Al-Neelain University

From the SelectedWorks of Professor Issam A.W. Mohamed

Summer March 14, 2011

Economic Perspectives of Indigenous Knowledge Systems, Technology Transfer and Rural Water Use in Darfur

Issam A.W. Mohamed, Professor

Available at: https://works.bepress.com/issamawmohamed/1/
Economic Perspective of Indigenous Knowledge Systems, Technology Transfer and Rural Water Use in Darfur

Professor Dr. Issam A.W. Mohamed

Abstract: There are growing increases in Darfur population's water demand in recent years due to rapid demographic expansions that led to increased consumption per capita associated with improved standards of living and water-related commodity production, agriculture and service industries. In addition to this, the problem of water stress which is attributable to increased per capita demand over fixed levels of supply and its concomitant land desiccation resulting from activities such as deforestation and overgrazing. Water scarcity continues in arid and semi-arid areas due to precursory climatic conditions of aridity and droughts. Together these have led to acute water scarcity and consequently, a shortfall in the amount of water available for human use. The current paper discusses issues of economic and sustainable utilization in Kutum area, Northern Darfur region using field data and economic model.

Key-words: Darfur, technology transfer, water supply...

Introduction

Sharp increases in Darfur population’s water demand in recent times have been due to rapid population growth, an increased consumption per capita associated with improved standards of living, and expansion in water-related commodity production, agriculture and service industries (United Nations, 1976). In addition to this human problem of water stress which is attributable to increased per capita demand over fixed levels of water supply and its concomitant land desiccation resulting from activities such as deforestation and

* Professor of Economics, Alneelain University, Khartoum-Sudan. P.O. Box 12910-11111. issamawmohamed@yahoo.com
overgrazing, there has been continued water scarcity in arid and semi-arid areas (ASA) due to precursory climatic conditions of aridity and droughts. Together these have led to acute water scarcity and consequently, a shortfall in the amount of water available for human use (Falkenmark et al., 1989; Clarke, 1993).

There is growing evidence of a decline in water availability in northern Sudan due to rainfall seasonality and variability (Woo and Tarhule, 1994; Hess, et al, 1995). At the same time, the competition for water by human activities is exerting tremendous pressure on the limited water resources and the environment (Kimmage, 1991; Dabi and Anderson, 1998a). The allocation of the water to these competing uses has been based entirely on traditional practice following indigenous knowledge systems. When inefficient decisions are taken, severe shortages may occur for some if not all the uses with inevitable adverse repercussions. This, in combination with the quest to increase food production, has contributed to the recent drive for western technology in the form of water pumps, tube wells, boreholes and dams to augment water supply particularly for irrigated agriculture (Kimmage, 1991). However, these innovations have been met with further complications and concomitant problems.

Over the past five decades, technology and growth have increased the total water use in the world up to four times. This has been achieved through the construction of dams, reservoirs and conveyance structures that made up to 44 percent of the world's reliable runoff water resources accessible to man. Also, through various means of water harvesting, an increased utilization of rainwater has been made possible. However, of all the water available, the challenge is to allocate it to the best possible use in order to maximize the benefits, particularly for people living in areas prone to droughts (Clarke, 1993). Essentially, the challenge is to promote a strategy which aims at proper management of the demand for water and not a continued supply-oriented management. The combined effects of complex environmental (climatic) conditions and human activities now threatening and regions have necessitated the development of methods for investigating the problem from a multi-disciplinary perspective and on a micro-scale. This will facilitate better management of water resources and enhance sustainability in the development process. This bottom-up approach will ensure a better understanding of the problem as experienced by the affected people rather than assumed from a larger perspective.
Part of the study seeks to account for the total water used in Kutum village in Northern Sudan. Also it is important to understand the knowledge systems scarcity and strategies to production from one adopts a bottom-up approach and examines four issues: for water sourcing and withdrawal, vis-à-vis seasonal fluctuations, to ensure long term availability and use; (ii) strategies at the household, activity and farm levels for ensuring safe delivery (conveyance and distribution) of water to final demand, through the production system and minimizing losses; (iii) technologies available for water processing (storage, retrieval, use, conservation), considering the high production requirement and excessive evaporative demand by the economy and environment respectively; and (iv) strategies employed during use (production) in order to maximize the utility of water in terms of reuse, recycling or reduction in quantity used. The use of introduced technologies for the same purposes will also be considered and compared with indigenous ones. We also report the findings of field observations and measurements made in this regard. Information generated from this study will be used in conjunction with results of an extended input-output model to address various policy options or water management strategies.

