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WATER RESOURCES PLANNING IN A TYPICAL STATE IN NIGERIA: A MANAGEMENT SCIENCE APPROACH

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ABSTRACT

Properly planned, using scientific method, water resources can be used to create jobs for a large number of people. Discussed in this paper is a study of water resources utilization in Adamawa State as a tool for poverty alleviation. Some twelve strategic water resources development projects were examined using the methodology and techniques of Dynamic Programming and Mixed Integer Programming.

Keywords: Water Resources, Adamawa State, Poverty Alleviation, Job Creation, Dynamic Programming.

INTRODUCTION

Water is one of nature's greatest gifts to man. Life in any form would be impossible without water. Thus with proper planning water can be used to solve a number of problems confronting man. Perhaps the most important of this is the food problem. Food is not a luxury; it is an essential necessity. Food production depends heavily on water resources. Besides the use of water for domestic and agricultural purposes, water can also be used for numerous other purposes including leisure and transportation, which is among the earliest uses of water resources. Given the vital roles which water plays in human life, we believe that well planned water resources utilization can be a lethal weapon in the fight against the pandemic poverty ravaging Nigerians today. Discussed in this paper is a study of the use of water resources to break the vicious circle of poverty in Adamawa State, Nigeria.

The Problem Situation

Water resource is defined as the entire range of natural waters that occur on earth and that are of potential use to humans regardless of its state-solid, liquid or gas: see G.B.Ka./V.D.B. (1981). The ones that are most readily available for humans are waters of the ocean, rivers, lakes, ground waters and deep sub-surface waters, see: (Engelman & Leroy 1993). Probably, next to air, water is the most abundant resource on the planet earth. The earth is nick named "The blue planet" because of the color of water that covers three-fifth of its surface: Traore (1996). But of all this body of water, only 3% of it is the absolutely vital *drinking* water that man can use. And even this 3%, most of it is frozen in icecaps and glaciers or is in underground aquifers: see Lean and Hinrichsen (1994). We need water to satisfy our biological needs, for our personal hygiene, to irrigate our land, to produce energy and most of all to survive. Lean and Hinrichsen (1994) stated that only about one-hundredth of 1% of the worlds total water supply is readily available for human use. They also asserted that if evenly distributed, this amount would be sufficient for current needs. But, of course,

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water is not evenly distributed on earth. In arid Saudi Arabia for example, about 40 people must share the same amount of water that is available to one person in tropical Malaysia: see F.A.O (1996).

As Idama (1999) indicated, water is an essential commodity yet it is a rare commodity in many developing countries. This cannot generally be attributed to its unavailability. The problem has been mostly attributed to poor planning and management: see Daura (1998). Water resources development in many countries is still in its infancy: see Idama (1999). Adamawa State, which is located within the Benue Basin, is not denied its fair share of water resources. According to Daura (1998), the water resource within the Benue Basin is sufficient to support water resource development projects particularly small scale irrigation projects, rural and urban water supply scheme and fishing for the population inhabiting the region.

THE STUDY AREA

Adamawa State came in to being on August 27th 1991 after the splitting of the defunct Gongola State into two States; Adamawa State and Taraba State, by the then military administration headed by General Ibrahim Babangida. The state is located at the north east part of the country, lying between latitude 7° and 11° North of the equator and between Longitude 11° and 14° east of the Greenwich meridian. The state is made up of 21 local government areas with a population of about 2,102,053 people based on the 1991 census. The state covers a land area of about 38,741km. The state shares boundary with Taraba State in the south and west, Gombe State in the North-West, Borno State in the North and an International boundary with the Republic of Cameron along its eastern border: see Adebayo and Umar (1999); Adamawa State Dairy (1999).

WATER RESOURCE AVAILABILITY IN ADAMAWA STATE.

Three main rivers flow in the state, each with its own tributaries. These rivers are River Benue, River Yadzeram and River Taraba.

The River Benue

The River Benue is the major river in the state. It rises from the highlands of Cameroon and flows south-wards to join the Niger at Lokoja. The Benue has a number of tributaries such as the River Gongola, River Belwa, River Inne, River Kilange, River Loko and River Faro. Some of these rivers are normally flooded during the rain season and dry during the dry season.

