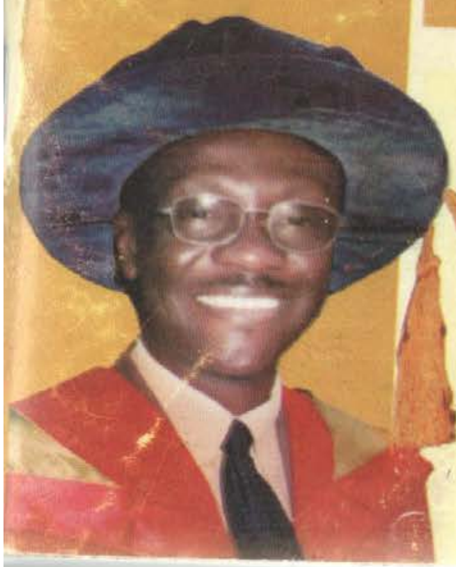
IRRIGATION
DEVELOPMENT AND PRACTICE IN NIGERIA

The Good, the Bad, and the Ugly



INAUGURAL LECTURE SERIES 7

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Great Ladokites,
Ladies and Gentlemen.

1.0 PREAMBLE

I feel greatly honoured to be given the opportunity to present the seventh in the series of inaugural lectures of this great University. Inaugural lectures either address contemporary issues which are germane to the progress of the society or encapsulate much of the research activities of the lecturer. Some inaugural lectures address the academic community on important issues of mutual concern, while some present the progress of activities in a discipline and the manner in which these represent contributions to knowledge and society in general. They also provide a unique opportunity for the lecturer, to discard the technical jargons of professional language and speak *ex-cathedra,*(that is, to just say anything about his discipline) and tell the community what he and his field of study are all about. This latter, Mr Vice-Chancellor, ladies and gentlemen is what I intend to do today.

This lecture is significant to me in three ways: first, it is the first inaugural lecture from the Faculty of Engineering and Technology and in particular from the Department of Agricultural Engineering. Secondly, today 1st March, 2012 marks my 20th year in the services of our own dear University; Ladoke Akintola University of Technology (LAUTECH) Ogbomoso and thirdly, this is the Seventh in the series of inaugural lectures of this great University, being delivered by the seventh child in a family of eighteen. The number seven (7) usually connotes completeness or perfection. Perhaps, that was why in my search for a topic for this inaugural lecture, the desire to take a holistic look at an aspect of my discipline- Irrigation in Agricultural Engineering- with a view of disclosing the benefits and limitations of irrigation development and practices with emphasis on the social, economic, and environmental impacts of irrigation practices, were topmost on my mind.

On one hand, most of my research works are in this area and on the other hand, being a former resident of Northern Nigeria, where irrigation practice predominates, especially during the early days of my career, I had on the spot experiences of some environmental impacts of irrigation. Mr. Vice-Chancellor, sir, distinguished colleagues, ladies and gentlemen, permit me therefore, to address you on the topic ***"Irrigation Development and Practices in Nigeria: the Good, the Bad and the Ugly"***

I want to pose this question: Is there anything or anyone who or that is all good and has no bad or ugly side (save God)? I challenge you to raise your hand, if your response is in the affirmative. Even the Levites (with due respect) do have their ugly side –after all they are human. What really makes the difference is in knowing, managing or preventing the bad and ugly sides. So Mr, Vice Chancellor, sir, I posit that in everything and everyone, there

exists the good, the bad and the ugly aspects. Irrigation Development and Practices, therefore, is no exception to this rather general rule.

I shall, therefore, in this lecture take us on a journey to these three "towns" in irrigation development and practices, with the aim of making recommendations that will assist us in attaining the goal of self-sufficiency in food and fibre production- after all, as the Yoruba adage goes: *"Ti ebi ba kuro ninu ise, ise buse."*Translated literally"Poverty disappears/diminishes when hunger is eliminated".

2.0 THE CATALYSTS / IN THE BEGINNING

Vice Chancellor, sir, my first conscious contact with "irrigation or its failure" was at the age of nine, when my beloved teacher, Mr. S.O.Fehintola (fondly called Up You),in 1964 while teaching Agricultural Science, instructed every pupil to produce a well-watered potted plant in three weeks. Sadly, my plant which germinated quite earlywiltedbefore the deadline after constant watering.He later explained, lovingly, that I had "added" too much water to my plant. Later on in my career, I realised that I may have held on to the age-old dictum that "if a little of something is good, then, more must be better." I had over irrigated. However, my earliest direct contact with formal irrigation was during the student Industrial Training in 1977/78 (now called SIWES) at the now defunct Funtua Agricultural Development Project (FADP) which covered the then Kaduna State (Now Kaduna and Katsina States), where I was exposed to and involved in the construction of small earth dams for small scale shaduf/pumped irrigation in and around Funtua to Katsina. A major problem observed was the large seepage through the constructed embankments, which perhaps led to the failure of the Yankara dam which was still under construction (Ojediran, 1978). This culminated into my B.Sc. project (Ojediran, 1979), supervised by Dr. G.A. Alade, on the "Design of a Small Earth Dam". The work traced the optimum seepage line through a small earth dam and recommended the inclusion of gravelly toe drain in small earth dams to accommodate the inevitable seepage through the embankment.

The vivid improvement in the level of crop production around Funtua, the observable excitement of farmers and the realisation that the water impounded by "us" had transformed the environment, thrilled me and the experience has kept me in researching and teaching irrigation till date.

I must say, at this juncture, that I am an ardent protagonist of irrigation, butan article by a colleague, Ezeh, F.C., in 1981 at the Polytechnic of Sokoto State (Now UmaruWaziri Federal Polytechnic) Birnin-Kebbi, titled "Mechanization: Is it all good and no bad?" challenged the whole essence of Mechanized Agriculture and Irrigation. This seeming "effrontery" on my profession may havefurther triggered-off my search into "Impacts of Irrigation".

3.0 IRRIGATION

As a way of laying a foundation for the main thrust of this Lecture and avoiding any confusion, I would like to start by attempting a brief discussion on the concept of Irrigation, its scope and methods to provide this "august" audience with the fundamental background of this very important aspect of my discipline; irrigation development and practice

3.1 Definition and Scope

Irrigation has been generally defined as the "application of water to the soil for the purpose of supplying the necessary moisture essential for plant growth." A more comprehensive and all encompassing definition by Hansen *et al.*, (1979) is that, irrigation is the application of water to the soil for any number of the following purposes: To

- supply the moisture essential for plant growth,
- provide crop insurance against short duration droughts,
- cool the soil and atmosphere, thereby making more favourable environment for plant growth,
- reduce hazard of frost,

- wash or dilute salts in the soil ,
- soften tillage pan and clods ,
- reduce the hazard of soil piping .

This latter definition is, perhaps, the reasonwhy irrigation is not just the exclusive preserve of a particular region of the world. It is practiced worldwide. In the arid and semi-arid regions of the world, where long drought is common, crops depend primarily on irrigation to curtail the adverse effects of the long drought between rainfall on their growth and yields – called **total irrigation.** Also, in the humid regions, normal rainfall has been observed not to supply throughout the planting season adequate moisture to satisfy the soil-plant water requirements and irrigation has been used as **supplement** to the rainfall to achieve adequate growth and yield.

Even in the rain forests of the world, natural rainfall sometimes fails during the sensitive period of crop development. This may be during the vegetative growth of some crops or fruiting stage of others. The only recourse, therefore, is to supply the deficit through irrigation. Agriculture is time-bound; hence moisture deficiency at such sensitive stages could lead to crop failure or drastic reduction in yield and consequently food insecurity that year or season. So, whether as total or supplemental, irrigation aids all-year round farming, adequate growth and consequently improved yield quality and quantity. Irrigation is all about control of water for food and fibre production.

3.2Historical Background

Irrigation has been practiced for millennia; it is, in fact, called an age-old art. The possible earliest record is found in Genesis 2: 8 -10.

"And Jehovah God planted a garden in Eden, in the east, and there He placed the man He had formed... A river went out of Eden to water the garden."

Another record was of an ancient Assyrian Queen supposed to have lived before 2000 B.C, who directed her government to divert the Nile to irrigate the dessert lands of Egypt. On her tomb were these inscriptions:

"I constrained the mighty water to flow according to my will and led its water to fertilize lands that before had been barren andwithout inhabitants" (Hansen et al., 1979).

Fukuda (1976) also confirmed that the earliest civilizations which developed along the Nile, Tigris, Euphrates, Indusand in Latin America about 6000B.C. were related to irrigation practices around these areas. Since these early dates, irrigation has developed from the very crude (simplest) method of wild flooding of the soil surface to the more modern or sophisticated Centre – pivot and Drip systems with the aim of maximising crop production and optimising water use.

Vice Chancellor, sir, ladies and gentlemen, let me proceed by discussing the different systems of irrigation used in distributing water onto the fields for crop production.

3.3 Methods of Irrigation

Clearly, the success of every irrigation project rests largely on the adequacy and dependability of its water source and supply. Sources of irrigation water are wide and varied; these include impoundment of large and small rivers, diversions of streams for storage and reservoirs, groundwater abstraction by pumping and off-stream water reservoirs. Water obtained from these sources is then spread on the field surfaces using different irrigation methods.

The methods of irrigation used on the very early schemes were simply uncontrolled flooding of the soil surface to ensure supply of essential soil moisture. These methods have been further developed taking cognisance of the inherent disadvantages of each method and other developments in technology.

The many types of irrigation methods/ systems developed to suit different crops, topography, soil types, water resources, climatic condition and costs fall into one of three main categories:

(i) Surface irrigation
(ii) Sprinkler or overhead irrigation and
(iii) Micro- irrigation (Drip/trickle)

i) Surface Irrigation.

The practice of surface irrigation is ancient and is used on more than 90% of the world's irrigated area. In this system, water is directly applied to the surface of the soil from conveyance system;channel or pipe located at the upper reaches of the field and is spread by gravity flow incidental to the slope of the land. The surface method of distributing or spreading water on the soilfalls into three categories viz: **Basin, Border or Furrow**, depending largely on crop,soil and topographic factors.

The **Basin** method consists of applying water to levelled fields bounded by dikes/ridges. Three different types are commonly used: one for paddy rice where ponded water is maintained during the cropping season, another for field crops where ponding time is short until applied volume infiltrates, and the other for tree crops called ring basin where the ridge is used to form a ring around each tree and water is applied until it infiltrates and fills the root zone.

In the **Border** method, the field is divided into sloping strips of land separated by parallel dikes or ridges. Water is applied at the upstream end and moves as a sheet down the border. It is used primarily for close growing crops and best suited for areas with low slopes, moderate soil infiltration rates and large water supply: Border width typically varies from 5 – 60m, while length as long as 900m may be used depending on advance and cut-off time and soil factors.

