Water Harvesting: Its potential in the greening and poverty reduction of Northern Cameroon

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ABSTRACT

Water is central to plant, animal and human life. But natural and human factors contribute to its scarcity. The North and Far North Provinces of Cameroon are particularly affected by water scarcity owing to low precipitation, irregular rainfall patterns and other environmental and technological factors. Based on personal interviews, document analysis and a combination of participatory observation methods, the authors collected data that culminate in an empirical analysis of six water harvesting technologies in the Far North Province. By descending order of complexity, cost and adoptability, the six technologies include rock-bed, roof-top, micro sand dams, watering ponds, mini dams and flood diversion water harvesting technologies. The paper further discusses the characteristics of each technology, the social, economic and cultural factors that would affect their adoption and how the various technologies might contribute to increase the volume of water available for greening the Province and to alleviate poverty in the area. An adoptability matrix and the implications of each technology are presented.

Key words: water harvesting, precepitation; rainfall, rock-bed; roof-top; micro sand dams; watering ponds; mini dams; flood diversion; adoptability.

RESUME

L'eau constitute une ressource essentielle pour la vie des plantes, des animaux et des êtres humains. Seulement, des facteurs naturels et l'action de l'homme contribuent à sa rareté. Les provinces du Nord et de l'Extrême-Nord du Cameroun sont particulièrement touchées par la rareté de l'eau à cause du niveau bas des précipitations, des pluies irrégulières ainsi que d'autres facteurs tant environnementaux que technologiques. Sur la base des questionnaires individuels, d'une analyse documentaire et de la combinaison des méthodes d'observation participative, les auteurs ont collecté les données qui ont conduit à une analyse empirique de six techniques de collecte des eaux de pluie dans la province de l'Extrême-Nord. Par ordre de complexité décroissante, compte tenu du coût et de leur faisabilité, les six techniques de collecte des eaux sont : le rocher, les mares, la toiture, les digues, les biefs, et les guimelthers. L'exposé examine davantage les caractéristiques de chaque technique, les facteurs socio-économiques et culturels qui pourraient entraver leur adoption ainsi que la manière dont les différentes techniques pourraient contribuer à augmenter le volume d'eau disponible pour verdir la province et réduire la pauvreté. Une matrice d'adoption ainsi que les implications de chaque technique sont également présentées.

Mots clés : techniques de collecte des eaux; precipitations; la pluie; le rocher; les mares; les digues; les biefs; les guimelthers; adoption

Introduction

Water is a necessary resource for the survival of human, plant and animal life. It is also the foundation for a sustainable biomass-based economy. Water scarcity is often a source of conflict, a threat to agricultural production and a determinant of abject poverty. Yet, one billion people of the world's population, (some 850 million of them living in rural areas), have difficult access to safe drinkable water.

It is estimated that "15 countries in North and West African and Western Asia are already facing acute water shortages (per capita supply below 500 mm)...(and) in other countries in North Africa and the Arabian peninsula, the amount of water being used far exceeds water capacity to regenerate", (Rodriguez, Heinbuch and Lotz, 1998).

Globally, about 2.7 billion people, representing 40% of the human race are without adequate sanitation, while 3.4 million people, mostly children, die every year from water-related diseases (Rodriquez et al, 1998; Development +Cooperation, 2001).

The apparent abundance of water does not preclude limited access. It is recognized that 75% of the earth is covered with water. Therefore, one could conclude that "there is water, water everywhere, but not enough to drink!" In North and West Africa as well as in Western Asia, 15 countries are reported to be facing acute water shortages and per capita water supply of below 500 mm per annum (Rodriquez, et al., 1998).

Reasons for water scarcity and limited access

Water scarcity and limited access are attributable to several factors. These include i) excessive uses of water; ii) inefficient management of available water resources; iii) water pollution by man-made as well as natural causes; iv) poor infrastructure for water handling and delivery; v) inappropriate technology; vi) increases in animal and human populations that together lead to pressure on available water resources; and vii) the prevalence of impotent water development and management committees and ineffective policies in many countries.

Thus, the scarcity of water is caused by its multifarious uses. It is estimated that irrigation makes agriculture the single biggest consumer of water resources, after domestic and industrial uses. Although in many developing countries where irrigation is not well developed, water withdrawals for domestic uses outweigh the quantity used in agriculture. For example, while 35% of Cameroon's freshwater withdrawals between 1970 and 1998 was for agricultural purposes, 46% was directed to domestic uses (World Bank, 1998).

Nigam et al.(1997) estimated that about 80 countries comprising 40 of the world's population already suffer from serious water shortages. These shortages which transform into a "water crisis" (Agarwal and Narain,1999) have serious social, political, and economic consequences. Pollution, the prevalence of fluoride, arsenic and iron deposits in ground water, ingress of sea-water into ground water aquifers reduce the quality of available water resources.

Consequently, "millions do not have enough water, particularly during summer months, and women and girls have to walk long distances to fetch water". In their search, "...people are going deeper into the ground, lowering the groundwater table and leaving wells dry." In India for example, "...the per capita availability of water in 2001 is expected to be half its 1947 levels (Agarwal and Narain, 1999).

Sources of conflicts over water

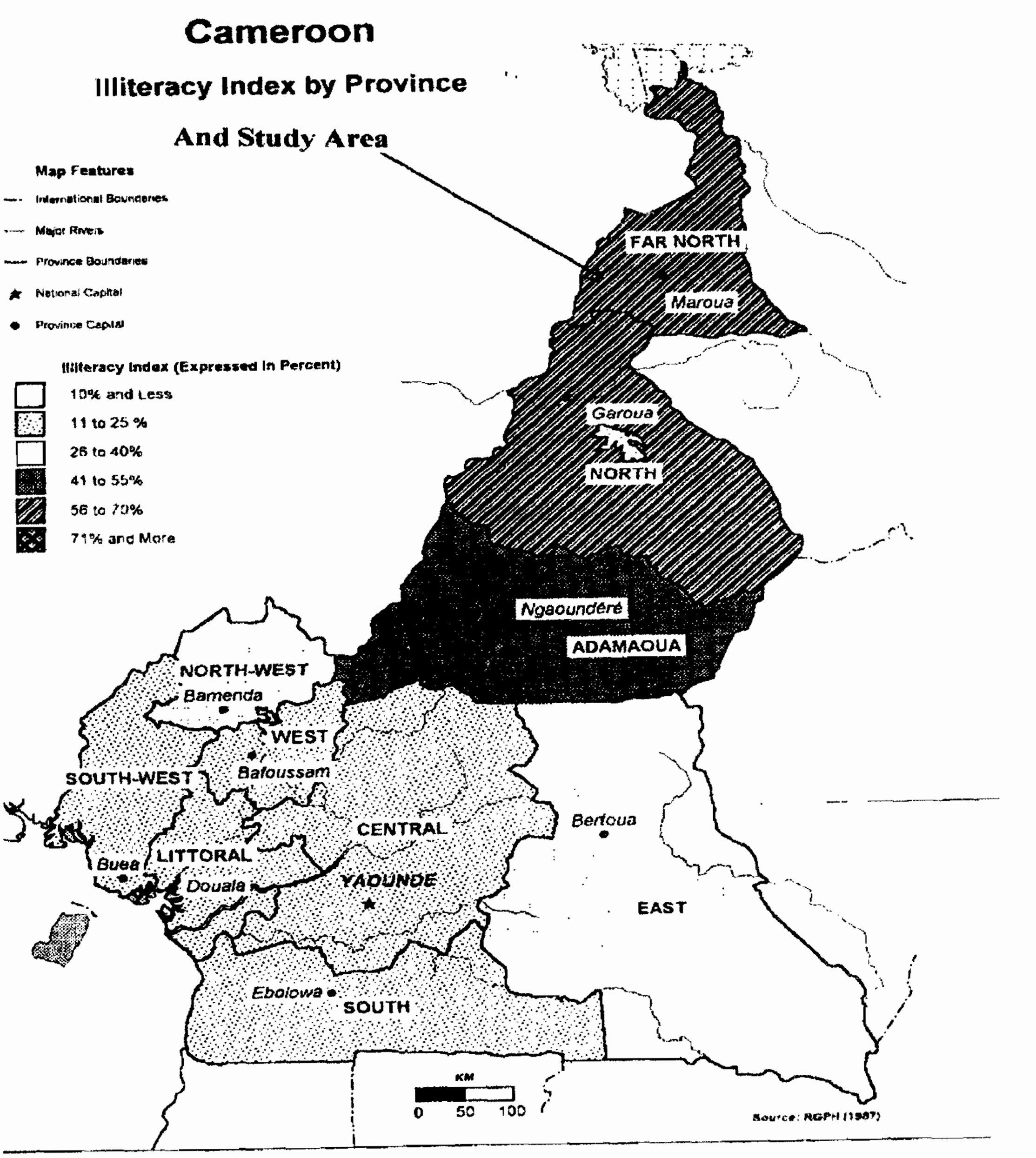
Major sources of conflict over water include "the traditional rights of farm communities versus the need of expanding urban and industrial centres, the rights of the land and water users in upper parts of river catchments versus the need for fresh water supply in downstream areas for drinking, sanitation, irrigation, river traffic, electric power generation and industrial development. Human migration also brings with it havocs that menace the environment, water supply and its ultimate uses vis-à-vis settled population groups." (Sombroek and Eger, 1997).