River Yadzaram.

River yadzaram takes its source from the Hudu hills in the eastern part of Mubi and flows Northward. The river eventually terminates into Lake Chad. Its major tributaries are rivers Moda, Dilashi, and Mayo Bani.

River Taraba

River Taraba rises from the Jombi Mountains in the extreme south of the state and flows westward to join the Benue in Taraba state. Its major tributaries are rivers Yim, Butula, Njuman, and Kam.

Underground Water.

The state is also endowed with an enormous amount of underground water found in most parts of the state. Underground water is also a very important water resource that is of vital human use. The occurrence of both the surface water and underground water in the state varies from place to place both in quantity and quality: see Adebayo and Umar (1999; Adamawa State Diary (1999). With water resources such as the Benue, Yadzaram, Taraba, and numerous streams and rivers and with the high potential of underground water in the area underlain by sedimentary rocks, one would say much water resources is available in the state. Inspite of these abundant water resources in the state, Adamawa remains one of the poorest states in Nigeria. We are therefore confronted with the question of determining the extent to which these abundant water resources can be exploited to improve the living standard of the people. As pointed out by World Bank (1996), large number of people in poverty generally implies that insufficient use of resources. The immediate objective of the study hence were two folds:

1. To find out the extent to which the abundant water resources available in the state is being utilized, and
2. To find out how the present use of water resources in the state can be significantly improved.

The ultimate objective of the study however was to find out how the abundant water resources in Adamawa State can be used to break the vicious circle of poverty ravaging the vast majority of the people in the state. This study is significant and timely because poverty eradication is the greatest task facing the world presently: see World Bank (1994). We are as a matter of fact in the UN decade of poverty eradication - 1997 to 2006: see UN (1997). The Federal Government of Nigeria as well as the Government of Adamawa State are presently engaged in the battle against poverty.

LITERATURE REVIEW

Water Resources Utilization

Water resources are generally used for drinking and domestic purposes, in irrigation, fisheries, transportation, recreation and leisure, power generation etc. The most important use of water however is for drinking and domestic purposes. As argued by Jong and Hofkes (1986), it is not enough just to have plentiful supplies of water, what people need is easy and hygienic access to it. This can only be achieved with creative and intelligent planning. For example, with "little" planning, a place like Tivalu Island whose source of portable water is only from the rain, have been able to get all the water a family needs for its consumption: The Courier (1986). As pointed out by Idama (1999), the problem of making good quality water readily available to the masses of the population for domestic usage is one which government at all levels take seriously. As reported by Adebayo and usman (1999), only some parts out of just twenty-one local governments in Adamawa State are presently provided with water from a centralized water treatment plant. In the state capital, for example, where there is a water supply scheme, theoretically capable of supplying about 21.4 million litres of treated water daily, only about 33% of the population are being served occasionally (Lekan 1989). Most of the cities and towns in the state get their water supply mainly from boreholes, wells, rivers, and rainfall: see Adebayo and Umar (1999). These sources of water are generally considered unsafe for drinking by humans.

Irrigation.

Irrigation is an age long and important area of water resources utilization. As pointed out by Traore (1990) irrigation is practiced in many countries of the world in different proportions and at different levels of success. Traore (1990) claimed that about a fifth of all arable lands are under irrigation, and these irrigated lands sustain about 40% of the world's agricultural output. For example, over the past 20 years, Israel's food production has doubled without using any more money because of the use of irrigation technology: see Engelman and Leroy (1993). Similarly, more than 60% of the monetary values of Asia's food production come from irrigated agriculture: see World Bank (1996). Although irrigation agriculture is not new to the peoples living in the river banks of the Benue, Gongola and other rivers in Adamawa State, the resource has never been economically utilized, this may account in part for the economic backwardness of the region: see Ray and Bashir (1999); and FAO (1990).

