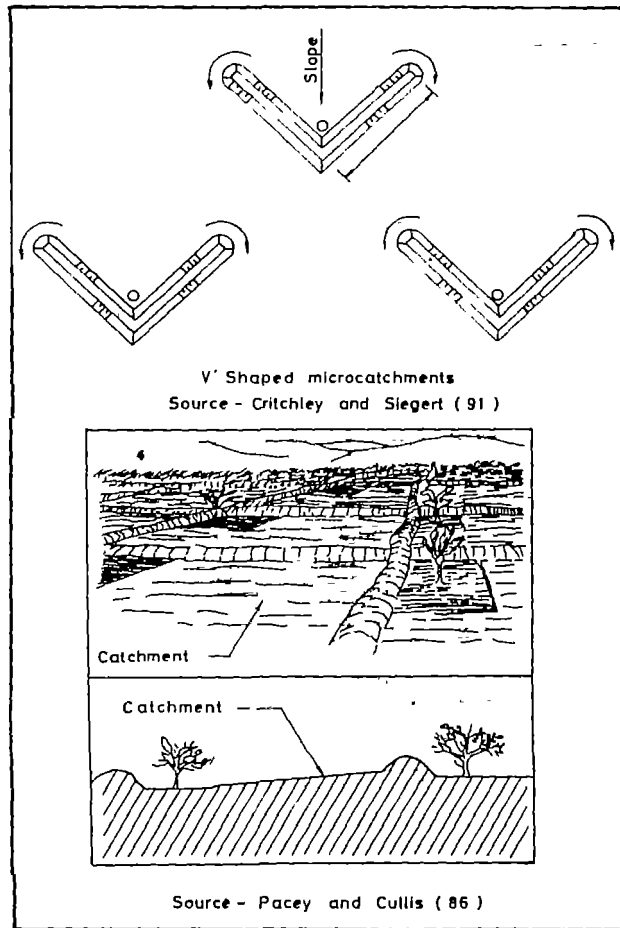


Fig. 2: Microcatchments for trees

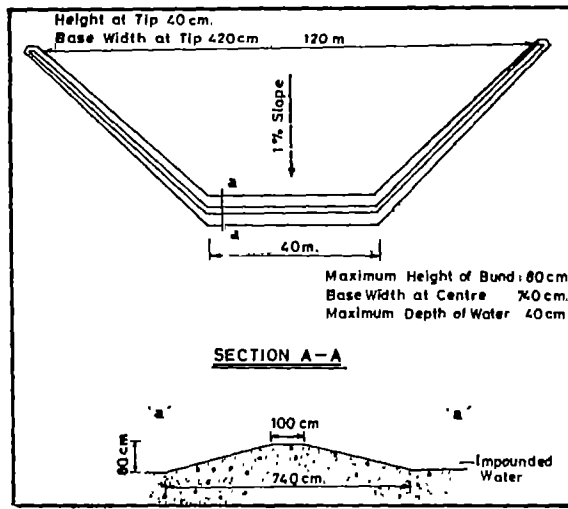


Fig. 3: Trapezoidal Bunds.

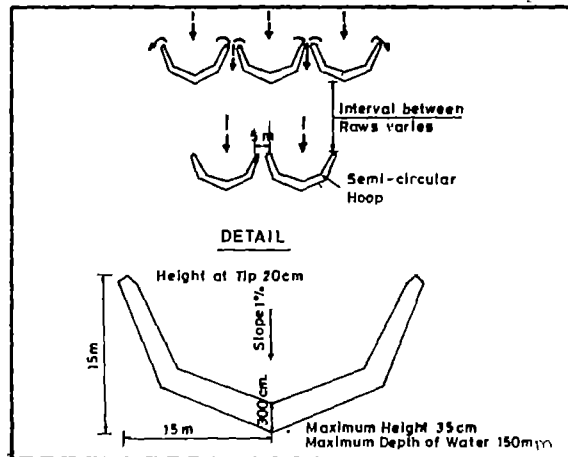


Fig. 4: Semi circular bunds

The system can be modified, depending on the configuration of the field as has been done by the Oxfam - ITDG supported projects in Lokitaung Division (Fig.5).

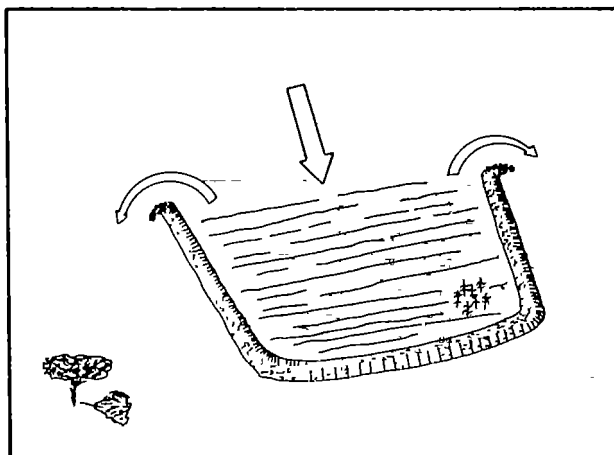


Fig. 5• The L.P.D.P. system: Rain water harvesting garden.

- v) **Spate Diversion and Water spreading** - these are large schemes which have been implemented by force. This involves the diversion of flood waters from ephemeral water courses ("luggas") and the spreading of the runoff waters on adjacent land. (Fig 6 and 7)

Technically, this is the most difficult system to design, and it is extremely vulnerable to damaging breakages caused by flash floods.

- vi) **Roof Catchment Water Tanks** - There are unknown number of these in various institutions especially; schools, dispensaries and individual homes. This technique is likely to feature because of the clean water harvested for domestic use.

Recently the Department of Agriculture, Lodwar constructed one roof catchment ferrocement tank in Nakamane primary school. The response from the school and the local community is positive . It will give a direct benefit when it harvests rain water.

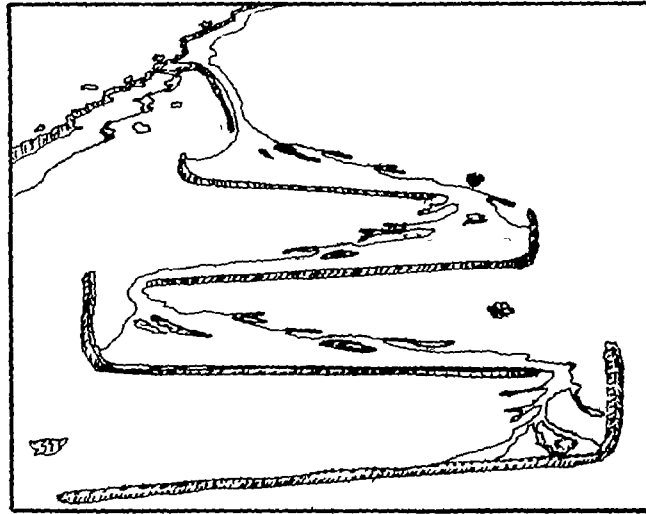


Fig. 6: Spate diversion: Source - Moald (86)

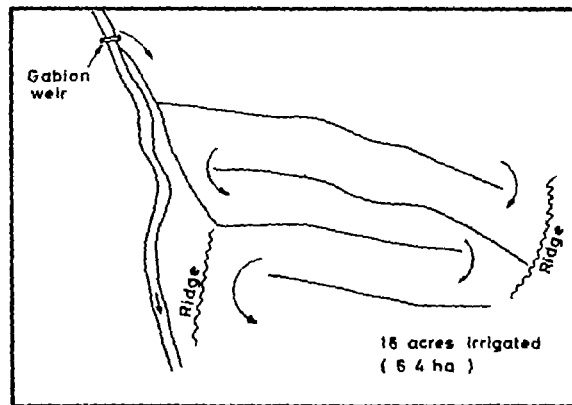


Fig. 7: Impala pilet water spreading scheme, Turkana Kenya.

(Source Fallon 1963)

3. APPROACHES ORGANISATION AND INCENTIVES

Water harvesting in Turkana has been implemented with two agencies namely. Oxfam/ITDG Project and Turkana Rehabilitation Project (TRP).

Oxfam/ITDG chose water harvesting so as to develop gradually in a small and discrete area, with food for work (FFW) used for support. In the case of TRP, the driving force was the need to maintain distribution of FFW, utilising water harvesting as one of the main vehicles. Each of these organisations used different approaches as shown in Table 1.

TABLE 1. ORGANISATION

| APPROACH | Turkana Rehabilitation Project | Lokitaung pastoral Development project |
|---------------------------------|---|--|
| 1. Strategies and target groups | <p>To maintain food security through the distribution of food-for-work, while assisting development of the resource base</p> <p>Target group has been all those who need assistance in the district</p> | <p>To help the target group rebuild herds after the massive stock losses of 1979/80. Water harvesting was seen as a means to this end: as well as providing some food security, surpluses of sorghum could be bartered for small stock.</p> <p>Target group: poor but not destitute pastoralists</p> |

TABLE 1 CONT

| | | |
|---|---|--|
| <p>2. Implementation and Incentives</p> | <p>Activities operated through field centres, where permanently employed staff are situated</p> <p>Staff identify sites themselves, without heed to local opinion.</p> <p>Sites of activities tend to be clustered, ensuring easier supervision</p> <p>Trapezoidal bunds have been allocated to families after construction sometimes causing conflicts. The approach has basically been "top down"</p> | <p>A person who wishes to improve his or her garden approaches the project extensionist who consults the local elders about the person's claim to plant on that piece of land</p> <p>The technician is then called to assess whether the site is suitable for improvement, and if this is so, makes a design of the garden. The applicant pays an ebacit (contribution) of KSh.150 to the project, and is responsible for providing a labour force (usually from their own family). They are given a capital grant of 7 bags of maize to assist in the construction, and technical guidance which includes training courses for those who wish to learn the techniques</p> <p>The sites in which the project is working are based on the Turkana</p> |
|---|---|--|

TABLE 1 CONT.

| | | |
|--|--|--|
| | | <p>institutions the ere or home area, where the gardens are traditionally found. Each ere sends two representatives (a man and a woman) to the committee meeting with the local project staff (Watson, 1990)</p> |
| <p>3. Training</p> | <p>Staff trained in workshop supported by NORAD in 1985, through a consultant 40 participants The new technical guidelines were presented and construction of WH systems was taught practically.</p> <p>Seminars in Lodwar in 1986 and joint TRP/MOA course in 1988 and regular training session for Area co-ordinators,</p> | <p>Built up a group of highly motivated and skilled staff through various courses Project technicians are now adept at the siting and construction of WH plots and have sharpened their skills through experience. Animal draft technicians have also been trained. In turn they teach the plot owners to use oxen and donkeys to plough land scoop earth for bunding and plot levelling</p> |
| <p>4 Monitoring and evaluation</p> | <p>Weak monitoring system which measures only basic parameters such as food distributed and metres of work accomplished.</p> | <p>Make efforts to improve monitoring, and has managed to collect an increased amount of information</p> |

TABLE 1. CONT.

| | | |
|--|--|--|
| | <p>No easily accessible records of accumulated achievements.</p> <p>No system of recording the utilisation of WH structures, breakages, crop yields or tree survival.</p> <p>No evaluation of TRPs water harvesting programme has yet taken place.</p> | <p>Records are kept of all the basic parameters, including numbers of plots improved, the food used, and the number of plots abandoned.</p> <p>Crop yields are recorded from certain plots.</p> <p>Various reviews and evaluations of the projects have taken place.</p> |
|--|--|--|

3. IMPACT OF WATER HARVESTING ACTIVITIES

A review of water harvesting activities in Lokitaung Division (Critchley and Erukudi, 1992) has come up with some lessons.

It is important to differentiate between the impact of water harvesting systems themselves and the effect of incentive, food-for work. The impact of food-for-work has been profound and widespread. Because almost all WH systems in Turkana have been set up using FFW, negative criticism of the way food has been used has tended to discredit water harvesting itself

3.1 Physical Achievements

Over the years many structures have been built. Unfortunately the implementing agencies have no clear records to establish the physical achievements. Given the paucity and unreliability of the data available, not even an estimate of the true extent of water harvesting works can be justified. A conservative estimate shows that there are 750,000 micro-catchments, 2, 000 semi-circular bunds, 500 trapezoidal bunds and/or improved gardens and 5 spate diversions.

3.2 Economic Impact

The structures that have been maintained and utilised are almost exclusively those planted with crops. There is no visual or reported evidence to suggest that any structures for fodder or range rehabilitation have been utilised or maintained.

Therefore, economic benefit is limited to water harvesting plots constructed for crops. The principal economic benefit has been increased production from the local Turkana sorghum which predominates by up to 20%. A useful yardstick is the increased number of small stock which have been acquired through the barter of sorghum harvested (about 4 goats per garden in a year)

3.3 Social Impact

The major social impact of water harvesting development has been related to the use of food. During the peak periods of activity with large scale use of food-for-work, large numbers of people were obliged to move to take advantage of the food. This caused, at least temporarily, major social disruptions.

In remote areas, there are relics of water harvesting structures built without consideration to settlement patterns or even the availability of drinking water.

There is little evidence that the Turkana have formed new settlements due to the construction of water harvesting works. This indicates that water harvesting development is only likely to be viable where there is already a semi-settled (or settled) community.

Water harvesting, through its contribution to seasonal food supplies and its indirect benefit of increasing small stock numbers, has evidently helped to consolidate some communities.

Both men and women have benefited from water harvesting activities through training, improved sorghum plots, and traditional land tenure arrangements

3.4 Ecological Impact

It is common to assume that arid or semi-arid areas are "ecologically fragile" or undergoing "degradation". Turkana District, in fact, shows little sign of degradation, and the range resources are evident and biomass relatively abundant. Particularly striking is the relatively good tree and bush canopy. Concentration of people in settlements in localised degradation.

Water harvesting, theoretically has an in-built "conservation factor" in that the erosive force of runoff is controlled and harvested to increase production.

Taking the district total area, water harvesting has had insignificant impact except on local scale, on the ecology of Turkana District

The area of land covered by structures is relatively minute. The number of microcatchments planted with trees - let alone the very small proportion surviving - is negligible compared with trees already existing. Furthermore, broken structures have made a net contribution to destructive flow when bunds fail.

The lessons from impact of water harvesting point out that there is need to change the vision in implementing this technology in terms of techniques, approaches and management strategies in the future.

4. LESSONS LEARNED

The already referred to recent review has thrown some light that:

4.1 Conclusions

- i. Water harvesting has a small but significant role to play as a supplementary activity in certain parts of Turkana District. There is a limited potential for expansion of activities.
- ii. Turkana district has been a "laboratory" for experiments on water harvesting, especially post 1980. There has been a stream of often conflicting advice from a series of "experts".
- iii. Techniques of water harvesting in Turkana district are characterised by being relatively labour intensive and expensive. There are, at present, no obviously simple and cheap technologies available.
- iv. Some systems of WH for crop production show promise for sustainability. However there is no evidence of any voluntary maintenance or uptake of systems for tree planting or fodder production.
- v. It is difficult to quantify the benefits of water harvesting due to lack of data. However where WH has been successful there are indications that sorghum yields have been more reliable In-

creased food security has resulted and surplus grain is often bartered for goats to rebuild herds.

- vi Water harvesting has been closely linked with food-for-work. When full rations of FFW have been used to construct WH systems, this has tended to encourage work-for-food rather than work for development. The result is that most sites have been abandoned after completion. Where FFW has been at lower level through a contract system, this has stimulated activity and has generally led to sustained water harvesting schemes
- vii. The WH structures which are in use are those sited close to areas of traditional cultivation where there are semi-settled communities
- viii. Monitoring of WH development has been weak, and the collection of data even weaker. Only basic information about volumes of earth and food distribution has been recorded and even this is not accessible.
- ix. Initially there was poor co-operation between the implementing agencies, GOK (i.e Turkana Rehabilitation programme and the Ministry of Agriculture) and NGOs (Lokitaung Oxfam/ITDG project) in the field of WH but there has recently been a better relationship.

4.2 Recommendations

- a) Institutions, Organisation and Incentives
 - i. The best institutional approach to WH development is to work through local community groups and respond to their felt needs. Participation is vital at all stages of planning and implementation.
 - ii. Where labour requirements are high, as is the case with current technical recommendations, some support incentives are required to assist the people with construction This is justified.
 - iii The level of incentive should be enough to stimulate activity, not to "pay" people to work. No incentives however should be given for maintenance of structures. The beneficiaries must be involved in discussing arrangements about incentives.

- iv. Other alternative incentive tools-for-work, cash, for-work, other agricultural inputs or even small stock should be considered.
- b) Techniques
- i. The most appropriate technical model for crop production is the variable shaped bund with its improved spillway design and land levelling. This design is a modification of the trapezoidal bund described in the Turkana WH manual.
 - ii. Neither spate diversion schemes nor "contour" bunds have functioned well technically or socially and no more should be constructed.
 - iii. Trials with alternative, cheaper techniques of WH for crop production should be initiated. These should include vegetative strips/trash lines and stone bunding where possible.
 - iv. Site selection for WH must be carried out very carefully, and done in consultation with the intended beneficiaries. The best sites for WH plots are:-
 - * Where there is a history of traditional cropping
 - * Where drinking water is available
 - * Where there are a group of semi-settled Turkana who are not destitute
 - * Where ground slopes are below 1% and soils are not cracking.
 - v. Assistance be given with improved agronomy, and especially with pest control.

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DISCUSSION

Prof. Thomas asked about the design of bunds and the methods of levelling. Mr. Erukudi replied that the Turkana Water Harvesting Manual has some standard designs but the important point is to fit the design to the configuration of the land. Levelling of the land is done manually or using draft animals. Spillways are used to ensure that the bunds are not breached.

Mr. G. Mailu asked about the success in crop production with water harvesting in view of the very high evapotranspiration and very low rainfall of the area.

Mr. Erukudi replied that water harvesting does make a difference and the storage of water in the soil has made it possible to get a crop of Turkana sorghum, which matures in sixty days, in Lokitaung and Kakuma divisions.

Mr. Kung'u Kimani commented that the Turkana are traditionally pastoralists who practise very little cropping and experience with other nomadic pastoralists indicates that irrigated agriculture is not sustainable because any profit from irrigation is used to buy more animals. Agriculture is left for the destitute. He wondered how the situation had been overcome in Turkana.

Mr. Erukudi replied that although livestock keeping has been the mainstay of the economy, agriculture has also been practised for a long time in areas where water concentrates naturally (Ngimanikorin). Some Turkana sections have lived entirely on crop production along the Turkwel River e.g at Ngikebootokk. The gardens are located in home areas for wet seasons (Eres) where some members of the family live almost permanently. It is unfortunate that irrigation schemes were started as a famine control measure where displaced people were forced to settle at designated sites where schemes were developed. This has confused outsiders who think that agriculture is only for the destitute. Agriculture is in fact the second most important economic activity after livestock production according to the Turkana District Development Plan (1989-1993).