**Conceptual Perspectives**

Indigenous knowledge systems are defined in the context of innovation, technical knowledge, associated social organization and decision-making processes (Brokensha et al., 1980; Kidd and Phillips-Howard, 1992). These four basic components of knowledge systems are based on 'factual knowledge' that relate to...
concepts, prepositions, symbols or memory derived through human perception, and 'procedural knowledge' that follow the rules of logic and empiricism. Here, technical knowledge is considered as factual; innovation as procedural; social organization as both factual and procedural; and decision-making as procedural. Together, these components enable the utilization of the knowledge systems that affect decision-making and cause a pattern of behavior.

The pattern of behavior determines the use of resources. Incorporating indigenous knowledge systems in rural studies is by targeting the practical realization of a viable development policy (Kidd and Phillips-Howard, 1992). Technology is defined as the skills, knowledge, and procedures used in the provision of goods and services for any given society (Hope, 1996). It is seen as a mode of production that carries within it economic, social, cultural and cognitive structural codes that differ between societies (Galtung, 1978 and Vanderburg 1986). Technology transfer involves the two-way relationship of sending and receiving technology primarily between and among firms, industries and governments (Hope, 1996). The transfer of technology (TOT) paradigm is a mutually supported set of concepts, analyses, methods, and behavior in which western-trained scientists generate technologies on research stations and in laboratories, to be transferred through extension services to farmers (Chambers, et al., 1989; Gladden and Phillips-Howard, 1992). Therefore the transfer of Western technology to the less developed countries (LDCs) is seen as a structural invasion, fragmented and perceived poorly because of the difference in structures (Galtung, 1978; Vanderburg, 1986). Appropriate technology is a term used to describe both a method and a movement. As a method it is considered to be the appropriate application of scientific knowledge to development, while the movement is believed to have started in the 1960s and is now active globally (Kerr, 1989). Appropriate technology is based on interactive innovation where an interactive process occurs, and its techniques or tools are transformed by incorporation into the recipient culture (Pacey, 1983). Idealistically, appropriate technology uses production methods that are less damaging to the environment of communities than
previously used methods, consume less energy and fewer resources, and recycles wastes or handles them more acceptably (Hope Sr., 1996).

The notion of 'appropriate technology' or 'intermediate technology' has been met with criticisms based on a neo-colonial connotation of superior goods for the developed nations and inferior ones for the third world or LDCs (Schumacher, 1991). But the fact is that LDCs need access to technologies which are appropriate to their stage of development, rather than 'state-of-the-art' technologies imported from the developed world. Needed are technologies that build on the structures of existing traditional (indigenous) technologies and take advantage of those from developed countries. Such 'intermediate' technologies would be immensely more practical and productive than the indigenous ones but more affordable and accessible than the sophisticated, highly capital-intensive technologies of the West (Schumacher, 1991).