In **furrow** irrigation, small regular channel, between ridges/or rows of crops direct water across the field. These channels, called furrows, serve both to convey water access to the field and as a surface through which infiltration takes place. This method is commonly used for row crops planted on beds or ridges. The length of furrow depends on furrow slope and soil infiltration rate. However lengths are commonly between 200 – 400m, while shorter lengths are required for soils with high infiltration rates.

These methods have the advantages of easy water application and requiring minimal skill. However, in real terms, they have disadvantages, a few of which are:

- High evaporations rate due to open water surface
- Lower end run-off Deep percolation (losses)
- Require large water volume
- Affected by soil variability
- Prone to erosion (if not well managed)

Fig. 1: Furrow Irrigation. (Source:CIGR Handbook of Agric. Engineering)

ii) Sprinkler/Overhead Irrigation.

In this system, water is applied to the soil in form of thin spray from above, similar to rainfall. This was developed to solve the observed problems of lower end run-off, evaporation from open water surfaces and deep percolation losses which were inherent in the surface irrigation methods.

A typical sprinkler system consists of a pump which lifts and conveys water under pressure, pipes or tubing for conveyance of water, sprinkler heads or

nozzles and risers which connect the sprinkler head with the pipeline. Based on the equipment with which spraying is done, the sprinkler system has been classified as the rotating head type and perforatedheadtype.

Fig. 2: Sprinkler Irrigation System. (Source:Jain Irrigation Systems Ltd.)

Self propelled sprinkler systems have been developed which move laterally or radially around a central pivot feeding line, namely Centre Pivot System (Fig. 2a,) and the Rain Gun (Fig.2b).

Fig.2a:Center Pivot System(Source: Spectrum Analytical Incorporation).

Fig.2b : Rain Gun.(Source:Vedant Enviro Agro & Irrigation(P) India)

Despite the numerous advantages of the above systems over the surface system, which include high efficiency and reduced water loss due to evaporation, problems inherent with this method include poor water distribution in windy environment, high initial capital cost, highlylabour intensive especially for portable systems, problems of intensity of application, droplet size, high energy cost and soil structure destruction due to impacts of water drops leading to crust formation on the soil.

iii) Drip Irrigation.

In a further attempt at solving some of the problems or disadvantages of the two earlier systems, the drip method (Fig. 3) was developed. This system of irrigation involves the slow application of water, drop by drop, directly to the root zone of the crop by the use of nozzles called emitters (Fig.3a). The equipment consists of a pumping unit to create pressure of about 2.5kg/cm^2, a filter unit to remove the suspended impurities in the water and pipelines which may be of PVC tubing with drip nozzles or emitters.

Fig. 3: Drip Irrigation System.(Source:Dupriez and de Leenar, 2002)

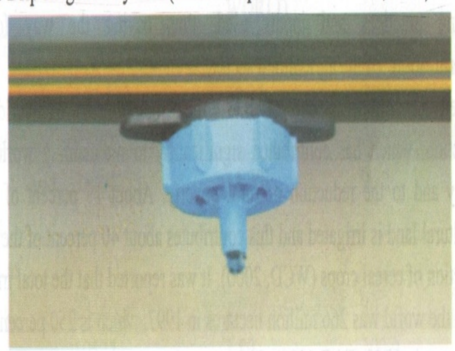

Fig.3a Drip Emitter(Source: Wikipedia, 2012)

The spacing of the emitters, and thus the layout and cost, depend on the crop spacing, rooting pattern and soil characteristics. Emitters may be as close as 20cm apart for closely spaced, water sensitive crops with small rooting system. This system is commonly used for vineyards/tree crops. Despite the advantages of efficient water use, minimal evaporation loss, and near zero deep percolation, the initial capital cost is very high. The emitter and tubing requirements for drip vary from 2500 emitters and 3000 in tubing per hectare for widely spaced trees and 20,000 emitters and 15,000m tubing per hectare for closely spaced vegetable crops.

Drip irrigation is used on less than two percent of irrigated lands Worldwide.

3.4. *Global Picture of Irrigation Development and Practice.*

Irrigation originated as a method for improving agricultural production by increasing the productivity of available land, especially in the arid and semi-arid regions of the world. Availability and access to irrigation was considered essential for crop production, asset creation and expansion of development frontiers. Rapid expansion of irrigated areas in the recent past, coupled with availability and access to new technology of high yielding varieties, fertilizers and water abstraction mechanisms, in the late 1960s and 1970s were major underlying factors for the success of the green revolution in most parts of the World. Better access to irrigation infrastructure facilitated intensification of cropping practices and inputs used, thus paving the way for the "modernization" of the agricultural sector.

Irrigated agriculture is one of the critical components of world food production, which has contributed significantly to maintaining world food security and to the reduction of rural poverty. About 17 percent of global agricultural land is irrigated and this contributes about 40 percent of the global production of cereal crops (WCD, 2000). It was reported that the total irrigated area in the world was 266 million hectares in 1997, which is 250 percent more than it was in 1950 (FAO 1998). The per capita per year cereal production in developing countries has increased from 200 kg during the early sixties (1961-65) to more than 260 kg in 1997. This is despite the fact that world population has increased from 3 billion to 6 billion during the same period; close to 5 billion in the developing world alone (FAO, 2000). In addition to food security, irrigated agriculture significantly contributes towards generating rural employment and maintaining rural livelihoods, which is particularly important in the context of declining real world market food prices during the last two decades.

Probably in awareness of the numerous benefits that are derivable from irrigation, several schemes were developed around the World. Ambitious engineering works were also included in most schemes, tagged medium and

large scale. Table.1 shows the detailed regional spread of irrigated areas in the World.

These data show that a total of approximately 277 million hectares of irrigated land around the World with Asia and Africa contributing about 70% and 5% respectively.

Table 1: Irrigated Areas in Various Regions of the World 2003.

REGION	IRRIGATED AREA'000(HA)	%OF TOTAL IRRIGATED AREAS IN THE WORLD	CUMULATIVE PERCENTAGE.
Africa	13,370	4.82	4.8
Asia	193,890	69.97	74.8
Europe	25,208	9.10	83.9
North and central Americas	31264	11.28	95.2
Oceania	2844	1.03	96.2
South-America	10522	3.80	100.0
TOTAL	**277,098**		

(Source : FAO, 2000)

TableA (Appendix A) shows the distribution of the irrigated area of countries in Africa. The table shows that the Sub-Saharan region contributes about 3% of the 5% with Nigeria featuring as the third largest in the Sub-Saharan region and the ninth country in Africa.

3.5 Water Resources and Irrigation Development in Nigeria

3.5.1 *Water Resources*

The hydrology of Nigeria (Fig. 4) is dominated by two great river systems, the Niger-Benue and the Chad systems. With the exception of a few rivers that empty directly into the Atlantic Ocean, all other flowing waters ultimately find their way into the Chad basin or down the lower Niger to the sea. The two river systems are separated by a primary watershed extending northeast and north-west from the Bauchi Plateau which is the main source of their principal tributaries. In North-west of the plateau lies the elevated, drift-covered plains of central Hausa-land which is drained by numerous streams all flowing outwards to join the major tributaries.

Nigeria is blessed with a vast expanse of inland freshwater and brackish ecosystems. Their full extent cannot be accurately stated as it varies with season and from year to year depending on rainfall. However, the water resources are spread all over the country from the coastal region to the arid zone of the Lake Chad Basin (Kuruk, 2007). Freshwaters start at the northern limit of the mangrove ecosystems and extend to the Sahelian region.

The country is divided into Eight (8) Hydrological Areas (HA) by the Nigerian Hydrological Services Agency (NHSA), Lagos. Table 2 and Fig. 4 show the divisions, locations, total and percentage area covered by each HA.

Fig. 4: The Hydrological Map of Nigeria.

Vice Chancellor sir, the common maxim "Water, water everywhere and non to drink" maybe apposite to the Nigerian State, given the available statistics which indicate that, Nigeria's surface water resources potential is estimated at 267.3 billion m^3 per annum, while ground water resources stand at 51.9 billion m^3 per annum (Okoye and Achakpa, 2007). These resources, if properly harnessed and utilised, are enough to satisfy all human, industrial, and agricultural as well as livestock needs of the country.

Also according to the National Water Resources Master Plan (NWRMP, 2007) study, the total irrigation potential of the country is about 3.14 million ha; 1.10 million ha for public irrigationprojects and 2.04 million ha for formal *fadama* irrigation projects. Yet only about 4% of the cultivated land area is under irrigation. Estimate of irrigated cropland varies from one source to the other but its total water managed area is estimated to be a little over 950,000 ha. This yields about 10% of the national crop yield. Notably and probably because of the rainfall distribution pattern, the major irrigated areas are found in the Sahelian region of the north especially in the Sokoto-Rima basin, Hadeija- Jama'are and the Lake Chad areas. Other places include the north central and some parts of the middle belt of the Country.

3.5.2 *Irrigation water quality*

Increasing demands for water, limited availability as well as concerns about water quality, make effective use of water essential. Since irrigation, recourse against famine, is a major water user, it thus becomes imperative that irrigation systems be managed efficiently. In order that this be achieved, knowledge of seasonal irrigation requirement would be invaluable to a modern farmer. Besides, the concept of seasonal irrigation requirement affords effective crop planning and irrigation scheduling. This concept was analyzed and a computer simulation of seasonal irrigation requirement carried out in one of my publications in 2002 (Ojediran, 2002a).

Earlier in 2001, I conducted an appraisal of irrigation water quality of a pilot irrigation scheme in the Sudan Savannah of Nigeria (Ojediran, 2003). The study reported the findings of a case study evaluating the quality of irrigation water at the Zauro Polder Pilot Project (ZPPP) of Sokoto Rima River Basin Development Authority (SRRBDA), Birnin-Kebbi, Nigeria. Results from the study indicated and the water sample analysis showed that the pH values were in the range of 6.3 to 7.0 while electrical conductivity ranged from 1.37 to 3.37mmhos/cm.

It was concluded that the water quality on this scheme was favourable for rice crop cultivation and that the drainage water from the scheme can, in fact, be re-used for irrigation purposes since it is within the USDA class C1 – S1.