Mr. S. Burgess asked what is the replicability of the water harvesting techniques and whether bunds would be constructed if there was no outside assistance.

Mr. Erukudi replied that those people who have been taught the technicalities and have been involved in decision making do try to extend water harvesting techniques to improve their traditional gardens but large scale water harvesting projects are not used or maintained. Bunds will be constructed so long as farmers are participating in other small scale activities that keep their interest. However some other assistance in the form of tools and extension are needed.

WATER HARVESTING FOR CROP PRODUCTION

S. Burgess
Irrigation officer, Diocese of Kirinyaga

1. INTRODUCTION

Situated to the north of Mount Kenya, Isiolo is in the semi-arid region of Kenya. The annual rainfall is 613mm with an annual average evapotranspiration of 1904mm. There are two rainy seasons, October to January, and March to May, with a six month dry spell; it is often very hot, dry and windy. The harsh climate coupled with low rainfall make crop production without irrigation a precarious occupation. With irrigation, crop yields are good, vegetable growing along the Isiolo and Ngaramara rivers supply Isiolo town and surrounds. However, these two rivers are heavily utilised, and more so in recent years since the 1984 drought. Irrigable land and particularly water for irrigation are in short supply and so most people to the north and south of Isiolo depend solely on rainfed agriculture.

In the past the land around Isiolo was mainly used for ranching and livestock production; this is still true for the Turkana and Samburu to the north; livestock keeping is their main source of food and income. But we live in a changing society and so do the pastoral people. Following the 1984 drought in northern Kenya they became used to eating maize, and there is a policy for the pastoralists to settle, send their children to school, and obtain access to medical care. The pastoralists of Isiolo have become semi-nomadic, the women and children staying in one place all the year round. So needs have changed. Water is a primary need and as part of the development work four windpumps were installed; the people wanted to grow crops instead of always buying, not to replace their livestock activities, but to supplement them. In fact a major part of the extension centre work is providing veterinary services to this area.

In the southern part bordering Meru district the Meru people are settling and cultivating. The Meru are agriculturalists and have, due to shortage of land in the higher productive areas, been forced to settle in this semi-arid area. Yet harvests fail two seasons out of three due to the poor and uncertain rainfall; farmers become reluctant to spend time and effort cultivating although they want to grow crops for food. In order to assist in making crop production viable and increasing food production some trials and demonstrations of water harvesting were conducted on the CPK Extension centre demonstration plot in Isiolo. The first year's trials with water harvesting were very encouraging showing much improved crop yields with water harvesting plots compared to

"normal" plots. This created considerable interest among the farming community around Isiolo and so some demonstrations were incorporated with the extension work already ongoing with local farmers.

This report attempts to share the experience of this work; a comparison is made between the trial plot results and the extension work.

2. CHOICE OF TECHNOLOGY

Water harvesting has in recent years been practised in Turkana and Baringo Districts of Kenya, with varied success (Pacey and Cullis 1986). The techniques tried in Turkana District include semi-circular hoops and trapezoidal bunds constructed through a food for work programme. These techniques and construction methods are detailed in a manual written by the Kenya Ministry of Agriculture and Livestock Development (MALD 1986).

The semi-circular hoops was the first method tried on the trial plot and later contour benches were made (Fig 1). The main reason for the contour benches was that the Meru farmers cultivated with oxen; the small size of the semi-circular hoops made them only suitable for hand cultivation with hoes. The size constructed in Turkana District were 15m radius or larger, often enclosing one acre. A smaller size, 7.5m radius, was chosen initially for the trials at Isiolo. Experience and discussion with the local community, as already described, determined the suitability of the technologies used

A key component of the extension work was training the farmers. Residential training courses and sharing workshops were held on water harvesting from the outset. This enabled farmers to participate fully in both the techniques used and implementation of the water harvesting work. Although the methods outlined in this report were new to the Isiolo farmers it would have been wrong to assume that they had no knowledge, the Meru farmers were conversant with terracing, the Turkana farmers tended to plant in areas where water collected. Building on existing knowledge was important.

3. TECHNICAL DESIGN

Rainwater harvesting for crop production is a technique of collecting the runoff water from heavy rainstorms and then directing or concentrating the water into the cultivated part of the field. A field, therefore, can be thought to have two sections; a catchment area and a cultivated area. The ratio of the catchment area to cultivated area is dependent on the amount of runoff which can be expected from the catchment area.

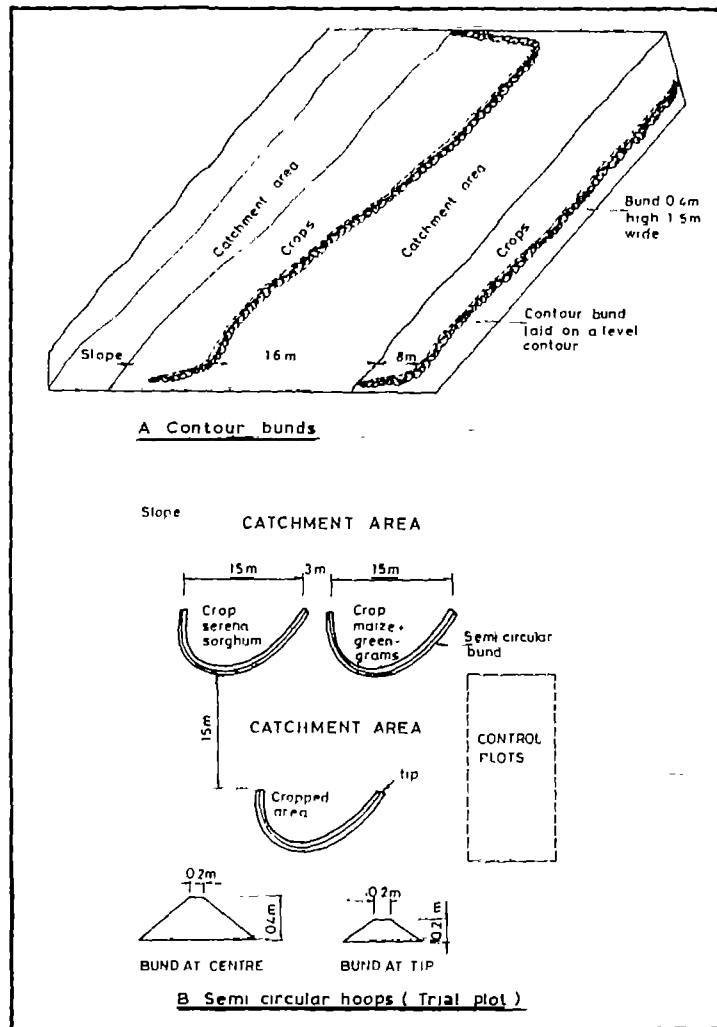


Fig. 1: Layout of water harvesting fields

The factors to consider are:

- Rainfall; total amount during season and intensity
- Soil type

- Slope of land
- Soil cover; i.e bare soil, pasture etc.
- Crop water requirements

A formula was developed by the Ministry of Agriculture, Kenya (MALD 1986), as follows:

$$\frac{\text{Catchment Area}}{\text{Cultivated Area}} \quad (R) \quad = \quad \frac{\text{Crop Water Requirements} - \text{Design Rainfall}}{\text{Design rainfall} * \text{Runoff factor}}$$

In the absence of empirical data runoff factors from Hudson 1975, page 43 were used.

A catchment area to cultivated area ratio of 2 to 1 is calculated for the Isiolo site. See Appendix A for full calculation.

4. TRIAL PLOT WORK

The trials were conducted on the extension centre plot in Isiolo where the soil type is black cotton (clay) with a 2% slope on the field. Semi circular hoops of 7.5m radius were constructed, later contour bunds of various types were also tried. The trials were to compare crop yields with water harvesting to non water harvesting, and therefore the crop management was exactly the same for both plots except for the water harvesting.

The bunds had a wall height of 40cm at the centre and were made of soil dug from behind the bund and well compacted. A typical field layout for 3 semi-circular hoops and the contour bunds is shown in Figure 1.

The yield is quoted as yield per acre. The plot size for the semi circular hoops was 0.02 acre, and the control plots 25 sq. metres. With a catchment of 2 parts and a cropped area of 1 part, the area contributing to the yield is $0.02 \times 2 + 0.02 = 0.06$ acre.

5. RESULTS

The trial results are presented for six seasons in APPENDIX B (1988-1990), average yield for 4 seasons (1988-1989) in Table 2 and for the first season in more detail as follows:

1st Trial - October 1987 to January 1988

A. Crops

Three semi circular hoops and control plots were planted

(1) Serena Sorghum

(2) Katumani Maize intercropped with Green Grams

(3) Peas (not harvested)

Planting date 2.10.87

Germination date approx . . . 15.11.87

Harvest date 10.2.88

Growth period 87 days

B. Rainfall and Runoff

No measurements of runoff were taken but after a heavy storm accumulation of runoff could be seen by the bund wall in the water harvesting plots. The rainfall for the season was 273 mm, slightly less than average 312 mm. According to local tradition the rains start on October 20th whereas daily rainfall figures (Appendix D) show that the rains commenced on November 7th. The rainy season November 7th to January 24 was 81 days, although for 24 days December 10th to January 4th, only 0.5mm rainfall was recorded. The effect of this rainfall pattern, one or two days of rain followed by a dry spell, is for crops to dry. With water harvesting the soil moisture content is increased considerably thus enabling the plants to continue growing through the dry days.

C. Soil Moisture and Plant Growth

Plant growth was evidently better in the water harvesting plots than the control plots. At the beginning of January, tasseling stage, the maize in the water harvesting plot was 4-5 ft tall and very luxuriant. In the control plot it was estimated that less than 5% of the plants had tasseled, most plants were visibly withered and less than 2ft tall. Similarly with the sorghum, in the water harvesting plot the sorghum had 90% heads and luxuriant growth, in the control plot it had less than 10% heads and many plants were withered.

Just before harvest the soil in the control plot was dry and crumbly to the touch up to 60 cm below ground level. In the water harvesting plots the soil stuck

together and felt wet at 10 cm below ground; a good indication that adequate water had been harvested.

D. Crop Yields

The crop was harvested when completely dry.

Table 1 Yield kg/acre (1)

| Crop | Without Water Harvesting | With Water Harvesting | Increase % |
|-----------------------|-----------------------------|--------------------------|---------------|
| Katamani Maize | 2.5 | 78 | 3120 |
| Serena Sorghum (2) | 10.0 | 325 | 3250. |
| Green Grams | 1.3 | 25 | 1930 |

(1) Equivalent yield per acre, plot size 0.02 acre.

(2) The maize and green grams were inter planted.

In the subsequent trials both semi circular hoops and contour benches were used. It was found that there was little difference in yield between the two methods. Table 2 presents the average results for four seasons.

Table 2 Average Yield (1988-1989) kg/acre (1)

| Crop | Without Water Harvesting | With Water Harvesting |
|-----------------|-----------------------------|--------------------------|
| Serena Sorghum | 102 | 276 |
| 954066 Sorghum | 91 | 188 |
| Katamani Maize | 60 | 127 |
| N26 Green Gram | 33 | 54 |
| K80 Cowpea | 45 | 53 |
| Mwezi moja Bean | 47 | 90 |
| Cotton | 89 | 202 |

(1) Equivalent yield per acre.
Average Rainfall per season 262 mm.

6. DISCUSSION

The purpose of the water harvesting was to increase the amount of water in the cropped area to enable crops to be grown in semi arid areas and increase crop yields. The average seasonal rainfall for the four seasons was 262 mm whereas water requirements for maize are about 600 mm, sorghum 450 mm, pulses 300-500mm. Although no estimates of runoff were obtained, the improved plant growth in the water harvesting plots and subsequent yield increases show that water was "harvested". The comparison of yields in tables 1 and 2 show that water harvesting does improve crop yields, all the water harvesting plots out - yielded their non water harvesting plots. In the first season trial the sorghum yield in particular was good, (325 kg/acre), relative to Kenya norms (220 to 660 kg/acre).

These trials were conducted on black cotton soil, which is a heavy cracking clay; in the dry season the soil develops large cracks and with the first rains runoff water can, literally, pour down these cracks thus preventing water flowing from the catchment area to the cropped area. However after the first rain the soil tends to cap, providing good runoff. Being a clay soil it has good water holding capacity compared to the red laterite soils also found in Isiolo, but there is a danger of ponding and waterlogging. As will be seen in section 3 trials were also conducted on a site with red laterite loam soil; the results suggest that water harvesting can also improve crop yields on these soils. The characteristics of each soil type should be considered when designing and planning the water harvesting.

In Table 2 the difference in the yields for maize and sorghum is striking. Katumani maize, developed specifically for dry areas was planted with water harvesting and yielded on average 127 kg/acre. It would seem not to be worth while to plant maize. Sorghum yields were much better, (276 kg/acre) and would suggest that greater emphasis be put on planting sorghum rather than maize. However, recent tradition has created the thinking that a farm without maize is not really a farm. There is also a major problem of birds with sorghum, particularly the white varieties such as 954066, and the sorghum crops of March to May 1989 and 1990 were destroyed by birds (Appendix B).

Pulses also responded well to the increased water in the water harvesting plots; yields were higher compared to non water harvesting (table 2). It was found, particularly on the heavy black soil, that the pulses were susceptible to waterlogging; the non water harvesting plots outyielded the water harvesting plots in the heavy rains of October to January 1990 due to ponding of water in the water harvesting plots. Careful design of the water harvesting system is needed to prevent this problem.

A part from the trials some new crops and varieties suitable for semi arid areas were tried (Appendix B) Tepary bean was the highest yielding bean with and without water harvesting; Makueni maize yielded better than Katumani in the drier 1990 season, but not in the very wet 1989 season

The economics of water harvesting compared to non water harvesting are considered. In Appendix C the gross margins are calculated for a variety of crops with and without water harvesting. The only positive gross margin is for sorghum with water harvesting at KSh.194 per acre. All other gross margins are negative. The costs per acre for a normal farm are twice those for the water harvesting farm, KSh.1512 compared with KSh.737, because three times the area of land needs to be ploughed, planted, weeded, and harvested.

For some farmers the costs of field operations would be minimal or zero because family labour would do the work, but many have to hire labour particularly at weeding and harvest time. In fact many farmers who cultivated and planted large areas around Isiolo had a problem with weeding on time, causing reduction in final crop yields. This would suggest that it is better to cultivate a small area well rather than a large area poorly. The results here support that suggestion since comparable yields and better gross margins can be obtained when using water harvesting methods and only cultivating a smaller portion of the field.

In this case the important aspect would be which crop and system would give the best return if selling, or yield if for home consumption. Economics aside, the most important factor in dry areas may be how to obtain any worthwhile yield.

One question often raised is what to do with the land between the semi circular hoops. Our experience at Isiolo suggests that good grass can be allowed to grow which would provide forage for cattle and goats or provide material for composting; it is not wasted land. However there is a cost in maintaining this catchment area, in terms of extra labour. Ideally for effective water harvesting the catchment area should be bare, or nearly bare soil, to encourage runoff. During the seasons of high and extended rainfall it was difficult to maintain this ideal with the result that runoff, and water harvesting, was reduced. One solution might be to plough the catchment area occasionally to kill the grass and weeds, leaving the soil bare.

7. CONCLUSIONS FROM THE TRIALS

The trials indicate that crop yields for cereals can be improved with water harvesting methods. Indeed, in very dry areas, cropping may only be possible if water harvesting is used.

Yields in the water harvesting plots were more than 2 times that of the control plots.

The sorghum yields were consistently better than maize yields, suggesting that greater emphasis be put on sorghum than maize in the Isiolo area.

The yield of pulses with water harvesting was greater than non water harvesting but due to waterlogging problems care should be taken to provide cutoff trenches above the semi circular hoops or contour benches to prevent too much runoff water entering the planted area.

From an economic point of view water harvesting farming has higher gross margins than "normal" farming.

Labour requirements are less with water harvesting compared to non water harvesting.

So, from food production and economic aspects, water harvesting shows definite promise in alleviating one of the problems of dryland farming around Isiolo. These techniques could be applied to other semi arid areas.

8. EXTENSION WORK

The goal of the CPK Extension Centre was, and is, to assist farmers to increase their food production in Livestock and Crops; this goal is to be achieved mainly by providing services to the community and training of farmers; the trials and demonstrations at the centre were for teaching purposes. Following the first seasons water harvesting work the techniques were introduced to the farming community by:

- Holding one day teaching seminars in the villages
- Conducting residential seminars for farmers from the community on water harvesting
- Making demonstration plots in the community
- Field tours to other parts of Kenya

A. Demonstrations

In the first year eight demonstration plots were established, four with the Turkana community and four with the Meru community. The demonstrations consisted of semi circular hoops or contour bunds with a "normal" plot adjacent; similar crops were grown in the water harvesting and "normal" plots. New varieties of crops were also planted.

Accurate records of yields were not kept at most of these demonstrations; where yields were measured the area planted was not recorded. However without exception the farmers reported that water harvesting crops were better than non water harvesting crops; one farmer reported a four fold increase in his sorghum yield, a women's group farm had a 30% increase in sorghum yield. One farm in the Turkana area experienced almost complete crop failure because the site had poor soil, but a farmer in the same area had good yields on better soils.

The demonstration at Kithima was on red laterite loamy soil, this site was south of Isiolo, slightly higher altitude and rainfall (average 318mm per season). Results for one season show an increase in yields with water harvesting compared to "normal" plots, Table 3.

Due to crop damage by wild animals the results for other seasons were not presentable.

TABLE 3 Kithima demonstration plot, comparison of water harvesting and non water harvesting. 1988-1989
Equivalent yield kg/Acre

| Crop | Without Water Harvesting | With Water Harvesting |
|------------------|--------------------------|-----------------------|
| Serena Sorghum | 2360 | 2473 |
| 954066 Sorghum | 847 | 1699 |
| Katamani Maize | eaten by monkeys | |
| N26 Green Gram | 708 | 897 |
| K80 Cowpea | 723 | 708 |
| Mwezi moja Bean | 371 | 782 |
| Mwita mania Bean | 933 | 1046 |
| Irish potatoe | 2420 | 6865 |

October 1988 - January 1989 Seasonal Rainfall 496mm

B. One day seminars

Many one day training seminars were held at the village level throughout the area of operation, initially on water harvesting and seed varieties suitable for dry areas. It soon became evident that a wider approach was needed particularly with the Turkana communities, to cover all the topics for good crop management, including: planting times, crop spacing, manure application etc. Water harvesting became one topic within the teaching package.

C. Residential Seminars

Seven water harvesting seminars were held at Isiolo from 1988 to 1990. Participants were from each village served by the extension programme, chosen by the community members. Initially the seminars were to introduce and train on water harvesting techniques and good crop management. Later one person from each community was chosen to become their own Mwalimu wa Ukulima (agriculture teacher); this group, trained in general agriculture, became a valuable resource to their village, in turn advising and teaching. This group formed the water harvesting committee and participated in planning the implementation programme.