Less developed countries in ASA need technologies that are sustainable, those that are acceptable, affordable, usable, and manageable by the users. Such technologies also consider the precariousness of environmental and economic conditions they face. Thus, the idea of appropriate technology must be looked at in terms of demand with basic needs as goals and supply using the desired production process (Hope Sr., 1996). This is only achievable if the needs and aspirations of the people, their capabilities, and deficiencies are known. An understanding of indigenous technical knowledge systems is therefore paramount. In Africa, as elsewhere, there is an increasing interest in traditional systems of agriculture and indigenous technical knowledge (Chambers, 1983; Richards, 1985; Adams, 1985; Gladden and Phillips-Howard, 1992). Most this interest emanated from the fact that the large-scale dam projects meant to replace the age long small-scale initiatives and to boost agricultural production and water supply in different parts of Africa, especially Sudan, have not performed to expectation (Mons, 1987; 1989; Mitchell, 1990; 1994; Salau 1990). Such introduced 'solutions' only outperform the indigenous initiatives in certain favored situations. Moreover, the formal irrigation schemes were very expensive in terms of construction costs, external management, and infrastructure (Mons, 1987; 1989). Other problems have been noted. Priorities were distorted as emphasis was placed on commercial crops to the detriment of food crops. And the large dams cut off the downstream seasonal flood affecting traditional practices (Scudder, 1980) or Wadi cultivation in parts of Sudan (Turner, 1985; 1986; Adams, 1986; Adams and Carter, 1987; Mods, 1989; Kimmage, 1991; Kimmage and Adams, 1990; 1992). In addition, there are the environmental and human problems associated with the water development projects (Biswas, 1978; Scudder, 1989; Mitchell, 1990; 1994; Salau, 1990).
The World Bank-sponsored work undertaken by Briscoe and deFerrartti (1988) is one major example of the use and performances of introduced technologies for water supply in rural community of developing countries. They observed that many water improvement projects have proved to be neither sustainable nor replicable. The gains of the new water supply systems were eroded because of the widespread failure attributed to inadequate maintenance. Such failure was more because of the top-down approaches in the design of systems and maintenance of facilities such as hand-pumps and boreholes or pipe connections, with central governments and donor agencies taking dominant roles, rather than the complexity of the technology. Furthermore, the improved systems often did not meet local expectations local institutional realities were not taken into account, while government support was very erratic. Moreover, the nonchalant attitude of the people toward water supply schemes, regarding such projects as governmental provisions and for which they need take no responsibility is pernicious.

Interestingly, Briscoe and deFerranti (1988) advocated for a community-based (bottom-up) approach to water development, in which communities develop primarily through self-help activities. Such an approach allows users to decide on the type of improvement to be made, pay for most of the costs (usually by providing the required labor), and take responsibility for maintaining the facilities they have chosen and implemented. While government and external donors create the enabling environment, supplemented with technical and training support, and provide materials.

Gladden and Phillips-Howard (1992) acknowledged that resource-poor farmers in LDCs posses active and useful indigenous knowledge systems including experimentation, technical knowledge, social organization and decision-making systems as noted by Warren et al. (1989). However, they suggested a combination of transfer of technology and farmer first paradigms. These permit mutual learning and effective ‘co-research’ and lead toward well-facilitated, participatory action programs. Again, in our
opinion, this is parallel to the idea of appropriate technology which Smith et al (1994) argued for in that it contributed to the intensification of agriculture more significantly than population and market driven forces.

Data Collection

The case study village for this study is Kutum in semi-arid zone of Western Sudan. Population growth has been largely due to immigration more recently due to natural increases. Islam is the sole religion with Arabic (Koranic teaching) as the basic form of education. Decision-making is mostly based on a hierarchy of community leadership and religious beliefs. As a typical village with similar environmental characteristics and human activities to the rest of the region, the prevailing conditions are similar to others in the region. As indicated in the introduction, drought conditions and water scarcity are prevalent; rainfall is limited to four months of the year; stream flow is seasonal; and groundwater which serves as the major source of water is declining. The extensive sedimentary Chad Formation, recharged by seasonal surface flow, is the main source of the groundwater. The undulating terrain is covered mostly by Sudan savanna-type vegetation, basically patchy grasses and scrub as well as scattered acacia and baobab tree species. These provide wild animals and fruits for their consumption and sale, leafs and pasture for their domestic animals; and wood for fuel and construction. Wood extracted from the bushes is also sold as export commodities at neighboring markets.
The major economic activity in the village is rain fed agriculture by sedentary farmers who grow staple crops mostly at subsistence level. All households are involved in rain fed agriculture but the activity is predominated by the more settled Zhagawa, Berti, Mahria and Ziadia groups. Animal husbandry of camels, sheep, goats and poultry is the next most widespread activity the households participate. Irrigated cultivation of vegetables and grains is also practiced. Irrigation is limited to a short period of the year and few locations accessible to surface and groundwater sources called Wadis that bypass the village. Other ethnic groups are also involved in animal and vegetation gathering for food, fuel and construction. Other economic activities include rural industrial production, e.g., small-scale manufacturing of goods such as processed food and handicrafts and services traded mostly within the local market by the Hausa and Kanuri groups. The village lacks most urban facilities such as piped water and electricity.

