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WATER SAVING TECHNIQUES – LESSONS LEARNED FROM IRRIGATION OF AGRICULTURAL LAND IN EGYPT

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WATER AVAILABILITY AND CONSERVATION IN SUDAN

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Abstract

A population growth running at an annual rate of two percent or more is facing Egypt with a challenge to produce its necessary food and natural fiber. Overcoming this challenge is viewed through the reclamation of desert lands, which is, again, encountered by an increasingly growing water scarcity. This is due to the country's limited share of Nile water, the non-renewability of fossil groundwater in addition to rainfall scarcity. To satisfy water requirements for reclamation activities, the promotion of water supply management was previously adopted. It is additionally deemed necessary to enhance an approach that implies a revision of wasteful water use countrywide. This step constitutes the cornerstone of a consequent water conservation program to be applied in Egypt on a national scale. In the same context, this paper reviews water saving measures vis-à-vis land reclamation endeavors in Egypt. The suitability of locally adopted water conservation techniques is investigated in the light of the irrigation system's characteristics. Attributed implications of different techniques are also highlighted and assessed according to technical and economic ramifications. Lessons are drawn from scrutinizing alternative measures aiming to promote the availability of water in the Egyptian irrigation sector. It is concluded that an amalgamation of different inducements of water demand control may be required for conceiving a comprehensive strategy to economize on irrigation water as dictated by local needs and priorities.

Introduction

Due to the increasingly constrained water resources, reconsideration of irrigation policies is taking place in water-short countries, among which Egypt is no exception. A review of the management techniques adopted in Egypt is deemed necessary for ensuring an efficient resource use that bear on how to more closely satisfy the country's goals. The current research probes the potential for strengthening the country's resolve to reclaim desert lands through a conservation approach that increases water availability countrywide. The objective is to assess the appropriateness of national land reclamation plans in the light of the increase in water availability achieved through the water saving measures adopted in Egypt. Lessons drawn from the Egyptian experience in this regard are expected to constitute the basis for developing a water use strategy that recognizes the growing scarcity of water in the country.

Attributes of Egypt's Water and Land Resources

In arid and semi-arid countries, including Egypt, agriculture depends mainly on irrigation. According to the Egyptian regime, irrigation water is abstracted from a canal network originally offtaking from the Nile River. Water accumulating in aquifers and drains as a result of irrigation processes constitutes an additional, however relatively minor, resource for irrigation. The country's share of water is limited by the 1959 agreement between Egypt and Sudan to 55.5 billion m^3 per year. In 1995, the country's full share of Nile water was abstracted to satisfy diverse requirements of "Old Lands" in the Nile Valley and Delta as well as reclamation needs for "New Lands" in the desert fringes of the floodplain. It is therefore anticipated that satisfying extra water requirements due to increased consumption of the growing population and/or further reclamation of new lands will necessitate increasing current rates of water supply and/or reducing actual patterns of water demand.

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As for the country's land resources, it is estimated that the area of agricultural land totals 7.8 million Feddans, mostly in the Nile Valley and Delta, while that occupied by urban and rural societies amounts to 4.7 million Feddans. These areas constitute five percent of the country's territory estimated at 238 million Feddans. The rest is considered desert land that is hardly exploited or inhabited. On the other hand, an area of 25,000 to 30,000 Feddans is considered lost annually to agricultural land in Egypt as a result of urban encroachment. This takes place despite several local constraints restricting the switch of old land use from agriculture to alternative purposes.

To achieve the country's development goals in the light of the increasingly fading water and land resources, decision makers at the Ministry of Public Works and Water Resources (MPWWR) are put in a dilemma as to whether to:

1. abolish constraints on agricultural land use, allowing an urban expansion at the expense of agriculture and saving irrigation water for alternative uses, such as industry, recreation, domestic use, etc., or

2. proceed with desert reclamation, taking into account the need for promoting the availability of water to satisfy requirements of the growing population in addition to those of actual and projected agricultural areas.

Analysis of Proposed Approaches to Remedying Resource Scarcity

It is noted that abolishing constraints on agricultural land use will result in losing the Nile floodplain as one of the most fertile soils that may hardly be considered of any use but agriculture. The value of this soil should therefore be quantified and taken into account if the typically agricultural land in the vicinity of the Nile is considered for alternative uses. In addition, due to the poverty of most farmers (more than 95 percent of the local farmers own less than five Feddans of land), it is believed that taking water from agriculture increases rather than alleviates poverty (Frederiksen, 1996). Finally, because agriculture accounts for about 36 percent of employment in Egypt, the scenario implying agriculture curtailment will be coupled with a resulting idleness of farmers. This will consequently necessitate securing alternative jobs for a mostly illiterate and technically unskilled labor force.

As for attempts to increase water availability, a review of the Egyptian experience in this regard shows that the potential for promoting the Nile supply system has been thoroughly tapped through external (i.e. outside the country) and internal measures. External improvements concentrate mainly on conservation schemes to reduce losses from evaporation and transpiration of the Upper Nile reaches. For example, Jonglei Canal project, planned to bypass swamps in Southern Sudan, aims at increasing the Nile water share of both Egypt and Sudan by 2 billion m^3 each. In the light of the rainfall scarcity and non-renewability of fossil groundwater, the internal supply system of Egypt is developed through several measures including the improvement and maintenance of control structures and distribution networks of surface water and the promotion of groundwater abstraction to the aquifers' safe yield limits.