The techniques for marking out and constructing the semi circular hoops and contour bunds were learned easily by the group and they were able to assist other farmers to make them. The tools required are a line level and levelling boards with string. Hoes and spades were used for the actual construction.

D. Field Tour

A visit was made with ten farmers to the Oxfam Turkana water harvesting project, in Turkana District, where a different technique of water harvesting was being used by the community. This method collected and impounded runoff water inside a large bund, the crop was then planted after the water had infiltrated into the soil.

The work involved in design and construction of this type is far greater than those in this report. Back in Isiolo one was constructed at Alamach on red soils using food for work with the Alamach farming group. At the time of writing, the water harvesting garden is not complete or being used for perhaps the following reasons:

- the food was finished before the work was finished, so workers disappeared.
- the incompleteness resulted in ponding of water in one part of the garden, so water did not spread properly and thus crops could not be planted.
- a lot of time and energy was spent on the group dynamics, but even so the group slowly disintegrated.

The Turkana project has been going on since 1977 under various organisations, and learning from experience has developed a good community organisation to implement the water harvesting gardens.

9. THE FARMERS' RESPONSE

If you ask the farmers in Isiolo what their problems are, in relation to growing crops, the answer is: Elephants and lack of rain. Shortage of tools, seeds and other inputs are mentioned.

The Extension centre opened a farm shop and assisted with tools; the Kikuyu have a saying "Gutire undu njogu" - there is nothing as big as an elephant, meaning that any problem can be overcome. Even the problem of elephants was reduced by community action, digging ditches and prayer. This report looks at the problem of rain, or lack of it.

Taking the hypothesis that water harvesting will improve crop yields, and that as reported in section 2 the trials support this hypothesis, what has been the response of the Isiolo farming community?

Initially it was very positive; anything that could enable crops to be grown is better than the existing situation said the Turkana. The Meru wanted to improve yields. So in eight communities demonstrations were made with groups of individuals. Farmers gave their time to attend seminars and learn the new method and some of them became volunteer agricultural teachers for their village. We could say that the knowledge of, and skills to implement water harvesting, was with the community. However, after nearly three years there are only a few farmers practising the water harvesting as described in section 1.

There are, from the Agricultural teachers reports, more than 320 farmers within the programme area who have benefited from the programmes' work, many of whom cultivate using some type of water harvesting and more who use the new dryland seed varieties. In one village they harvested crops for the first time after several years of trying. In one Samburu village, crops were grown for the first time. In Alamach, although the Turkana type water harvesting is not operating, the number of individuals cultivating and harvesting increased from two to over thirty during the period; a surprising keenness by the farming community.

It seems, therefore that although the take up of the water harvesting method as in the trial plots was not great, the farmers have used the ideas: they direct water into their gardens and make small bunds to trap the runoff water. It was noticed that the bunds often broke during heavy rain. Most important, the number of people farming has increased. In some ways, this will fulfil the programme's aim of increasing food production.

At the water harvesting seminars, the agricultural teachers were encouraged to share their thoughts and problems in relation to the water harvesting. These could be summarised as follows:

- it is hard work to make the bunds to the size recommended.
- the people don't have enough tools
- land is wasted in the catchment areas (a particular thought of the Meru who have less land).
- it is difficult to keep the vegetation short in the catchment area (True in the higher rainfall Meru areas).
- water harvesting does help and is good
- At a later seminar the same group was asked "what aspect of the Agricultural programme has most assisted with growing crops in your village?"
The replies were as follows:-

| Aspect | Number of replies | Comment |
|--------------------|-------------------|------------------------|
| Water harvesting | 8 | Mainly Turkana farmers |
| Provision of tools | 5 | |
| Teaching on Agric. | 9 | |
| New dryland seed | 8 | |

Note some respondents gave multiple answers

It would seem that teaching on Agriculture was most beneficial, but since the difference in number of replies is not great, all the above aspects contributed to growing crops.

A study undertaken to look at the impact of the CPK Isiolo extension programme on the community (Mwija 1990) supports the above views in that a number of aspects (tools, seeds, teaching, water harvesting, farm supply shop) were seen as beneficial, by the community. The study goes on to say that the uptake of water harvesting by the farmers was small, but it gives no reason for this finding.

10. LESSONS LEARNED

The farmers' response has been mixed:- There is agreement that water harvesting can improve crop yields or, in the drier northern parts, enable crops to be grown

Give the community the skills through training, in this case volunteer agricultural teachers. At the same time building on the existing skills and knowledge of the community is vital.

The construction techniques are fairly simple but the farmers see the work, particularly of bund construction, as too much. Perhaps the benefits of water harvesting are not sufficient compared to the effort involved.

Water harvesting is part of a package which can help to grow crops in dry areas. In this case, tools, better seed and teaching were all essential parts.

A participatory approach is needed, to involve the community at each stage of planning, testing, implementation and review. It has been interesting to see how the farmers of Isiolo have adapted the water harvesting techniques to suit their own perceived need and capability.

Intervention takes time. The farmers of Isiolo want to grow crops, even the Turkana pastoralists have a need to supplement their livestock activities, but change cannot be hurried. So let us work with the farmer at his pace rather than force a "better" method.

Asking the community what are their needs, problems and solutions is important. This report suggests the need to ask further the farmers perceptions of the water harvesting work and how it can be of benefit - what changes are necessary? It would be better to admit mistakes and change than to continue blindly on.

Farmers take and use what they see as beneficial.

11. CONCLUSION

From the trials, water harvesting does improve crop yields and the field work confirms this.

The farmers see water harvesting as part of the solution to growing more food. Thus continuing with the training and other support programmes, with full participation of the farming community, is necessary.

The Agricultural Programme activities have led to an increase in crop production around Isiolo.

The particular technique of water harvesting as used in Isiolo was adapted by the farmers suggesting that further work is needed in two areas.-

To discover the problems of the technique used for the trials.

To continue working with the farmers and the Agricultural teachers group to find a suitable technique and/or improve, the ones now being used.

Finally, a quote from William Critchley, who is involved in similar work (Critchley 1989)

"Rainwater harvesting only forms part of the solution to production in just a section of the semi-arid areas, but it does have an important role to play. It is much more than a passing development fashion. Learning from the experience of projects and particularly from the traditions of the people, will point the way to better systems and better approaches".

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APPENDIX A

CALCULATION OF RATIO OF CATCHMENT AREA TO CULTIVATED AREA

DATA

| | |
|-------------------------|-------------------------------|
| Soil type | Black cotton, clay |
| Crop water requirements | 500mm |
| Design rainfall | 312mm (mean rainfall Oct-Jan) |
| Runoff factor (Note 1) | 0.3 |
| Land slope | 2% |

$$\frac{\text{Catchment Area}}{\text{Cultivated Area}} = R = \frac{500 - 312}{312 \times 0.3} = 2.0$$

For a ratio $R = 2.0$

$$\begin{aligned} \text{Cultivated Area :} \\ \text{bund radius} &= 7.5\text{m} \\ \text{area} &= (7.5 * 7.5 * 3.142) / 2 \text{ m}^2 \\ \text{Area} &= 88 \text{ sq. metre } (= 0.02 \text{ acre}) \end{aligned}$$

Therefore:

$$\begin{aligned} \text{Catchment Area:} \\ 2 \times 88 \text{ sq. metre} \\ \text{Area} &= 176 \text{ sq metre} \end{aligned}$$

In practice the width of the catchment area would be twice the width of the cultivated area since the width of the field is constant. (see Figure 1)

NOTES

1. From Hudson 1975, page 43
Soil texture: clay
Topography and Vegetation: Flat pasture
Runoff Coefficient = 0.3

CPK ISIOLO EXTENSION CENTRE

WATER HARVESTING TRIALS 1987 TO 1990

WH = Water harvesting

YIELDS KG/ACRE

NWH = Non Water Harvesting

| CROP | Oct 87-Jan 88 | | Mar 88-May 88 | | Oct 88-Jan 89 | | Mar 89-May 89 | | Oct 89-Jan 90 | | Mar 90-May 90 | |
|----------------------|---------------|-----|---------------|-----|-------------------|-----|---------------|-----|-------------------|------|---------------|-----|
| | WH | NWH | WH | NWH | WH | NWH | WH | NWH | WH | NWH | WH | NWH |
| Serena Sorghum | 325 | 10 | 118 | 21 | 385 | 275 | 0 (B) | 0 | 1099 (A) | 1099 | 64 (B) | 48 |
| 954066 Sorghum | NP | NP | 113 | 30 | 149 | 152 | 0 | 0 | 466 | 466 | 0 | 0 |
| Katumani Maize | 78 | 2.5 | 30 | 0 | 367 | 234 | 32 | 2 | 827 | 647 | 53 | 41 |
| Makueni Maize | NP | NP | NP | NP | NP | NP | NP | NP | 560 | 450 | 164 | NP |
| N26 Green Gram | 25 | 1.3 | 55 | 48 | 98 | 79 | 39 | 4 | 146 | 153 | 236 | NP |
| K80 Cow Pea | NP | NP | 19 | 26 | 120 | 96 | 20 | 14 | 200 | 242 | 71 | NP |
| Mwezi Moja Bean | NP | NP | NP | NP | 151 | 81 | 28 | 13 | 193 | 455 | 198 | NP |
| Tepary Bean | NP | NP | NP | NP | NP | 130 | NP | 109 | 413 | 505 | 344 | NP |
| Dolichos Beans | NP | NP | NP | NP | NP | NP | NP | NP | 351 | 113 | | |
| Cotton _x | NP | NP | NP | NP | Harvest in May | | 202 | 89 | Harvest in May | | 298 | 303 |
| Rainfall mm | 273 | | 267 | | 314 | | 192 | | 475.8 | | 293.2 | |
| Season Length (rain) | 53 | | 48 | | 72 | | 60 | | 74 | | 65 | |

Note: (A) Results mixed : average of WH and NWH

(B) Crop destroyed by birds

NP: Not planted.

APPENDIX C

ECONOMICS OF WATER HARVESTING

(Calculation of Gross Margins)

Consider 1 acre field for non water harvesting compared with twelve 7.5 radius semi circular hoops for water harvesting (one acre field) catchment area to cropped area 2:1)
Crop yields as in Table 2

COSTS KSHS (1)

| Item | Water Harvesting | Non Water Harvesting (2) |
|--|------------------|-----------------------------|
| Constructing 12 hoops @ 60/- each = 720/= | 144 (3) | 0 |
| Ploughing or Digging 12 hoops at 15/- | 180 | 270 |
| Planting 12 hoops at 5/- | 60 | 180 |
| Weeding 12 hoops at 15/- | 180 | 540 |
| Harvesting 12 hoops at 12/- | 144 | 432 |
| Seed 15/= per kg | 30 | 90 |
| Total | 737 | 1512 |

Notes

- (1) Using hired labour
- (2) With a 2:1 catchment to crop ratio, field operations in the non water harvesting field will be three times those of water harvesting field except for ploughing. (ploughing costs 270/- per acre)
- (3) Assuming the hoops will last 5 years. Annual cost is KSh.144.

No costs are assumed for manure and insecticide.

APPENDIX C continued

BENEFITS

Assuming that all 12 hoops are planted with the following crops.
Crop yields as in the trials, Table 2.

| Crop | Market Price KSh/kg (1) | Value KSh. | |
|-----------------|-------------------------------|----------------------------|-------------------------|
| | | Water Harvesting (2) | Non Water Harvesting |
| Serena sorghum | 10 | 930 | 1020 |
| 954066 sorghum | 10 | 627 | 910 |
| Katumani maize | 5 | 212 | 300 |
| Green Grams | 14.40 | 264 | 475 |
| Cowpeas | 8.80 | 155 | 396 |
| Mwezi Moja Bean | 6 | 179 | 282 |

Note

(1) Market price, Isiolo July 1988

(2) The apparent low value of the yield is because the area contributing to the yield is only one third of the area. Catchment to cultivated area 2:1

| Crop | <u>GROSS MARGIN (KSh/acre)</u> | |
|-----------------|--------------------------------|----------------------|
| | <u>BENEFITS</u> | <u>less COSTS</u> |
| | Water Harvesting | Non Water Harvesting |
| Serena sorghum | 194 | -492 |
| 954066 sorghum | -110 | -602 |
| Maize | -525 | -1212 |
| Green Grams | -473 | -1037 |
| Cowpeas | -582 | -1116 |
| Mwezi Moja Bean | -558 | -1230 |

APPENDIX D

DAILY RAINFALL RECORD October 1987 to January 1988

Millimetres rainfall

| Date | October | November | December | January | |
|------|---------|----------|----------|---------|-------|
| 1 | 19.5 | | | - | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | 31.8 | 5.4 | |
| 5 | | | 5.0 | 3.3 | |
| 6 | | | 3.5 | | |
| 7 | | 17.6 | 1.3 | | |
| 8 | | 32.5 | 3.8 | | |
| 9 | | 0.8 | 20.7 | 2.4 | |
| 10 | | 0.2 | 1.0 | 0.3 | |
| 11 | | | | | |
| 12 | | 1.1 | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | 22.1 | | | |
| 17 | | 13.1 | | | |
| 18 | | 6.4 | | 7.1 | |
| 19 | 2.1 | | | | |
| 20 | 11.0 | 8.9 | 0.5 | | |
| 21 | | 4.3 | | | |
| 22 | | | | | |
| 23 | 5.4 | | | | |
| 24 | | 6.3 | | 9.8 | |
| 25 | | 5.3 | | | |
| 26 | | | | | |
| 27 | | | | | |
| 28 | | 2.5 | | | |
| 29 | | 12.7 | | | |
| 30 | | | | | |
| 31 | | | | | |
| | 38.0 | 138.7 | 67.6 | 28.3 | |
| | TOTAL | | | | 272.6 |
| | | | | | ===== |

Source: District Agricultural Office, Isiolo

APPENDIX E

DAILY RAINFALL RECORD March 1988 to May 1988

Millimetres Rainfall

| Date | March | April | May |
|-------|-------|-------|------|
| 1 | - | 1.5 | 13.1 |
| 2 | - | - | - |
| 3 | - | - | - |
| 4 | - | 7.1 | - |
| 5 | - | - | - |
| 6 | - | - | - |
| 7 | - | 1.5 | - |
| 8 | - | 1.1 | 2.2 |
| 9 | 0.2 | 11.7 | - |
| 10 | 5.8 | 1.1 | - |
| 11 | 8.4 | - | - |
| 12 | - | 2.5 | - |
| 13 | 15.1 | 0.6 | - |
| 14 | 0.6 | - | - |
| 15 | - | - | - |
| 16 | - | 5.1 | - |
| 17 | - | 5.0 | - |
| 18 | - | 2.1 | - |
| 19 | - | 7.8 | - |
| 20 | - | 0.3 | - |
| 21 | - | 22.5 | - |
| 22 | - | 6.2 | - |
| 23 | - | 8.2 | - |
| 24 | 23.6 | 3.7 | - |
| 25 | 55.2 | 10.5 | - |
| 26 | - | - | - |
| 27 | - | 34.5 | - |
| 28 | 1.1 | - | - |
| 29 | 6.0 | - | - |
| 30 | 2.4 | - | - |
| 31 | - | - | - |
| TOTAL | 118.4 | 133.1 | 15.3 |

TOTAL

266.8

=====

Note

Rainfall for February 1988 was 19.3mm

Rainfall for June 1988 to September 1988 was 0.00mm

Source : District Agricultural Office, Isiolo

DISCUSSION

Prof Thomas asked whether the yields were expressed per unit of the cropped area alone or per unit of the total land area used including the catchment. Mr. Burgess replied that the yields given in tables 1 and 2 and appendix B are per unit of cropped area of land and include a figure for labour although most subsistence farmers use family labour which is not paid. In arid and semi-arid areas the major concern is how to get any crop to grow and to produce a harvestable yield. In these areas land is often not limited i.e. the catchment area for runoff is not farmed but is grazing land. Thus it is justifiable to use yield figures per unit of cropped area. However in the Isiolo area the Meru farmers do often think of the catchment area as wasted because their land is limited.

Mr. Vernon Gibberd suggested that the catchment area need not be wasted and that cattle could be tethered on the area for a few days during the dry season to reduce vegetation and increase runoff. This could be particularly useful on vertisols where the trampling of animals would help to fill the soil cracks with loose soil and encourage runoff when the rains started.

Dr. F.N.Gichuki asked how the gross margins for the contour bund water harvesting compared with semi-circular hoops and was told that the gross margins were for semi-circular hoops. He also asked whether there is potential for using ox cultivation to prepare land with contour bunds and thus reduce costs and improve timeliness. Mr. Burgess replied that the contour bunds method of water harvesting was introduced after discussion with farmers who wanted to cultivate with ox ploughs. Bund construction with animal ploughs would require special equipment and it may be necessary to make bunds by hand to ensure that they are large enough and strong enough.

Mr. P.K.Karimi commented that water harvesting is part of a package for growing crops in dry areas and that if all factors are taken into consideration it should be possible to identify areas where certain practices are viable without the need for extensive trials. Mr. Burgess agreed that on macro-scale it may be possible to identify areas for rainwater harvesting but experience suggests that implementation involves a participatory approach at a micro-scale. This approach includes training of community members, identifying suitable designs and consideration of local rainfall, soil, crop and topographic factors. Trials and demonstrations with the local community is part of the participatory approach. The Isiolo trials provided information and raised questions which can be tackled as the programme develops.

FURTHER COMMENTS ON WATER HARVESTING FOR CROPS

V. Gibberd
Overseas Development Administration

Vernon Gibberd gave a preliminary summary of results from the EMI/ASAL Dryland Farming Project and Dryland Applied Research Project to clarify the role of water harvesting in two situations, first where land is limited and the farmer would have to reduce normal cropping area in order to introduce water harvesting and secondly where land is not limiting and the farmer can add a runoff catchment without restricting the normal cropping area. In the first situation, where land is limited, the farmer has to weigh up the advantages of getting a better yield off part of the area versus a poorer yield (or none at all) over the whole area. In the second situation land is not limiting and the farmer has little or nothing to lose by introducing water harvesting.

The figures were obtained from plots of 5m x 5m at nine research sites in the area of lower Embu, lower Meru and near Isiolo town (1 site). Three replications were used at every site. The design for water harvesting incorporated a 1:1 catchment to crop area ratio. The runoff was retained by a contour bund (as made by an ox plough) and on the upper side there was a 2.5m strip of bare ground as the catchment. The latter was not tilled. Ground slope varied from 0.5 - 5.0%.