Turner (1985:18) defined Wadi as land seasonally flooded or waterlogged. In other words, low land seasonally inundated due to water intrusion. Assistance is limited forcing the people to depend on their traditional heritage and environmental resources. Therefore, water procurement, delivery and processing for the activities enumerated above rely on traditional initiatives with few modern methods. This has made water use and conservation a problem in the area. In a previous work (Dabi and Anderson, 1998b), we reported the use of water for commodity production in this village. The agricultural sector consumes more than 60% of the groundwater, basically for irrigation and animal watering. And later (Dabi and Anderson, 1998c) we developed and applied a product-by-industry economic-ecological model (CLEEM) which accounts for the direct and indirect use of groundwater in the village. This provides the major analytical tool for the research. This analytical procedure is ideal for depicting water use under normal circumstances. It incorporates input-output relations defined under normal rainfall conditions. However, it is expected that during drought periods (dry spells) there will be severe water shortage and people are bound to develop alternative measures for coping with the situation.
They may develop new water sources and storage systems, new methods of water use, and new water saving strategies. Such strategies are revealed through field monitoring of indigenous knowledge systems and technologies reported here. Cases of introduced, transferred technologies and strategies for future development appropriate technologies are also considered.

Data required for this research were collected during two field seasons (wet and dry) in the study village. Most of the data required were gathered during the dry season. The field exercises targeted activities undertaken during this dry period. Resultant changes in water use and their effects on the economy and environment were noted. Key informants, including the village head, ward or tribal group heads, major farmers and school teachers, were consulted to ascertain changes in activities and possibly water use. Field assistants were then selected and trained before actual data collection. Data gathering was based on 10% sample survey of households engaged in industries that exhibited the highest demand for water in an initial study. Therefore, emphasis was placed on the agricultural sector particularly, irrigated agriculture and animal watering.

Field observations and measurements were made regarding indigenous knowledge systems and technologies for water demand, use and management, and water shortage coping strategies including:

1. changes in water sources,
2. water use behavior and decision-making process,
3. methods of water procurement (withdrawal or abstraction),
4. methods of water processing (storage, retrieval, use and reuse or conservation),
5. methods (techniques) of water delivery (conveyance and distribution), and
6. Economic and social costs involved.

Facilities for water withdrawal and conveyance were noted. And quantities of water Dabi and Anderson (1998b) have indicated a total population of 2,734 people with 424 households engaged in 27 industries and producing more than 100 commodities in Kutum village. The
agricultural sector especially irrigated agriculture and animal husbandry is the highest consumer of groundwater as it is extracted and conveyed to households and industries determined. Quantities were determined by measuring the volume of containers used for water extraction (withdrawal from wells) and those used for conveyance delivery. For example, households were observed to withdraw between four (4) and 18 liters of water per day for domestic use, and up to 200 liters for other activities like construction or sale by vendors.

Quantities of water used by animals were measured by monitoring the number of times animals are watered and the quantity consumed in the process. The average size of containers, usually 4 liters used for hauling water from the wells was determined. This was multiplied by the number of times the water was poured into the animal’s drinking container a half-sized barrel or an opened gourd. The result was then divided by the number of animals that drank from it. Results from these measurements were similar to estimates given. The quantity of water extracted for irrigation was determined from two perspectives. First, the traditional methods of delivering water from the source to the crops whereby the number of calabashes of water delivered to the cropped area are counted. Second, the introduced form of technology in which the rate of pumping and quantity of water released is multiplied by the duration of irrigation, using 2-3 horse power engines water pumps. These quantities were calculated for a week and multiplied by the number of weeks the crops were irrigated. Irrigation and animal watering were done in situ, that is at location of the shallow wells. Data were collected on a daily basis from morning to late evening by monitoring the number of times individuals visited the wells. The monitoring was spread over the sampled industries and households during the period of the survey.

Indigenous Water Management

The various indigenous equipment or facilities used for water procurement, delivery. Techniques for water procurement, sourcing and withdrawal, and those for delivery conveyance and distribution, are labor intensive, time consuming and perhaps inconvenient. Men are responsible for sourcing as digging wells. This requires a lot of energy and expertise. Water withdrawal, fetching or extraction, does not follow gender lines and is performed by men, women and children, male and female. The same goes for water delivery, but adults convey larger quantities of water and perform more of the skilled labor. Children carry smaller containers and assist with the menial jobs at home and at the production unit.