Table 2: HYDROLOGICAL AREAS (HA)IN NIGERIA

HA	*DESIGNATION*	*NOOF PRINCIPAL SUB-BASINS*	*LOCATION*	*(STATE AND ABUJA*	*TOTAL AREA*
1	Niger North	15	Sokoto	1.Kastina 2.B/Kebbi	13.6
2.	Niger Central	23	Kaduna	1.Ilorin 2.Minna	16.9
3.	Upper Benne	17	Gombe	1.Bauchi 2.Yola	16.9
4.	Lower Benue	16	Makurdi	1.Lafia 2.Wukari	8.0
5.	Niger South	12	Asaba	1.Lokoja 2.Yenegoa	5.9
6.	Western Littoral	16	Lagos	1.Benin 2.Akure	11.1
7.	Eastern Litoral	17	Enugu	1.Calabar 2.Owerri	6.5
8.	Lake Chad	21	Maiduguri	1.Kano 2.Damaturu	21.1
		153	Nigeria 92.4million Ha		

Source: Oyebande (1981)

3.5.3 *Irrigation development in Nigeria*

The trends in irrigation schemes in Nigeria can be traced from subsistence agriculture which characterized family efforts to the period when animals were used to transport water to farm plots and the introduction of the shaduf system around 700 AD into what is now Northern Nigeria especially the North-eastern Nigeria (Kanem – Borno) from Egypt in North Africa (Nwa and Martins, 1982). In addition to using the shaduf, the people of Northern Nigeria learnt how to divert the water from streams into the fields to irrigate their crops. The people of Sokoto were able to extend their knowledge of constructing small "tanks" for domestic purposes to constructing small dams for irrigation. However, modern irrigation was introduced into Nigeria in 1926, when the first formal irrigation scheme the "Kwaire Irrigation Scheme" was opened in the now Sokoto State (Nwa, 2003).

It has since developed and expanded to formal medium-and large-scale schemes spread all over the country. The setting up of the eleven (11) River Basin Development Authorities (RBDA's) between 1975 and 1976, and the World Bank assisted Agricultural Development Projects (ADP) between 1980 – 1985 were milestones in the development of medium/large scale irrigation schemes and of irrigated *"fadama"* (alluvial river beds), respectively in Nigeria. Some large and medium scale irrigation projects establishedin the country include Nigeria Sugar Company Estate, Bacita (NISUCO), Uzo-Uwani Irrigation Scheme, Kano River Irrigation Project (KRIP), South Chad Irrigation Project (SCIP), Savannah Sugar Company Estate Numan, Peremabiri Rice Project, DadinKowa Irrigation Project, Lower Anambra Irrigation Project and Bakolori Irrigation Project (BIP), Itoikin Rice Scheme, Kampe Irrigation scheme(Ojediran, 1997 and Nwa,2003).

This spread of irrigation schemes in the country and the consequent increase in the agricultural output probably resulted in Nwa and Martins' (1982) observation that

"The importance of irrigation development for food and fibre production is nolonger an issue in Nigeria. The issue is how to sustain irrigated agriculture for the permanent benefit of the Nigeria population." This situation was replica of happenings in irrigated agriculture around the world, which

culminated in higher intensity of irrigation development and practices in several countries since the focal point – self-sufficiency in food and fibre production – is the same worldwide.

Some of the Asian as well as African economies succeeded in increasing agricultural production significantly over a short span of time by accelerated provision of irrigation facilities. Irrigation infrastructure is one of the critical factors for improving agricultural production, farm incomes and rural wealth accumulation. The massive investments in irrigation infrastructure in India, China and Pakistan in the 1960s and the 1970s and their success in achieving food self-sufficiency were also driven by the same underlying philosophy. These countries have succeeded in reducing the scale of poverty to a large extent. The lifting of mass populations above the poverty line in some of these Asian countries, with the overall success of poverty reduction due to irrigated agriculture, was considered one of the significant achievements of the 20th Century.

Mr Vice Chancellor sir, this 20th century achievement which also spilled into the 21st century is laudable and deserves applause. However, there is a need for a holistic look at the impacts with a view of knowing, preventing and perhaps managing the negatives, for the sole purpose of sustainability.

4.0 ENVIRONMENTAL IMPACT OF IRRIGATION.

The development of medium and large scale irrigation schemes, which came up in the wake of the realisation of the immense benefits derivablefrom irrigation, led to the construction of dams and reservoirs and in cases where surface methods of irrigation were to be employed, canals were also constructed. Alsoopening up large tracts of lands for agricultural purposes characterised this era. All sorts of methods were used in applying water to the soil to obtain the desired results of increased crop yield. These developments came up with attendant positive and negative effects on the environments.Some of these effects were overt and anticipated at the planning stage, while a myriad of them were actually covert at that stage.

I have taking the liberty of this lecture to categorise the positive impacts of irrigation on the environment as GOOD, and the negative impacts as BAD, and UGLY.Bad, yes, but why ugly? Developments are expected to be for the benefit of mankind and not to his detriment, especially health wise. So, when the latter happens, even to a debilitating extent, I posit, it qualifies to be referred to as ugly!!!

4.1 *Impacts of Irrigation* – THE GOOD

Literature is replete with 'the good' or benefits of irrigation. These benefits are the factors often advanced as justifications for the introduction and establishment of irrigation schemes around the world. The benefits are truly enormous and the introduction of a scheme by putting in place irrigation infrastructures ushers into the environment various benefits and impacts.

Irrigation benefits could be direct or indirect. One of the main direct benefits of irrigation development and practices worldwide is increased food and fibre production.Ojediran and Sangodoyin, (2000) evaluated irrigation at the Zauro Polder Pilot Project (ZPPP) (Fig.5) and presented an analysis of the impact of irrigation development on the soil regime and crop yield on the scheme. Results from the study revealed positive trend in crop yield with consistent increase in annual average crop yield from 1.5 ton/ha in 1990 to 2.3 t/ha in 1993 (Fig.6) before the 1994 flood, and general opinion of sampled farmers (100%), indicated an increase in average annual income and greater prospects for the full-blown project.

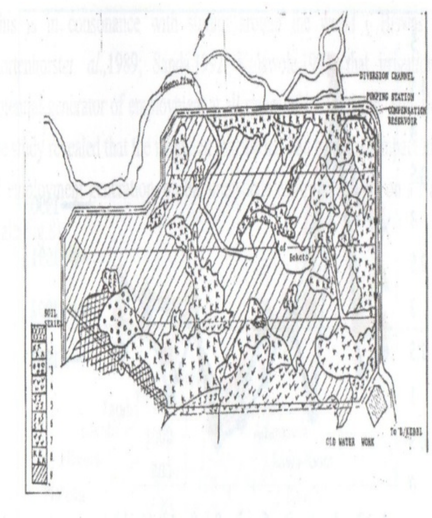

Fig. 5: Zauro Polder Pilot Project (ZPPP)

In addition to increasing crop production and farm and family incomes, improved irrigation access significantly contributes to rural poverty reduction through improved employment and livelihoods within a region (Chambers, 1988; Barker *et al.,* 2000). In the study of the benefits of irrigation in a large scheme (fig.7) of theNigeria Sugar Company, (NISUCO), Bacita., (Ojediran, 1997), an analysis of 30years records of the company revealed an annual average employment of 4066 persons (Table 3) at the peak of the irrigation season. The records further revealed that the workforce at the agricultural unit is about 67% of the total number of employees at NISUCO. Notably, a large percentage of the workforce in this unit consists of seasonal field labourers, often referred to as landless farm labourers.

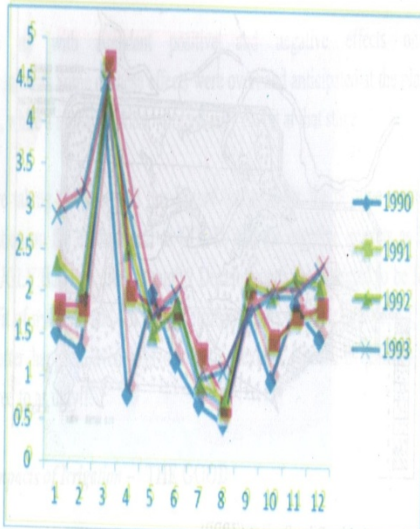

Fig. 6: Four Consecutive Years Rice Yield on ZPPP

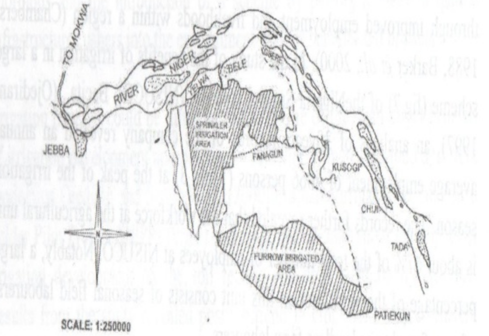

Fig.7: Irrigation Areas on The Nigerian Sugar Company Limited, (NISUCO) Bacita (Adapted from Nwa, 2003)

This is in consonance with studies around the world (Biswas, 1988; Kortenhorst*et. al.*,1989; Sanda,1992; Kolawole,1993) that irrigation is a potential generator of employment at all stages of its operation. Significantly, the study revealed that the irrigation scheme has had a positive impact in terms of employment generation, on the immediate environment and on a National scale(Fig.8)

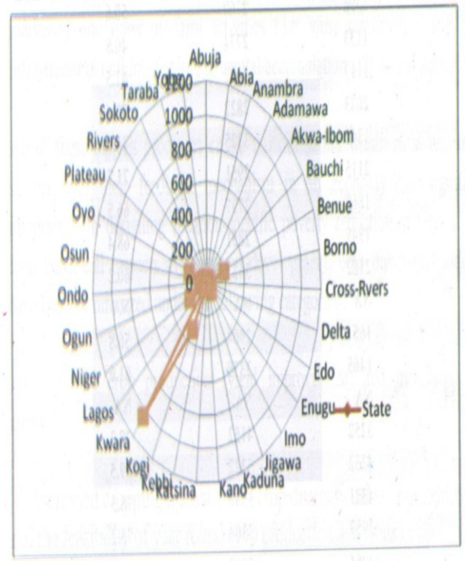

Fig. 8: NISUCO, Bacita .Effect of Contiguity to Scheme on Staff Strength (1994)

This work further studied the influence or effect of contiguity to irrigation scheme on employment. In the analysis, the employment, according to state of origin of the employee, was x-rayed and the outcome presented in Fig.8 confirmed the positive influence of contiguity to scheme on employment, with all states contiguous to the scheme having high representation at the following levels: Kwara 1035 (43.8%), Kogi 310 (13%), Niger 199 (8%) , Oyo 194 (8%) and Benue 193 (8%) ranking top five among the states.

Table 3 Annual Employment :NISUCOBacita, (Dec. 31st of each Year)

YEAR	NO. EMPLOYED BY AGRIC. UNIT	TOTAL NO EMPLOYED	% EMPLOYED BY AGRIC. UNIT
1965	1396	2760	50.6
1966	1133	2774	40.8
1967	1117	2627	42.5
1968	2043	2822	72.4
1969	1362	3325	46.2
1970	2115	2951	71.7
1971	1860	2797	66.5
1972	1949	2851	68.4
1973	2182	3623	60.2
1974 – 77	NA	NA	NA
1978	1651	2904	56.8
1979	1465	2379	61.6
1980 – 84	NA	NA	NA
1985	3252	4152	78.3
1986	4232	5322	79.5
1987	4321	5507	78.5
1988	3987	5304	75.2
1989	4064	5668	71.7
1990	4625	6150	75.2
1991	4189	6143	68.2
1992	3866	5582	69.3
1993	3321	4907	67.7
1994	3019	4831	62.5

Mean = 4066 **Average % = 67%** **NA = Not Available.**

SOURCE: Employment Records at NISUCO (Saidu, 1994)

Yield improvement and intensive production practices, better irrigation infrastructure and reliable water supply also enhance uses of other inputs like fertilizers. This intensification of agricultural practices generates additional employment opportunities in other sectors of the irrigation community.