The yields obtained with water harvesting have been calculated firstly per unit of the total land used i.e the cropped area plus the catchment area representing the situation where land is limited. Secondly the yields have been calculated per unit of cropped area alone which represents the situation where land is not limiting. The yields have been compared with those from the control plots without water harvesting and they are presented as a percentage increase or decrease in overall yield. The general conclusion is that where land is limited the farmer will get a lower total output by dividing it into a catchment area and a cropped area. However if land is not limited the farmer will gain in overall output by introducing water harvesting.

The provisional results (in tonnes per hectare) are as follows:

I CEREALS

| CROP | PEARL | MILLET | SORGHUM | PEARL | MILLET | |
|-----------------|-------|--------|---------|-------|--------|---------|
| Season | 11/90 | 1/90 | 11/90 | 4/91 | 11/91 | 4/92 |
| Rains | good | fair | good | fair | poor | v. poor |
| Control | 0.8 | 0.7 | 2.2 | 0.6 | 0.9 | 0.1 |
| With runoff | | | | | | |
| -land limited | -31% | -15% | -40% | -10% | -29% | +87% |
| -land unlimited | +38% | +70% | +29% | +79% | +42% | +274% |

II LEGUMES

| CROP | GREEN | GRAMS | COWPEAS | GREEN | GRAMS | |
|-----------------|-------|-------|---------|-------|-------|---------|
| Season | 11/89 | 4/90 | 11/90 | 4/91 | 11/91 | 4/92 |
| Rains | good | fair | good | fair | poor | v. poor |
| Control | 0.7 | 0.4 | 1.3 | 0.6 | 0.5 | 0.2 |
| With runoff | | | | | | |
| -land limited | -45% | -32% | -26% | -35% | -25% | -50% |
| -land unlimited | +10% | +33% | +47% | +30% | +49% | -1% |

III INTERCROPS

| CROP | MILLET + GRAMS | SORGHUM + COWPEA | MILLET+GRAM | | | |
|-----------------|----------------|------------------|-------------|------|-------|---------|
| Season | 11/89 | 4/90 | 11/90 | 4/91 | 11/91 | 4/92 |
| Rains | good | fair | good | fair | poor | v. poor |
| Control | 1.0 | 0.6 | 2.2 | 0.7 | 0.8 | 0.1 |
| With runoff | | | | | | |
| -land limited | -31% | +1% | -35% | -12% | -31% | -16% |
| -land unlimited | +39% | +101% | +29% | +75% | +38% | +68% |

WATER HARVESTING FOR SORGHUM PRODUCTION

S. B. Masibo
Lokitaung Pastoral Development Project, Kenya

1. BACKGROUND

Turkana district is situated in the arid northwest of Kenya. It covers an area of approximately 77,000 square kilometres with a population of about 300,000 people. Rainfall is erratic and ranges between 300-650 mm annually. The soils are mostly sandy loam or loamy sand and vegetation varies a lot depending on location. Well developed tree cover is found either in wetter zones, along water courses or hill ranges. The main occupation of the Turkana people is Pastoralism, keeping cattle, sheep, goats, camels and donkeys. Some people practice rain-fed farming as a supplement.

Limited availability of water in most arid and semi-arid regions is the major problem for rain-fed agriculture. Turkana district is no exception to this. Sometimes it is not even the quantity but the uneven distribution of rainfall that makes farming a difficult undertaking in such areas. Furthermore, even if the rainfall is sufficient for crop production most of it is lost as surface run-off. It is in this context that rain water harvesting for farming and other purposes, becomes important.

Since the early sixties, the government and NGO's have attempted to introduce rainwater harvesting and spreading techniques in Turkana district. Their major and common objective has been to increase the land's productive base by means of semi-circular bunds for improved pasture and browse production, micro catchments for tree planting and trapezoidal bunds to exploit the crop production potential. This paper will deal solely with the last activity - trapezoidal bunds

Following the 1979 drought, many Turkana were left as destitutes and a massive relief measure had to be undertaken to avert starvation. On the whole this was successfully done. Later on food for work was introduced as a way of trying to rehabilitate the district. One such activity, to which FFW was directed, was rainwater harvesting. Due to technical and managerial problems among others, there has been limited success (District plan 1989-1993).

In Lokitaung division, (situated far north and bordering Ethiopia) two bodies have been carrying out RWH activities for well over 5 years. These are the

Turkana Rehabilitation programme and the Lokitaung Pastoral Development Project otherwise known as TRP and LPDP respectively. This paper now examines the two project approaches in detail.

2. TURKANA REHABILITATION PROGRAMME

The Turkana Rehabilitation programme was established in 1980 following agreement between Kenya Government and EEC/Netherlands. Its top priority was to bring famine under control. Food aid was distributed through famine relief camps mostly in Central and Northern Turkana. The second phase saw TRP take on the challenge of rehabilitating the district through activities done on a food for work basis. One of the activities picked up by TRP and on a large scale was water harvesting for crop production.

Initially lack of technical know-how or training ensured that most of the bunds served no purpose at all except creating work. Later on in 1985 a workshop was organised for all TRP field staff.

This necessitated a fresh approach to building of bunds. Trapezoidal bunds were started. The idea following this was to make the size of the bunds big enough to withstand breakages when flooded. By that time, it has been realised that simply increasing the size of bunds is not an adequate solution to the problems.

TRP does not appear to have a clearly identified target group. At times, it is said that TRP is actually there to help those people who need assistance in the district. Their activities are carried out through field centres. At each centre, there are TRP's permanent and casual staff headed by Area Coordinators.

In the activity of rain water harvesting, the approach has been that the Area Coordinator identifies suitable sites for constructing bunds, mobilises an adequate workforce and together with his staff member supervises construction. On completion, the trapezoidal bund which is now actually a garden is allocated to individuals or families for ownership after paying off the workers. It can be clearly seen here that community participation, especially in decision making, is lacking - with the inevitable consequences of creating conflicts, e.g. siting gardens where, although otherwise suitable, people have never lived before probably due to lack of water because the area has been their grazing ground during wet seasons.

The final results have revealed lack of maintenance leading to breakages and eventually abandonment.

Since TRP has put a lot of emphasis on FFW rations (3 kg of maize cooking oil per cubic metre of soil moved) the tendency has always been to favour work that requires a large workforce. Consequently needy people have had to turn up willingly to work on the activity as it is supported by FFW regardless of its intrinsic development value (Critchley and Erukudi 1992).

Due to this top-down approach by TRP, gender which is an issue that requires consideration in any development endeavour is ignored. Though women form the majority of the workforce on gardening, TRP staff i.e. office bearers, extensionists etc, are almost entirely male.

3. LOKITAUNG PASTORAL DEVELOPMENT PROJECT

The Turkana Water Harvesting Project now called LPDP began in 1984, as one of the many development projects initiated in the wake of the 1980-81 famine. At that time, the EEC-funded TRP was also in operation constructing rain water harvesting gardens using food for work throughout northern Turkana.

Since its inception, LPDP has been mainly community based. This means that the project has always sought to use and respect people's own experience and knowledge. The project started working in one area - Kachoda for a period of time.

FFW initially played a very important role in LPDP water harvesting programme but because FFW normally fosters an attitude of dependency, the project has been quite keen to ensure this does not happen. Food for work allocation per garden has been reducing over the years since 1986 (from 32 bags per garden in 1985 to 7 bags by 1990). This in itself has had the effect of FFW being viewed as a stimulus and not reimbursement for work. It is not overly surprising therefore to note that even at this moment when FFW has ceased, LPDP construction work continues.

(Note: LPDP is funded by Oxfam UK).

4. CONCLUSIONS

Water harvesting for improved crop production in Lokitaung division should be viewed as a supplementary activity mainly supporting the pastoral economy. Two projects, working in the same region but with different approaches all geared towards common beneficiaries have had the side effect of confusing them.

Some of the achievements realised by LPDP though limited in the field of RWH are attributed to the high degree of local decision making. Formation of local committees has ensured that existing local institutions have taken over the role of self-management. Training local people in the use of simple and appropriate techniques has enabled the technology to remain with the people

On the other hand, TRP's approach coupled with non clear cut objectives or target groups has had negligible successes.

LPDP has all along sought to have technology and technical innovations under local control. This transfer has been done through several ways, one of which has been using traditional institutions. The community decides on who is to have a garden - normally based around "ere" the traditional home area. Local staff from the community have been employed in all the project areas to assist the committees on the technical matters that are beyond the committee's scope. Perhaps it is worthwhile to note here that the committees have got the mandate together with the management board to hire and fire their staff. Local committees are formed from 2 representatives from each "ere" in a given area. (1 man + 1 woman)

Tools for designing and working on RWH structures have been mostly simple ones i.e use of line-level instead of the complicated theodolites; use of the maresha plough in preference to the conventional mouldboard plough in the case of animal traction etc To date, many of the local experts include women with very little or no formal education who have been trained as trainers. In some cases women are in charge of work teams constructing bunds around the sorghum garden. Turkana women trained by the project tended to share their knowledge with other women whereas men rarely did

Lessons and experiences learnt here were extended to other areas several kilometres away. Currently the project is operating in 4 areas namely: Kachoda, Kaleng, Loarengak and Nachukui Local committees have been formed in all these areas Committee members to date comprise mainly gardeners. Sitings are organised monthly and are chaired by a locally elected elder as chairman. It is in this forum that achievements, problems, needs and plans are discussed

Initially the project had an expatriate manager in charge. When eventually the manager's contract finished, people expressed a wish of not having another expatriate manager. The idea of a local manager was also not very welcome as it was thought by project members that the would-be manager will always eventually take the role of a "boss" (This is following experiences with other projects in the district). Therefore a local Management Board was formed to

oversee project work. The Board has been running the project now since 1988 with relatively limited external input.

The target group for RWH in the project has always been marginal pastoralists and definitely NOT destitutes. This has been so following a convincing belief within project partners that agriculture can never be a substitute for a pastoral economy but could instead play a vital role as a supplementary subsistence alternative which could in some cases enable poor pastoralists who are on the brink of destitution to recapture pastoral life.

Nearly all gardens built under TRP have been abandoned while the majority built through LPDP have been maintained.

Water harvesting packages should be built on indigenous techniques and local environmental knowledge. The best starting point as experienced by LPDP is to identify those communities who already practise gardening. There is an urgent need to initiate common water harvesting techniques/approaches by all organisations in the district especially in Lokitaung division. Perhaps the District Water Harvesting Committee could facilitate this by offering coordination.

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Watson C. and Arupe P. 1990. Lake shore study, Dryland Food security Programme ITDG.

DISCUSSION

Mr. Kung'u Kimani asked what type of livestock water development options have been adopted and how successful they are in Lokitaung in view of the comment that "agriculture can never be a substitute for the pastoral economy".

Mr. Masibo replied that semi-circular bunds for improved pasture production have not been very successful as it was not the peoples' top priority when it was started and the pastoralists still use their traditional grazing posts. Micro-catchments have been used in a limited way for some exotic trees such as *Prosopis* sp. which have pods that are useful for goats. Trapezoidal bunds have been used for crop production but experience has shown that most families use the produce to exchange for animals which shows that even the destitute are very willing to rejoin the pastoral life.

Mr. Wanyonyi asked why most programmes fail due to technical and managerial problems and why there is a conflict when it comes to site selection for pilot projects.

Mr. Masibo replied that some technologies are imposed on people and are sometimes too expensive or complicated for adoption by the local people. Managerial problems come in when the intended beneficiaries are left out in the planning, implementation and evaluation of the project. In fact the problem often starts at the needs assessment stage if the priorities of the local people are overlooked. Conflicts come in when the beneficiaries are not consulted and problems can arise when few people understand the usefulness of the pilot project.

Mr. Burgess asked what the speaker meant when he said, in reference to bunds across wadis, that "... it have been realised that the idea of size is a futile one".

Mr. Masibo explained that however big the bund that is placed across a wadi, it will still be breached.

Mrs. Mukui asked the speaker to comment on the yields obtained with various techniques of water harvesting.

Mr. Masibo replied that there is a distinct difference between the gardens of the Turkana Rehabilitation programme and that of the Lokitaung Pastoral Development Project in that there is no levelling done within the enclosures of TRP. Consequently water is not infiltrated evenly and there is no advantage over traditional gardens. Yields are obviously higher in the improved gardens of LPDP. The highest yield realised in LPDP was in 1991 when a yield of 800 kg (8 bags) was obtained from 0.75 acre (0.3 ha).

SIAYA HEALTH EDUCATION, WATER AND SANITATION (SHEWAS) PROJECT

A. Oluoch
CARE International, Kenya

1. INTRODUCTION

CARE gets into the community by the use of Participatory Rural Appraisal (PRA) where by the community prioritize their needs and get involved in planning designing and even implementing these technologies

Presently SHEWAS is assisting communities with low cost technologies e.g spring protection, lining and equipping of shallow wells and roof catchments. Although CARE uses PRA, other relevant agencies (GOK and NGOs) collaborate during the entire exercise.

Although the community has various needs for water eg. domestic use, livestock, irrigation etc, by and large, the provision of water is determined by the availability of water resources depending on geographical conditions of the area. The priority for water needs goes to domestic use. In order to meet this need we consider the most economical system that can provide potable water to the community. Over the years, we have found out that rain water harvesting meets these requirements at low costs.

2. RAINWATER CATCHMENT

CARE has focused its assistance on roof catchments in schools (primary and secondary) and also other institutions like health centres and polytechnics. It is hoped that the low cost technologies in water storages can be duplicated in the homes by community members.

3. ROOF CATCHMENT TANK

CARE has developed three main types of roofcatchment water storage tanks in various parts of the country depending on availability of local materials and skilled labour (artisans) in order to minimise the cost of building the tanks. These type of tanks are made using:

1. Rubble stones/undressed stones
2. Baked Bricks
3. Ferrocement

During the planning of these tanks, the community and CARE work out the cost sharing in terms of materials and labour. The community also plans for operation and maintenance costs.

In SHEWAS project, CARE is mainly assisting the community to construct ferrocement water storage tanks.

4. FERROCEMENT TANKS

In SHEWAS project, the community recommended the surface water tank designs to be constructed at various institutions for easier management.

The sizes of the tanks vary as the water demands in these institutions may dictate. Normally it is planned that the daily water consumption per pupil/student is about 2 litres. The storage should therefore aim at supplying water during the driest period of the year which is about three months. Consideration of annual rainfall and the area of catchment cannot be omitted in these plans.

In most cases, we construct tanks ranging in sizes from 20 cubic metres - 40 cubic metres. When a roof has been identified for the target group who have contributed their shares, the skilled artisans, trained by CARE's technical team, move to the site for construction work as briefed below.

5. FOUNDATION

The foundation is normally dug about 200 mm and levelled. Hardcore is then placed of about 50mm - 75 mm. Blinding is then poured to keep the hardcore firm on place.

Before BRC reinforced floor slab, is laid a sheet of polythene paper is spread out to keep off loss of water in case of seepages.

Pipe work is also laid out through the reinforced concrete work. During the floor casting, the BRC weld mesh for the wall is also put up and tied to the floor mesh.

6. WALLS

The walls are reinforced with BRC weld mesh for tension. Chicken wire mesh is used to hold the sand/cement motor during plastering of the walls. Binding wire is used to tie the BRC such that the shape of the structure is maintained.

Final plaster, has the water proof compound to avoid leakages. The wall thickness is finishedd at 100 mm and normally about 2 m high.

7. ROOF

The roof is supported with a pipe pillar. The reinforcement is still BRC and chicken wire mesh for funtions mentioned above.