The nature, size and capacity of facilities for water processing, storage, retrieval and use/reuse in households and most other industries are
rather small. Quantity of water stored in these containers is equally small, less than 100 liters. Thus, the need for more effort and time investment for water procurement emerges. The construction or building industry uses larger containers up to 200 liters for water storage, although most of it or even more can be used in a day. Only irrigation and animal watering use water at location of shallow wells, as indicated earlier. Water contained or stored in these wells depends on recharge and withdrawal rates. At the peak of the dry season, the recharge rate is minimal but withdrawal rates very high. All these indicate that water management and conservation are in jeopardy.

Table 1. Indigenous Techniques for Water Procurement

<table>
<thead>
<tr>
<th>Activity</th>
<th>Item</th>
<th>Description and Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging</td>
<td>Digger</td>
<td>Metallic tool for digging with sharp end</td>
</tr>
<tr>
<td></td>
<td>Shovel</td>
<td>Flat metallic blade for shoving dug soil</td>
</tr>
<tr>
<td></td>
<td>Iron bar</td>
<td>Heavy spear bar with sharp end</td>
</tr>
<tr>
<td></td>
<td>Bucket</td>
<td>Metallic container to collect and remove soil</td>
</tr>
<tr>
<td>Withdrawal</td>
<td>Habil</td>
<td>Rope for drawing water from the well</td>
</tr>
<tr>
<td></td>
<td>Dalow</td>
<td>Rubber or plastic container to withdraw water</td>
</tr>
</tbody>
</table>

These observations show that local techniques for water extraction, storage, retrieval and delivery in the village are very simple capital extensive but manually operated labor intensive and perhaps sustainable because they are based on local materials and initiatives thereby reducing purchase and maintenance costs. But there are no specialized skills for rainwater harvesting and farming to take advantage of the ‘excess’ rainfall and runoff water stored in ponds and stream at the end of the rainy season. This may be attributed to their lack of interest in developing these measures as confirmed by the comments, made by some of the key informants. For example, water from the mud-constructed roofs gets contaminated with sand, thatched roofs do not yield sufficient water for us to bother with and water in ponds does not look good for use. However, these sources of water could be developed as discussed later. The water can be stored and retrieved for use during periods of scarcity.

The annual scheduling of activities tends to depend on water and labor availability. Generally, activities start at the end of the dry season in agricultural societies such as this. Just before the rains in June, land is prepared (clearance and tillage), to at the new planting season for rain fed crops. All other activities (including animal husbandry, the rural industry, trade, and services) except for irrigated agriculture also take place during the rainy season. Activities undertaken at this period rely on direct
rainfall, stream flow and ‘abundant’ water in the village wells and ponds. During the dry season, irrigated agriculture thrives along the Wadis. Other activities with the exception of rain fed farming are intensified at this period. Unfortunately, the only dependable source of water is the shallow wells. Deep groundwater may not be accessible because most of the village (deep) wells are dry and Tube-wells/water pumps broken down. The diagram illustrates the scheduling of activities during the year. These have been spread around in form of a clock. Starting with January at one o’clock and going clockwise with December at twelve, the activities and water availability are located appropriately.

The main activities requiring so much groundwater during the dry season are irrigated agriculture, animal rearing and building construction (Dabi and Anderson, 1998b). It is very disheartening to note that all these high water demand activities are concentrated at about the same time of the year during which groundwater from shallow wells is the main source of water. At this period, deep groundwater becomes inaccessible as most of the deep village wells dry up. This arrangement seems to create undue pressure on the limited water sources and increase the potential for conflict among users.

However, the daily timing of water extraction during the water scarce dry seasons is based on a well defined social and cultural organization which allows for the use of shallow wells at different times of the day by the different users. For example, water for domestic and other activities requiring less water, is extracted early in the morning (from about 6.00am) while animal watering is done in the afternoon (starting from 2.00pm), while other high water demand activities like irrigation and construction extract theirs afterwards. Some of the irrigated farms have private shallow wells for use at other times of the day, especially in the morning and late afternoon. In between these schedules, the wells are given 'sufficient' time to recharge. This process has tended to minimize or eliminate any possible conflict between the different users.