In view of the above, horizontal expansion is deemed necessary for counterbalancing the loss in agricultural land mindful of a population growing at an annual rate of two percent or more and raising a challenge to produce necessary food and natural fiber. Concurrently, in the light of an almost fully exploited source of water, the Nile, a water management approach that neither takes water requirements as given nor exclusively concentrates on finding new resources to meet them is considered crucial for sustaining the "leaving old land" scenario. It is additionally believed that a conservation (or demand management) approach is generally preferred to working out new water supplies for being able to rise levels of consumption to be met using less investments (FAO, 1995). In addition to their role in strengthening reclamation endeavors, Nile water savings are viewed as a means of avoiding frustration to the promotion of Egypt's main source of water through an adoption of various measures that aim at reducing water waste and losses.

Promoting Water Availability through Recycling

To get the maximum benefit from Egypt's available water sources, a recycling approach is considered by the MPWWR when planning and operating local water systems. In this context, the pursued measures include (Chitale, 1997):

- Reuse of 0.4 billion m^3 of treated municipal wastewater.
- Reuse of 0.4 billion m^3 of industrial waste.
- Reuse of drainage water to the extent of 4.5 billion m^3.
- Reuse of groundwater to the extent of 3.8 billion m^3 (from recharge by irrigation to the closed aquifer underlying the Nile Valley and Delta).

These measures add a total of 9.1 billion m^3 or a little more than 16 percent to its available surface water supply of 55.5 billion m^3 and groundwater of 0.7 billion m^3. Egypt aims at stepping up the augmentation to 16.7 billion m^3 by the year 2010 when it will also have added a desalinated quantity of 0.5 billion m^3, i.e. to reach a level more than 28 percent of its natural resources of 58.7 billion m^3 likely to be available by then. Details of the reuse-source vis-à-vis the water supply are delineated in table 1.

Table 1. Volume of Reuse-Source vis-à-vis Water Supply in Egypt

		Current (billion m^3)	Projected for 2010 (billion m^3)
REUSE - SOURCE	Municipal wastewater	0.4	1.6
	Industrial effluent	0.4	1.8
	Desalinated	N/A	0.5
	Drainage water	4.5	7.0
	Groundwater (Reuse)	3.8	5.8
	TOTAL of reuse-source	9.1	16.7
SUPPLY	Nile River	55.5	57.5
	Groundwater	0.7	1.2
	TOTAL of supply	56.2	58.7
Augmentation %		16	28

Source: Chitale, 1997.

Penalizing Excessive Cultivation of High Water Consuming Crops

Another approach to economizing on irrigation water implies cutting back on crops of high water consumption. The application of this approach is underway in Egypt through imposing financial penalties on farmers for excessive cultivation of rice and sugar cane. Despite the free delivery of irrigation water to farmers, which is a fixed policy of the MPWWR, a valuation of Nile water supplies to agricultural fields is deemed necessary for determining the value of due penalties.

The economic value of local water diversions for irrigation purposes includes the operation, maintenance and replacement costs (OM&R), the opportunity cost (or economic price) resulting from the limited availability of water, and the sunk costs of existing infrastructure (Ahmed, 1995). OM&R value is averaged over different approaches to calculate the Nile system cost at LE 0.03/m^3 of water (WSP, 1993). This cost is primarily incurred by the Egyptian Government to maintain irrigation and drainage services and is subsequently recuperated from local beneficiaries. As for the opportunity cost, it is noted that this value is taken into account only in the case of short water supply. In such case, the opportunity cost of water may be rated at LE 0.07/m^3, thus bringing the cost of water to a total of LE 0.10/m^3 (Ahmed, 1998). Farmers cultivating high water consuming crops in areas beyond those licensed by the MPWWR are likely to be penalized by paying the full cost of water supplies to non-licensed areas. Finally, it is estimated that carrying out a reduction in rice and sugar cane areas while satisfying the local consumption demand of both crops will result in water savings of up to 4.7 billion m^3.

Practicing Less Fresh Water Consuming Irrigation

In the context of enhancing the water conservation approach adopted by the MPWWR, farmers are introduced with new irrigation practices that aim at reducing the consumption of fresh water in agriculture. These practices include:

- Promotion of night storage: Because it is difficult to expect that farmers can be obliged to irrigate at night, particularly during the winter months, the design of irrigation systems is modified to provide the maximum feasible degree of night storage. If sufficient storage cannot be provided within an irrigation block, the alternative options include: i) allowing spillage to the drains at night and reusing this excess water, or ii) making adjustments at the head so as to reduce the discharge at night.
- Increasing the supplementation of water supplies: Water supplies at canal command level are supplemented, where feasible and appropriate, by means of formal drainage reuse schemes, groundwater development and desalinated water. The main application of local formal drainage reuse schemes for supplemental irrigation is in El Salam Canal, carrying water to Sinai. Groundwater is developed as a means of relieving local water shortages particularly in the Nile Valley and in the Upper fringes of the Delta. The use of desalinated water is developed in the coastal regions mainly to supplement reclamation projects by the North Western coast.
- Introduction of short age varieties of crops: Many high water consuming crops are currently replaced with new varieties of shorter age. This include the cultivation of short age varieties of rice that may last down to 100 days compared to 180 days attributed to traditional varieties. The objective is to reduce the exposure time of water ponds, associated with rice cultivation, to evaporation. In addition, this approach will eventually allow the cultivation of two crops per season, thus doubling the production of rice.
- Land leveling: Laser technologies are increasingly being used for a precise leveling of agricultural land. The objective is to prevent the formation of water ponds resulting from irrigation processes, thus reducing water evaporation.
- Miscellaneous improvement measures: These measures are introduced in the Egyptian irrigation system to ensure good operational and hydraulic efficiencies. They include controlling losses from the distribution system, rehabilitating canals and structures, raising low level mesqas and using modern irrigation systems in new lands.

Market and Non-Market Water Saving Inducements

The market-based water conservation generally refers to using the incentive principle for encouraging farmers to practice less water consuming agriculture. Incentives can entail drawing on the economic value of water to induce farmers to adopt conservation measures. Few experiences of irrigation water pricing have been carried out worldwide (e.g. the San Joaquin Valley in California, USA) with varying indicators of success. However, the Egyptian Government's attitude against irrigation water pricing is supported by several technical reasons, including:

- ❖ The generally small ownership of agricultural land in the Nile Valley and Delta, which renders the issue of metering water supplies to a large number of small farms rather impractical.
- ❖ It is not expected that the high overall efficiency of the Nile irrigation system will be significantly improved as a result of water pricing. This is due to the fact that most water that is lost via canal/drain seepage or from irrigation application onto agriculture fields replenish the underlying closed aquifer, and can subsequently be retrieved by pumping devices.

Moreover, water drained from agricultural lands in the Nile Valley is routed back into downstream reaches of the Nile.

- ❖ Water pricing will have insignificant impact in parts of the Nile catchment where soil has a physical structure that allows the cultivation of specific crops only, thus decreasing the opportunity to consider alternative cropping decisions. For example, the poorly drained soils in the northern parts of the Delta are considered suitable for flooded crops only, such as rice and berseem, being rather inconvenient for alternative crops (Ahmed, 1998).

Non-market water saving inducements include exhortation and education in addition to regulation on water supplies. The latter may include reallocation to less water crops or to more necessary urban purposes. According to the Egyptian experience, the Central Directorate for Water Distribution at the MPWWR is responsible for regulating on water supplies in case of emergencies, e.g. inadequacy of Lake Nasser contents to satisfy diverse water requirements. Regulation on water supplies cannot therefore be considered a sustainable conservation technique that would yield permanent water savings. On the other hand, exhortation and education are practiced through the Water Communication Unit of the MPWWR to promote individual awareness of the importance of water saving measures. As a result of education and exhortation, the formation of local Water Use Association (WUA) is underway to enable a better control over water distribution. Although the WUA experience in Egypt is fairly juvenile, it has a considerable potential for organizing regular maintenance and resolving conflicts (El-Zanaty & Associates, 1998). No quantifiable results of water saving due to non-market inducements are yet available.

Egypt's Resolve to Reclaim New Lands

The best alternative use of irrigation new supplies resulting from the depicted conservation approach is envisaged through one of the following courses of action:

- Increasing irrigation quantities on existing cropping patterns, which implies diverting more water to the current patterns in order to obtain maximum yields.
- Changing cropping patterns to more water consuming crops.
- Reclaiming desert lands and maintaining the current profile of cropping patterns in the traditionally cultivated alluvial lands.

Scrutinizing these alternatives would reflect the fact that increased irrigation quantities are unlikely to generate improved crop yields because the heavy clay soils of the old land are generally over-irrigated. Moreover, changing cropping patterns to more water consuming crops is in a collision course with the principle of water conservation. On the other hand, desert reclamation is viewed by local experts and decision makers as an ideal alternative that will bring about optimum benefits of water savings achieved in the light of the country's need for both "food" and "space".

Desert reclamation has increasingly been considered in the context of strategic development since 1952. Starting from 1997, the MPWWR has launched two reclamation plans of short and long-term scopes. The short-term plan 1997-2002, delineated in table 2, implies the reclamation of 1.2 million Feddans remaining from previous five-year plans. Having a longer time span (up to the year 2017), the second plan aims at completing reclamation of a total area of 3.4 million Feddans of which 2.55 million Feddans are planned for reclamation using surface water, reused drainage water and treated sewage. Details of these areas and attributed water resources are shown in table 3.