Migration may lead to overgrazing where pastures and farm land are scarce. Overgrazing and inappropriate cultivation practices not only cause soil degradation; they lead to soil infertility which push down the downward spiral of the poverty trap (Pieri and Steiner, (1997). This problem is more acute in Sub-Saharan Africa where soil fertility (Pieri, 1989) and poor water retention capability (Driessen and Dudal, 1991; Dudal, 1980) are a great threat to the development of a sustainable agricultural system.

While quality and access remain central to the water problem world wide, the management of water resources is increasingly being recognized as a crucial factor in providing access to drinkable water in all societies. Where water resources are scarce, good management can ensure minimal access to water, thus guaranteeing the survival of human, animal and plant life in arid environments.

Objectives of the Study

This study presents indigenous approaches to water harvesting as a coping mechanism for survival in the water-scarce Far North Province of Cameroon. The overall



World Bank, 1995:182

objective of the study was to identify the Water Harvesting Technologies (WHT) in the region and assess their economic performance and impact on the farming systems in the region.

Three specific objectives sought to:
- ascertain the economic potential of WHT with a view to their promotion;
- give a better understanding of the potential and scope of WHT;
- increase knowledge on WHT so as to enhance their replication in Africa.

By Water Harvesting, we mean simply the process of collecting rain water and storing it for various uses in the immediate future. The processes, techniques, equipment, methods and organizational arrangements involved in collecting, storing and using the water are what we call technologies. Nji (1992) defines technology as an object, tool, equipment, idea, skill or process applied to a problem in society.

Methodology

Choice of Study Site

The study was conducted in the Mandara Mountains of the Far North Province of Cameroon between January and April 1998. This site was chosen for the following reasons:
- Irregularity of rainfall in the region compared to other parts of Cameroon;
- Severity of soil and water management problems in

the region;
- High relative concentration of soil and water management activities in the region involving the public and private sectors;
- The region's notoriety as the bread basket of the Far North Province, accounting for 80% of the tubers, 73% of Soya beans, 70% of cocoyams, 65% of sorghum, 35% of the cotton crop and 55% of livestock production in the Province.

How the data were collected

The data used in this analysis were collected using a combination of participatory research methods: document analysis, personal interviews, and field observations. Since the primary objective of the study was to carry out an environmental scan of Water Harvesting Technologies in the region, no formal sampling procedure was used.

However, to ensure the validity and reliability of the data, the "Positional Power" technique was used to identify respondents who are:
- knowledgeable on water harvesting technologies in the area of study;
- currently using WTH either for agriculture, domestic or industrial purposes;
- involved in the water sector either as researchers, service providers or policy-makers;

WHT was the dependent variable and unit of analysis in this study. Library research was devoted to conceptualization and the operationalization of the dependent variable. The factors that influence adoption of the WHTs were the independent variables Field observations and interviews with key informants enabled the researchers to establish the independent variables such as the value system, farm size, farm household income and other intervening variables.

The Physical Environment

The climate in the region is described as "tropical sudan-sahelien" (Neba, 1987) characterized by a very distinct long dry season lasting seven months (October-April), and a short rainy season from May to September. The mean annual rainfall varies from about 582 mm to 1024 mm (Beauvilain, 1995)

The relative humidity is generally low at 20% for 5 months of the year. The evaporation rate is very high, at about 6mm/day in the dry season, giving an estimated annual total of 1800 mm. (Seiny-Boukar, 1990). Were it not for the variability and uneven distribution of rainfall, experts agree that the total amount of rainfall would be reasonable for rain-fed agriculture.

Hydrology and Soils

The high evaporation limit the flow of the numerous ephemeral rivers in the area to 4 months of the year (July to October), with no waterways that run year round. The area is dominated by light, porous and sandy soils with low organic matter contents of 1-3%. Yet, these soils are rich in minerals such as quartz and feldspar (Brabant and Gavand, 1985). They are fragile and prone to erosion, leading to low water retention. To achieve good yields, organic matter supplements must be added to the soil.

Soil characteristics differ from one location to the other. In the plateau areas under investigation, the soil is mainly alluvial with fine particles and some sand, while in the plains or valleys, the soils are alluvial and sandy-clay. Millet and groundnuts do well on these soils.

Two types of soil in the plains that need special mention in order to highlight the problems with water harvesting in the region are: a) *harde* soils, which are degraded, compacted and unproductive soils. They consist of a thin sandy top layer followed by a sandy clay layer amenable to serious impermeability.; b) *karal* soils are heavy clay soils in new alluvial plains with slopes of less than 2%.

The clay content varies from 10-45%. The good water holding capacities of these soils make them suitable for growing cotton in the rainy season and sorghum (*muskwari*) in the dry season.

Socio-economic environment

In 1995, the population of the Mandara Mountains Region was 769,895 inhabitants. In Mokolo sub-division which covers the vast geographical space included in this study, the density is 300 inhabitants per square kilometer, against a national average of 22 persons per sq. km (Ministère de l'Economie et des Finances, 1995). Whereas 11% of the population are non-rural residents, 55% of the entire region's population are below 20 with little or no resources of any kind.

The youthfulness of the population, limited rainfall scarce financial, physical and management resources aggravate the problems of scarce water resources noticeable in the agricultural sector which employs the majority of the people. The population has adopted a number of coping mechanisms over years:-

- Internal migration especially with exodus from villages with limited rainfall to areas with more water resources such as the valleys. For example, the movement of farmers from the mountains to the lowlands and from the Far North to the Benoue area in the North Province;

- The escalation of conflicts between crop producers and livestock breeders in the Far North, North and Adamawa Provinces, caused principally from scarcity of fodder and watering areas;
- Inventions and innovativeness in soil and water management such as described further in this paper;
- Over-cultivation and over-grazing in areas of more water resources;
- Carrying back to the mountains in order to restore soil fertility, soil that has been washed off from the hilltops to the valleys by water erosion.