The irrigation induced benefits are not limited to farming households but also affect broader sectors of the economy by providing increased opportunities such as employment creation for landless labourers in agro-industries, rural marketing and other off-farm activities like house construction and basic infrastructural building leading to capital accumulation in the rural sector.

All of these benefit processes create transformation within rural and urban sectors, and their feedback mechanism in an economy has significant importance in designing location-specific poverty reduction strategies. The total beneficial impacts of irrigation development, both direct and indirect, have been summarized under the following categories :

(i) Increased crop production (yield improvement) and increased farm income.

(ii) Increased cropping intensity and crop diversification opportunities and the feasibility of year round crop production activities.

(iii) Increased farm employment: more employment opportunities for farming families as well as for hired labourers in the locality.

(iv) Increased farm consumption and increased permanent wealth (permanent asset accumulation due to irrigation). This has significant implications for reducing intrinsic food insecurity in a region.

(v) Reduced food (crop) prices allowing access to food for all, which is more beneficial to landless and subsistence families and provides better nutrition intake. This is also equally beneficial to urban poor and city dwellers, since they spend more than 50 percent of their daily income on food items.

(vi) Reduced friction in the rural economy and reduced transaction costs including reduced farm marketing costs due to increased access to farm link roads and to other improved farm and non-farm related services in the region.

(vii) Multiple uses of water for bathing, washing, livestock and home gardens.

(viii) Increased recharge of groundwater, easy access to groundwater and less drudgery for women in fetching water for daily household needs.

(ix) Aesthetic and recreational benefits accrue out of irrigation facilities.

(x) Increased farm income (for farmers) and increased farm and off-farm employment opportunities for rural landless labourers result in better school attendance of children of farm labourers and improved social capital in society. This is due to the ***income effects***of irrigation, since education is still a luxury compared to other basic needs such as foods, clothes, shelter and health.

(xi). Export tax revenue accruing to government coffers; this is important particularly for the major agricultural (rice) exporting countries like Thailand, Vietnam, USA, and the like. Improved rural infrastructure always coincides with irrigation facilities. This greatly reduces transaction costs and rural marketing costs and other frictions associated with the farming sector.(.Bhattarai*et al.,* 2002)

The full benefits of irrigation are not only captured by farmers, but are also spread to wider sections of society. These externality effects are the unintended income (also employment) equivalent of welfare changes brought about by the irrigation project. The extent of such irrigation induced positive externalities, or spillover impacts of irrigation benefits, is much wider in scope in large-scale irrigation projects, contributing significantly to the regional and national development pace of a country.

With a clear understanding and in agreement of the positive impact of Irrigation Development and Practice, our research work,Ojediran and Sangodoyin (2000),was published to sensitize the Kebbi State and the Federal Governments of Nigeriato the necessity of harnessing the immense and untapped potential of the main Zauro Polder Pilot Irrigation Scheme and the probable positive impact of this scheme on the food production effort of the country. We stated assertively, using an on-going successful project, that the success of the three year trial cane plots which led to the establishment of a large scale commercial Sugar project at Bacita, Nigeria in 1961 should have served as an impetus to the Sokoto Rima River Basin Development Authorities, (SRRBDA) which established the Zauro Polder Pilot Project (ZPPP) in 1980 at Birnin-Kebbi, Nigeria to quickly commence thefull scale scheme to boost the food and fibre production efforts of the Country. Sadly, thirty-one years after the commencement of the pilot scheme, the main Zauro Polder Project (ZPP) had not taken off.

4.2 *Impacts of Irrigation* - THE BAD

Mr. Vice Chancellor, sir, more than ever before, we live in turbulent times with myriad of problems, ranging from unemployment to starvation and as if to aggravate an already bad situation, extensive degradation of the environment has become rampant. Whether we are in agreement with this or not, the survival of this generation and that of the future depends on the environment!! The realities are already unfolding before our own very eyes-with pollution, drought, floods, soil erosion, climate change and increasingly barren and unproductive lands. So, as I have stated earlier, the need to identify and prevent or ameliorate the prevailing negative or adverse environmental situations should be the compelling or driving force in all areas, irrigation inclusive.

Irrigation has continued to contribute significantly and positively to poverty alleviation, food security, and improved quality of life for rural and urban populations worldwide. These contributions, I have described, justifiably as THE GOOD.

However, despite these positive effects, irrigation development and practices have been associated with several negative impacts, both during infrastructural construction and operational stages.Hence, the sustainability of irrigated agriculture is being questioned, both economically and environmentally since the positive impacts of irrigation in the expansion and intensification of agriculture have been observed to have the potential for causing negative side effects.There exists evidence that following irrigation, large tracts of land have become unsuitable for agriculture and studies have also shown adverse environmental effects on public health, soil and water regimes, water quality and in some cases socio-economic conditions of the people. Specifically, in the large and medium scale irrigation projects, there exists the potential of major environmental disturbances posing stresses, disorientation, pollution and health hazards. These disturbances have had serious deleterious effects on both man, animals and the environment.

The negative impacts of irrigation appear to occur in two phases viz: during development and practicewhichcan be categorized as:

(i) impacts during construction stage**(development)** (ii) when scheme becomes operational.**(practice).** (Afoz and Singh, 1987 and 1991; Ojediran, 2004a)

As I have earlier reported on case studies of irrigation schemesin three River Basins in Nigeria (Ojediran, 2004a), the development of medium – large scale irrigation schemes quite often involves the construction of dams and reservoirs and in cases where surface methods of irrigation are to be employed, canals are also constructed. These constructions often lead to removal of vegetal covers, displacement of human and animal population and submergence of large tracts of agricultural and grazing lands. The construction of dams leads to the impoundment of large body of water, with consequent submergence of land areas upstream of the dams. Inhabitants of such lands are usually evacuated before the construction commences and resettled in totally new environment.Examples of these abound worldwide.

In India,2800 people were displaced from the canal site of Mahi-Kadanairrigation project (Mistry and Purohit, 1985). In Nigeria,Kiri and Dadin-Kowa reservoirs on the River Gongola led to the displacement of15,000 and 26,000 people respectively (Adams, 1995);44,000 peasant farmers were displaced byKainji lake,12,000 by Tiga lake in Kano, another 40,000 by other reservoirs in Kano; 14,000 people were displaced by the Bakolori scheme, while Goronyo displaced 20,000 people(NEST,1991). In Ogun state, prior to the impoundment of the Oyan river,a number of villages existed on both banks scattered over an area of 42km^2.These villages were evacuated and resettled in 169 housing units in a new environment.The stress and disorientation caused by such displacements, dispossessing farmers of their farmlands and unsatisfactory resettlements have worsened the situation of evacuees and have in some cases led to outright revolts. This is considered bad and unhealthy.

The impoundment of water upstream of dam also leads to loss of natural forest (deforestation), wild lifeand grazing lands. That is, the flora and fauna are also adversely affected. In Nigeria, NEST (1991) noted that much needed vegetation, such as woodlands, forests, and grazing lands have been wiped out in areas where irrigation has been introduced. In Kano state alone, some 3,000 km^2 of what was forest reserve and farmlands now lie under artificial lake. Similarly,in Kabini project of Karnataka State, India,a total of 6400 hectares of land was submerged, but the forest cleared for rehabilitation was almost three times the actual area submerged. The dispute in this developmental phase is the disproportion between the actual area submerged by the scheme and the forest area cleared for rehabilitation of the submerged habitat. The latter area sometimes amounts to three or four times the submerged area. These losses constitute some of the adverse impacts of irrigation development on the environment.

When irrigation schemes become operational, problems which were covert during the planning and construction stages are soon noticed. This is because, this phase of irrigation development involves the application of one or more of the irrigation methods (i.e. the practice) described earlier in this lecture. The problems which emanate are well captured in Fig.9 most of which have both short and long-term effects. Generally, the major potential negative environmental impacts observed on large and medium irrigation projects include: Soil degradation, crust formation, water logging and salinisation of soils, groundwater and downstream pollution, increased incidence of water – borne and water – related diseases.

4.2.1 Degradation of soils (Soil Crusting)

Soil crusting on agricultural lands became an issue when poor seedling emergence and significant decrease in crop yield were observed on some fields as early as 1934 (Carnes, 1934). Soil crusts which are formed by the impact of

falling water dropon the soil cause mechanical destruction of aggregates, washing-in of fine particles into the inter aggregate pores and rupture of the soil aggregates by air entrapped in the previously dry soil. Upon drying, the layer of soil thus formed hardens to produce crust. Several studies (Hanks and Thorp, 1956; Edwards, 1977; Goyal, 1979 and 1980; Bilbro*et al.,* 1981) reported poor seedling emergence and inadequate crop stands in capped soils as a result of the impact of water drops from rainfall and sprinklers during overhead irrigation. Also, due to the surface sealing that occurs in the crust forming process, infiltration is grossly reduced leading to increased surface runoff and overland flow and consequently loss of topsoil due to erosion.

This issue of soil crusting/capping was of great concern in the 1980's in the Agricultural sector of the United Kingdom (U.K.). This culminated into my research at M.Sc level, at Silsoe College of Cranfield Institute of Technology (now Cranfield University) Bedford, U.K, which was an "Investigation into Soil Crusting under different Irrigation Intensities and Durations" (Ojediran, 1984) .

This work involved the design and construction of a 60 – degree cone penetrometer (Plate 1) (Ojediran, 1992a). The penetrometer measures crust strength between 0 – 50N and depth 0 – 150mm with the aid of a force transducer and an optical switch respectively. Output signals from the transducer and optical switch are recorded in a data logger via a connection block.