Water requirements of reclamation areas may be calculated according to evapotranspiration rates recorded in different reclamation regions. Accordingly, averaging records of evapotranspiration results in an annual water requirement in the range of 8,000-10,000 m^3/Feddan, including a leaching requirement estimated at 20 percent of the total water requirement. Taking 9,000 m^3 as an average value of water required per reclaimed Feddan and assuming a net area of 90 percent of the gross reclamation area, it is estimated that some 20.7 billion m^3 of water are required to satisfy the gross 2.55 million Feddans projected for reclamation using Nile originated water. Excluding potential desalinated water, previous sections of the current study showed that a total amount of 20.9 billion m^3 could be saved through recycling of water and penalizing the cultivation of high water consuming crops, which is deemed an adequate amount for covering the depicted reclamation requirements.

Discussion and Conclusions

The present research brings into focus water saving techniques adopted to promote water availability in Egypt. In addition to avoid frustration to the development of the country's sources of water supply, the objective of the conservation approach is to allow carrying out desert reclamation plans. The latter are identified as a means of alleviating population intensity in the Nile Valley and Delta as well as bridging the gap between food production and population growth.

The study showed that saving irrigation water through cutting back on agriculture provides no practical solution to the issue of country development. This is because of small land properties and the dependence of a large sector of Egyptian workers on agriculture as their only opportunity for employment. Because studying the potential for augmenting water supplies was almost exhausted in previous research endeavors, water conservation is viewed a new promising approach to promoting water availability. In this context, reviewing several measures of water conservation in Egypt resulted in a possible saving of 20.9 billion m^3 (excluding a 0.5 billion m^3 of potential desalinated water) through recycling of water and penalizing the cultivation of high water consuming crops. This water amount is deemed satisfactory for covering the requirements of a gross area of 2.55 million Feddans planned for reclamation using Nile originated water.

The unique characteristics that typify the Egyptian agricultural system necessitate tailoring a special water conservation system to suit local conditions. A plain replication of international water saving experiences that imply water pricing may be unfavorable in the light of technical and political hindrances against the application of irrigation water pricing in Egypt. A conservation approach is alternatively required to offset the absence of full market forces through amalgamating suitable water saving measures in an integrated conservation policy that recognizes the growing scarcity of water without upsetting diverse local concerns. It is recommended that further researches be carried out for conceiving the best approach to be adopted in this regard.

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Table 2. Projected Reclamation Areas up to 2002 (1000 Feddans)

Region	Projected Reclamation Areas	Reclaimed Areas	Areas under Reclamation	Remarks
El Salam/Sinai	620	75	545	
East Delta	517.5	193	324.5	
Middle Delta	124	51	73	
West Delta	686	372	314	
Middle Egypt	96.5	60	36.5	
Upper Egypt	135.6	64	71.6	
TOTAL	2179.6	815	1364.6	of which 148 have already been reclaimed away from the Government plan

Table 3. Projected Reclamation Areas up to 2017 (1000 Feddans)

Water Resources	Land Areas in Million Feddans	Land Location
Surface Water and Reused Drainage Water	1.2 0.5 0.55 0.05 **2.3**	• Achieved through previous plans • Toshka Project in the South of Egypt • Upper Egypt • West Delta
Groundwater in Western Desert and Sinai	0.5 0.1 **0.6**	• Western Oases, East Oweinat and Darb El Arbain • Sinai
Treated Sewage Water in Greater Cairo and Alexandria	0.2 0.05 **0.25**	• Areas between Ismailia and Suez Desert Roads, in addition to areas surrounding the southern part of Alexandria Desert Road up to Sadat City • Green belt around South Borg El Arab city
Water Yield from Jonglei Canal	0.25 **0.25**	• Middle Sinai
TOTAL	**3.4**	

WATER AVAILABILITY AND CONSERVATION IN SUDAN

Ahmed Adam Ibrahim[1] & Salih Hamad Hamid[2]

1. INTRODUCTION

Water conservation programs in Sudan are necessitated by the fact that Sudan is already categorized to be one of the African countries suffering water scarcity problems (850-1275/m^3/cap). A condition, which seriously threatens the future of the coming generations under the current relatively high growth rate (2.8%).

Overarching policies have been formulated, mainly focussing on sustainability of water resources development through first: the encouragement of more efficient use of the available water to boost the agricultural production in a way to enhance the welfare of farmers and consumers. Second: increasing water availability through the conjunctive use of ground water and water conservation programs. Third: protecting the natural water resources to ensure their use in an environment friendly manner.

As the country depends largely on the waters coming from outside its borders, basin wide water resources development is necessary. The Sudan national water policy recognizes the scarcity of water resources confronting all the sub-basin states and the consequent necessity for basin wide cooperation to develop and conserve the shared water resources.

This paper addresses water resources availability and utilization issues in the Sudan, and highlights the current efforts to conserve water to maximize its productivity.

2. WATER RESOURCES AVAILABILITY

Local precipitation, surface flow coming from across the borders and ground water are the only type of water resources in Sudan. The main topographic and climatic characteristics that govern the nature of these water resources are the following (Ibrahim 1997)):

(1) The continental climate, with mean annual rainfall gradually decreasing from about 1400 mm in the southwestern borders to almost zero in the northern parts of the country (Sahara desert);

(2) The river Nile and its tributaries traversing the country from south to north;

(3) The topography dividing the country into three distinct drainage systems; inland system, Red Sea system and Lake Chad system, occupying 92.3%, 4.3% and 3.4% of the area of the Sudan respectively; and

(4) Scattered water bearing aquifers, under not more than 60% of the area of the country.