Farm household size

The average farm size in the areas is 5 hectares, although there are a few wealthy farmers with farms ten times bigger than the average farm. There large farmers are generally persons who have benefited from the cotton industry that dominates the local economy. Apart from isolated cases of capital accumulation by a few individual farmers, social and political power brokerages have given room to unequal access to water resources.

The average household size in the study area is 4.8 persons compared to the national average of 5.2. Farm productivity is low consequent upon a predominantly traditional mixed farming system characterized by low technology, low farm incomes, high illiteracy, power brokerages and above all, limited access to water.

Farm income

In a simulation of production systems, the farms were classified into three groups: a) **Mountain Farmers** who live on the mountain tops; b) **plateau farmers** who cultivate the flat spots on the mountains with relative access to water catchments; and c) **foothill farmers** who cultivate farms located in the valleys at the foot of the mountains. This stratification of the farming population will be essential in our analysis of the adoption and diffusion of water harvesting technologies in the region.

Based on a simulated calculation of returns in farm income, and fixing the post harvest losses at 20% as against a national average of almost 30%, the average annual farm income for a mountain was 73,202 CFA (US$105). That of a plateau farmer was 219,919 CFA (US$314) and 369,269 CFA (US$ 528) for a foothills farmer. The same variations for economic power were noticed for livestock farmers. Meanwhile, 34% of the households had annual farm incomes of less than 100,000 CFA (US$143), while only 17% earned more than 250,000CFA (US$357) per annum.

As will be seen later, the physical and socio-economic environments as well as the characteristics of the technology itself conspire to help or hurt the invention, discovery innovation and widespread adoption of water harvesting technologies in the area. These relationships are analyzed in subsequent sections of this paper.

Water Harvesting: An Old Tradition

Pande (1997), as cited by Agarwal and Narain, 1999:5) opined that water harvesting is an old tradition that has been practices in India for more than two millennia, because "Hindu texts like the *Puranas*, *Mahabharata* and *Ramayana* and various Vedic, Bhudhist and Jain works contain several references to canals, tanks, embankments and wells". Evidence from Dholavira, a major site of the Indus Valley civilization dating back to the third millennium BC, discovered in the 1960s reveals that the site lies in an arid area that gets an average annual rainfall of 260 mm. There are no perennial sources of water in the form of lakes or rivers, and subterranean water is unsuitable for consumption and other purposes.

The indigenous peoples of Dholavira thus invented reservoirs "...to collect the monsoon runoff flowing down the flanking streams of the Manhar and Mansar" (Agarwal and Narain, 1999). Thus, water harvesting may be an invention in the Mandara Mountains but it is neither an invention nor new discovery in human communities as a whole.

What is Water Harvesting?

Water harvesting in its broadest sense can be divided into three types: *roof top* harvesting, *runoff* harvesting and *floodwater* harvesting (Reij and Begemann., 1998). Rooftop water harvesting involves collecting the rain water that drops on the tops of roofs into either a cistern or other receptacle for future use. Rooftop water is used mainly for domestic purposes (drinking, washing and cooking).

Runoff and floodwater harvesting involve canalizing rain water on the ground surface for collection or channeling the water directly into specific uses. Water harvested through these methods is generally used for crop and livestock production. Runoff water harvesting is further divided into two forms:

> "*micro-catchments*" or within-field catchment systems in which the usually short catchment walls are immediately adjacent the cultivable area;
>
> "*external catchments*" with long slopes where runoff is harvested from the upper and middle part of the hillside and conveyed into the cultivated area.

Reij and Begemann refer to water harvesting as the umbrella term used to describe a whole range of methods of collecting and concentrating various forms of runoff (rooftop, overland flow, stream flow, etc.) from various sources for such uses as agriculture and domestic purposes. For example, rainwater harvesting (Boers and Ben-Asher, 1982); water spreading (Newman, 1963); floodwater farming (Bryan, 1990), runoff farming (Ben-asher and Berliner, 1994); and rainwater harvesting agriculture (Bruins et al., 1986).

In general, *water harvesting* is distinct from *irrigation.* While *water harvesting* includes surface runoff from slopes, rooftops and ephemeral streams, *irrigation* almost exclusively involves runoff from perennial streams specifically for agricultural purposes. Yet, the adoption of any of the technologies depends on its appropriate assessment, utility, cost as well as its integration into the social system for which it is intended.

Although not enough empirical evidence has been accumulated on the ecological impacts of rainwater harvesting on groundwater and river flows, scientific imagination leads us to assume that since rainwater harvesting improves ground water recharge, it could improve the perennial flow of rivers.

Rationale for water harvesting and/or irrigation technologies
As a result of growing ecological threats to water resources, common sense and good judgement now impel policy-makers and development scientists to seek alternative strategies such as water harvesting and irrigation to manage precipitation for sustainable development.

In Western Africa much of the agricultural land is located in arid or semi arid regions characterized by irregular rainfall and excessive surface runoff (Nji & Fonteh, 1998). Yet, to obtain the optimum yields from crops, the moisture content of the soil has to be within a certain range, to ensure the uptake of nutrients from the soil and respiration of plant roots.

High moisture content in the soil limits oxygen for the plant and reduces crop yields. This problem is often solved by *drainage*. On the other hand, an exceedingly low moisture content in the soil subjects plants to moisture stress leading to low or no yields at all. Water harvesting, soil conservation or a combination of both technologies can improve yields significantly.

Although irrigation is reported to be the best technology from the point of view of technical efficiency to increase soil moisture in semi-arid lands, irrigation schemes are not always affordable by the majority of resource-poor peasants. On the contrary, more powerful and economically influential farmers have greater access to technology, including irrigation, and other agricultural inputs (Nji, 1992).

In the face of these limitations, *in situ* water conservation and water harvesting present sustainable alternatives to the management of soil moisture in the semi-arid zones of Africa. With *in situ* water conservation technologies, rainwater can be harvested, stored and used in times of water scarcity.

Based on this rationale, a number of water harvesting projects have been set up in Sub-Saharan Africa during the past decade "...to combat the effects of drought by improving plant production .....and in certain areas rehabilitating abandoned and degraded land", (Nji & Fonteh, 1998). Unfortunately, few of these projects have succeeded in combining the advantages of technical efficiency, affordability and acceptability by the poor (Nji, 1981). Furthermore, there is a dearth of knowledge on the socio-cultural, economic and technical dynamics of water harvesting on the African continent.

Findings

Water Harvesting Technologies

Six water harvesting technologies were identified in the region. By order of complexity, these are: i) flood diversion or water spreading, ii) mini dams locally called *biefs;* iii) watering ponds also referred to locally as *mares;* iv) micro sand dams; v) roof top rainwater harvesting, and vi) rock-bed rainwater harvesting.
Water harvested by means of these technologies serves household domestic purposes, agriculture and livestock production.

1. Flood diversion or water spreading

This indigenous water harvesting technique referred to locally as *guimelther*
(Fig 1.), is used exclusively for agricultural production. It consists of diverting water from ephemeral streams into cultivated basins enclosed by a permeable dry stone wall. Because this technique enables the peasants to grow taro (*colocasia esculenta*), the people describe the technology as *house of taro.*

A channel is constructed upstream from the spot where the water is expected to be diverted into. Water diverted from a stream is directed into the farm plot. Each plot is divided into compartments by small stone dikes of varying heights. The height of the stone wall which almost never exceeds 30 cm, is determined by the flow rate during floods. The width and length vary from 1-3 metres (Van Oostrum, 1994).