There are other indigenous knowledge systems used for water conservation by the villagers. For example, at the farm level, farmers do a lot of mulching to reduce the rate of evaporation and to maintain soil moisture. Irrigation activities are usually de-intensified when water becomes inaccessible. Farmers resort to delivering water at a per plant basis rather than pouring water into the whole plot through a channel. From field data, some of which is discussed Dabi and Anderson (1998b), this practice can save at least 15% of irrigation water or up to 2.12% of total groundwater used in the village.
Animal herders embark on transhumance activities to take advantage of distant watering points and to reduce pressure on existing sources of water around the village. And at the household and industry levels, some form of water reuse is practiced. Normally, people do not pour away water they may have used for washing or cleaning but it is stored to be used again for some other purpose, say, wetting fiber or grass for weaving and sand for mending cracked or fallen walls. Such water could even be poured under a plant to add soil moisture for its growth. If all the wastewater generated from household and industry is reused, another 10% of groundwater would be saved, although this may be too ambitious for Kutum village because of technological constraints. The seasonal transfer of livestock to areas of greener pasture is practiced by pastoral nomads in arid and semi-arid areas.

The Role of Transferred Technology

The nature and type of introduced technology are available in the community. Most, if not all, are for water sourcing and storage for agricultural purposes. A wash borehole is used for extracting deep groundwater with the aid of water pumping machines or hand pumps. There are two types of facilities for water storage in the village: two commercial manufactured water tanks and one ground cistern. The tanks were used to store water extracted from the wash borehole and the ground cistern was meant for a fish pond. None of these contains water now all but seem to have been abandoned. This attests to the argument that local people are nonchalant about facilities provided by government or other external organizations as discussed earlier. This is often the case, when they do not initiate or participate in planning for such facilities. At the household or place of production, facilities like connection pipes and standing pipes/taps are not available for water delivery. Neither are facilities for water storage, except for containers like empty oil barrels and jerry cans that are converted into storage tanks. The most sophisticated introduced technology in this village, as is the case in most parts of northern Sudan, is the water pumping machine.

The pumping machines are very efficient facility for water extraction, either from a shallow well or tube-well. It has enabled farmers to increase production and thereby increase their income. This has led to the overwhelming acceptance of the innovation here in Kutum and elsewhere. Detailed differentiation between traditional initiatives of indigenous technology and the use of water pumps transferred technology for irrigation in the village are illustrated. Almost 80% of the irrigation farmers use water pumps on their farms. Although only four of the farmers own the machines, the others lend them to use on their farms. The rest (a little more than 20%) use the traditional method to
irrigate their crops. However, those who rely entirely on the water pumps have had tremendous disappointments at times due to the sudden breakdown of engines. Farmers have had to abandon parts or even a whole farm prepared for irrigation farming during the dry period. For example, the farmers had to delay his irrigation activity for the season because his machine broke down. He had to purchase the part required to fix it at centers more than 400 km away because we could not even find it nearer. Even then, the owner would not do it immediately. Asked why he made such a decision, he said if I fix it now, other farmers would want to lend it from me and soon there will be a breakdown again and I may not cultivate any crops this year. Water in the shallow wells were fast declining and reducing the amount available for irrigation. Soon the rains would come and it would be time to prepare other lands for raided crops, thus diverting labor.