2.1 Rainfall

The normal amount of rainfall in the Sudan is estimated by about 1050 km^3 (Adam et al 1999). As is the case for the annual precipitation rates, the rainy season also decreases from about 260 days in the south to few days in the north. Accordingly, Sudan is divided into seven climatic zones ranging from the tropical super humid to the desert characteristics. It is worth noting here that about 65% of the country falls under continuously water deficit climatic zones which include desert, semi-desert, dry and semi-dry zones, (fig. 1).

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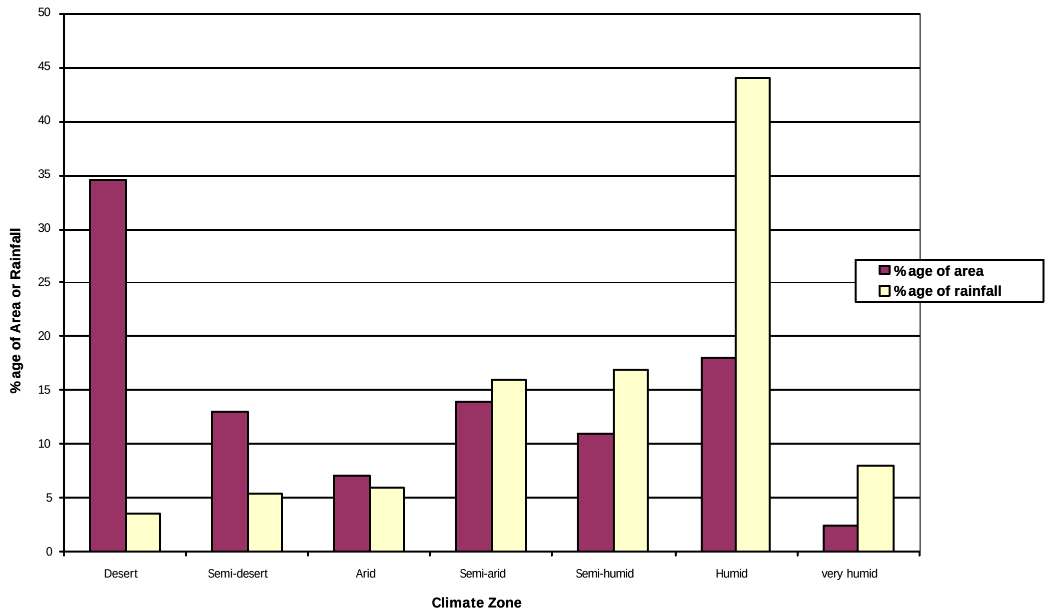
Fig .1 : Percentage of Rainfall on the Different Climate Zones in the Sudan



It is also worth mentioning that clear decreasing trends of the annual rainfall in the different climatic zones are shown in the last seven decades (Ibrahim 1997). The reduction being more significant in the semi-dry and semi-humid climatic zones. This has reduced the reliable rainfed agriculture zone to less than one fifth of the area.

2.2 Surface Water

Surface water resources are of two origins:

(a) Water coming from across the border represents 77% of the total annual renewable water resources. These border crossing water resources are the following:

- the Nile basin system contributing about 20.55 km^3 as restricted by the 1959 Nile Water Agreement; and
- the Non-Nilotic seasonal streams, namely: Gash and Baraka rivers which contribute about 1.2 and 0.8 km^3/year respectively on an average.

(b) Inland generated surface runoff, which is estimated by about 47.9 km^3/year (only 4.6% of the normal annual rainfall).

Almost 80% of the surface runoff generated within the inland drainage system is lost through evaporation in the Sudd area (White Nile System). The remaining 20% is mostly lost in the form of infiltration and ground water recharge under sand dunes and the loose soils of the northern parts of the country.

2.3 Ground Water

Ground water is estimated by about 560 km^3, with an annual recharge of about 1.6 km^3. Reasonable water bearing aquifers are found at considerable depths below the ground surface (25-400 m), and mostly in remote areas of the Sudan. Nevertheless, ground water is one of the most important water resources in the country, contributing to about 80% of the present domestic water needs, and almost all the prospective agricultural developments in the areas far from the reach of the Nile waters.

3. WATER UTILIZATION

Recent reports (Ibrahim 1997) & (IGAD 1999) have shown that Sudan falls among the countries that suffer water scarcity in Africa (850-1275 m^3/cap.). Moreover the latest census has revealed a relatively high average growth rate (about 2.8%), which implies that Sudan population will double within the coming few decades. Thus, the limited water resources of the Sudan need to be carefully managed in order to attain to efficient and sustainable management levels that comply with the diverse needs e.g. domestic, agriculture, industry, recreation, navigation, …etc.