The cost of construction of a *guimelther*, an ingenious

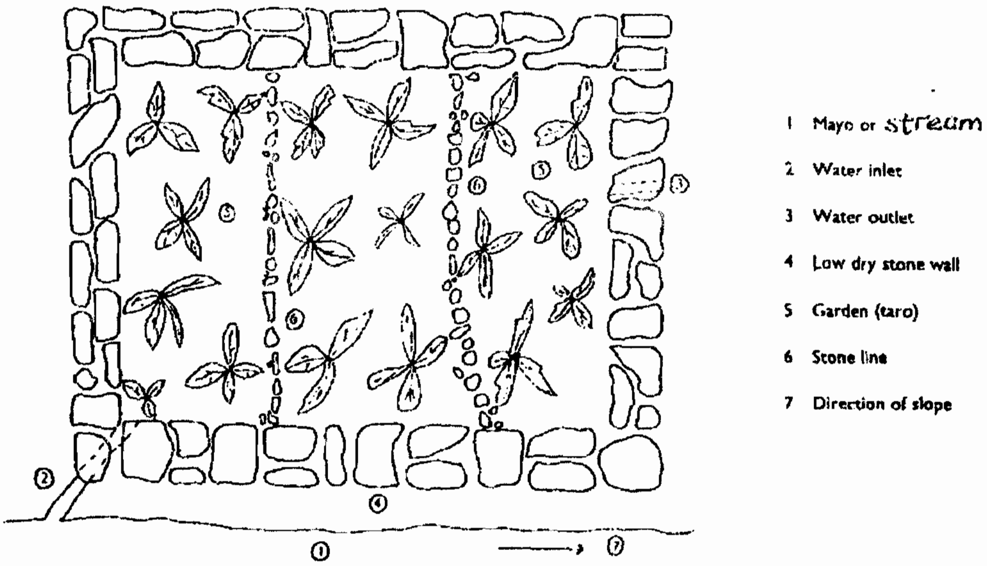


Fig. 1: Aerial view of a Guimelther (Flood diversion)

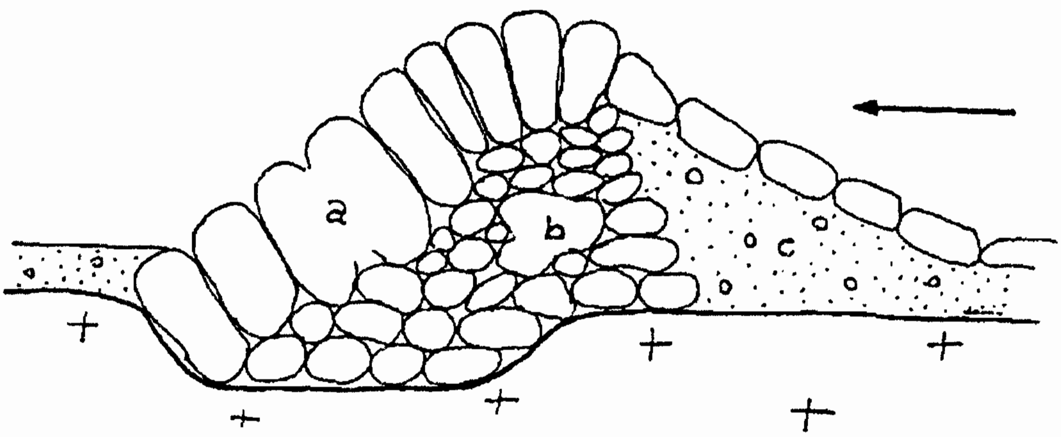


Fig. 2: Section of a Bief (interlocked dry stone wall)

indigenous invention, is low since only local labour and skills are used. The technology is easy to build, and no external technical or financial support is required. Farmers interviewed reported that this technology significantly increases taro yields (Hiol et. al; Van Oostrum, 1994). It became quite popular in some Divisions of the Far North Province within the last ten years.

2. Mini dams or *Biefs*

A *bief* is basically a small dam (Fig. 2) or water harvesting technology designed to reduce the speed of water flow in small ephemeral streams in the region. By reducing the velocity of the stream, the water is retained temporarily so that it infiltrates into the soil to recharge the ground water (Damien, 1990). Wells are subsequently constructed downstream from the *bief* so that the water harvested empties into them.

Biefs are constructed successively in the pathway of small ephemeral streams that dry up often when the water table is low. Charniaux, (1996) noted that this technology was invented and introduced in the region in 1985, and the name *bief* was locally coined to differentiate the structure it describes from a micro dam usually constructed for surface storage of water. A *bief* requires only stones which are locally available and the skills to align the stones well enough to form a solid wall. Since the stone wall serves as a retainer for the sand and debris that flow from upstream, the structure soon becomes reinforced by the deposits of sand and soil

Source of Innovation

A Swiss technician working in the region in 1985 recognized that most of the water used for domestic consumption is from ground water. But their levels and yields have been falling as a result of reduced recharge (Damien, 1990). To solve the problem of low groundwater recharge, Clement Damien introduced biefs to provide a system for ground water recharge.

Some of the innovations in the Manadara Mountains date back several centuries in some parts of the world. For example, the archealogical evidence from Dholavira (Pande, 1997) revealed that stone bunds were raised across the Manhar and Mansar rivers, and rainwater harvesting practiced as " a way of life".

3. Micro Sand Dams

These consist of water-tight stone/mortar or concrete walls built across the rivers or *mayos* on relatively flat sections of a waterway. The target is to reduce the flow rate, increase infiltration and store water in the sand that accumulates behind the embankment (Fig. 3). Since the water thus collected sinks beneath the sand, this process reduces evaporation. Micro sand dams are similar to the *biefs* described above, except that the structures are larger and backfilled with sand.

To ensure that the water is stored in the accumulated sand, micro dams are constructed in series at distances

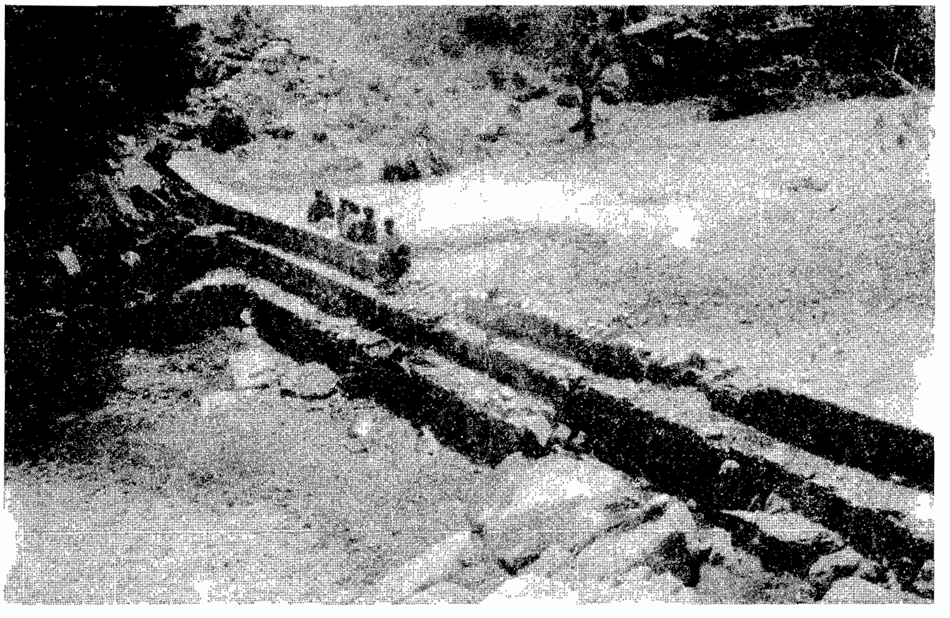


Fig. 3: A mini sand dam (Photo: Ajaga Nji, 1998)