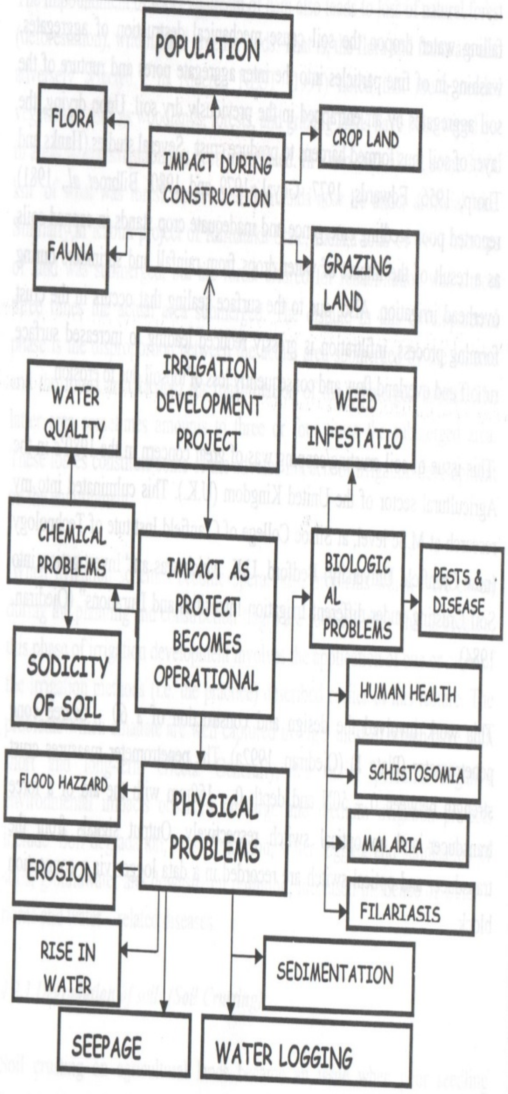

Fig. 9: Environmental Impacts Associated with Irrigation Development Project(Adapted from Afoz and Singh,1991)

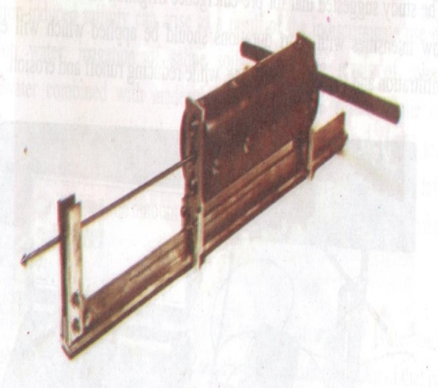

Plate. 1: The Cone Penetrometer

The penetrometer was found to be portable (about 34cm long), simple to operate, facilitates replications on a single crust sample, measures force and depth to maximum of 50N and 150mm respectively and above all has large storage capacity in a data logger .

The satisfactory performance of the cone penetrometer was ascertained in a study I conducted on the effects of rainfall intensities and durations on crust strength of a sandy loam soil (Ojediran, 1992b). The study was carried out under simulated rainfall intensities of 15, 30 and 50 mm/hour for durations of 5, 15, 30 and 60 minutes. The sixty-degree (60°) cone penetrometer was used in measuring crust strength at depth D. 1.5mm, D. 10.5mm (Plate 2)

The data obtained showed that the soil crust strength increased with rainfall durations for intensities of 15 and 30mm/hour, while at a higher intensity of 50mm/hour there was a noticeable reduction in crust strength in the course of the 30mins and 60mins treatments, with attendant surface flooding.

The study suggested that for pre-emergence irrigation on the sandy-loam soil, low intensities with short durations should be applied which will enhance infiltration and seedling emergence, while reducing runoff and erosion.

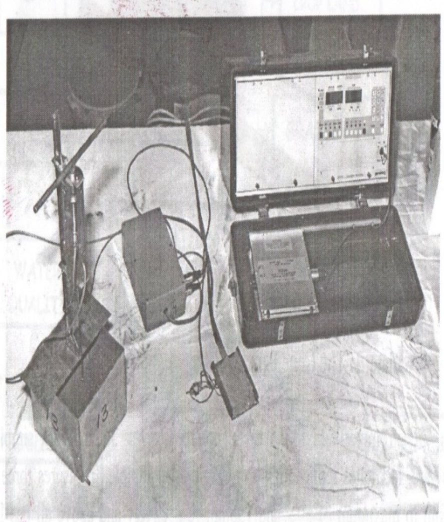

Plate 2: The Crust Strength Measuring Equipment

4.2.2 Water logging and salinization

Waterlogging and salinization of soils are physical problems associated with surface irrigation. Waterlogging results primarily from over-irrigation, inadequate drainage and seepage from canals and ditches. Waterlogging concentrates salts, drawn up from lower part of the soil profile, in the plants' rooting zone. Alkalization, the build-up of sodium in soils, is a particularly detrimental form of salinization which is difficult to rectify due to its destructive effect on soil structure.

Irrigation-induced salinity can arise as a result of the indiscriminate use of irrigation water, irrigation of saline soils, and rising levels of saline groundwater combined with inadequate leaching. When surface water or groundwater containing mineral salts is used for irrigating crops, salts are carried into the root zone. In the process of evapotranspiration, the salt is left behind in the soil; since the amount taken up by plants and removed at harvest is quite negligible.

The more arid the region, the larger is the quantity of irrigation water and consequently, the salts applied, and the smaller is the quantity of rainfall that is available to leach away the accumulating salts.

Fig. 10: Water-logged Land

Excess salt within the root zone reduces plant growth due to increased energy that the plant must expend to acquire water from the soil. Thus acute soil degradation results from salinity and consequently waterlogging.

These physical problems which emanate on irrigation schemes after the completion of infrastructural constructions are of great concern and are termed "bad", as they affect the overall performance of the scheme and sometimes result in permanent damages. These problems include water logging, salinity, risein ground water table, seepage from canals, erosion and flood hazards. Seepage, rise in water table, water logging and salinity are closely related with the increased incidence of one leading to the aggravation of the other.

It is generally believed and several studies have confirmed that a high percentage of water entering irrigation canals is lost to seepage before reaching the field. Figures between 40-60% have been widely reported while dotted cases of 70-80% have also been reported. In Nigeria, 14% overall irrigation efficiency was reported for Kadawa sector of Kano River Project(Olu, 1991), while Maurya and Ibrahim (1993) corroborated by stating that irrigation projects in Nigeria suffer from low water utilization efficiency with estimates of between 25-35% and 50-60% overall irrigation efficiency for surface and sprinkler irrigation systems respectively. Consequent on the high seepage rates reported contributions to the groundwater table in irrigated areas have been substantially through seepage losses from canals and aggravated by poor or sometimes lack of proper drainage leading to rise in water table.

In recent times, the rate of rise in water table has become a global concern, having reached an alarming level in some irrigation projects. In India, water table in Bhakra canal catchment area was reported to have risen at an alarming rate of one meter per year between 1965 and 1981 (Bhumbla, 1981). In Nigeria, Nwa(1982) reported a rise in water table from 1.5m below soil surface to 0-60cm and 40cm within 6 to 10 years of irrigation in the Kadawa sector of theKano River Project. Ojediran (2003) reported also that within 15 years of irrigation on the Zauro Polder Project, the water table had risen generally to within 30 -60cm below soil surface from pre-project levels of 30 - 147cm(Table. 4).

Table 4: Ground Water Table levels on Zauro Polder Pilot Scheme, Birnin-Kebbi, Nigeria.

Soil Series	*Water Table Level (cm)*	
	*1980	+1995
1	108	>60cm
2	48 – 72	35 – 60
3	43	>60cm
4	101	>60cm
8	115	35 – 60
9	30 – 147	45 – 60

SOURCE: *Wakuti (1980) and +Ojediran (2003)

The consequences of high seepage and rise in groundwater table are water logging and increased soil salinity. Water logging generally develops due to one or a combination of the following factors:

(i) obstruction of the natural flow of run-off;
(ii) creation of a link between surface and groundwater, mostly by seepage and high water table;
(iii) lack of or poor drainage.

The second factor has been reported to constitute a danger resulting in severe water logging and consequently the introduction of dissolved salt into the crop root zone. These two factors have virtually become serious menace on irrigated fields as several hectares of lands are been abandoned due to the low productivity of such lands immediately salinity and water logging set in. Peggy(1994) reported thatworldwide, about half of previously productive irrigated lands have been affected by water logging and have been abandoned.

Specifically, in India, 2,189,400 ha of irrigated land have been affected by water logging, while 3,469,100ha has been affected by salinity(Tyagi, 1996; Singh, 2005). Stockle(2011) in a review estimated that roughly one-third of the irrigated land in major irrigation countries is already affected by salinity with about 13% in Israel, 20% in Australia, 15% in China,50% in Iraq and 30% in Egypt. In Nigeria, Mudiare andMohammed(1987)reported extensive water logging in the Kadawa sector of the Kano River Project while Kolawole (1993) estimated that about 50% of the surface irrigation area of the Bakolori irrigation project in Sokoto state is already water logged. Ojediran (1997) also noted the abandonment of once productive areas on ZPPP (Fig.11), Itoikin Rice Scheme (IRP)of Ogun-Oshun River Basin(Fig.12) and on the Surface irrigated areas of the NISUCO scheme due to water logging.The above losses of agriculturally once productive lands due to deterioration of soil quality are a negation of the efforts geared towards food security and food and fibre production worldwide.

4.2.3 Chemical problems (salinity)

One major threat to the permanence of irrigated agriculture World- wide is the deterioration of soil and water quality on irrigation schemes. The ions responsible for this deterioration in quality include: Na^+, K^+, Ca^{2+}, Mg^{2+}andCl^-. As the Na^+ (sodium) predominates, soils can become so*dic*. Salinity is aggravated by accumulation of some salts in both soil and groundwater. The status of such chemical factors as, pH, Sodium (Na^+), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ion concentrations,) and Electrical Conductivity (Ece) determines the salinity level of the soil and water regimes. The concentration of Sodium, Calcium and Magnesium ions are used for the computation of Sodium Adsorption Ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\frac{Mg^{2+}+Ca^{2+}}{2}}}$$

Fig. 11: Waterlogged area on Zauro Polder Pilot Project

Soils of various schemes have been observed to be impacted by the introduction of irrigation, due to increase in their salinity status, which is the consequence of increase in one or a combination of the above listed salts.

About 2 to 3 million hectares are going out of production worldwide each year due to salinity problems. On irrigated lands, salinization is the major cause of land being lost to production and is one of the most prolific adverse environmental impacts associated with irrigation. In quantifying the economic impact of irrigation induced salinization, measurements have generally been limited to the amount of land affected or abandoned. Estimates of the area affected have ranged from 10 to 48% of worldwide total irrigated area. The arid and semi-arid areas have been reported to have extensive salinity problems (FAO, 2007).

Fig. 12: Abandoned area on Itoikin Rice Schemedue to High Water Table

In an analysis of questionnaires from thirty (30) countries on environmental impacts of irrigation, the pollution of surface and ground waters were perceived as a major concern in roughly 1 in 5 replies (Brabben,1989), and soil salinity was described as a real hazard on irrigation schemes.

Worldwide, over 20% of irrigated lands have been damaged by this menace,with distribution as shown in Table 5. The Christian Daily Monitor (2003) estimated that nearly 1.6 million ha/year (16,000 km^2/year) is lost globally due to salinization.