Another problem associated with water pumps is the loss of water during delivery to the crops. During irrigation, water delivery is usually through small channels (furrows) into a larger farm plot. This process allows excess water loss by infiltration, seepage and evaporation, without reaching the targeted crops. Therefore, more water has to be extracted and delivered before the plants get sufficient moisture for their growth and development. The point to note here is that, although the water pumping machine is very useful in accessing groundwater and making the irrigation process more efficient and rewarding, there are problems associated with it as enumerated above. These problems tend to make the whole irrigation operation using water pumps counterproductive and unsustainable. This is because the cost of engines is prohibitive as they require expensive maintenance because of sometimes total breakdowns and contribute to excessive water demand. This is always met with technological dilemmas, whether to go traditional or rely on introduced technology (machines). Farmers who own water pumps keep complaining about the problems involved with using and maintaining the engines. Many who do not have water pumps keep yearning for theirs, while ‘skeptics’ stick to the traditional methods. Numerous strategies for water procurement, delivery and processing exist especially in and around the ASA, all of which can be enhanced or introduced in this village. Such technologies have been tried and proven useful in areas with similar physical and human characteristics but will be deemed appropriate only when tried and accepted in the village. These include simple, sometimes, complex technologies such as rainwater harvesting and fanning (e.g. in India and Botswana); earth dams, and wind pumps (in the Turkana desert); solar pumps (in Somalia); Ferro-cement tanks (Papua New Guinea) and so forth (Pacey and Cullis, 1986; Kerr, 1989, Lee and Visscher, 1992). Notwithstanding, the appropriate technologies are those that will ensure adequate supply procurement, moderate water use, processing and at the same time convenience in terms of
maintenance and functionality (delivery) and thus, be sustainable (Mons, 1989). If we consider rainwater harvesting and farming as an example, changes may be required in the roofing style of buildings. Thatched roofs may have to be replaced with corrugated iron sheets (zinc) as seen over a few buildings including the primary school, dispensary and staff quarters. Alternatively, mud roof surfaces may have to be paved with cement or other similar impermeable material. Rainwater incident on these ‘new’ surfaces (roofs) can then be channeled down into ground tanks or cisterns through gutters. The cistern can be made from local material like earthen pots or other larger containers, jerry cans and fabricated metal tanks and the gutters made from local carved wood, bamboo or fabricated metal sheets. Blacksmiths in the village indicated that they can construct some of these materials. The large ponds around the village can be converted into water storage tanks or cisterns during the rainy season for use in the dry period. The sides and floor of the ponds can be straightened and built with brick and cement with some reinforcement, and then plastered into a kind of Ferro-cemented ground cistern similar to the one meant for the fish pond. Some material, such as a plastic sheet or a thin oil layer, can be used to prevent or reduce the excessive evaporation. With this arrangement, water can be secured for use in activities as brick making and building construction which do not require higher quality water.

For all of these, local materials can be used except for the cement, plastic and oil and constructed using direct labor by the villagers. These innovations are possible as they have been done in water scarce areas of Zimbabwe, Kenya, Indonesia and Thailand (Pacey and Cullis, 1986). The Darfur state government has proposed building a dam across some wadis. Dam construction is another form of introduced technology for large-scale water supply and irrigation development projects in parts of Northern Sudan. The problems associated with these have been discussed earlier but are perhaps unfamiliar to the people. Thus, the people of Kutum, and the neighboring settlements received the news with great enthusiasm. However, this may not necessarily be a good idea for the village and other users downstream. This is due to the problems
associated with large-scale dam projects discussed earlier. Rather, simpler strategies for water storage and conservation such as groundwater dams including sub-surface dams and sand-storage dams may be worth considering (Nilsson, 1988).

Other conservation methods may include the 3 R water saving strategies of reduction using less water per activity or modifying the irrigation practice/crops to reduce water use, reuse, using already used gray water again for activities requiring low quality and recycle as a long term attempt to improve the quality of larger volumes of waste water for subsequent use especially for activities requiring water of medium quality). This idea is consistent with the 3R policy approach to waste management (waste recycling, reuse and reduction described by Baetz et al. (1991) and Huang et al. (1994). Moreover, the reuse of waste water for irrigation is very important as it can supply almost all of the nitrogen, most of the phosphorus and potassium, as well as the important micronutrients required by many crops (Bartone, 1991).

Nonetheless, a better conservation measure may rest on the rescheduling of activities during the year to correspond with the timing of water availability. Figure 5.3 illustrates some of the suggested strategies for the annual rescheduling of activities in the area. By and large, the diagram is similar to figure 5.2. But rather than congesting the higher water demanding activities when the 'only' source of water is the shallow wells, some of the activities are spread to take advantage of the 'surplus' rain and surface water during the rainy season. For example, construction activities are rescheduled to commence soon after the rains and before irrigation activities.

Although the villagers understand the need to schedule activities more appropriately when water is available, they enumerated a number of problems associated with such an arrangement. For example, one farmer said that if we leave our crops in the farms for too long, animals will intrude and consume everything. But we also have to mend our houses and fences too. So we have to harvest the crops and bring them home first before building. And if we build in the rainy season, the rains will destroy the walls.