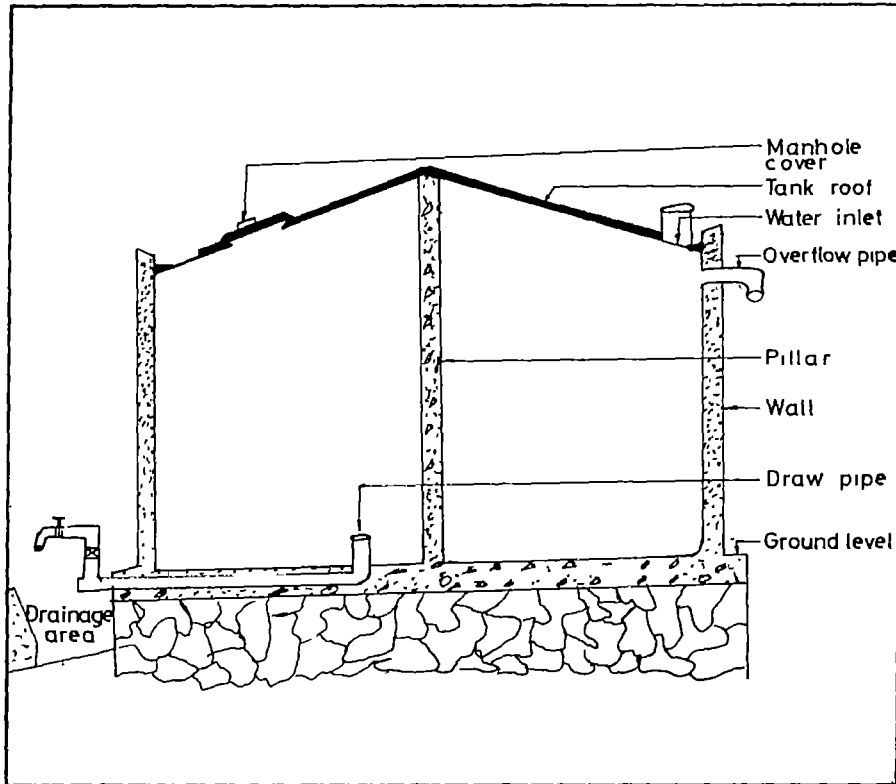


Fig. 1: Ferro-cement tank cross section

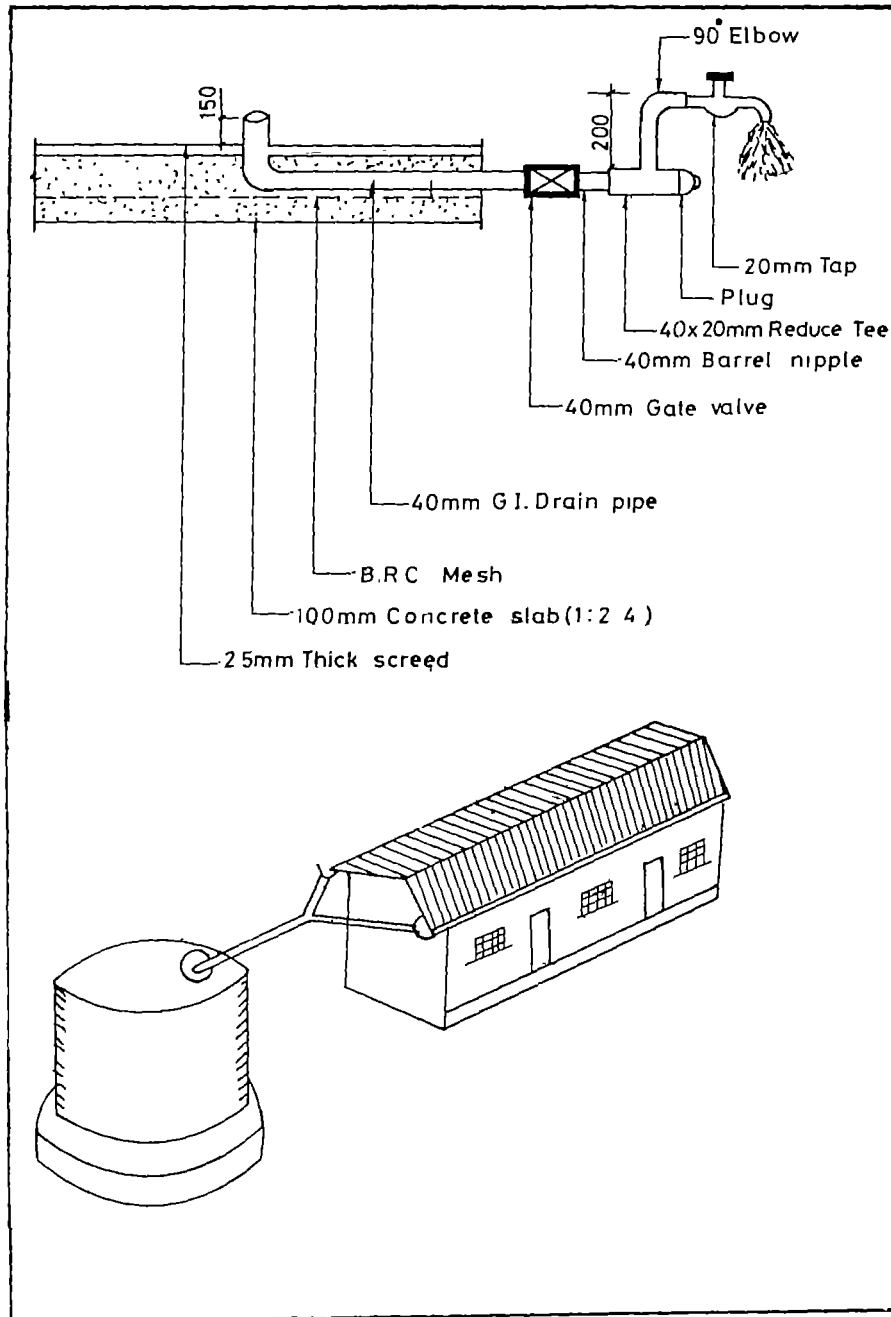


Fig. 2: Drainage detail at base of tank

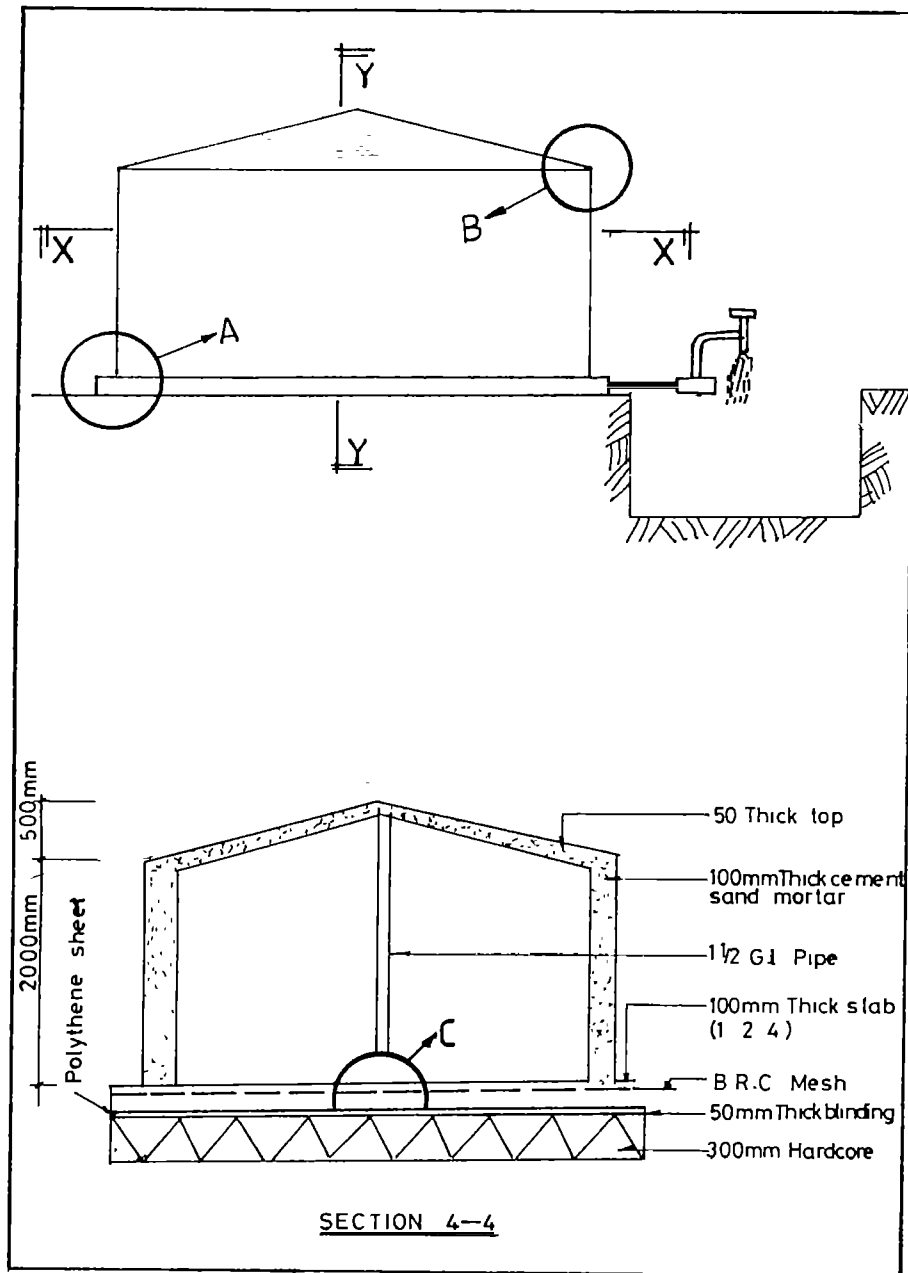


Fig. 3a : Side view of tank

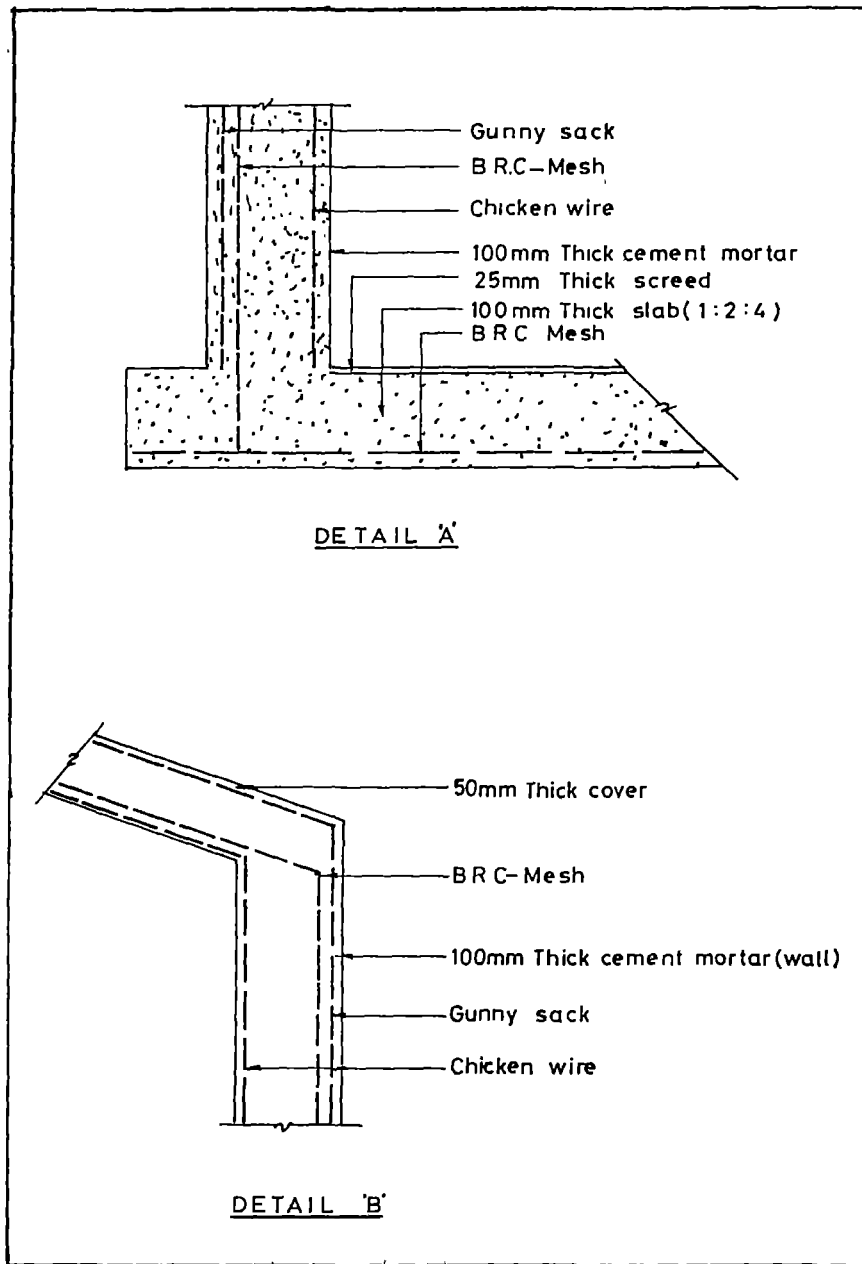


Fig. 3b: Tank details

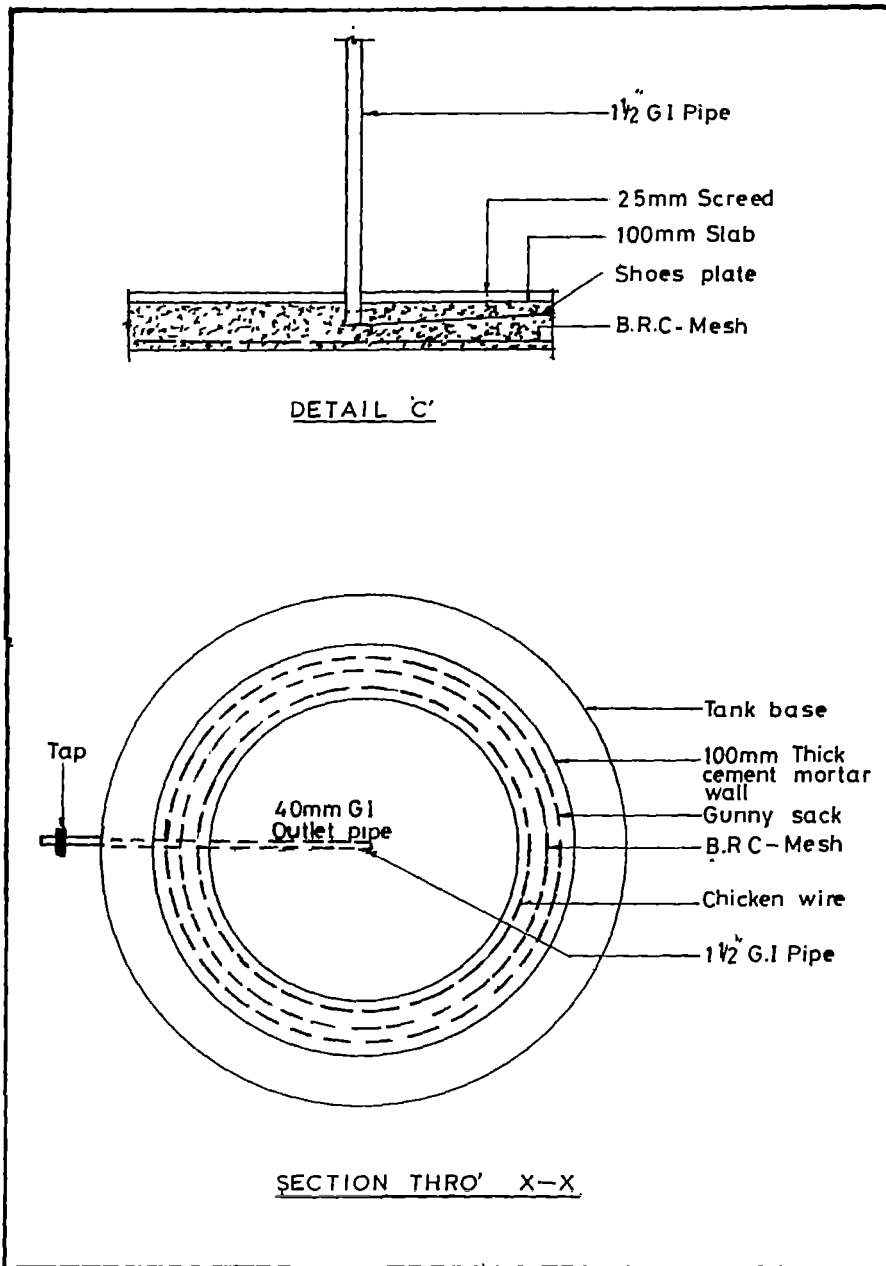


Fig. 3c: Tank details

DISCUSSION

Mr. S. Ngao asked about the siting of the wells and the depth and was told that they get assistance from the Ministry of Water Development geologist in selecting suitable sites. The depth is in the range of 10 - 25 metres

Mr. Wanyonyi asked how the wells are protected from damage by livestock and wildlife and what is done to ensure that a well continues to produce good quality water after several months of use.

Mr. Oluoch replied that protection of wells is by planting live fences around them. Cutoff drains to prevent the inflow of surface water are maintained by the communities. No toilets or rubbish pits are sited near the wells (especially upstream) and biological tests are carried out periodically to ensure that pollution is controlled.

Mr. G. Mailu asked what chemical or biological problems had been identified in existing wells and was told that tests done before construction sometimes indicate a high content of chloride in areas along the valleys. Sites near houses sometimes indicate the presence of E. coli and if so the site is moved or adjacent toilets are moved

Mr. D. M. Kingoo asked if the project included a training element and was told that at all sites two people are trained during construction to take care of future operation and maintenance.

IMPACT OF ROCK CATCHMENTS ON WATER RESOURCES OF KITUI DISTRICT

G. M. Mailu
Ministry of Research, Science and Technology

ABSTRACT

Kitui District is a semi-arid land according to the agro-ecological classification of Kenya. Water is therefore one of the major pre-requisites for the socio-economic development in the district. In this paper it is observed that river and groundwater resources are scarce and hence the need to resort to rock catchments for augmentation purposes. Rock catchments are not uniformly distributed in the district and hence their limitation as a single source of water supply. Other constraints are associated with lack of data for quantity and quality of water.

Finally, suggestions have been proposed for sustainable development and management of rock catchment in Kitui District.

1. INTRODUCTION

For the purpose of this paper, a rock catchment is defined as a reservoir located in a bare rock surface, with sufficient catchment to capture enough rainwater at any rainy season, for use during the dry season. The catchment may be natural or man-made. The period during which the water can be sustained during the dry season varies with, among other factors, the size of the catchment and the reservoir.

In attempting to assess the impact of rock catchments on water resources of Kitui District, background information on the geology and geography of the district has been offered. Diminishing surface and groundwater resources have necessitated the need to resort to rock catchments as augmenting sources of water supply. These sources have been discussed under the following headings: Controlling Factors, Constraints, Conclusion and recommendations.

2. LOCATION

Kitui is one of the six districts that constitute North Eastern Province. It borders Tana River to the east, Meru and Embu to the north west, Machakos to the west and Taita-Taveta to the south.

It is bounded by latitudes $0^{\circ} 01'S$ and $3^{\circ} 45' S$ and longitudes $37^{\circ} 30' E$ and $39^{\circ} 20' E$. Its area is approximately 29,388 square kilometres with a population of approximately 464,283 people (CBS, 1981) (see fig 1).

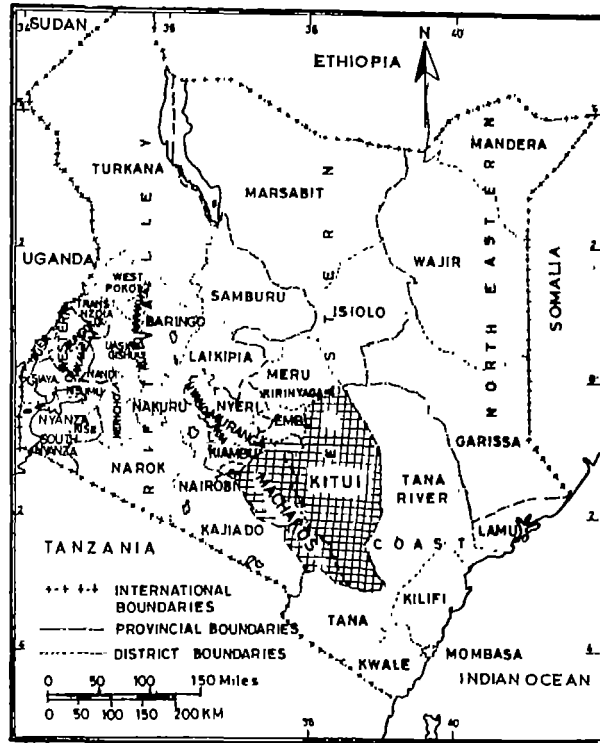


Fig. 1: Map of Kenya showing the location of Machakos and Kitui Districts

3. WATER RESOURCES OF KITUI DISTRICT

Most of the Rivers in Kitui District are seasonal. The only perennial rivers of importance are Tana and Athi rivers. It will be noted from Fig 2 that - the two rivers are located along the northwestern and southwestern fringes of the district, respectively, and their water benefits a negligible population in the district.

Efforts to drill boreholes to tap groundwater have been made from as early as 1930s. Some of the borehole sites are shown in Fig 2. The mean yield of the boreholes is 2.8 cubic metres per hour. The yield is characteristically low not only in Kitui but also in other parts of Kenya underlain by metamorphic rocks (Mailu, 1987). Most boreholes tap their water from weathered metamorphic rocks.