Table 5 :Irrigated Lands Damaged by Salinization

Country	Irrigated Land Damaged by Salt (million Ha)	Total irrigated Land Damaged by Salt (percent)
India	7.0	17
China	6.7	15
Pakistan	4.2	26
USA	4.2	23
Uzbekistan	2.4	60
Iran	1.7	30
Turkmenistan	1.0	80
Egypt	0.9	33
Subtotal	28.1	21
World Estimate	47.7	21

Source: Adapted from F.Ghassemi, A.J.Jakeman, and H.A. Nix,(1995)

In Australia salinity is amajor concern as it has been observed to be ravaging agricultural lands. Bruce, (2002)in a report by a committee on environment comprising of over 100 scientists, government agencies and private sector groups,stated that Salinity is increasing in the Murray-Darling basin, which provides 40% of Australia's agricultural value land and that it (Salinity) posed a risk to 57,000 km^2 of land in 2001, and is expected to impact 170,000 km^2 by 2050. Also In the Southwestern Australia, 4400 km^2, of land once used as cropland or pasture, are now salt-affected .

Fig. 13: Salinity affected land in Peruvian land. (Source: Wikipedia August, 2008).

In Peru some 300.000 ha of the 1.050.000 ha of irrigable land suffers from this problem.

In the United States(US) about 25% of irrigated land suffer from some degree of salinization or water logging ,while Salt accumulation is reported to be

lowering crop yields on 25-30% (50,000 km^2) of US irrigated land (Sandra,1992).

In China, 20% of irrigated land are reported to be suffering from salinization and this has cut yields on nearly 25% of China's irrigated land . Mean whilethe combination of Water logging and salinity has also reduced productivity on 15% of China's irrigated land(Bruce, 2007) .

In Nigeria, the salinity status of some irrigation schemes located in the old six Northern states revealed the absence of salinity earlier in 1962 and 1973. However,Maurya, (1982) and Olu (1991) observed that salinity of varying severity now exist in some of those schemes previously known to be free of salinity.

In realization of the devastating effects of salinity, the salinity status of the soil and water regimes on three irrigation schemes(ZPPP, Birnin-Kebbi, NISUCO, Bacita and IRP, Itoikin) in Nigeria were studied, Ojediran,(2004). Data obtained from these studies indicate generally low salinity level. Specifically, soils within the top 30cm in the ZPPP area which were saline (mean pH =4.6; Ece =120 x 10^{-3}mmho/cm and SAR =0.40Meq/100g) at inception now tends towards alkaline status (mean pH =6.4; Ece =35 x10^{-3}mmho/cm and SAR = 0.27Meq/100g) while the groundwater within the top 30 – 60cm below soil surface are also towards alkaline with pH range of 6.3 -7.0; ECw = 0.004 - 0.015mmho/cm and SAR from 1.32 -3.37. At IRP, the results indicate that the soil of the project are normal with low salt concentration (Table 6). At NISUCO, Bacita the mean pH, ECe and SAR values in 1987 indicate that six of the soil series were in the saline range (Oni, 1987) but had shown significant pH increase in all series by 1995 (Ojediran,1997) attributable to the 1994 destructive flooding of the scheme.

Vice Chancellor, sir, distinguished ladies and gentlemen, in the wake and realization of these menace the world over, studies and reviews of environmental implications of irrigation practices began to make calls for environmental impact assessment (EIA) for new schemes, environmental auditing of existing schemes and frequent environmental surveillance of major factors/ parameters on irrigation schemes.

TABLE 6Mean pH, Electrical Conductivity ECe, and Sodium Adsorption Ration (SAR) of soil on each field of Itoikin Rice Project

SOIL UNIT	SOIL DEPTH (CM)	PH	ECe (mmho/cm x 10^{-3}	SAR
1	0 – 30	6.30	13.7	0.31
	30 – 60	6.09	18.0	0.27
2	0 – 30	6.24	15.8	0.24
	30 – 60	6.57	14.1	0.23
3	0 – 30	5.74	12.9	0.29
	30 – 60	5.53	11.3	0.24
4	0 – 30	7.30	14.3	0.32
	30 – 60	6.67	11.7	0.34
5	0 – 30	7.30	15.5	0.25
	30 – 60	6.90	42.7	0.29
6	0 – 30	6.45	12.2	0.34
	30 – 60	6.26	11.3	0.28
7	0 – 30	6.81	9.1	0.28
	30 – 60	6.49	11.8	0.26

Therefore, on environmental impact of irrigation on soils, we developed a computer program designed for rapid assessment of impact of irrigation practice on Sodium, Calcium and Magnesium ion concentrations, pH, Electrical Conductivity (ECe) and Sodium Adsorption Ratio (SAR) of scheme soils (Ojediran, 1997; Ojediranand Sangodoyin, 2000b).

The program is able to output baseline data for first time assessment. While for monitoring, surveillance or auditing the program,

- assesses the difference between the previous and current status of each soil factor,
- establishes the significance of the difference at 5% level,
- updates the status of these factors for the purpose of future monitoring and
- predicts possible future effects through simulation using projected values of factors.

The computer program was validated using field data from impact assessment/ auditing studies of three irrigation schemes in Nigeria. The schemes are Ogun-Oshun River Basin Development Authority (OORBDA) Rice Scheme, Itoikin, Zauro Polder Pilot Project (ZPPP) Birnin-Kebbi and Nigeria Sugar Company (NISUCO) irrigation scheme Bacita.

4.3*Impacts of Irrigation* - THE UGLY

Mr. Vice Chancellor, sir, I wish to reiterate that every aspect of any development in whatever form and in whatever sphere of life, must be prosecuted with a view to improving the lots of humanity. However, whenever this objective is negated, or the effect(s) of any component become(s) detrimental to the target population, especially to their wellbeing and health, such aspect/component of the development, can, without mincing words be described as UGLY and concerted efforts must be made to either reverse the trend, prevent further effects, or in the least minimise such effects.

Earlier on, in this lecture,I had posited that irrigation development and practices is no exception to the rather general rule of everything and everyone having,the good, the bad and the ugly aspects. I had also mentioned increased food and fibre production, food security etc. as positive effects of irrigation development and practicewhich should translate to improved health of the farmers and other operators of the scheme. However, diametrically opposite effects on the health of farmers and other operators of irrigation schemes have been observed and reported. Carter *et al.*, (1990); NEST, (1991); Tiffen, (1991), Jensen, (1993) and Ofoezie, (2002) have observed the prevalence ofcertain diseases on dam sites and irrigation schemes at varying degrees.

Afoz and Singh, (1991), as noted in Fig. 9, categorised as biological problems, some adverse effects which emanate after the completion of infrastructural constructions and when irrigation schemes have come into operation to include;human health, pests and diseases,and weed infestation. These three appear inter related as the increase in one aggravates the other. The presence of reservoirs or large surface areas of impounded water and open water surfaces all over the field ,which often characterize irrigation developments evidently have impact on the micro-climate of the area. Ojediran, (2003) noted consistent high Relative Humidity (RH) during erstwhile dry periods prior to irrigation developmenton two schemes studied in Nigeria. This high RH provide conducive environment for pests and some disease vectors to thrive.Of greater concern, in this lecture is the effect on human health, since this deal with the wellbeing of the immediate beneficiaries of the development and those of the nearby residents.

4.3.1 Water-borne and Water-related Diseases

The water related diseases prevalent in irrigated areas, in order of significance,are classified as water based; vector water-borne; water-borne and water-washed (Olu, 1991) and these includemalaria, bilharzia(Schistosomiasis), river blindness(Onchocerciasis), yellow fever and brain fever. These have been singled out as of particular importance because they either

- cause death and/ severe disability or
- a large proportion of the population at risk becomes ill, or
- they are particularly difficult to control once they become widespread or when they are endemic, or
- the resulting ill-health lasts a long time. (Tiffen, 1991). .

Other irrigation-related health risks include those associated with increased use of agrochemicals, deterioration of water quality, and increased population pressure in the area. The reuse of wastewater for irrigation has the potential, depending on the extent of treatment, of transmitting communicable diseases. The population groups at risk include agricultural workers, consumers of crops and meat from the wastewater-irrigated fields, and people living nearby. Sprinkler irrigation poses an additional risk through the potential dispersal of pathogens through the air.

The risk that one or more of the above diseases is introduced or has an increased impact is most likely in irrigation schemes where (FAO, 2007):

- soil drainage is poor, drainage canals are either absent, badly designed and/or maintained;
- rice or sugar cane is cultivated;
- night storage reservoirs are constructed;

- borrow pits are left with stagnant water;
- canals are unlined and have unchecked vegetation growth.

Malaria

Malaria is by far the most important of the diseases occurring on irrigation schemes, both in terms of the number of people annually infected, and whose quality of life and working capacity are reduced, and in terms of death rate from it. Worldwide, some 2 billion people live in areas where they are at risk of contracting malaria. The total number of people infected with malaria is estimated at 100 to 200 million with between 1 and 2 million deaths per year, with almost 90% of the cases in Africa.

Several instances in the recent past have shown that substantial economic losses have resulted from low health status of farmers, irrigators and other agricultural workers on irrigation schemes. For instance, Sharma, (1987) reported that in parts of Nepal, India and Afghanistan certain lands could not be developed in part due to malaria, but once the disease was brought under control there was phenomenal growth in settlement and agricultural production. The debilitating effect of this disease was observed amongst cotton growers in the Gezira, Sudan in1974 when over 20% of the normal labour force was down with malaria and soldiers and students had to be brought in to save the crops. Similarly, on Bura irrigation scheme in Kenya, malaria deaths amongst children were one of the main reasons why many first settlers abandoned the scheme.

Drug treatment has become difficult recently because the parasite has become resistant to certain drugs that have been used for a long time in many parts of the world. Interruption of disease transmission chemicals for the control of the vector, the mosquito, has become less effective because some mosquito vector

species have become resistant to previously effective insecticides and some insecticides have been banned for environmental reasons (FAO, 2007).

Bilharzia

Bilharzia is almost as widespread as malaria, but rarely causes immediate death. An estimated 200 million people are infected and the transmission occurs in some 74 countries (FAO, 2007). The infection is particularly common in children who play in water inhabited by the snail intermediate host.

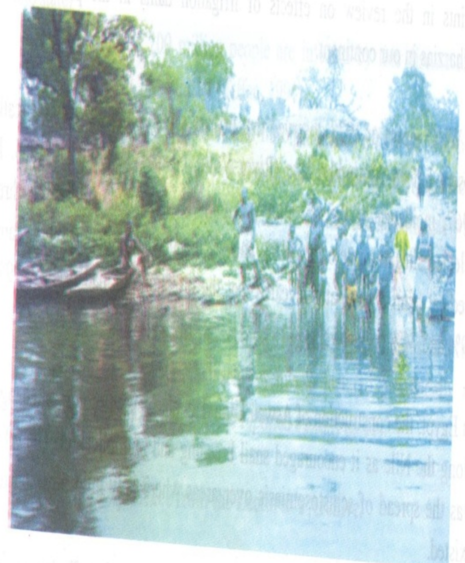

Fig.13. Exposure to Water borne diseases around Kampe (omi) dam in Kogi State Nigeria.Araoye (2002).