These constraints are understandable, but labor availability is apparently the main impediment to any kind of adjustment that can be made. Evidently, the rescheduling of activities is achievable if communal effort (participation) is employed in carrying out tasks rather than individualistic production. Groups of four to five people were seen constructing roofs for friends or colleagues who indicated that such effort was meant to save money, time and energy. In the same disposition, larger groups can come together and be involved in different aspects of farm work and construction. Such an arrangement will make more labor available, thereby saving even more effort and time to warrant the rescheduling of activities. Wadi farmers in Sudan have
demonstrated the value of such communal effort and the possibility of shifting activities to take advantage of the dry season farming period which would otherwise be almost impossible once the rains come (Dabi, 1992).

As indicated earlier, decision-making is mostly based on a hierarchy of community leadership and religious beliefs. The village head is at the top of the hierarchy answerable to the local and state governments. These people are vested with other responsibilities including decision making from domestic and household, through the ward back to the community levels in a reverse order. The imam (religious leader) and school teachers also partake in decision-making on religious matters and when prayers are required to invoke rain and making water available. Other bodies also play significant roles. These bodies have a great deal of knowledge to handle most of their immediate problems. However, they look forward to external assistance when it comes to major ones such as intermittent droughts and water perennial scarcity as well as the need to increase water supply.

Ultimately, the people have to be educated and empowered to be able to achieve most, if not all, the suggested strategies. Most importantly they must be involved right from the planning and implementation stages for the projects to be fully participatory and acceptable. The dissemination of information is also through the same channel as decision-making, community and religious leaders. One major example of innovation diffusion and acceptance is the use of water pumps for irrigation. The people also need encouragement in order for them to exploit further their own technologies and knowledge systems. This is exemplified by the recent collaboration between researchers and the Kutum people to improve on earthen pots for water storage. Besides, there is general consensus and evidence supporting conventional knowledge, that education has a positive effect on the performance and efficiency of rural people in LDCs (Lockhead, et al., 1980; Phillips, 1994).

**Summary and Conclusions**

Increase in the demand for water during the dry season is attributable to two major factors: inherent scarcity at this period of the year; and an escalation of activities requiring larger quantities of water. Irrigation farming, animal watering, brick making and housing construction are intensified just when water is most scarce in the area. The findings have revealed that little or no sophisticated technologies exist in the village for water procurement, sourcing and withdrawal, water delivery, conveyance and distribution and processing, storage, retrieval and use. The villagers tend to depend on a number of introduced technologies for water procurement the tube well and water pumping machines and for water storage tanks. These technologies have proved to be unsustainable due
to high purchase and maintenance cost, and contribute to excess water loss by infiltration, seepage and evaporation. Additionally, the scheduling of activities does not take proper cognizance of the timing of water availability. The villagers lack specialized skills for rainwater harvesting and farming, and making the best use of excess water stored in ponds and stream at the end of the rainy season.

However, a number of indigenous technologies are available for these processes. Such technologies are locally fabricated tools and facilities manually operated by the villagers. Although these are labor intensive, they are capital extensive, have the advantage of water conservation, and are perhaps sustainable. There is also evidence of wastewater reuse and the villager’s willingness to accept new innovation and/or technologies. All these efforts are geared toward reducing the impact of water scarcity and therefore sign of the drought mitigation process. But the perpetuation of the problem and the people’s yearning for assistance also indicate the need for alternative approaches to water conservation in the area. Therefore, a number of appropriate strategies based on a combination of indigenous knowledge systems and the transfer of technology to enhance water use and conservation in the area are suggested. These among others include: rainwater harvesting and farming, utilization of water ponds, construction of groundwater dams, rescheduling of activities and communal participation. However, the ultimate strategies are education, empowerment and encouragement. These will enable the people exploit further their own technologies and knowledge systems and to participate in the planning and implementation of any strategies or projects for them to be fully acceptable and sustainable. Some of these ideas are being simulated as policy scenarios for water use efficiency using a product-by-industry economic-ecological model. Results of these simulations will serve as policy options for economic development and technology use.