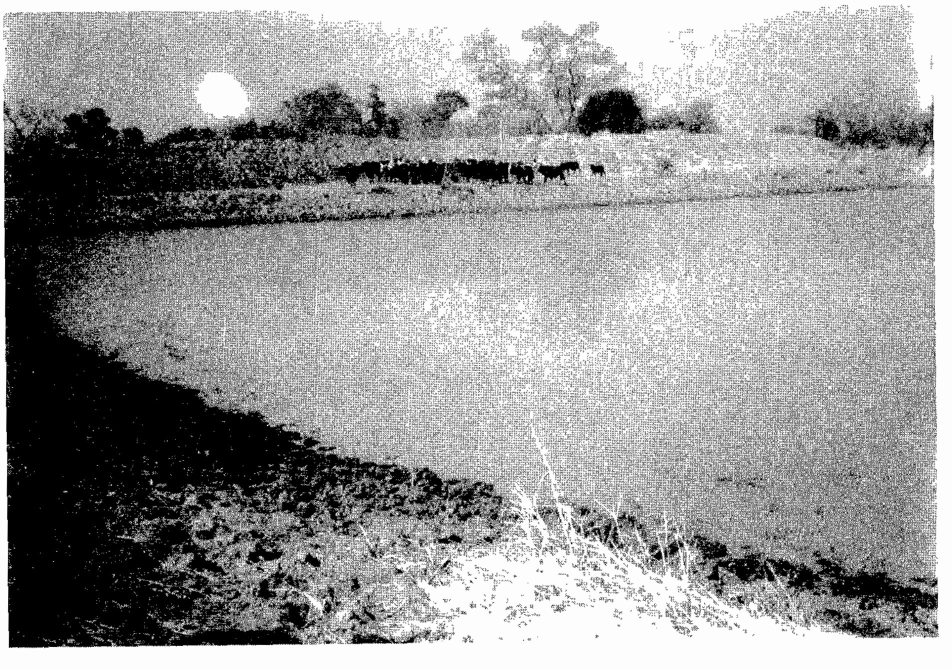


Fig. 4: A watering pond (mare). (Photo: Ajaga Nji, 1998)

Table 1. Location of Watering ponds and animal population serviced in 1997.

Division	Animal Population		No. Of Ponds
	Cattle	Small Ruminants	
Mayo Diamare	172,000	253,000	17
Mayo Sava	45,000	248,000	14
Mayo Tsanaga	75,000	296,000	13
Total	292,000	797,000	44

Source, Zakariaou, (1997).

of 50 metres, with the top of each succeeding dam measuring a height difference of 1 metre. The effect is that even if the river does not continue to flow throughout the dry season, the river bed will at least remain wet, thanks to the reservoir of water that accumulates behind each structure.

4. Watering Ponds (*Mares*)

Watering ponds locally called *mares* are constructed to collect (harvest) water during the rainy season. The ponds are essentially large holes dug 4-6 metres deep into the ground to collect and hold surface runoff during the rainy season for use in the dry season to water livestock (Fig.4). Ponds are generally constructed in the path of runoff flow in areas with clayish soils so as to reduce percolation. A sedimentation basin is constructed at the entrance of the pond to reduce silting. The ponds are constructed to harvest rainwater mostly for cattle, goats and sheep (Fig.4 &Table 1).

5. Rooftop rainwater harvesting

The roofs of houses have served as traditional means of collecting rainwater for centuries in many parts of the world. This is an old practice in the Mandara Mountains by households with tin roofs. Rainwater is collected from the tinned roof into specially designed reservoirs mounted above the ground or in underground storage tanks (Fig. 5). The water is then used mainly for domestic purposes. In the dry season, the water is drawn from the reservoir with the help of either a hand or electric pump.

6. Rock bed rainwater harvesting

This method of water harvesting consists of a large flat rock upon which rain falls, serving as a rockbed catchment with a 40cm retaining wall of cement and mortar constructed on the edges of the rock. The surface of the rock must be large enough to collect large quantities of water (Fig. 6). The rainwater thus harvested is canalled into a rectangular stone-walled tank constructed below

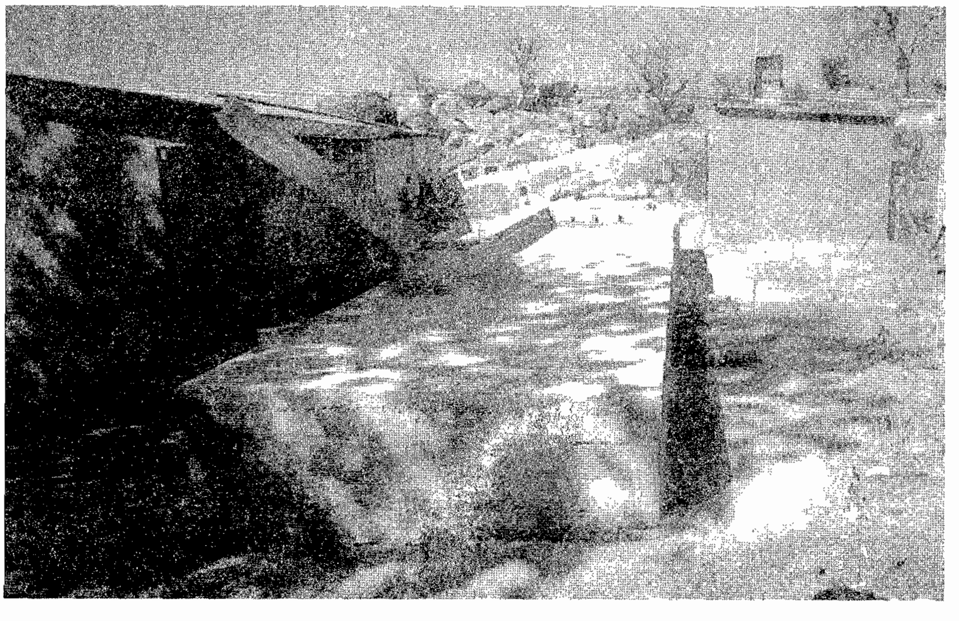


Fig. 5: Rooftop water harvesting. (Photo: Ajaga Nji, 1998)

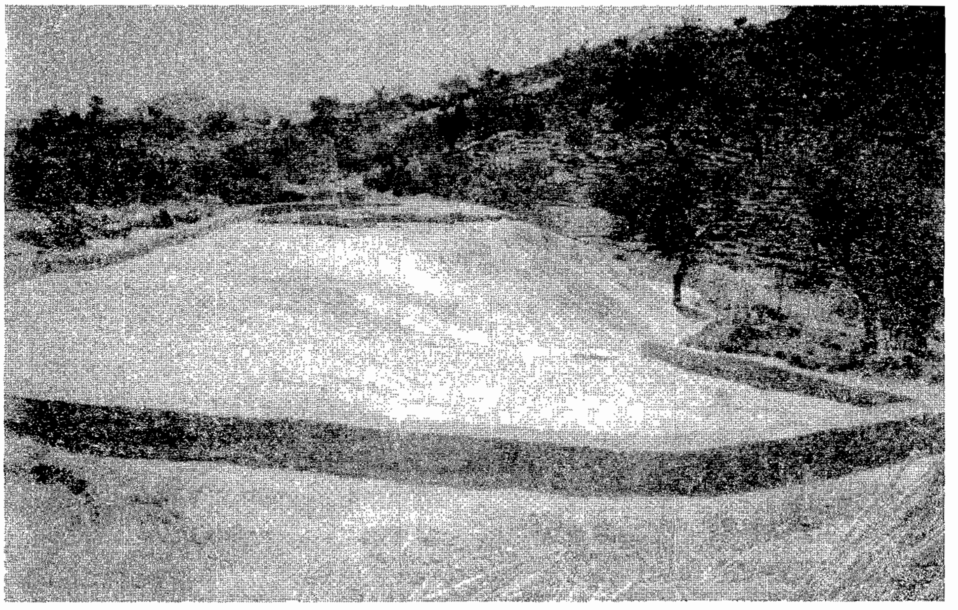


Fig. 6: Rock-bed water harvesting. (Photo: Ajaga Nji, 1998)