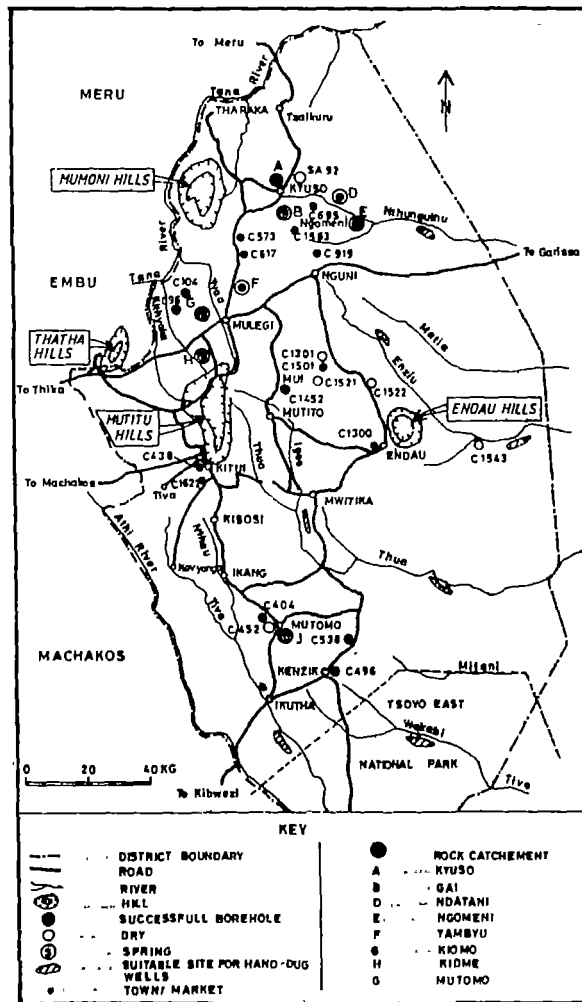


Fig.2: Water resources map of Kitui District

However, those which tap water from fractured zones have high yields of good quality (Mailu, 1983). This is true of boreholes drilled along the Kitui fault at Ithokwe, a few kilometres south of Kitui Town. Most of the boreholes have poor quality water which is mainly brackish (above 1000 mg/l). On the basis of the poor quantity and quality of groundwater and the high cost of drilling (about if KSh.300,000 per borehole) deep aquifers are discouraging as shown by the distribution of boreholes in the district. (Fig.2)

4. ROCK CATCHMENT

4.1 Introduction

As stated earlier, most of the rock catchments in Kitui are located in main watersheds which have been subjected to intensive destruction of vegetation and subsequent soil erosion resulting in bare masses of rock. The old well known rock catchments in Kitui District include Ngomeni, Ndatani, Kiome, Kyuso, Yambyu, Ukasi, Gai and Mutomo. (see Fig 2)

4.2 Factors affecting rock catchments

Many factors affect the suitability of a rock catchment. The scope of this paper covers geological and geographical factors only.

4.2.1 Geological Factors

The most suitable rocks include granite and granitoid gneisses. They have poor permeability and they are resistant to weathering.

It is important that the rocks have weak rocks which are embedded in them so that when the latter weather they leave big depressions which serve as suitable reservoirs. Rocks such as basalts and limestone are the poorest as they have columnar jointing and cavities which cause percolation of water instead of holding it in the reservoir. Loose sediments are equally bad. Evaporites such as gypsum halite are unsuitable as they could render the water salty due to their high solubility.

Geological structures such as faults and anticlines of thinly bedded or banded rocks are not suitable. However, rock catchments located in synclines with impervious outcrops are quite suitable. (figures 3,4, 5, and 6)

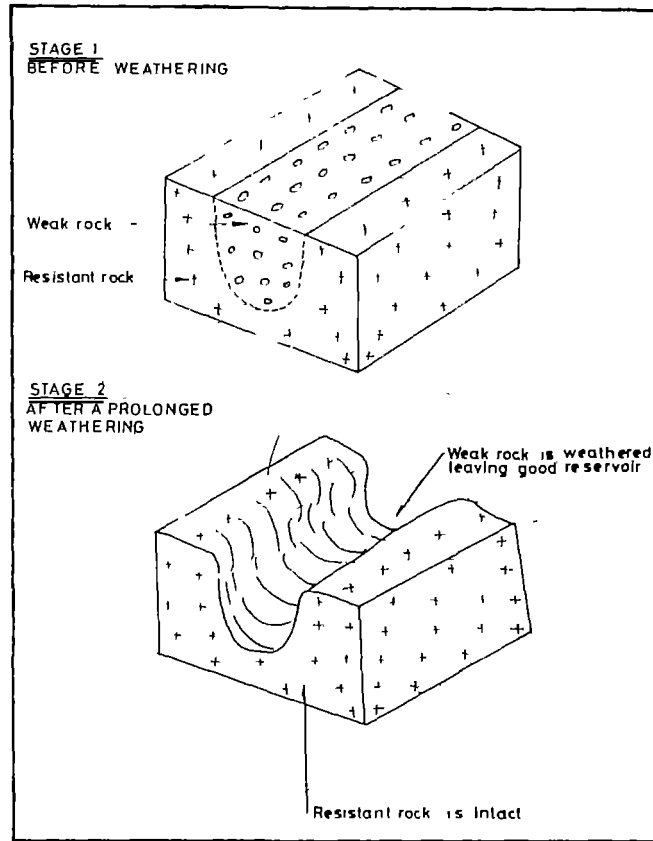


Fig. 3: Lenses of Weak Rocks or Miners in Resistant Rocks.

4.2.2 Geographical Factors

The main geographical factors include the size of the catchment, siltation, wind and steepness of the surrounding area. The catchment and the reservoir should be large enough to capture and store as much water as possible for a given rain season. The catchment should be as bare as possible to avoid siltation of the reservoir. The slopes away from the catchment should be as steep as possible in order to discourage people and livestock from having direct contact with the reservoir. The distribution of rock catchments is poor as they are confined to hill masses which have been subjected to heavy erosion.

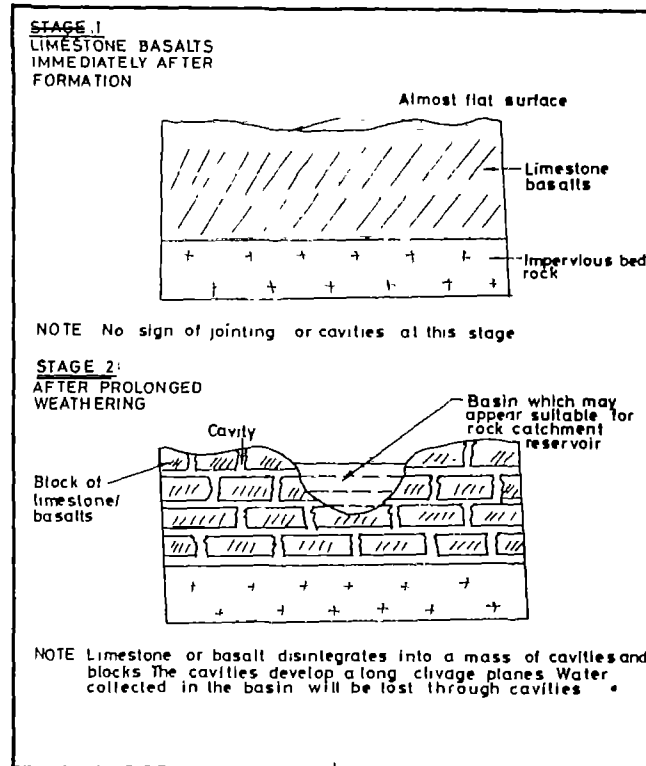


Fig. 4: Disadvantages of limestone and Basalts

4.3 Constraints

4.3.1 Geographical Constraints

The geographical constraints include spatial distribution, the size of the catchment and reservoir, and exposure to wind action. As stated earlier rock catchments are confined to watersheds which have been subjected to heavy erosion. The eastern and south western parts of Kitui which are underlain by sediments and volcanic rocks are unsuitable for rock catchments. Consequently about 10 percent of the district may benefit from rock catchments.

Although there could be a lot of bare rocks they may lack the concave shape which is necessary for the reservoir and this factor limits the availability of rock catchments where other factors are otherwise good. Generally, deep long reservoirs are suitable as they are sheltered from winds which can aggravate evaporation.

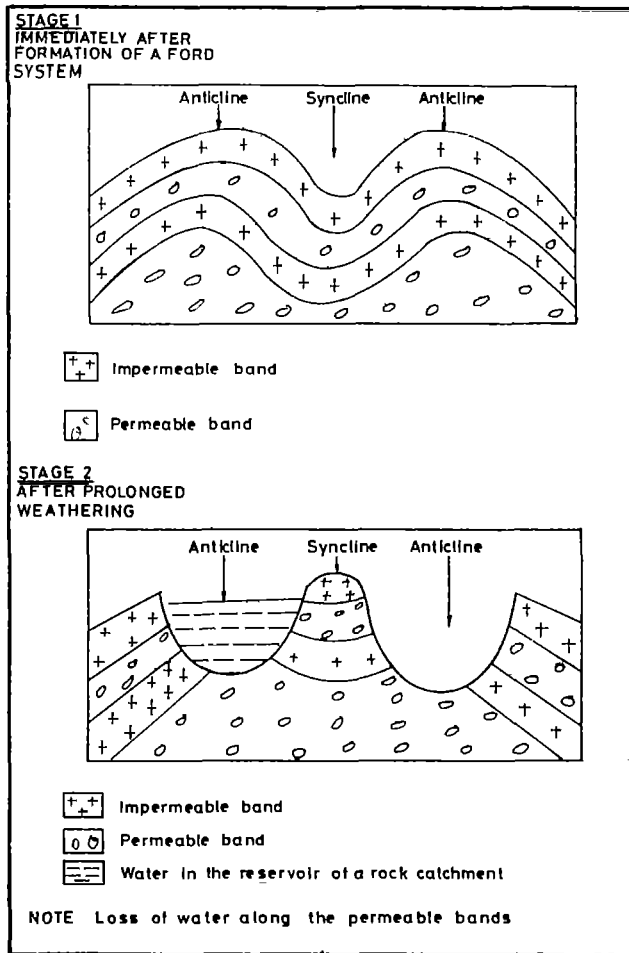


Fig. 5: Disadvantages of Anticline

4.3.2 Geological Constraints

Geological constraints are mainly lithological and structural in nature. Lithological constraints include among others, easily weathered rocks which have high permeability.

Fortunately these are limited in areas where rock catchments are found in Kitui. Biotite gneisses and thinly banded gneisses have high degree of permeability and reservoirs located on them may suffer heavy losses of water.

Structural constraints in Kitui District are more than lithological constraints. The former constraints include anticlinal depressions with permeable bands and fractured and faulted zones. In areas where the depressions suitable for

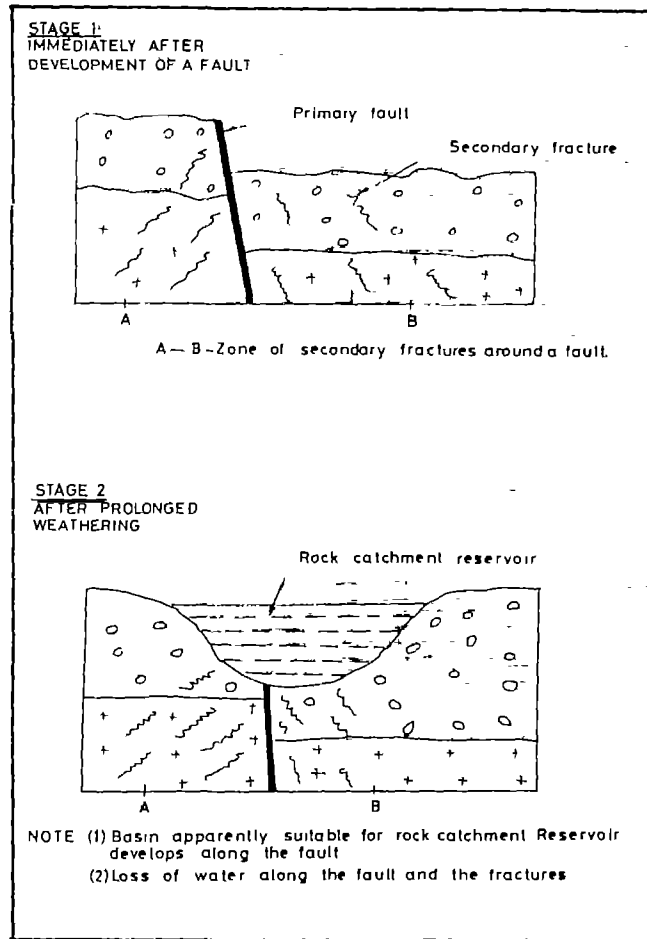


Fig. 6: Faulting

reservoirs are covered with scree, there may be need to carry out geological surveys to avoid excavation which may expose unsuitable geological factors after incurring heavy expenses in terms of labour.

4.3.3 Technical Constraints

The main technical problems include lack of data and coordination of construction works. This has resulted in lack of assessment of effective development and management of rock catchments in the district. Selection of sites has not been preceded by appropriate technical advice and a lot of money and labour have been invested in construction works which do not adequately meet the needs of people. Examples of such works have been observed in Waita and

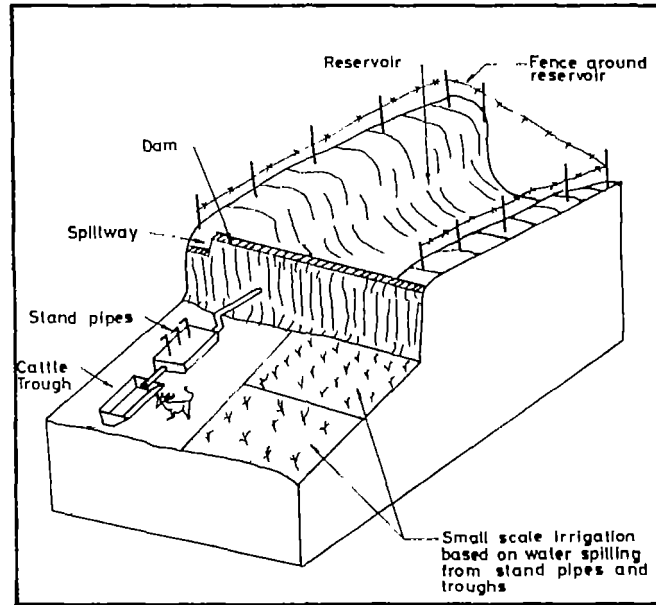


Fig. 7: Well Managed Rock Catchment

Kyuso areas where the reservoirs have either been located on convex surfaces or in fractured depressions which cannot hold adequate water for a reasonable period. Lack of monitoring of water quantity and quality in existing rock catchments and the impact on the community served have discouraged professional planning for new rock catchments. Lack of adequate infrastructure attendant to rock catchments such as adequate and well located stand pipes and troughs for watering animals and human beings have resulted in fast deterioration of rock catchments mainly through pollution and wastage of otherwise needed water (Fig 7).

5. CONCLUSION AND RECOMMENDATIONS

It has been pointed out that most rock catchments are located along the main watershed of Kitui District which does not benefit adequately from hand-dug wells as the river beds do not have enough sand to store water. Boreholes

drilled in most parts of the watershed have been abandoned because their water is too saline for domestic purposes. Consequently development of rock catchments as sources of water supply is not a choice but a necessity for the communities of Kitui District.

Rock catchments are seen as the sure answer for supporting settlements particularly in northern parts of Kitui District and they have played a major role in easing population pressure in central Kitui which has relatively sufficient surface water and ground water supplies.

The land tenure in the central Kitui is characterised by fragmentation to very small pieces of land per household, thus drastically reduced land carrying capacity.

On the other hand, the land tenure in northern Kitui is characterised by large tracts of land per household. These have supported better pasture for livestock and arable land than the central part of Kitui. When sufficient rainfall is received good crop harvest is obtained and the food supports a large population of Kitui.

It will be noted that although rock catchments support about 10 percent of the Kitui population water is the backbone for livestock and crop production in the district. Consequently, it needs planned development and management for the socio-economic benefits of the district.

In order to attain the desired development and management of the rock catchments the following measures are recommended.

- Immediate inventory of all existing rock catchments in the district
- Regular monitoring of the water quantity and quality
- Protection of direct watering from the reservoirs by provision of adequate stand pipes and troughs down stream of the reservoir, and fencing around the reservoirs.
- Construction of canals from the watering points to sites where small scale irrigation could be carried out using the water which could otherwise be wasted as a result of leakages.
- Central co-ordination of development and management of rock catchments preferably by the Ministry of Water Development.

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DISCUSSION

Mr. John Musya asked what can be done if a rock catchment is fractured and whether it can be reinforced.

Mr. Mailu replied that reinforcement could be done by grouting but it is too costly for poor communities and alternative sites which do not require sealing should be selected.

Mr. S. Ngao asked how long water can be stored during the dry season assuming there is no seepage.

The speaker replied that it depends on the amount of rainfall and the size of the catchment and the reservoir. It will also depend on the rate of evaporation and the rate of consumption.

6. FIELD TRIPS, DISCUSSIONS AND CONCLUSIONS

FIELD EXCURSIONS TO MACHAKOS AND KITUI DISTRICTS

By G. Mailu and S. K. Mutiso

1. INTRODUCTION

1.1 General

Kenya is bounded by latitudes 5 00 N and 4 30 S and longitudes 33 55 E and 41 52 E. It borders Ethiopia and the Sudan to the north, Uganda to the west, Tanzania to the south, Indian Ocean to the south-east and Somalia to the east. The area of Kenya is approximately 583,000 square km. The country is divided into 8 provinces which are further sub divided into 41 districts (Fig 1). The population is approximately 23 million. It will be noted that Machakos and Kitui Districts are within the Eastern Province. Although Machakos District has been

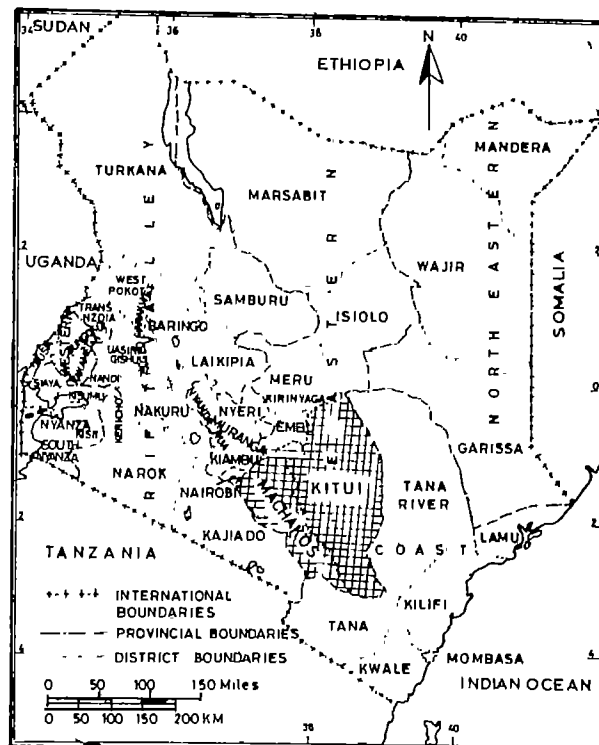


Fig. 1: Map of Kenya showing the location of Machakos and Kitui Districts

sub divided into Machakos and Wote Districts (1991), they are treated as one district under the name "Machakos District" for the purpose of these notes.