Fishing Activities

According to Disney (1984) and FAO (1995), although the demand for fish is rising, there is a decline in the fish capture due mainly to water pollution and overfishing. Fish farming is therefore being encouraged both for domestic consumption and export. For example, the people of Capiz, a poor country on the Island of Panay in the Philippines, turned to fish farming crab fattening and have improved their standard of living. They earned more money and their children were able to stay longer in school: see Hinrichsen (1994). Although fish farming is not new to Africa: see Balarin (1984); it has not been as successful as in the Asian countries. Mauritania for example exported $40 million worth of fish in 1981, this was about 20% of its total export trade: see Glaser (1984). Mozambique, Senegal, Ghana, Namibia, and the Seychelles are examples of countries that earn over 5% of their foreign earnings from fisheries: see FAO, (1996). Fisheries development in Adamawa State however has not been successful inspite of the enormous efforts made by many government agencies over the past years. FACU and GADP (1992) attributed the failure to many factors including:

(i) Poor extension services due to lack of planning, support, qualified and experienced personal.
(ii) Inadequate supply of inputs due to scarcity or high cost
(iii) Low productivity of some of the rivers and streams.
(iv) Lack of adequate post harvest technology and poor marketing and distribution.

The Senegalese Example

While the enormous water resources in Adamawa State remained untapped, Senegal has put its vast underground water resources to use (Boubee 1990). Senegal started by sinking boreholes, creating small scale irrigation, creating fish farming etc. and sensitizing the public on opportunities available to them from the use of water resources. In the process of time the people began to perceive the opportunities, the result was:

(i) Jobs were created for a large number of people in the rural areas. It also motivated and brought about the settlement of the nomadic population.
(ii) There were improved supplies of food to the local markets and better food for the rural dwellers.
(iii) It contributed to learning better techniques of growing, harvesting, storage, and

processing of produce.

(iv) It encouraged the people to get organized and take over responsibilities for their own survival and development.

DATA COLLECTION

Data for this study were collected using two methods namely; Questionnaire administration, and interviewing. Forty questionnaires were administered on prominent citizens of the state, top politicians, policy makers, commissioners, legislators (i.e. Members of the State House of Assembly), permanent secretaries and top civil servants. These were expected to respond to some policy questions on water resources utilization in the state. The second group were experts in the field of water resources utilization. The experts, each from the selected project areas for data collection, were extensively interviewed. Investment in water resources development often involves large capital outlay. Hence government or an investor must have well articulated objectives in order to be able to obtain the necessary funds. For this study our objective was on poverty alleviation; hence the project must produce at least two direct results:

(i) Create jobs, and/or
(ii) Boast food production.

With these objectives in mind, twelve water resource projects having the prospects of large job creation and/or massive food production were selected for consideration. These are:

(a) Developing a tourist attraction at Kiri dam,
(b) Developing an organized fishing activities at Kiri dam,
(c) Developing the irrigation activities at Kiri dam to its full capacity,
(d) Developing the mayo-Ine irrigation scheme,
(e) Developing fully the Gerio irrigation scheme,
(f) Developing fully the Dasin Hausa irrigation scheme,
(g) Developing the Loko irrigatin scheme,
(h) Developing the Tallum irrigation scheme,
(i) Developing an organised fishing activity at Njuwa lake,
(j) Developing an organised fishing activity at River Gongola,
(k) Developing recreational activity on the bank of River Benue in Jimeta, and
(l) Developing a means of River transportation around the state via Benue and its tributaries.

DATA ANALYSIS

Priority of project Execution

Let the letter a, b, c, to l represent the 12 listed projects "1" represents the project with the highest priority while "12" represents the project with the least priority. For the purpose of this analysis, the priorities were grouped into four:

1 to 3 – Highest Priority
4 to 6—High priority
7 to 9—Low priority
10 to 12 –Lowest priority

The priorities attached to the projects by respondents show that the most favored projects among the highest priority projects are "Developing the irrigation activities at Kiri dam to its full capacity" (c) and "Developing the Gerio irrigation scheme" (e). See Table1 for full details of respondent's selection.