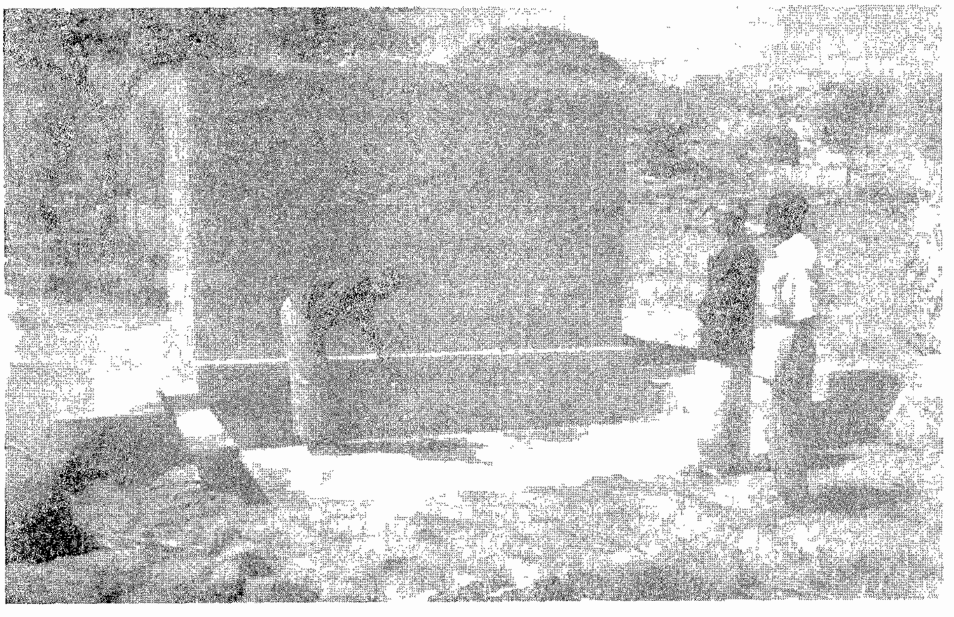


Fig. 7: Water storage tank for rock-bed water harvesting. (Photo: Ajaga Nji, 1998)

the catchment from where the water will be released through taps for distribution to users (Fig.7). One of the rock-bed water harvesting structures identified in the study area had a catchment area of about 1125 square metres with a storage reservoir of 235 cubic metres. From our investigations, this technology is unique in its kind and considered an innovation in the Far North Province of Cameroon.

Discussion

Biefs

According to field reports, the local population did not initially adopt the *bief* technology within the first year of its introduction. It was accepted only after one year of trial following the construction of nine demonstration *biefs* in different spots, accompanied by wells that were constructed downstream from the biefs.

At the beginning of the rainy season that followed, water appeared in the wells downstream from where the *biefs* had been constructed much faster than in wells not linked to the *biefs*. The dry season following the rains, the water table in the associated wells was higher and the associated wells retained more water for longer periods than wells not associated with *biefs*. This positive experience, escalated the adoption of *biefs*.

Watering Ponds
Available data indicated that in the 1980s, the Ministry of Livestock and Animal Industries constructed 100 of such ponds and wells in the area to collect water for animals (Zakariaou, 1997). But due to lack of maintenance, most of the ponds were abandoned. Only a few "barely functional" ones have survived the initiative. We observed during the study that some of the ponds were dry; the water having been used up, evaporated or infiltrated into the soil . Almost all the ponds *(mares)* showed evidence of neglect or poor management.

The rate of evaporation appeared to be quite high, leaving most of the ponds dry before the next rains. Some of the indigenous methods invented to reduce evaporation in the area have included i) Piling up the spoil from the excavation around the hole to form a wind break, and ii) planting trees around the pond to provide as much shade as possible.

Another ingenious invention to reduce evaporation consisted of building mats that were laid over the entire surface of a *mare* (pond) to cover the water from the scorching sun. However, neither the potential inventor nor the researchers involved in this evaporation saving device were sure about the efficiency of the proposed technology especially as prolonged contact of the material with water was likely to reduce its life span.

Apart from the evaporation, we observed that maintenance of watering ponds was the next serious problem after the cost of the technology. We also noticed that animals would move into holes uncontrollably, damaging the sides and contaminating the water. Although the water in the troughs was treated to prevent infectious diseases, there was no guarantee that such prevention was taking place regularly for three reasons. First, there was no regular or established system of treatment or disinfection. Secondly, the chemicals for disinfection were not regularly available. Thirdly, the cost of the products was said to be prohibitive.

Watering ponds as a WHT may be considered an innovation in water conservation in the Mandara Mountains Region. But in Indian communities where land was not a limiting factor, indigenous peoples developed "customized rainwater harvesting structures called kundis, ...artificial wells which store runoff from an artificially prepared catchment surrounding them so that rainwater falling on the catchment rapidly runs into the well and gets stored," (Agarwal and Narain, 1999:6).

Micro dams
The construction of micro dams requires good basic skills in civil engineering and a minimum of economic and sociological imagination to ascertain the durability, economic and technical efficiency of the structures. When the water harvested in the dams is filtered through the sand, it serves as portable drinkable water for the population. An outlet pipe is then installed below the dam for water collection. This system requires very little maintenance, although regular verifications must be made to redress occasional damages caused by cattle for whom the dam is also a drinking trough in the dry season.

Rooftop water harvesting
This is the main method of water harvesting practiced by missionary communities in the Region. One such system identified in the region was estimated to cost 6 million francs CFA (approximately US$9,500 in 1999 prices). This technology requires high technical skills in construction and maintenance, a considerable amount of equipment such as pumps, storage tanks and chemicals reagents and electricity. Key informants declared that this WHT is "very expensive" for the local people because of the high initial costs involved and the prevalence of poverty in the area.

This analysis is consistent with the World Bank (1995) poverty study which revealed that "*per capita* consumption in the urban north, i.e. in Adamawa, North and Far North Provinces, (CFA 217,700 (US$570 exceeded that of the urban south); whereas the per capita consumption of the rural south CFAF 160,600 (US$113, 800) was more than that of the rural north estimated at CFAF 98,800 (US$250) respectively". In 1983/84, the Northern region of Cameroon also had "...the highest incidence of extreme poverty and the lowest mean consumption".

It may be noted that poverty levels are also directly related to the levels of illiteracy in a country or region. This is illustrated by the illiteracy index of Cameroon which shows that more than 71% of the population of the Far North and Northern Provinces are illiterate compared to 11-25% in the South West, West, Centre and Southern Provinces and 41-55 $% in the Adamawa Province (World Bank, 1995).

Based on this analysis, rooftop water harvesting presents special problems with regard to its adoption in the region principally for economic (financial) and socio-cultural reasons if it is reasoned that the higher the complexity of a technology, the higher the costs and the greater the need for literacy skills to read and understand instructions.

Rock-bed water harvesting
Rock-bed water harvesting was an exalting discovery of technological innovativeness. The invention, if anything, confirms the trite but meaningful adage that "necessity is

the mother of invention". As rocks are not conventional water catchments, it was the ingenuousness of a young water and sanitation technician on a short-term assignment to the Far North province with an NGO, CARE-International, that gave birth and life to the invention. The technician observed that the rock was naturally "harvesting" a lot of water but there was no immediate system to collect and retain it for future use.