Severe infection in childhood leads to long-term damage to bladder, kidneys and liver, which may cause death many years after the original infection. Infection at any age may make people feel unwell and reduce working capacity.

Bilharzia is an infection caused by parasitic worms or blood flukes of certain species of the genus Schistosoma. Adult parasites live in the blood of mammals, but their life cycle requires a phase of asexual multiplication within a fresh-water snail host. The flukes infect humans who enter their exposed skin in water, usually through swimming, bathing or wading. There exists either urinary or intestinal schistosomiasis. The type and extent of health complications associated with schistosomiasis appear to vary with species and strain of parasite and by the characteristics of the human population.

Mr. Vice-Chancellor, permit me to briefly bring to our notice a few salient points in the review on effects of irrigation dams in the prevalence of bilharzias in our continent.

A WHO report of 1978 observed that urinary schistosomiasis was practically absent before Akosombo lake (River Volta, Ghana) was filled in 1964. In 1967, incidence of the infection was reported in school children on three selected sites at a rate of 9%, 38% and 42% respectively. Report by the same medical team a year later revealed that the infection rate had risen by 99%, 99% and 74% respectively.

In Egypt, the construction of Aswan High dam also caused ecological changes along the Nile as it encouraged snail breeding and multiplication. The effect was the spread of schistosomiasis over areas where only mild infection had existed.

In Nigeria, it is also evident that water resources development projects have made bilharzias worse, and there are serious public health consequences in many cases.Gadzamaand Gadzama (1987) reported a 55% increase in prevalence level of schistosomiasis in Malumfashi after the construction of small earth dams meant specifically for irrigation. Oni(1990), also reported increases in pre-project level of schistosomiasis and malaria from a low less

than 10% to 30% and 70% prevalence levels respectively one and three years after the construction of the Kainji dam.Fatokun, (1987) reported incidences of schistosomiasis in the Oyan River dam project, while (Ofoezie, 2002) reported that the Communities in Oyan dam, Ogun state, witnessed an outbreak of urinary schistosomiasisin 1988, four years after its construction, with an overall prevalence of over 80% and high rates in all age and sex groups was recorded. In the Northern state of Kano, there has been widespread development of earthdams. Many of such water bodies have been found tocontain potential snail intermediate hosts (Betterton *etal*., 1988). Rabiu (2007) reported the presence of *B.globosus* and *B. pfeffeiri* in Jakara dam (Kano state)

Globally, an estimated 200 million people are infected by this disease and transmission occurs in 74 countries (Tiffen, 1991).

The effect of this disease on the food and fibre production efforts on schemes is enormous. In Cameroon, a study of health and productivity of ricegrowers showed that a 10% reduction in the incidence of urinary schistosomiasis was accompanied by a 4% increase in production.

Ojediran, (2004b) in analysis of the records of annual reported cases in three schemes in Nigeria observed that schistosomiasis featured prominently at NISUCO with an annual average of 100 reported cases.(Fig. 15).

4.4The Nigerian Experience from the Lecturer's Archive.

Substantial efforts in my research were geared towards environmental impact assessment of irrigation. Effects of irrigation practices on human health in Nigeria were no exception (Ojediran, 1997; Ojediran and Sangodoyin, 2000; Ojediran, 2004). Environmental impacts of irrigation schemes in three sub-ecologic zones in Nigeria were investigated. These schemes are exemplified by the Zauro Polder Pilot Project (ZPPP) scheme of the Sokoto Rima River Basin Development Authority (SRRBDA) Birnin-Kebbi, in the ***Sudan***

Savannah; The Nigerian Sugar Company (NISUCO) estate scheme, Bacita in the ***Southern Guinea Savannah*** zone; and the Itiokin Rice project, of the Ogun – Osun River Basin Development Authority (OORBDA)in the ***Rain Forest*** zone. The effects of irrigation development on Health of operators and inhabitants in each of these schemes were studied.

As a result of lack of data on pre-irrigation development health status of residents in all the schemes, only post-irrigation development data, where available, have been used to interpret the prevalence or otherwise of certain diseases in the areas,which may be used as baseline for future studies.

1. NISUCO Scheme

The available health records on the NISUCO scheme indicated that the commonly reported cases were: Malaria, Dysentry/Diarrhoea, Schistosomiasis, Filariasis, Sexually Transmitted Diseases (STD) and Onchocerciasis. Figures 14 and 15 show the number of cases reported annually for these diseases around the project area. Malaria, expectedly, is the most prevalent with over two thousand cases reported annually.

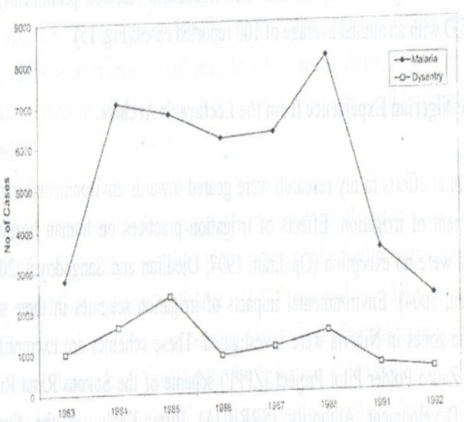

Fig.14: Variation in Annual Reported Cases of Malaria and Dysentry in NISUCO Estate Irrigation Scheme, Bacita, Nigeria

The highest number occurred in 1988, a year in which comparatively low rainfall and relative humidity were recorded. This tends to suggest that intensive irrigation may have been carried out that year with the attendant increased open water surfaces for mosquito breeding. Next in prevalence on this scheme is dysentery/diarrhoea. This disease might be due to the drinking of irrigation water by field workers/farmers during working hours in the field.

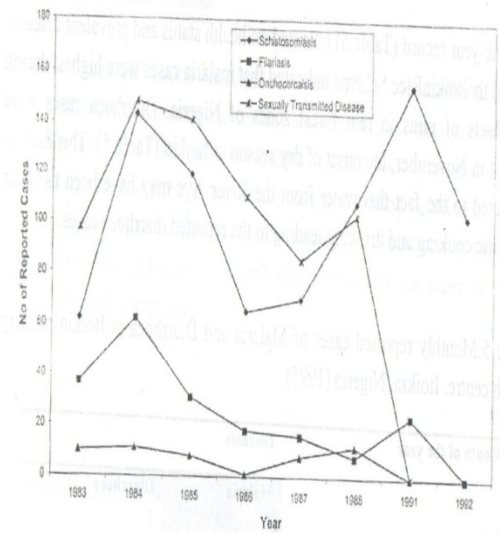

Fig.15:Annual Reported Cases of four Diseases on NUSICO Estate Irrigation Scheme, Bacita, Nigeria

Notably also, are the other four endemic diseases on this scheme viz; sexually transmitted disease (STD), schistosomiasis, filariasis and onchocerciasis. The STD appears to top the list in this group perhaps due to the employment of itinerant workers, called seasonals, whose nature and lifestyle predisposes them to this disease. This agrees with the assertions of Arya et al (1980) and Lucas and Gilles (1984) that itinerant traders, workers and businessmen around irrigation schemes are among the risk groups of this disease. Schistosomaisis, another prevalent disease, is observed to have been on the increase with only 60 reported cases in 1983 compared with 156 in the 1995. This is attributed to the habit of most seasonal workers walking around the scheme with bare feet or uncovered shoes.

2. ItiokinRice Scheme

The one-year record (Table 5) obtained on health status and prevalent diseases around theItoikinRice Scheme indicated that malaria cases were highest during the onsets of rains in rain forest zones of Nigeria. Diarrhoea cases were highest in November, the onset of dry season at Itoikin (Table 5). This may be attributed to the fact that water from the River Aye may have been used for domestic cooking and drinking leading to the reported diarrhoea cases.

Table 5:Monthly reported cases of Malaria and Diarrhoea at Itoikin primary health centre, Itoikin, Nigeria (1995)

Month of the year	Diseases	
	Malaria	Diarrhoea
January	6	1
February	11	2
March	9	2
April	13	-
May	42	3
June	36	-
July	7	3
August	13	1
September	11	4
October	10	7
November	15	22
December	7	3

3. Zauro Polder Scheme

Fig.16 indicates the annual reported cases of malaria and diarrhoea at the Basic Health Centre covering the scheme area. The highest cases occurred in 1993 with 1715 and 1045 cases for malaria and diarrhoea, respectively. The cases of reported diarrhoea may have occurred during prolonged water shortage periods (i.e. dry season), which is said to be common in the area being in the semi-arid zone of Nigeria when inhabitants use water in River Rima for domestic purposes.

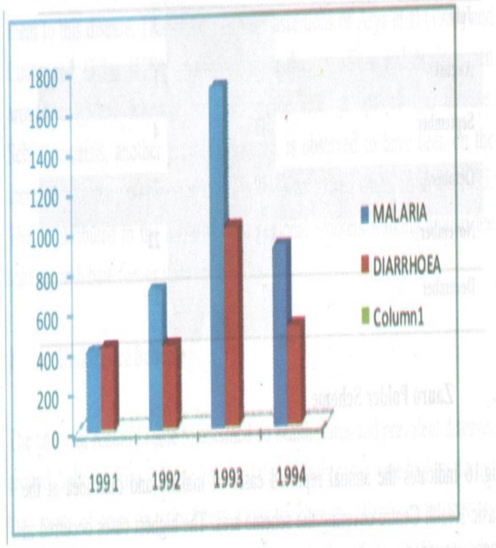

Fig 16: Annual Reported Cases of Malaria and Diarrhoea on ZPP Scheme, Birnin – Kebbi, Nigeria.

The control of the water-related diseases

The control of the water-related diseases can be effected in a number of ways, some of which are mutually reinforcing. Three types of measures are distinguished:

- measures aimed at the pathogens: immunization, prophylactic or curative drugs;
- measures aimed at reducing vector densities or vector lifespan: chemical, biological and environmental controls;

- measures to reduce human/vector or human/pathogen contact: health education, personal protection measures and mosquito proofing of houses.

Of the above, environmental control measures are considered to be long-lasting and environmentally-sound. These include preventing or removing aquatic vegetation, lining canals with cement or plastic, regularly fluctuating water levels, periodic rapid drying of irrigation canals, preventing contamination of water bodies with feaces, supply of safe and clean drinking water, appropriate siting of housing of the farmers etc. For example, in Zimbabwe, in a communal small-holder irrigation project at Mushandike, adoption of these measures resulted within three years in a drop of the infection rate from an initial 70 to 80% to virtually nil.