Table 1 Priority Attached to Projects Cumulated

Project Priority	a	b	c	D	e	f	g	h	i	j	k	l
Highest priority	6	8	21	12	20	11	3	4	4	4	2	5
High priority	5	4	6	7	7	10	17	12	7	4	1	2
Low priority	7	14	2	5	3	6	6	7	16	11	5	2
Lowest priority	12	4	1	6	-	3	4	7	3	11	22	21

As might be seen from Table 1, six projects are the most favored by the respondents
These projects are:

1) C—Developing the irrigation activities at Kiri Dam to full capacity
2) E—Developing fully the Gerio irrigation scheme
3) D—Developing the Mayo-Ine irrigation scheme.
4) F—Developing fully the Dasin irrigation scheme
5) G—Developing the Loko irrigation scheme.
6) H—Developing the Tallum irrigation scheme.

Reasons for Choice of Project

Over 70% of the respondents gave "economic importance" as the basis on which they selected their priorities. This is in harmony with the objective of the study. Table 2 shows the broad reasons given for selection of priority project or prioritization of projects.

Table 2. Reasons for Choice of Projects.

Reasons	Percentage of Respondents
Feasibility	16%
Cost	3%
Economic importance	76%
Political Consideration	5%
Others	0%

Biodata on Selected Projects

The six projects most favored by respondents are now examined on the basis of the following

criteria (Where data is available).

1. Project size: Examined are the proposed size of the project, size already developed, size under irrigation, and the size yet to be developed.
2. Crops Grown: The types of crops that can be grown in each of the areas.
3. Estimated Crop Yield: The estimated crop yield for each area in tonnes per hectare of goods produced.
4. Development Cost: The estimated cost of developing one hectare each on the projects based on the prevailing economic situation as at August 2000.
5. Project Benefits: An estimated value of the benefits derivable from the execution of the project. For the purpose of analysis, this value was estimated as the size of land that can be reasonable allocated to a farmer and is translated into the number of farmers that can benefit from the project.

A summary of these considerations are shown in Table 3

Table 3. Development Prospects for Projects.

Projects	Project No	Proposed Size (ha)	Size Developed (ha)	Size under Irrigation (ha)	Size yet to be developed (ha)
Kiri	1	12000	6000	6000	6000
Gerio	2	1200	250	250	950
Dasin	3	1000	100	100	900
Loko	4	150	10	4	140
Tallum	5	400	160	10	240
Mayolne	6	-	-	-	-

Table 3 Cont.

Project	Crop grown	Yield Ton/ha	Cost of developing per(ha) (□m)	Total cost of developing (□b)	Reasonable Allocation to a farmer (ha)	Total value of the project. (people allocated)
Kiri	Sugar cane	100	0.5	3.0	2.5	4800
Gerio	Rice & veg	7	0.3	0.3	1.0	1200
Dasin	Vegetables	12	0.4	0.4	2.0	500
Loko	Vegetables	-	0.4	0.06	3.0	50
Tallum	Vegetables	10	0.2	0.2	2.0	200
Mayolne	-	-	-	-	-	

Note: "-" Indicates no data available

THE OPTIMAL INVESTMENT POLICY

In order to obtain the best (optimal) investment policy a management science model (also known as Operational Research or Operations Research) was used to analyze the data. To optimally select which area of water resources to develop first, we formulated the problem using integer programming (IP) in a formulation generally referred to as Capital Budgeting Problem and solved it

using Dynamic Programming (DP) algorithm. The capital budget problem is mathematically formulated as follows: see Taha (1992); Hastings (1973); Wagner (1973); Ravintran et al (1987); and Rose (1982).

$$Maximize: f(x) = \sum_{i=1}^{n} a_i x_i$$

$$Subject\ to: \sum_{i=1}^{n} c_i x_i \qquad (1)$$

$$X_i = \begin{cases} 1\ if\ project\ i\ is\ selected \\ 0\ otherwise \end{cases}$$

$$i = 1,2,3,4 \ldots n$$

Where a_i = the value of project i,
c_i = the cost of project i
x_i = the available amount for the investment
b = the available amount for the investment

Let p (t b) denote the optimal value of a problem with project i, i + 1, ... n and budget b, then, the following relation will be recursively used to obtain the solution for the capital budgeting problem represented be equation (1)

The projects to be founded are:
1) Developing fully the Gerio irrigation scheme
2) Developing fully the Dasin Hausa irrigation scheme
3) Developing the Loko irrigation scheme

OPTIMAL WAY OF DEVELOPING THE OPTIMAL INVESTMENT POLICIES.