In some parts of the Mandara Mountains, the ground water table is either very deep or non-existent. In most places the profile is composed of hard rocks that must be broken in order to access the water underground. The absence of good road infrastructure and the prevalence of boulders throughout the region preclude access and the transportation of heavy well-drilling and other earth-moving equipment.

The rock-bed technology was designed to fit into the socio-economic context of its users. For example, the inventor used the population size of the village (1,260 people) as the basis for calculating the amount of water needed. The variation of climatic changes, the polygamous marriage structure in the village and the need to put in place a water rationing system that would last at least 3 months in the dry season were all determinant factors in the invention of the technology.

With regard to management of the water system, water use rights were designed to take into account the socio-cultural dynamics of the area with the number of wives per household as the basis of calculation of water consumption. And since the size of the household in the region is a function of the number of female spouses in the household, this formula turned out to be very effective in adjudicating cases of equity in water access and use. That is, each adult female and her children were allocated 20 litres of water a day for a number of days a week. The quantity of water collectable was, therefore, a function of the number of wives and children in each household.

The rock-bed technology uses local materials such as stones and gravel which are abundant in the area. Stones are used to construct the reservoir, canal and sand filter. It was estimated that the rock-bed rainwater harvesting system under analysis cost 16.3 million CFA (about US$25,840) when it was completed in 1997.

Cost-sharing and participation was introduced into the project from the onset so that the villagers contributed 2.2 million CFAF (13.5% of total cost) plus local materials such as stones, gravel, sand and labour (Dzali, 1998).

The economic and technical efficiency of WHTs

One of the lessons learned from the analysis of WHTs is that it is possible, and it pays to conserve every drop of rain water. Conserving and trapping it *in situ*, as and where it falls, is not only cost effective but also technologically feasible, economically viable and offers far greater returns in terms of both the volume of water conserved and the distribution of benefits (Lobo and Samuel, 2001). And because of the high decentralization qualities of harvested water, WHTs also score favourably on the issue of equity across communities and between social groups in arid lands.

For example, individuals who desire to harvest rain water may do so from a variety of opportunities. Secondly, persons who collect rain water are more likely to share it with their friends or neighbors than persons connected to conventional pipe borne water supply systems, particularly if they have to pay a water rate or user fees. It was seen from the WHTs applied in agriculture in the study area that rich farmers and poor farmers alike had equal right to the water harvested in the mares or by help of the biefs.

Furthermore, if an area receives only 100 mm of rainfall – which would make it an extremely arid environment – this rain harvested over one hectare of land would provide one million litres of water a year. As a family of five would not need more than 10-15 litres a day for drinking and cooking — or 3,650 – 5,475 litres a year – 180-270 families could meet their most critical water needs by building a one hectare kundi", (Agarwal, 1998a).

However, the cost of constructing a watering pond is high as shown on table 2. This was cited by farmers interviewed as well as researchers and developers as a sufficient deterrent to the adoption of the technology.

The data presented on table 2 show clearly that watering ponds are cannot be affordable by a majority of the farmers. Only the rich privileged farmers can afford to construct pond on their fields. This may explain why even the three ponds in table 2 were not constructed by the breeders themselves but by SODECOTON, the cotton producing Public Corporation that dominates economic life in the region. Their construction is impossible without the heavy-duty earth-moving equipment needed for excavation, and the skilled manpower needed for building the concrete works for inlets from sedimentation tanks, reservoirs, outlets and watering troughs.

The data on table 2 also suggests that there is an inverse relationship between depth of the ponds and evapora-

Table 2. Actual Construction Costs for three watering ponds in the Far North Province

Estimated # of cattle	Cubic metres of water	Dimensions in metres	% lost by evaporation	Cost in Francs CFA	
				Head of cattle	Total
350	7,500	60x40x4 54%	54%	37,500	13,125,000
650	11,500	70x45x5 44%	44%	30,962	20,125,000
1,000	16,000	70x50x6 38%	38%	28,000	28,000,000

Source: Compiled from Teyssier, 1997.

tion: the deeper the ponds, the lower the evaporation loss. Also, the bigger the size of the pond, the lower the cost of watering per head of cattle. Yet, in all three cases, the unit cost of watering remains high (between 28,000 and 37.,500 francs CFA). This averages out to be 32,154 FCA per head of cattle which represents approximately 1/3 (33.3%) of the farm-gate price of a two year old bull in the region.

Respondents reported that maintenance of the technology is labour intensive and demands considerable financial outlays. Additional maintenance costs occur and inconveniences are experienced since and electric pump is necessary for lifting the water from the reservoir into the drinking troughs. Also, the barbed wire fence inlet, and outlet physical structures require regular maintenance from damages caused by both cattle and intruders. The breeders confessed that they will not even think of constructing a watering pond if massive and sufficient inputs of financial and technical assistance were not provided by external sources.

In addition, the necessary construction materials such as iron rods and cements are not available locally. It is also time consuming and requires specific skills in construction. Major maintenance often include repairs of broken banks and removal of silt from the sedimentation tanks and reservoirs. Much silt is deposited into the ponds along with the runoff that washes the limited soil down from the hill slopes.

Table 3. Adoptability Matrix for Water Harvesting Technologies

Technology	**CT**	**Inv.**	**Raw Mat.**	**Costs**	**Mnt Needs**	**Adopt.**
Guimelther	Lt*	Local	Local	Lc	Local skills**	H
Bief	Lt	Local	Local	Lc	Local skills	H
Sand Dams	Mt	Ext.	Local+	Hc	M, skilled	M
Rooftop	Mt	Local+	External	Hc	M, skilled	M
Watering Ponds	Ht	Ext.	External	VHc	VH, skilled	L
Rockbed	H	Ext.	External	VH	VH, skilled	L

Source: Constructed from research data by authors

CT= Complexity of the Technology Inv. = Source of Innovation

Lt= Low. A low level of technology means the level of complexity for the technology is that which can be handled by the users.
Mt=Medium. A medium level of complexity indicates that a minimum amount of specialized knowledge is required on the part of the users to operate the technology.
Ht=High, meaning the level of the technology is too high for the local population to handle without specialized knowledge. In most cases, such specialized knowledge would come from outside the social system.
Raw. Mat= Raw Materials. The source of supply is either local or external
Mnt. Needs=Maintenance Needs. Whether local or highly specialized skills are required

Local: The source of the innovation or raw materials is 100% from local resources within the social system (community or region).
Adopt. Adoptability
Local+: The source of the innovation or raw materials is both local and external.

Lc,Hc,VHc: The costs range from Low (Lc) to Very Higher (VHc). For the purpose of this study, we classified all the WHTs with costs below 1,000,000 CFA as low; 1 000 001 – 2 500 000 CFA as medium; 2 500 001- 3 000 000 CFA as high, and >3 000 000CFA as very high. These calculations are based on 1998 prices at the exchange rate of US$1 = 600FCFA.

Once the technology is in place, the users have to learn how to manage the new technology for their mutual benefit. Management of watering ponds again is another technology for which the local population has to be trained.

Adoptability of WHTs

Based on the foregoing discussion, the adoptability in the region of our study, of either of the WHTs identified will be high or low, depending on a number of factors (Table 3).

Conclusion

Water harvesting holds enormous potential for the greening and poverty reduction in the far North Province of Cameroon in particular and for arid regions with low rainfall in general. Water is necessary for green pastures to grow, and for animal and human life to flourish. In the far North where poverty is acute, careful and sustained water management could contribute to agricultural expansion and better health.

The experience of our team work has shown that effective and careful combination of agricultural and social engineering are required to conduct research on, and develop the potentials that water harvesting portend. The adoption of WHTs depends on several factors, particularly those relating to the characteristics of the technology itself such as the cost of the technology, its complexity, maintenance and the source of inputs.