5.0 CONCLUSIONS AND RECOMMENDATIONS/CONCLUDING REMARKS.

Mr. Vice Chancellor, sir, distinguished ladies and gentlemen, while I seek not to diminish the fact that irrigation development and practice are GOOD and indeed VERY GOOD, and that they have globally contributed immensely to increasing food and fibre production, year round cropping, enhanced poverty alleviation through declining world food prices, provision of immense sources of employment and income generation to a large population of landless labourers. I have also not come to "bury" irrigation development and practices as it may appear to some, and since bad news travel faster than good news, in actual fact, I have come, through this lecture, to extol the importance and immense advantages of irrigation and to sensitize one and all to the pitfalls and the devastations that have occurred in other countries, create awareness with a view to ensuring that the bad and ugly aspects as detailed in this lecture are prevented, avoided, ameliorated where they have been detected and minimized where it may be difficult to prevent totally.

Distinguished ladies and gentlemen, there are two sides to every coin, this we cannot "shy away" from, if we must be holistic in dealing with any situation. This sensitization, I consider more relevant now than ever before, especially with the government pre-occupied as it is now with economic recovery and the restoration of peace and order, it should not relegate the issues of agriculture, food and fibre production, irrigation and the environment to the background. Also considering part of the advertorial of the Federal government of Nigeria in THE NATION newspapers in January 2012, during the fuel crisis, that more dams will be built, more irrigation schemes will be established from the expected windfall from the removal of fuel subsidy. Good as the intentions may be, the expected level of success may be marred by the pitfalls discussed in this lecture if precautions are not taken.

Mr. Vice Chancellor, sir, distinguished ladies and gentlemen; there is therefore the need to mitigate the environmental impacts of irrigation because as the world's population continues to grow, dams, aqueducts and other kinds of infrastructure will still have to be built, particularly in developing countries where basic human needs have not been met. Such projects must be built to higher standards and with more accountability to local people and their environment than in the past. In regions where new projects seem warranted we must find ways to meet demands with fewer resources, minimum ecological disruption and less money.

Series of interventions aimed at preventing, mitigating, or reversing soil and water degradation at various levels within irrigated agriculture must be applied, some of which are applicable at field or farm level, others at system, regional, or sub regional level. These interventions may be in terms of stringent governmental or sectorial policies, engineering applications, system management, and irrigation/agronomic practices

 Governmental or Sectorial Policies. The federal and states governments must;

1. insist on regular publication of Environmental impact monitoring, auditing and surveillance reports (EIS) on all existing irrigation schemes and water resources projects every 5years.
2. provide incentives for monitoring and reduction of observed impacts of existing irrigation projects.
3. ensure regular independent survey of very sensitive aspects of the schemes(e.g. health status, water quality, salinity and level of water table, etc)
4. provide comprehensive Environmental Impact Assessment (EIA) reports for new projects with detailed methodology, data used in the assessment and farmers input. The justifications from this report must also be publicised for possible input from the public.

 Engineering Applications. The following engineering interventions must be enforced by the government on the supervising authorities with close monitoring and accountability requirements.

1. incorporation of environmental impact considerations in the design, construction, and operation of new irrigation projects.
2. maintenance of existing irrigation infrastructure.
3. Provision of drainage facilities (where not available), make continuously functional existing drain and ensure proper disposal of drainage effluent.
4. Prevention or reduction of canal seepage, especially through lining of main canals and secondary canals conveying large quantity of water.
5. Minimal sediment concentration in runoff water.

 System management. The operators of the scheme and supervising authorities must be visibly on ground and must be seen by the farmer as joint partners in the business of irrigation. This must be done by proper dissemination of information to farmers and operators by ensuring that:

1. existing irrigation and drainage infrastructure are improved, managed and maintained through proper communication between management and operators of scheme.
2. Top-down and bottom-up approaches are used on issues of provision and maintenance of irrigation and drainage facilities.
3. on-demand water delivery to farms are applied with caution to reduce conflicts.

- **Irrigation/Agronomic practices interventions.** These supervising authorities should put on ground adequate agronomic and extension units considering that the focal point is improved food and fiber production by:

1. implementing more efficient irrigation methods taking cognizance of soil and crop types.
2. growing different crops or introducing different crop rotations, less-water demanding crops, more drought- and salt-tolerant crops.
3. encouraging farmers and operators to irrigate according to reliable crop water requirement estimates and leaching requirement calculations.
4. managing fertilizer programmes so as to minimize nutrients available for detachment and transport, and
5. applying soil amendments and reclamation practices as and when due.

The lesson in the following story must be applied if the above recommendations are to be effective. It's the story of four people named Everybody, Somebody, Anybody, and Nobody. There was an important job to be done and Everybody was sure that Somebody would do it. Anybody could have done it, but Nobody did it. Somebody got angry about that, because it was Everybody's job. Everybody thought Anybody could do it, but Nobody realised that Everybody wouldn't do it. It ended up that Everybody blamed Somebody when Nobody did what Anybody could have done.

Mr Vice Chancellor,sir, distinguished ladies and gentlemen this implies that all stakeholders must be involved in the development and practice of irrigation

to maximize the GOOD and keep the BAD and the UGLY aspects at the barest minimum.

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First and foremost , I give glory, honour and adoration to the Lord Almighty, the God who is called El- Shaddai, my God who has been MORE THAN ENOUGH!! The God who has shown himself faithful to me in all situations.The God who made today a reality.The One who promised and never failed, who has been there for me through thick and thin.The God who ordered my steps. The God with the light at the end of every dark tunnel of my life- The preserver of my soul- The one who had told me and had kept His word that – TOMORROW WILL BE OKAY!!. You were there in my every YESTERDAY, my todays and you've always assured me of a better tomorrow – thank you my DEPENDABLE & MERCIFUL GOD!

Through it all

I've learnt to trust in Jesus

I've learnt to depend upon His WORD!!

All roads lead to the market- they say – but they only bring you to the gates. I owe debts of gratitude to a lot of people, who God has used to bring me to the gates and into the market.

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I thank my ever quiet and thoughtful-philosopher mother- she is here today sitting quietly, as usual, but taking-in all happenings for deeper talks later, Thank you.

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FOR THIS GOD IS MY GOD,

FOR EVER AND EVER
HE WILL BE MY GOD,
EVEN UNTO THE END!!

Mr Vice Chancellor sir, distinguished ladies and gentlemen, I thank you most sincerely for listening. God bless you all.

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INTERNET RESOURCES

Human impacts on Ecosystems (www.orst.edu/instruction/bi301)
International Water Management Institute (www.cgiar.org/iwmi)
International Water Resources Association (www.iwra.siu.edu)
Pacific Institute for Studies in Development, Environment and Security (www.pacinst.org)
The World's Water, Information on the World Freshwater Resources (www.worldwater.org)
United Nations Food and Agricultural Organization, Land and Water Development Division (www.fao.org/ag/AGL)
Universities Council on Water Resources (http://www.uwin.siu.edu/ucowr)
Pollution prevention/environmental impact reduction checklist for agricultural irrigation (http://es.epa.gov/oeca/ofa/pollprev/agric.html)

APPENDIX A

Country	Year	Full/partial control irrigation	Spate irrigation	Equipped irrigation	Total irrigation	%of cultivated areas	Part of equipped area actually irrigated	Annual increase rate
Unit		ha	ha	ha	ha	%	%	%
		(1)	(2)	(3)	(4)=(1)+(2)+(3)	(5)	(6)	(7)
Algeria	2001	513368	56050	-	569418	6.9	80	0.3
Angola	1975	80000	-	-	80000	2.4	44	-
Benin	2002	10973	-	1285	12258	0.4	23	2.3
Botswana	2002	1439	-	-	1439	0.4	-	0.4
Burkina Faso	2001	18600	-	6400	25000	0.6	100	0.3
Burundi	2000	6960	-	14470	21430	1.6	-	2.7
Cameroon	2000	22450	28000	404	25654	0.4	-	1.6
Cape Verde	1997	2780	-	-	2780	6.2	66	0.0
Central African Republic	1987	135	-	-	135	0.0	51	-
Chad	2002	30273	-	-	30273	0.8	87	5.7
Comoros	1987	130	-	-	130	0.1	65	-
Congo	1993	217	-	1783	2000	1	11	-
Cote D'lvoire	1994	47750	-	25000	72750	1.1	92	-
Democratic Republic of Congo	1995	10000	-	500	10500	0.1	70	-
Djibouti	1999	1012	-	-	1012	100	38	4.1
Egypt	2002	3422178	-	-	3422178	100	100	0.6
Equatorial Guinea	-	-	-	-	-	0.0	-	-
Eritrea	1993	4100	17490	-	21590	4.3	62	-
Ethiopia	2001	289530	-	-	289530	2.5	-	6.2
Gabon	1987	3150	-	1300	4450	1	-	-
Gambia	1999	2149	-	-	2149	1	65	3.2
Ghana	2000	30900	-	-	30900	0.5	90	30.1
Guinea	2002	20386	-	74528	94914	6.2	100	0.3
Guinea-Bissau	1996	8562	-	13996	22558	5.1	100	14.8
Kenya	2003	103203	-	-	103203	2.0	94	4.1
Lesotho	1999	2637	-	-	2637	0.8	3	-
Liberia	1987	100	-	2000	2100	0.3	-	-
Libyan Arab Jamahiriya	2000	470000	-	-	470000	21.9	67	0.0
Madagascar	2000	1086291	-	-	1086291	31	100	0.0
Malawi	2002	56390	-	-	56390	2.3	96	7.3
Mali	2000	97499	-	138292	235791	5.0	75	20.1
Mauritania	1994	45012	-	-	45012	9.4	51	-
Mauritius	2002	21222	-	-	21222	20.0	98	2.8
Morocco	2000	1458160	26000	-	1484160	16	98	1.1
Mozambique	2001	118120	-	-	118120	2.8	34	1.3
Namibia	2002	7573	-	-	7573	0.9	100	2.1
Niger	2005	13663	-	60000	73663	1.6	89	0.9

Nigeria	2004	238117	-	55000	293117	0.9	75	1.8
Rwanda	2000	3500	-	5000	8500	0.7	-	11.4
Sao Tome and Principe	1991	9700	-	-	9700	23.7	-	-
Senegal	2002	102180	-	17500	119680	4.8	58	6.7
Seychelles	2003	260	-	-	260	3.7	77	-
Sierra Leone	1992	1000	-	28360	29360	5.4	-	-
Somalia	2003	50000	150000	-	200000	18.7	33	0.0
South Africa	2000	1498000	-	-	1498000	9.5	100	2.8
Sudan	2000	1730970	132030	-	1863000	11.2	43	-0.9
Swaziland	2000	49843	-	-	49843	26.2	90	-
Togo	1996	2300	-	5000	7300	0.3	86	0.7
Tunisia	2000	367000	27000	-	39400	7.9	100	0.3
Uganda	1998	5580	-	3570	9150	0.1	64	0.0
United Republic of Tanzania	2002	184330	-	-	184330	3.6	-	2.3
Zambia	2002	55387	-	100525	155912	2.9	100	12.9
Zimbabwe	1999	173513	-	-	173513	5.2	71	6.9
Africa	-	12478592	411370	554913	13444875	6.4	81	0.88