The present water consumption is about 16 km^3, about 90% of which is contributed by the Nile system. The future needs are targeted to reach some 30 km^3 by the year 2010 (Ibrahim 1997) Table (1). However, irrigated agriculture has shown to continuously consume far more than 90% of the tangible water resources. Thus, all national and/or regional water conservation programs must focus on the irrigation sector.

The targeted goals however are obstructed by the seasonal variability patterns of the tangible water resources, namely:

- Flows of the Nile system which fluctuate between about 6 million m^3/day in April to about 700 million m^3/day in August. A condition which can only be overcome by sufficient storage.
- High coefficient of variation of the annual rainfall, which increases from about 13% in the tropical super humid zone to more than 80% in the desert zone.

Table 1. Present Use and Future Needs of Water Resources

Consumption Sector	**Present Use Km^3**	**Future Need Km^3**
(1) Domestic	0.78	1.50
(2) Industrial	0.15	1.00
Sub-total	0.93	2.50
(3) Agriculture		
Nilotic	14.0	24.20
Non-nilotic	0.70	2.60
Ground water	0.40	1.0*
Sub-total	15.10	27.80*
Grand Total:	16.00	30.30*

*Subject to groundwater studies

Source: "Sudan Water Resources Assessment" A.A. Ibrahim, 1997.

3.1 Overarching Policy Principles and Objectives

Out of the 12 overarching principles and objectives which ultimately discharge into conservation of water resources in terms of sustainable water resources development and management, the following may be recited (Sudan, National Water Policy 2000):

(1) water is a scarce and valuable commodity which has to be adequately, economically and efficiently used;

(2) all water, including surface and ground water, form part of the hydrological system and should be managed in an integrated manner;

(3) the development of water resources will be undertaken in order to maximize its benefits in the public interest whilst ensuring minimum adverse impact on the environment;

(4) water and water related issues are an integral part of a wider economic domain and have direct effects on many other sectors which require interdepartmental and inter-sectoral communication and cooperation;

(5) the environment needs to be protected in order to ensure sustainable utilisation for present and future generations;

(6) public institutional arrangements at federal and state levels should be integrated, accessible, efficient and transparent whilst avoiding duplication of function and responsibilities.

Additionally, there are policies and objectives that focus on the public awareness and stake-holders participation in the development and management of water resources in a sustainable and environmental friendly.

3.2 Existing Legislations

As legislation is the most important tool for driving the Government policies, Sudan has experienced legislation in water resources since 1928 (resolutions of Gash delta and Tokar Act of 1928). Since then, and prior to 1922 there was fragment development of legislations in the different water resources sectors (ElMufti 1999)..

After the resolution of the national comprehensive strategy of 1992, the Water Resources Act of 1995 has been in effect. The act mainly states the following points:

(1) the ultimate statal sovereignty on water resources and the equal right on the utilisation of water;

(2) giving the Ministry of Irrigation and Water Resources (MOIWR) overwhelming authority on water resources sector; and

(3) establishment of the National Council for Water Resources (NCWR), by a resolution of the president of the republic to be chaired by the Minister of MOIWR.

The NCWR mainly addressed to draw the broad lines for the development and management of water resources through scientifically sound driving tools, taking the sustainability of these resources as a top most goal.

3.3 Water Conservation Related Institutions

As mentioned above, the seasonality pattern of the tangible water resources emphasises the integration of all organizations and institutions working in the diverse sectors of water resources, in order to ensure efficient and effective use of these resources.

The Hydraulic Research Station (HRS) of the Ministry of Irrigation and Water Resources and the Agricultural Research Corporation (ARC) are the main institutions working in the field of water conservation. The two institutions happened to collaborate in most of the interrelated research studies. The broad objectives of the two institutions are the following:

a. **HRS**: to attain sustainable water resources management level through the appropriate research activities that serve the national economic, environmental and social requirements;

b. **ARC**: to maximize the production, improve the quality and to reduce the agricultural production cost.

In the field of water management, procedures being generally followed by the two institutions, are as follows:

- Implementation of the relevant scientific approaches for water resources assessment and allocation;
- improvement of on-farm water use efficiency for the existing irrigation projects. A conservation of about 500 Million m^3 is expected if attended irrigation method is perfectly adopted for sorghum and groundnut crops in the Gezira irrigation scheme (Ibrahim 1992), and a conservation of about 600 Mm^3 is expected if 3 weeks irrigation interval instead of 2 weeks is applied to cotton in the period October to February in the Gezira (El Awad, 2000);
- Reduced system losses and/or adoption of higher efficiency irrigation methods, such as sprinkler and drip irrigation methods;
- Application of relevant water harvesting techniques and supplementary irrigation methods in the non-reliable rainfed regions (ARC 1993/94, 1994/95); and
- Adoption of the most appropriate reservoir operation methods that conserve the storage capacity.

4. IRRIGATION WATER CONSUMPTION

Modern irrigation technology was introduced in the Sudan by the colonial power in 1907 (Zeidab pump scheme: 670 ha), solely for the commercial production of cotton, which was needed to solve the problem of supplies of raw material to the textile industry at the occupiers home country, and simultaneously to provide revenue for the foreign administration of the Sudan region (Fadl 1984 and Yousif 1992).