Low initial construction costs are positively related to maintenance needs. Where local materials are predominantly used, the costs of construction and maintenance are much cheaper compared to technologies that involve imported inputs such as the (watering ponds), rock-bed and rooftop WHTs. As can be seen from Table 3, the technologies with low inputs, based on indigenous knowledge, using local materials, with less complexity and less dependent on external sources of funding and maintenance, have the highest potential for adoption.

Bibliography

AGARWAL, ANIL and SUNITA NARAIN. 1999. Making Water Management Everybody's Business: Water Harvesting and Rural Development in India. London: International Institute for Environment and Development.

ANON. 1998a. Traditions, Technologies, Policies and Social Mobilisation. CSE Briefing Paper: Potential of Water Harvesting. New Delhi, India: Centre for Science and Environment.

ANON, 1998b. Draft Recommendations of the CSE Conference on Water Harvesting - Technologies, Policies and Social Mobilisation. October 3-5. New Delhi, India: Centre for Science and Environment.

BEAUVILAIN, A. 1995. Tableau de la Pluviometrie dans les bassins du Tchad et de la Benoue. Djamena, Chad: CNAR.

BEN-ASHER, J. and P.R. BERLINER. 1994. Runoff Irrigation. Pp 126-154 In: "Advance Series in Agricultural Sciences , Vol. 22. K.K. Tanji and B. Yaron (eds). Heidelberg: Springer-Verlag.

BOERS, TH. and J. BEN-ASHER. 1982. A Review of Rainwater Harvesting. *Agricultural Water Management* 5:145-158.

BRABANT, P. and B. GAVAND. 1985. Les Sols et les Ressources en Terres du Nord Cameroun. Collection Notice Explicative No. 103: OSTORM/MESRES.

BRUINS, H. J. , M. EVENARI, and U. NESSLER. 1986. Rainwater Harvesting Agriculture for Food Production in Arid Zones: The Challenge of the African Famine. *Applied Geography* 6: 13-32.

BRYAN, K. 1929. Floodwater Farming. *Geographical Review* 19: 444-456.

CHARNIAUX, C. 1996. Le Problématique de l'Eau dans les Monts Mandara et les Biefs. Booklet # 2. Maroua, Cameroun: P Comite Diocesain de Développement.

DAMIEN, C. 1990. Manuel Technique pour la Réalisation de Biefs: Dans le Cadre d'une Maitrise de l'eau a échelle Villageoise sur les Monts Mandaras, Extrême-nord, Cameroun. Unpublished Manua. Maroual, Cameroun: Comité Diocesain de Développement.

Development + Cooperation. 2001. Safe Drinking Water – Immediate Solutions 4:6

DRIESSEN, P.M. and R. DUDAL. 1991. The Major Soils of the World. Agricultural University, Wageningen, The Netherlands.

DUDAL, R. 1980. Soil-related constraints to Agricultural Development in the Tropics. In "*Priorities for Alle-*

viating soil-related constraints to Food production in the Tropics", Pp 23-40. Los Banos, The Pilippines: International Rice Research Institute.

DZALI, D. P. 1998. Projet d'Approvisionnement et de Gestion d'Eau. Maroua, Cameroun: CARE International. *Personal Communication*.

HIOL, HIOL F. DIEUDONNÉ, M. NDOUM, TCHALA-ABINA FRANÇOIS. 1994. Techniques Traditionnelles de Conservation de l'Eau et du Sol dans les Monts Mandaras: Situation Actuelle et Perspectives d'Avenir. Research Report. Dschang, Cameroon: Faculty of Agriculture, University of Dschang.

LOBO, C. and A. SAMUEL. 2001. Slaking Thirst – Retrieving Desertified Living spaces.
Development + Cooperation 4:9-13.

Ministère de l'Economie et des Finances. 1995. Programme de Développement de la Région des Monts Mandaras: Définition des Indicateurs de Suivi-Evaluation. Yaoundé, Cameroon: Author.

NEBA, AARON SUH. 1987. Modern Geography of the Republic of Cameroon. Camden, New Jersey: Neba Publishers.

NEWMAN, J.C. 1963. Waterspreading on Marginal Arable Areas. *Journal of the Soil*
Conservation Service of New South Wales 19: 49-58.

NIGAM, A., B. GUIJA, J. BANDYOPADHYAY and R. TALBOT. 1997. Fresh Water for India's
Children and Nature: A draft report based on local level studies. Delhi, India: WWF/UNICEF.

NJI, AJAGA. 1992. The Dialectic between Appropriate Technology, Public Policy and Rural Development: Implications for Discovery and Innovation in the Third World. Discovery and Innovation 4 (1): 33-43.

——————— 1981. The Revitalization of Rural Communities Through Integrated Rural
Development. Buea, Cameroon: National Printing Press Annex.

NJI, AJAGA and MATHIAS F. FONTEH. 1998. Farming Systems Assessment of Water Harvesting Technologies in the Mandara Mountains Region of Cameroon. Consultancy Report. Dschang, Cameroon: Departments of Agricultural Engineering and Rural Sociology and Extension, University of Dschang.

OBALE, F. 1991. Plan d'Action de Lutte Contre la Désertification au Cameroun: La Gestion des Ressources en Eau au Nord Cameroun. Rapport Technique Sectoriel # 2. Yaoundé, Cameroun: Ministère du Plan et de l'Aménagement du Territoire.

PANDE, B. M. 1997. A multi-millennial mission. In: " Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems, State of India's Environment: A Citizen's Report". A. Agarwal and S. Narain (eds). New Delhi, India: Centre for Science and Environment.

PIERI, C. 1989. Fertilité des terres de savannes. Paris: Ministère de la Coopération.

PIERI, CHRISTIAN AND KURT G. STEINER. 1997. "The role of soil fertility in sustainable agriculture with special reference to sub-Saharan Africa". Agriculture + Rural Development 4(1): 22-25.

REIJ, C. P. MULDER and L. BEGEMANN. 1998. Water Harvesting for Plant Production. World Bank Technical Paper # 91. Washington, D.C.: The World Bank.

RODROQIEZ. SANTIAGO ALONSO, UTE HEINBUCH and RAINER E. LOTZ. 1998. "The Water (time) bomb – development policy action required". *Agriculture + Rural*
Development 5(2):3-5.

SEINY-BOUKAR, L. 1990. Régime Hydrique et Dégradation des Sols dans le Nord-Cameroun. Thèse de Doctorat de 3eme Cycle en Sciences de la Terre. Yaoundé, Cameroon: University of Yaoundé.

SOMBROEL, WIM and HELMUT EGER. 1997. "What do we understand by land use planning: A state-of-the-art report." *Agriculture + Rural Development* 4(1): 3-7.

TEYSSIER, A. 1997. Créer et gérer un Point d'Eau pour les Troupeaux de son Village: Guide Méthodologique a l'Usage d'Agents de Développement Rural. Deuxième version. Maroua, Cameroun: DPGT, SODECOTON.

VAN OOSTRUM, K. 1994. Sustainable Land Use and Social Change: A Study On Ecological Knowledge, Soil and Water Management and Social Dynamics of Mafa in North Cameroon. M.A. Thesis. Leiden, The Netherlands: Institute for Cultural and Social Studies.

WORLD BANK. 1998. African Development Indicators. Washington, D.C.: Author.

—————————— 1995. Cameroon: Diversity, Growth, and Poverty Reduction. Washington, D.C.: Author.

ZAKARIAOU, B. 1997. Etudes de Faisabilité du Projet de Réhabilitation des Points d'Eau d'Abreuvement du Bétail dans les Provinces de l'Extrême –Nord et de Nord. *Personal Communication*

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