The purpose of the excursions was to expose the participants of the Rainwater Harvesting Conference to the environmental constraints in semi-arid lands of Eastern Kenya. The participants had an opportunity to see the measures taken by the Kenya Government, NGOs and the local community in coping with the aforementioned constraints.

It will be appreciated from the onset that all development activities revolve around the availability of water. However, water resources are limited in the District. Only 1/3 of the district receives 750mm of annual rainfall which is considered necessary for most forms of crop production (Mutiso & Thompson, 1987). There are few and widely spaced perennial rivers, the groundwater aquifers are poor both in quality and quantity, and drilling of boreholes to extract groundwater is extremely expensive (Mailu, 1987). Consequently the local community has resorted to any form of water harvesting including roof and rock catchments, and surface and sub-surface dams. The water harvested from these sources is used for domestic, livestock, range improvement and crop production purposes.

1.2 Climate and Drainage

The main climatic element that influences the socio-economic activities of the Machakos and Kitui districts is rainfall. It is bimodal in nature with short rains (Oct-Dec) and long rains (March-May). It is characterized by low total amounts, strongly seasonal concentration and high temporal and spatial variation from year to year and season to season (Mutiso et al, 1991). The mean annual rainfall in Machakos varies from about 900-1270mm on the hill masses, 762-1016mm on the eastern plains and 381-635mm on the south eastern plains (Kikumbulyu plains), and 457-635mm on the Athi-Kapiti Plains (Owako 1971).

The mean annual rainfall in Kitui District varies from about 500 to 750mm on the hill masses, which constitute only 30% of the district and 250mm to 500mm on the lowlands which constitute 70% of the district.

The stated mean annual rainfall figures have to be treated with care for practical land use planning. The effectiveness of the rainfall is adversely affected by relatively high rates of evapotranspiration and soil conditions. The rain seasons are associated with high runoff which causes soil erosion. Conservation measures could be taken to prevent soil erosion and harness water for irrigation during dry seasons to avert crop failure and attendant famine.

1.3 Early Settlement

Akamba are the dominant tribe in Machakos and Kitui Districts. The time of the first settlement of the Akamba in Machakos is not accurately known. It is probably certain that they first settled in Mbooni Hills (Ominde, 1971; Mutiso, 1988). Since the time of first settlement, the Akamba changed from pastoralists to sedentary farmers. Mbooni was probably selected because permanent surface water was available and the steep slopes provided protection against the raids by the Masai neighbours. Probably due to population pressure, about three hundred years ago, the first major migration out of Mbooni took place to the east (Kitui District) and north (Mua - Iveti hills, Kanzala and Ol Donyo Sabuk hills) (Ominde 1971). The first settlement in Kitui District is assumed to have taken place in the central highlands of Kitui which has an assured source of water supply.

1.4 Land Use

To the Akamba, land is virtually the only security the farmer has besides livestock and institutions of family aid. The importance of land to the Akamba is recognised when it becomes a scarce commodity through population pressure and the need among sons to inherit family land (Mutiso, 1988). This land tenure system has led to land fragmentation which has drastically lowered the land carrying capacity.

The overall effect of population-land relationship is reflected in the severe soil, water and vegetation resource degradation.

Individual efforts have proved inadequate for land rehabilitation by way of soil and water conservation. Team work has, therefore, become imperative and harambee effort has been resorted to. Government and NGOs have provided expertise and funding and the local people have provided labour. In some cases some communities have generated funds through sale of their produce. In the excursion, the institutional contribution was observed by the participants. The summary of the contribution is discussed in the description of the stations visited.

2. BACKGROUND INFORMATION ON MACHAKOS DISTRICT

Machakos is one of the six districts that constitute Eastern Province. The other five are, from south to north, Kitui, Embu, Meru, Isiolo and Marsabit. The district is bounded by latitudes 0 47 S and 3 0 S and longitudes 36 53 E and 38 31 E. The area is approximately 14,178 km (sq) and the population is approximately 1,022,522 (CBS, 1981).

The geological foundation of the present relief forms is composed of three major rock types, namely: Precambrian metamorphic rocks and Tertiary and Quaternary volcanic rocks (Fairburn, 1963). The Precambrian metamorphic rocks include mainly schists, quartzites, biotite gneisses, metadolerites and granitoid gneisses. The biotite gneisses and schists are associated with lowlands and granitoid gneisses and dolerites are associated with the central hill masses of Machakos District (Fig 2) The Tertiary volcanic rocks are mainly phonolites which underlie Kapiti Plains and Yatta Plateau. Quaternary volcanic rocks form the Chyulu Hills.

3. LAND MARKS ON THE MACHAKOS EXCURSIONS

The following are landmarks on the Machakos excursion (see Fig 3)

LM 1 NAIROBI CITY

Nairobi City is the starting point of the excursion. It is located at an altitude of 1500 metres a.m.s.l. To the west the land rises gradually to an altitude of about 2400 metres a.m.s.l. around Limuru and Ngong Hills. The city is underlain by volcanic rocks of Tertiary Period. Good and well drained volcanic soils and favourable climatic conditions have supported agricultural economy.

The City is characterised by heavy floods during the rain seasons. Dry seasons are associated with water rationing. Conservation of flood water could alleviate shortages during the dry seasons.

LM 2 ATHI RIVER

Athi River Town is 26 km south east of Nairobi and it is located in the undulating Athi Plains which are underlain by the oldest Tertiary volcanic rocks called Kapiti phonolites. About 6km east of Athi River is the Lukenya Range which is underlain by granitoid gneisses. Further east Mua hills can be seen in the background.

Athi River area is characterised by much lower and less reliable rainfall than Nairobi. Crop failure is common. Water obtained from boreholes has the highest level of fluoride content east of Nairobi. Average concentration of 8 mg/l is common (Mailu 1983). Currently the town gets water for domestic purposes from Nortureh Springs some 300 km away on the slopes of Mount Kilimanjaro.

LM 3 MACHAKOS TOWN

Machakos Town is the headquarters of Machakos District and approximately 69 km south east of Nairobi. It is located in a lowland which is surrounded by

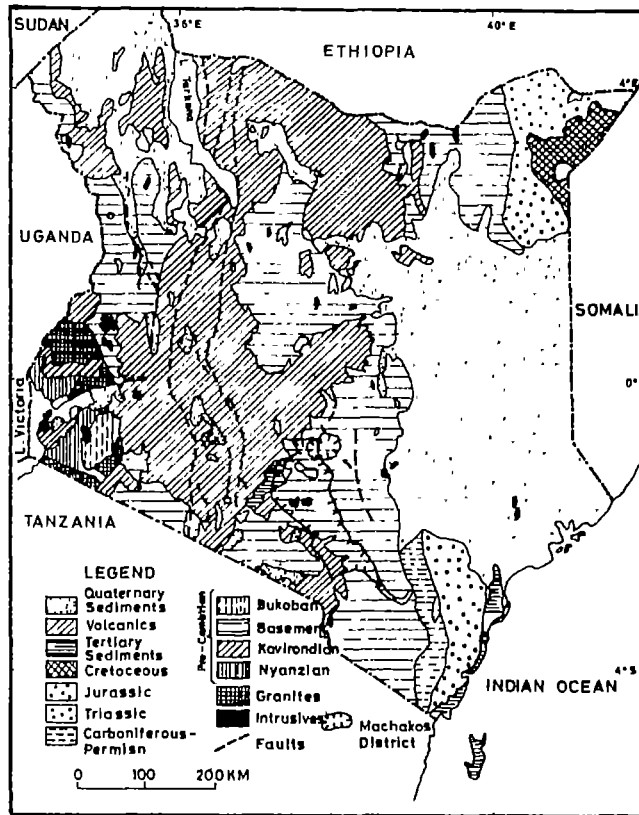


Fig. 2: Geology of Kenya

a horse-shoe hill mass comprising Mua, Mitaboni, and Iveti Hills. The area is underlain by metamorphic rocks which are mainly schists, granitoid gneisses and biotite gneisses. The surrounding area is heavily populated.

LM 4 IKIWE RIVER

About 1 km west of Machakos town the river is seasonal. However, about 8 km south of Machakos town the river carries sewage perennially and the water has turned green in colour. Immediate action should be taken to make the river environmentally friendly.

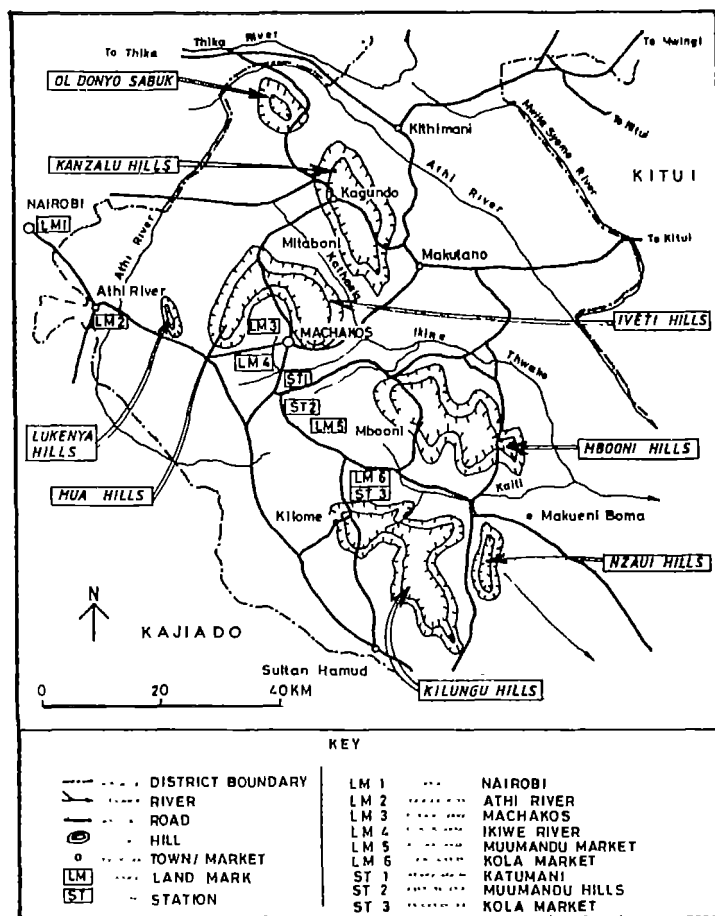


Fig. 3: Location of Important Sites along the Route of Machakos District Excursion

LM 5 MUUMANDU MARKET

Muumandu is 24 km south of Machakos Town. Efforts for afforestation on the hill summit and soil conservation on the slopes are important features.

LM 6 KOLA MARKET

Kola Market is the centred for Utooni Community Development Project. It is 35 km south of Machakos Town. It is the last market in the excursion.

5. STATIONS VISITED ON THE MACHAKOS EXCURSION

Stopovers were made at the following places which are shown in Fig 3.

ST. A KATUMANI

Katuman Research Centre is one of the most important research centres of Kenya Agricultural Research Institute. The main mandate of the centre is research on dry land farming. In the centre the Government efforts to improve dry land farming and to ensure food security in arid and semi-arid lands can be appreciated. Donor agency efforts can also be noted.

ST. B MUUMANDU HILLS

About 22 km south of Machakos town the participants can observe the contrast between soil and water conservation in arable and pasture lands. Soil conservation measures by bench terracing have been taken in the arable land and land degradation is low. However, in the pasture land soil conservation measures are minimal. This is characteristic of most of the land use in Machakos district.

ST. C UTOONI COMMUNITY PROJECT

The centre of Utooni Community Development Project is the Kola Market about 35 km south of Machakos. The project has an integrated development approach which has evolved from efforts to conserve water and soil. The main activities to be observed include, among others:

- Water conservation through surface, and subsurface dams and roof catchments.
- Animal husbandry which has a big promise for sufficient milk and manure.
- Polytechnic Training centre
- Primary health care centre
- Posho mill
- Small scale irrigation for vegetables

The participation of NGOs and the local community should be noted.

6. BACKGROUND INFORMATION ON KITUI DISTRICT

Kitui is one of the six districts that constitute Eastern Province (see Fig 1). The other five are, from south to north, Machakos, Embu, Meru, Isiolo and Marsabit.

The district is bounded by latitudes 0 01 S and 3 45 S and longitudes 37 30 E and 39 20 E. The area is approximately 29388 sq km and the population is approximately 464,283 (CBS, 1981)

The geology of Kitui District is dominated by outcrops of Precambrian metamorphic rocks. Younger rocks include the Tertiary volcanic rocks, mainly phonolites which form the Yatta Plateau along Kitui- Machakos border in the South western region of the district, and the Quaternary sediments which overlie the metamorphic rocks on the lowlands to the east near Kitui-Tana River district border (Dodson, 1955, Baker 1963, Saggerson, 1957). The precambrian rocks are characterised by schists and biotite gneisses which are associated with lowlands, and granitoid gneisses, granites and quartzites which are associated with hill masses. The Tertiary volcanic rocks are mainly phonolites. The Quaternary sediments are characterised by unconsolidated clayey sands. (Wright 1961, Schoeman, 1948)

The topography of Kitui district is characterised by lowlands with isolated hill masses (inselbergs). The main masses include Mutitu, Endau, Kiomo, Gai and Mumoni to mention a few. Most of them rise to an altitude above 1200 metres a.m.s.l. (Fig 2)

7. LAND MARKS ON THE KITUI EXCURSION

The following places of interest are shown in Fig.4

LM THIKA TOWN

Thika is an industrial town about 45km north of Nairobi. The main industries include textiles, car assembly, tobacco, canning, leather and chemical industries. The only factory in Kenya which manufactures alum is in Thika. Domestic and industrial water comes from Thika River a few metres to the north of the town. There is insufficient data to facilitate conclusive impact of the industrial effluent downstream of Thika River from Thika town.

LM 3 KILIMAMBOGO

The most outstanding feature is Ol Donyo Sabuk hill, the slopes of which are a national park. The dominant wild life include rhino, buffalo, antelopes, hyena, leopards and jackals. Cold water springs are common on the western slopes of the mountain. Hot springs occur on the lowlands north west of Donyo Sabuk market. Fourteen Falls, about 5 km south east of Kitui-Tala junction is one of the most important tourist attractions in the area.

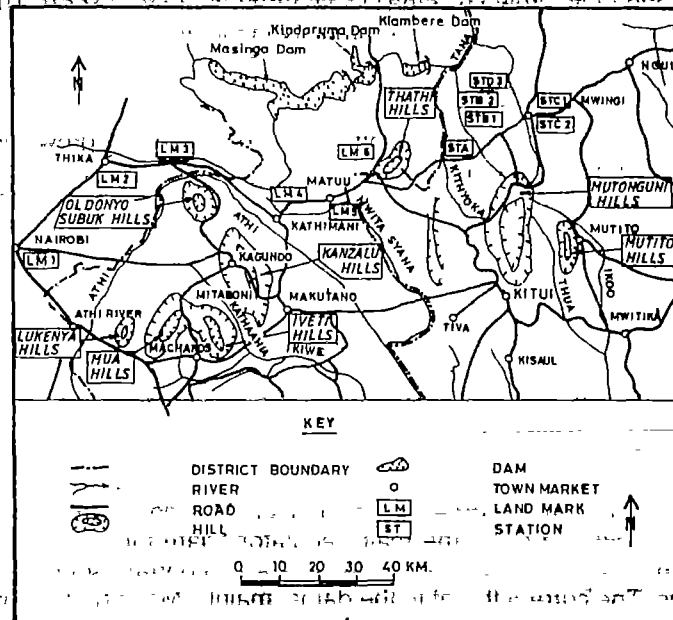


Fig. 4: Location of Important Sites along the Routes of Kitui District Excursion

Groundwater quality is poor with total dissolved solids values which exceed 1500 mg/l (Mailu 1983). Consequently the main source of water for most purposes is Athi River.

To the south farms which, hitherto, had sisal as the dominant crop have horticultural crops and coffee. To the north an extensive farm of pineapples is observed. Water for irrigation is obtained from Thika and Athi rivers.

LM 4 YATTA FURROW

Yatta Furrow was dug in early 1950s. The labour was provided by Mau Mau detainees. The furrow is about 60 km long. It is fed by water from Thika River. It has greatly boosted horticultural farming along its length. Most of the

vegetable and fruits grown by small scale farmers are for export. The farming has provided a lot of jobs for the community in the area.

LM 5 MATUU MARKET

Matuu is a fast growing market in Yatta Division. It owes it's growth to the high potential farming area around it. It has a ready market in Nairobi, Thika, Kitui and Garissa for the agricultural produce. The construction of the hydroelectricity dams on Masinga, Kindaruma, Kamburu and Kiambere has provided a substantial market for Matuu. The main water supply source is the Yatta Furrow. Treatments works for the water are about 4 km south of the market.

LM 6 KANGONE

This is the area where the road to Embu and the hydroelectricity dams branches from the Thika-Garissa road. It is an area which is located very far from perennial rivers. It can benefit much from rainwater harvesting by roof catchment.

The biggest among the hydroelectricity dams is Masinga Dam which is 60 km long. It is considered to be the main regulatory dam for the series of dams downstream. Tourism and fishing industries are important sources of income at the dams. The current threat to the dams, mainly, Masinga Dam is siltation.

8. STATIONS VISITED ON THE KITUI EXCURSION

The places visited are shown on Figure 4

ST A THITANI

Thitani is a market about 143 km east of Nairobi where a Catholic Mission is situated. The market has experienced serious water problems for many years. Efforts to drill boreholes for water supply have been made. Roof catchment is another technology which has been tried in Thitani Market and the surrounding areas where most other technologies have failed.

The participants can observe a water tank with a roof catchment. It has been funded by UNICEF and construction work has been implemented by the Catholic Diocese of Kitui.

ST B KIOO

Kioo Hills are good examples of the inselbergs which rise above the lowlands of Kitui District. They are approximately 10 km west of Mwingi Town. It is the

area which displays the typical efforts of various institutions in search of water summarised in stations B1, B2, and B3.

ST B1: Rock catchment reservoirs and an earth dam have been constructed. The contribution of ALDEF, USAID, Diocese of Kitui, Danida and local community should be noted.

ST B2: A rock catchment under construction can be observed. The Catholic Diocese of Kitui is undertaking the work.

ST B3: A visit will be made to a sub-surface dam which is under construction. The contribution of the Diocese of Kitui and the community should be noted.

ST C: MWINGI TOWN

Mwingi Town is approximately 173 km east of Nairobi. The visit to the town will focus on various technologies of roof catchments as briefly stated below.

ST C1 : A water tank 46 cubic metres with V-gutters and splash guard can be observed. It is being constructed through the Kitui Integrated Development Programme.

ST C2: A water tank built of interlocking concrete blocks can be observed. It has been constructed by the women groups from African Housing Fund.