Over the following decades deep political, administrative and social changes occurred, such that diversification and intensification were conducted with expanding irrigation projects; bringing the total irrigated area to about 1.8 million ha, in late 1970th. Areas and crops of the main irrigation schemes are shown in Table 2.

Table 2. Main Irrigation Schemes Areas & Crops

Scheme	Sources of Water	Operation Date	Area 10^3 ha	Main Crop
Gezira & Managil	Blue Nile	1925	925	Cotton, Groundnut, Sorghum, Wheat
El Guneid	Blue Nile	1961	16	Sugarcane
New Halfa - A	Atbara River	1964	168	Cotton, Groundnut, Sorghum, Wheat
New Halfa - B	Atbara River	1964	17	Sugarcane
Es Suki	Blue Nile	1971	38	Cotton, Sorghum, Groundnut
North West Sennar		1974	13	Sugarcane
Kenana	White Nile	1976	38	Sugarcane
Asalaya	White Nile	1977	15	Sugarcane
Rahad	Blue Nile	1979	126	Cotton, Groundnut, Sorghum, Wheat
Total			**1356**	

A direct result of the vast increase in irrigation projects was ultimate increase of the irrigation water consumption to account for about 94% of the current consumptive use of water in the Sudan, and to remain more than 90% of the targeted consumptive use in the near future

(Table 1). This is due to the fact that irrigated agriculture accounts for 50% of the total agricultural output, though it represents only 20% of the annual cropped area. The variability of rainfall in most of country is behind the extremely small and non-stable contribution of rainfed areas.

It is worth mentioning here that:

(1) More than 97% of the irrigated areas fall within the Sudan Central Clay Plain, which is known for its negligible water losses through deep percolation, thus:

- subsoil moisture fluctuations under cropped fields are confined within the root zone (Ibrahim et al 1999).
- On-farm water use efficiency is governed by the irrigation practices and any amount of water left on the surface will be lost as free surface evaporation.
- No canal lining is ever needed, and the conveyance losses are also limited to the evaporation processes.

(2) A combination of short furrow and basin irrigation method is commonly used in Sudanese irrigated agriculture. The technique is unique to Sudanese agriculture. However, the long furrow method is being adopted in the sugarcane schemes.

(3) National schemes comprise about 70% of the Sudanese irrigated area. Thus the national irrigation schemes must be addressed if saving and/or conservation of water is concerned. A good example in this respect is the Gezira irrigation scheme (0.925 million ha) which almost consumes 50% of the irrigation water of the Sudan. Savings of only 25% of the Gezira water could enable the development of extra 130000 ha.

5. WATER CONSERVATION IN THE SUDANESE IRRIGATED AGRICULTURE

Almost 70% of the irrigated areas are served from the Blue Nile Waters which is known by its high variability. Large storage facilities are therefore necessary to ensure a smooth water supply throughout the different hydrologic seasons. However, and due to the limited storage sites, the existing storage capacity on the Blue Nile is only 29% of the system's total crop requirement. Thus the irrigation requirements in the Blue Nile system are usually met by supplementing the river natural inflows.

The problem arises in drought years or even in abnormal years when the recession flow curves fall below the normal, thus leading to early withdrawal from the storage, which could be completely exploited midway before the following flood and subsequent shut-off of the main hydropower station in the country. Consequently, the irrigation authorities are obliged to implement a water conservation policy aiming at optimizing the use of the available water, together with the decision on:

- Whether to reduce cropped areas, or
- Whether to allocate the available water for the full command area, with high possibility of shutting-off the main hydropower station in the middle of the dry season.

During the last two decades, the Blue Nile irrigation system has experienced two distinct hydrological years, namely 1984/85 and 1995/96 seasons. In the former, the river flow was at the lowest record during the last 50 years, while in the later, although the river flood was not significantly lower than the average, the recession flow curve was abnormally lower than all expectations.

The decisions to cope with the problem of water supplies in both cases were completely different. In 1984/85 dry season, a traditional decision of restricting the irrigated area to a portion of the command area was taken. A direct result was the abundance of over 100,000 ha already planned to be cropped with wheat in the Gezira Scheme alone.

However, in 1995/96 season, and under the pressing needs to keep the main hydropower station operating at least at its minimum generating capacity during the dry season, as well as optimizing the food grain production, a well designed and implemented water conservation policy was enforced.

A High Committee for the Best Utilization of the Blue Nile Waters has been formed. It is an inter-disciplinary technical committee in which water users of different sectors are represented. The high committee is answerable to a high Ministerial Committee. Scheme level committees comprised of irrigation Engineers, agricultural officers and farmers leaders to ensure their full participation are also set up. Water is released from the system to each scheme according to its actual crop water requirements to be distributed under close supervision of the scheme level committees.

To guess the success of that policy, one example is given below in which the productivity of water use in one of the Blue Nile irrigated schemes is increased by 68% compared to the previous year. This is achieved while water saving amounted to 14% in one of the main crops which are sown and harvested under the 1995/96 water conservation policy.(Table 3).

Table 3. Productivity & Water Savings
Rahad Scheme Season 1994-95 & 1995-96

Season	**1994-95**	**1995-96**
Area (feddan)		
Cotton	58560	68770
Wheat	47410	39430
Water Use in Million m^3/feddan		
Cotton	6330	5490
Wheat	3920	3380
Productivity of Water Use Kg/m^3		
Cotton	0.035	0.038
Wheat	0.101	0.170
%age Increase in Productivity		
Cotton	-	8.6%
Wheat	-	68%
%age in Water Saving		
Cotton	-	13%
Wheat	-	14%

Source: Salih Hamad Hamid & Osman E. Hamad, June 2000
1 feddan = 0.42 ha.

The 1995/96 season exercise and the great efforts and success achieved by the High Committee in the following seasons, have shown not only the capability of the irrigation authorities to manage water under scarcity conditions, but also their success in getting different water users aware of water as a valuable scarce commodity, thus participating actively in decision making process as well as in the implementation.

6. IRRIGATION FINANCING ISSUES

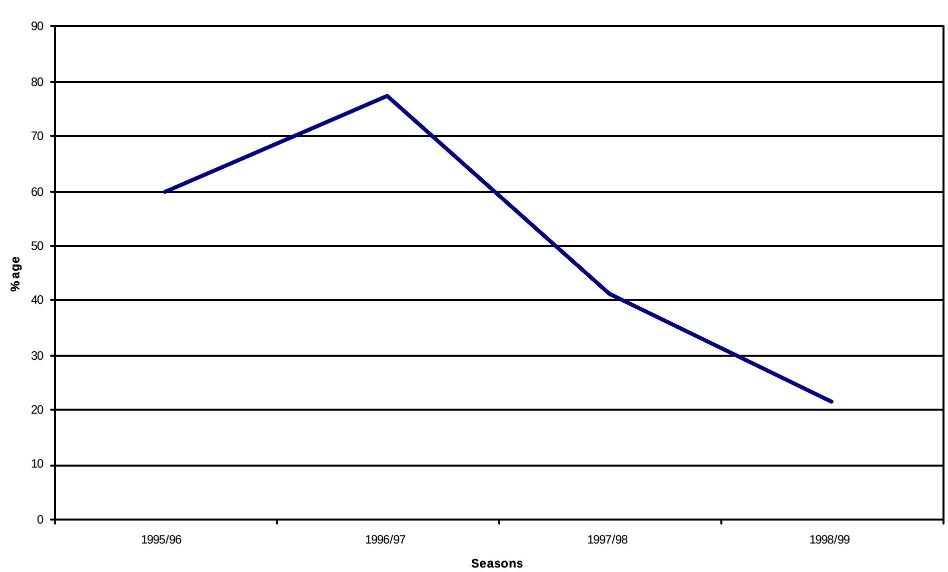
Irrigation systems in Sudan are dominated by four large scale irrigation schemes which represent more than 60% of the total irrigated area (Gezira and Managil = 925,000 ha, Rahad = 126,000 ha, Es Suki = 38,000 ha, and New Halfa = 185,000 ha). While small scale irrigation systems are operated and financed by the private sector, the government owns, operates and finances the large scale systems.

Historically governmental funds were available in accordance to distinct production relations. A joint account relation was in operation until 1980/81. Under this method the shares have essentially remained the same with slight modifications in favor for the tenants, and ended up as follows: 38% to the government, 49% to the tenants, 10% to the management body and 3% to the social development fund.

Being not encouraging among the producers, the joint account was abolished in 1981 and replaced by the individual account in which each tenant is responsible for all costs of production. He also has to pay for land and water charges to the government, and the net profit would go to the tenant after the deduction of all individual costs.

In 1993, the Government decided the implementation of the policy of restructuring and reforming of the agricultural schemes in accordance with the state policies of liberalizing the agricultural sector and removing procedural and institutional barriers that hinder the production. Accordingly, a consortium of commercial banks was set up to provide the necessary funds to meet the agricultural production needs. As well as the Operation and Maintenance (O&M) costs for the irrigation systems. However, the bank consortium could not manage to meet the financial requirements properly, (due to the high amounts of money required) (Fig.2).

Fig. (2): %age of Available Funds for the O&M Activities



The financial problem has thrown its shadow on the irrigation systems. As a result of insufficient funds to meet the O&M activities. This has, consequently been reflected as sharp decline in the productivity of all crops. (Hamid S. H. & Mohammed Y. A. 1999). The irrigation systems have been serious affected.

As a result the Government decided in 1999/2000 to provisionally retain financing arrangements. Meanwhile efforts for improvements in the fields of irrigation water use and the agricultural performance are underway. It includes the improvement of the irrigation systems for effective use of the available water, boosting the production for the benefit of the producer, liberalizing the prices and eliminating all the previous procedural handicaps that used to cripple the producer and disable him from obtaining the best from his efforts. It is aimed to create a real tenant who will at the end have all the chances to participate actively in deciding and setting the policies of his agricultural production. Water users participation is one of the promising ideas which is currently getting momentum to be introduced in the Sudanese large irrigated schemes, as that is the only way which may guarantee the utilization of the resources to the best levels.

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