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REPORT ON MACHAKOS FIELD TRIP

H. Mukui
Church of Province of Kenya, Nakuru

1. INTRODUCTION

Several areas were visited. The main station included Katumani Dryland Research Centre, Muumani Hills and the Utooni Community Project.

2. TYPES OF TECHNIQUES OBSERVED

The following techniques were observed:

Sub-surface dams, surface dams, ferrocement tanks, G.I tanks, masonry tanks, VIP toilets, terracing and minor irrigation.

The techniques observed were acceptable, affordable and easily understood by the community. However, the following were noted:

The members of the Utooni community project work together communally and have managed to construct several sub-surface and surface dams for the whole community, but the management was left to the administration .

They have also managed to construct a ferrocement water tank for each member through sponsorship as the tanks bore the name of whoever sponsored it. This, we felt should be discouraged as it had an element of dependency which might discourage the other members of the community.

The community also had a polytechnic and a posho mill project and houses to let.

3. LEADERSHIP

It was observed that the project had initially started very well with a membership of about two hundred people, but at the moment the membership was less than a hundred and it appeared to be a one man show

4. WATER QUALITY AND SANITATION

The water quality from the ferrocement and masonry tanks harvesting from roof catchments was good and safe for drinking. The community was aware of covering the tanks and boiling water if necessary

The water quality from the sub-surface dams was not of good quality but it was of merit for livestock and a bit of crop production.

It was observed that sand for sale was being collected from some sub-surface dams and this should be discouraged.

5. APPROACH AND COLLABORATION

It appeared that the community project approach was very good and indeed a lot has been observed both at community and individual levels. However, at the time of the visit, leadership seemed a one man job. Due to poor leadership, it appeared that the project did not collaborate well with other organisations including the administration.

6. SUSTAINABILITY OF THE PROJECT

The project is self sustaining because most of the work is done by the community members themselves. The community contributes to all the labour input and a bit of cash contribution. There was also the element of taking care of those members of the community who cannot afford the cash required.

7. OBSERVATIONS ON TECHNICAL ISSUES

On the construction of the tanks it was noted that the construction of the foundation, the base of the tank and curing was not done well and this could lead to cracks and leakages.

Some of the sub-surface dams were not constructed in stages as required so as to get rid of silt. Some of the dam walls were also too thick hence increasing overall construction costs.

The abstraction methods of water and management of the surface and sub-surface dams was not good enough as this could increase contamination and hence lead to waterborne diseases such as cholera.

8. RECOMMENDATIONS

Community leaders should be trained on leadership skills by various sponsoring bodies.

There should be change of leadership or management committees through the annual general meetings (AGM's) in order to avoid or remove poor and or domineering leaders who can lead to collapse of community projects.

There should be collaboration and co-operation among technicians/engineers in various organisations and government ministries so that communities are properly advised on the correct technologies.

There should be documentation or inventory of what has been done and what various organisations are doing in rainwater harvesting.

Materials, chemicals and designs used in rainwater harvesting should be standardised.

REPORT ON KITUI FIELD TRIP

J. M. Wanyonyi
Kenya Polytechnic, Nairobi

1. INTRODUCTION

The objectives of the field trip were :

- to observe the type and level of technology in rainwater harvesting projects
- to assess the appropriateness of the technology in terms of affordability, acceptability and sustainability
- to observe the water quality and sanitation issues with regard to rainwater harvesting techniques
- to observe the implementation approaches adopted in Kitui
- To assess the level of inter-agency collaboration with respect to rainwater harvesting and the environment.

Several areas were visited. The main stations included Kithimani, Yatta and Mattu urban centres. The projects visited included Nguatani (Thitani) catholic church, Mbithini River dam site, Kioo 1,2 and 3 rock catchment sites, Mwingi area (Thumbi primary school and Mwingi health centre).

2. TYPES OF TECHNIQUES OBSERVED

The following types of technologies were observed:

- roof catchments
- rock catchments
- ferrocement tanks
- concrete block tanks
- sand storage and sub-surface dams

3. LEADERSHIP

Implementation of the projects was a community based approach on voluntary basis. This method has proved very successful generally throughout Kitui and has attracted many donor agencies due to reduced costs

Community participation was ninety eight percent in nearly all projects as through this approach, the beneficiaries had been educated in various issues pertaining to the running of the project e.g operating bank accounts and interrelated income generating activities.

4. WATER QUALITY AND SANITATION

Quantity of water was given first priority vis a vis water quality, especially on the rock catchments, in spite of the dust particles, bird droppings and other possible contaminants.

5. APPROACH AND COLLABORATION

In all the stations visited there was very little inter-agency collaboration, though the roles and obligations of each agency were clearly defined and understood by the community.

This, sometimes resulted in duplication of works e.g between ICRAF and Kitui Diocese.

6. SUSTAINABILITY

The group noted with satisfaction that the level of technologies in use were affordable and acceptable due to the high level of community participation and enthusiasm among the new applicants

However the projects were not completely self sustaining and though the roof catchment and ferrocement tanks were comparatively cheap at seventeen thousand Kenyan shillings, the payments had to be affected on a fifty fifty percent basis paid in installments.

7. TECHNICAL ISSUES

Drainage problems were observed on all ferrocement tanks due to use of poor quality fittings like taps, valves etc. Use of soak pits as well as training on water usage, operation and maintenance of fittings and facilities is therefore required on these projects. It was noted that this type of technology was already being introduced in Namibia.

8. RECOMMENDATIONS

The group made the following recommendations during the excursion:

- There is need to establish a socio-economic baseline to correctly identify who is poor so as to qualify for assistance.
- Construction of roof catchments supported on reinforced pillars should be re-examined in view of the loadings as the design should encourage the use of locally available materials e.g bricks, blocks, quarry stones or timber posts to minimise costs.
- The type and level of technology should be commercialised to hasten the spread of this technology and services, to other neighbouring districts by using local artisans and funds e.g as noted at Thumbi and Mwingi primary schools.
- The rock catchments technology requires refinement as the sites are not easily accessible to children and elderly persons. Thus extension pipes to a suitable collection point would ensure safety of children and quality control by fencing.
- In view of the large surface area (rock catchment), underground tanks could be incorporated to harness all the available rainwater.
- Forced technology through forced labour such as in the construction of the Yatta furrow for irrigation, forced development of rock catchment at Kioo B1, in 1955 cannot succeed as these sites are being abandoned for new sites despite their suitability.
- The newly introduced ways of building water jars now may justify its re-introduction to cater for small families and a further reduction in cost of construction.
- There is need to establish an inventory of available resources such as materials, labour and technology within the donor and implementing agencies as this will effectively create good relationships between the agencies and the beneficiaries.

REPORT ON GROUP DISCUSSIONS

J. M. Wanyonyi
Kenya Polytechnic, Nairobi

1. INTRODUCTION

The aims and objectives of the discussions were:

- to find out within the group who is doing what in the field of rainwater harvesting either directly or indirectly.
- to find out what approaches have proved successful both from a technological and socio-economic perspective.
- to find out what problems have been encountered either technologically or socio-economically in implementing rainwater harvesting systems
- to identify the areas for which information is lacking
- to identify ways of hastening the spread of appropriate technologies and compare both in urban and rural areas.
- to identify needs for investigation and/or research

The first objective of who is doing what is compiled and reported elsewhere in these proceedings, under the heading who is who and the list of participants.

2. SUCCESSFUL APPROACHES

2.1 Community Participation Approach

This type of approach allows the community or the beneficiary to learn, accept and appreciate the newly introduced technology, making the project more sustainable and cost effective since the beneficiary will feel a sense of ownership. Forcing technologies on people has a high risk of failure as exemplified by the Kioo B1 site in Kitui where rock catchment is being abandoned in favour of a new site.

2.2 Community Based Approaches

This is where the new technology is based on the existing techniques, materials, skills and labour i.e. starting from the known to the unknown.

3. PROBLEMS IN DEVELOPING RAINWATER SYSTEMS

These include the following:

- Lack of appropriate technology based on the local environment
- Insufficient initial construction fund e.g. for the purchase of both materials, skills and technology.
- Inadequate dissemination of information concerning available materials, resources etc.
- It requires time for a community to learn, understand, accept and appreciate a new technology, for it to become affordable and sustainable
- local politics of the environment where imposed leaders would like to dominate, or accept such technology from particular zones, regions or countries with strings attached
- Inadequacy and unreliability of design data e.g. rainfall, wind speed suitability of local materials e.g. sand, timber etc.

4. INFORMATION REQUIREMENTS

Information is lacking in the following areas:

- Lack of policy guidelines e.g. how donor/funding agencies should implement projects, and their political and socio-economic impact.
- Lack of inventory of materials, skills, resources, technologies to assist in the development of new ideas.
- Lack of information on leadership skills of designers, implementors and the beneficiaries, based on cultural values.
- Lack of technological advancement due to inadequate training facilities.

5. SPREAD OF APPROPRIATE TECHNOLOGY

This can be achieved through the following.

- through community participation at the planning and design stage and during implementation.
- through training as a component of funding projects either locally or internationally, through workshops and seminars.
- through inter agency collaboration at community, national and/or international levels
- through publication and exchange of technologies.

6. NEED FOR INVESTIGATION/RESEARCH

There is an urgent need to investigate and or research on:

- locally available materials for use in rainwater harvesting systems e.g roofing materials, gutters etc.
- research on the new and old technologies in terms of affordability, acceptability and sustainability.
- cultural values of the beneficiaries in terms of socio-economic impacts of the new technologies, viability and priority rating of projects.
- type and level of training to be offered to designers, implementers and beneficiaries such as on the operation and maintenance of the project, accountability and sustainability etc.

7. RAINWATER HARVESTING FOR DOMESTIC USE

With the above five general objectives the group discussed in detail some suggested topics and questions pertaining to rainwater harvesting for domestic use only. The few guiding questions were:

- what alternative materials are available for gutters and downpipes? Are there any particularly cost effective ways of collecting and conveying rainwater?

- what precautions should be adopted to a) prevent dirt getting into the tank b) prevent mosquitos from breeding c) prevent algal growth?
- what are the advantages/disadvantages of tanks made above/below ground or half above/below ground?

8. URBAN AND RURAL CHARACTERISICS

| URBAN AREAS | RURAL AREAS |
|---|---|
| a) Centralised areas such as estates are easily accessible to donors and designers, hence problems are community based and easy to solve. | Sparsely distributed and single homes which require family based approach in problem solving. |
| b) High population density with varying interest and hence not easily manageable. | Small population with almost similar problems due to geographical and economic set up. |
| c) Less community participation from urban dwellers due to varying population composition. | High community participation due to the social set up. |
| d) Easy access to technology materials , skills etc which are of high quality such as iron sheets, pipes, steel etc | Materials and technology are not easily available since few local materials e.g roofing and gutters |
| e) Requires high quality water for domestic use. | May not conform to high standards. |
| f) Existing infrastructure is not fully used for RWH. | Require large quantity of water for multiple uses |
| g) Projects are more sustainable and hence economical to run due to constant monthly income. | Infrastructure unsuitable for RWH, hence projects less sustainable due to low income and scarcity |
| h) Legal aspects of urban centres minimises the use of rainwater harvesting. | Laws encourage and support use of rainwater harvesting. |

9. APPROPRIATE MATERIALS

There are many types of roofing materials available for rainwater harvesting in many parts of developing countries such as iron sheets, tiles (concrete, timber, clay, slate, fibre tiles etc.), Asbestos cement sheets and tiles, grass thatch; cow dung or mud, shingles, concrete slabs, Mukuti, banana fibres, polyethylene sheets, paper, animal skins and reinforced fibre glass. However, some of the materials listed above are unacceptable for rainwater harvesting such as:

- concrete tiles with lead based paints (red lead Peroxide)
- painted iron sheets with toxic materials
- Asbestos cement based sheets (these require technical confirmation as to how the danger is spread i.e through inhalation or via drinking the water)
- grass thatch, Mukuti, banana fibres, cow dung, mud and animal skins require further examination in view of the quality of the water being harvested. These materials can therefore be regarded as suspect.

Alternative materials for gutters and downpipes especially in developing countries are:

- Bamboo, Sisal poles, timber planks with grooves or 'V' shaped
- Aluminium sheets both for gutters and downpipes due to corrosion resistance

Tests have shown that the 'V' shaped gutter used with guides have a higher efficiency in rainwater collection than the normal circular shaped gutters.

10. OPERATION AND MAINTENANCE

The following precautions should be taken to prevent dirt getting into water tanks:

- removal of gutters during the first rains
- use of appropriate design at the inlet (box or chamber)
- provision of scouring and overflow arrangements
- provision of secondary tank/chamber to collect the first rains for other uses

- sweeping the roofing surfaces frequently to remove dust, leaves and bird droppings.

To prevent mosquitoes breeding in and around the water tanks, the following measures may be adopted:

- provision of an efficient drainage system
- provision of a well sized mosquito gauze to both the inlet and over flow pipe
- clear any thick trees and empty cans around the tank.

To prevent algae from growing in and outside the water tank adopt some of the following:

- prevent sunlight entering the water tank by suitably covering it
- use appropriate chemicals such as Vandex or water proofing cement to prevent leakages or breathing of the tank on the outside surfaces
- apply proper rendering to the outside surface to give a smooth surface for easy collection of rain drops.

11. TANK LOCATION WITH RESPECT TO GROUND LEVEL

The advantages and disadvantages of tanks built above/below ground are given below:

a) Tanks built below ground level

| Advantages | Disadvantages |
|--|--|
| Keeps water cool in hot climate prevailing in RWH. | High construction cost due to elaborate foundations. |
| Takes less space on the ground leaving room for other developments | Method of withdrawing water is not very safe (bucket and rope) |
| Requires cheap construction i.e excavation, stabilisation or plastering and roofing. | Requires more down pipes to channel rainwater into it. |

Can be used to harvest water both from roofs and ground

Requires pumps (diesel or hand pumps) hence costly

cleaning/repair difficult.

Leaks not easy to detect

It is prone to pollution from underground seepage

b) Tanks built above ground level

Advantages

Disadvantages

Easy to construct and maintain.

Take up space on the ground useful for other purposes.

Easy withdrawal of water using taps etc.

More resource intensive.

If well designed, portray architectural beauty.

Design and construction must be structurally sound.

CLOSING SESSION

J Mbugua
Church of Province of Kenya, Nakuru

The closing plenary session was chaired by Mr J Mbugua and addressed the following topics:

1. International Rainwater Catchment Systems Association

Participants noted that the sixth International Conference on the Rainwater Catchment systems would be held in Nairobi from the first to the sixth of August 1993.

2. Kenya Rainwater Harvesting Association

Participants noted that efforts were being made to register a Rainwater Harvesting Association for Kenya, which would be affiliated to the International Rainwater Cistern Systems Association (IRWCSA). The conference endorsed this move.

3. Promotion of Rainwater Harvesting in Kenya

Participants agreed that rainwater harvesting should be promoted and made the following recommendations to this effect:

- National conferences should be held at regular intervals. The next one should be held in August 1994 and should be organised by the Kenya Rainwater Harvesting Association.
- Consideration should be given to holding parallel sessions whereby one could be devoted to rainwater harvesting for domestic use and the other to runoff harvesting for crop production.
- A decision on the frequency of holding National Conferences should be deferred until 1994
- Ways and means should be given to identifying problems which require research and institutions or individuals who can carry out the research.

A meeting should be arranged between Non Governmental Organisations and the relevant Government Ministries (Ministry of Water Development, Ministry of Agriculture, Ministry of Livestock Development, Ministry of Health and Ministry of Reclamation and Development of Arid, Semi-Arid and Wastelands) to find ways to promote rainwater harvesting and to improve research, implementation and training.

CLOSING SPEECH

**D. B Thomas
University of Nairobi**

"Progress towards the target of safe water supply for all mankind by the year 2000 will be as good a guide as any to real human progress in the last decade of the twentieth century." (UNICEF, "The State of the World's Children, 1991")

It is an honour to be asked to make the closing speech for this second National Conference on Rainwater Harvesting.

Through the presentations, discussions and field trips, I am impressed by:

- **the large number of organisations which are actively involved in promoting rainwater harvesting**
- **the enormous importance of NGO's in assisting people at the grass roots level to improve their situation**
- **the enthusiasm, dedication and capability of so many people who are involved in rainwater harvesting activities**
- **the consensus about the need to find out what communities want and help them to find solutions to their problems on their terms.**

There appears to be general agreement that:

- **the technology used must be simple, understood by the community and under their control**
- **whatever is done should be capable of maintenance by the local community and, as far as possible, should be replicable**
- **a community's own skills and resources should be maximised and donor assistance kept to a minimum to encourage self-reliance and avoid dependence**
- **improvement in water supplies should be linked to improved sanitation, improved health care, improved fuel wood and improved nutrition**

- the need for a high degree of technical skill is just as great or greater where projects are simple and cheap as where they are complex and costly. The possibility of taking care of bad workmanship by overdesigning and spending more does not arise due to shortage of funds
- the search for even cheaper solutions for the poorest families should not be abandoned and there is still a need for low cost measures e.g for lining a hole in the ground
- in efforts to harvest water, we should pay more attention to ways of minimising evaporation, reducing seepage losses and avoiding wastage. There still appears to be a need for a foolproof tap
- improving the quality of water must be given the same attention as improving the quantity even though the latter may be given the first priority for people who are trekking many kilometres to collect water
- women are currently playing the biggest role in rainwater harvesting for domestic use

I would like to take this opportunity to thank those who have worked so hard to make this conference a success. It may be unwise to mention names as many have contributed but I think that I must mention the efforts of :

- Mr J Mbugua not only in the field, which we did not see, but in chairing the organising committee, negotiating with the donors, planning the field trips and arranging for the support of CPK, Nakuru
- Dr Bambrah who has chaired the finance committee and kept careful control of all financial matters, and made arrangements for the meals and transport
- Stanley Mbagathi and the secretarial staff who helped with the organisation and provided the secretariat
- Mr Gilbert Mailu and Mr Samuel Mutiso who prepared the excellent handouts for the field trips and the staff in the field who made the arrangements including Eric Nissen-Petersen, Dr Wafula, Dr Itabari, Mr said, Mr Joshua Mukusya
- Mr Lars Kallren and the staff of his office at the World Bank who multiplied all the documents

- the ASAL Ministry for the interest shown in the *conference*
- the presenters who took time to share their knowledge and experience with us
- UNICEF for providing the conference facilities and financial support and SIDA for financial support.

Finally, on behalf of the organising committee, I must thank all who participated. I believe that we have all gained something from being here and that this conference is a step on the road to closer collaboration between individuals and organisations. Before long there should be a local Rainwater Harvesting Association which we hope you will join . Meanwhile we wish you success in your endeavours to improve the quality of life through rainwater harvesting and related activities.

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THE ORGANISING COMMITTEE
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