The first phase of the problem of water resources development has now been solved, it still remains to be determined however the optimal way of developing the optimal investment policies. This problem was formulated as a Mixed Integer Programming. Mathematically, the Mixed Integer Programming is formulated as follows: see Taha (1992); Hastings (1973); Wagner (1973); Ravintran et al (1987); and Rose (1982).

$$Maximize: Z = \sum_{j=1}^{n} a_j x_j$$

$$Subject\ to: \sum_{j=1}^{n} c_{ij} x_j \le b_i$$

$$x_j \ge 0 \qquad j = 1,2,\ldots,n \qquad i = 1,2,\ldots,m \qquad (4)$$

$$Some\ X_{ij}\ are\ integers.$$

Where a_i = coefficients of the decision variables,
X_j = decision variables,
C_{ij} = coefficients of the constraints,
b_i = Limitations on the constraints,
n = number of decision variables,
and m = number of constraints

The data requirements for solving the problem are:
1) The values of the decision variables which we seek to maximize
2) The inter-relationships on these variables, and
3) The limitations which are naturally, economically, or socially imposed on these inter-relationships.

The objective which the project seeks to maximize is taken to be the Internal Rate of Return (IRR) of the irrigation project. The constraints to be considered include:

(i) Construction rate: An upper limit should be set in the physical rate of progress for both land clearing and development, canal construction etc. should be calculated so that no solution assumes rate in excess of that limit.

(ii) Labour constraints: Upper limit should be imposed to ensure that human resources in the vicinity of the project area is not exceeded. Similarly a lower limit should be imposed to maintain the involvement of the number required to make the project viable.

(iii) Market constraints: To prevent over production of a particular crop, limit should be set, this will prevent flooding the market and depressing demand for the produce.

(iv) Other constraints to be included include canal capacities, crops, water itself, cropping pattern, land, capital, technical ability etc.

Obtaining the data necessary for the formulation and computation of the Mixed-Integer Programming model was beyond the scope of the study being discussed. We have shown however that in order to find the optimal way of developing the optimal investment policies a Mixed Integer Programming formulation should be considered.

Findings and Recommendations

Analysis of the data has shown that with an investment of 10% of the state annual budget, three irrigation schemes can be developed to provide fadama farmland can be reasonably allocated to at least 1,750 people. Given that the 1,750 people can also employ a number of people to work for them, the benefits that can be derived from the execution of these three irrigation projects is enormous. We estimate that jobs can be created for an estimate 7,000 people in the state, with the multiplier effect, these projects can infact benefit over 8,000 people in the long run. The execution of these projects would of course significantly improve food supply in the state and the nation.

We recommend, based on our survey results and data analysis, that the following irrigation projects be executed in the priority order listed:

1) Develop the Gerio irrigation scheme fully. It has the possibility of providing jobs for about 6,000 people. The scheme may require about N0.3 billion to be executed.
2) Develop the Dasin Hausa irrigation scheme. It has the possibility of providing jobs for about

2,500 people. It may require about N0.4 billion to be executed.

3) Develop the Loko irrigation scheme. It has the possibility of providing jobs for about 250 people. It may require about N60 million to be executed.

CONCLUSION.

This study has been able to establish that the are abundant Water Resources in Adamawa State and that these Water Resources are being under utilized. Some areas of Water Resources Utilization were identified. Data collected on these areas were analysed. The result of the analysis indicated that significant improvement on the present state of Water Resources Utilization in the state is possible. To achieve these improvements, emphasis should be made on developing the Gerio, Loko, and Dasin Hausa irrigation schemes. If these schemes are fully developed, jobs will be created for thousands of people in the state, food supply will significantly improve and hence, alleviating the poverty of significantly large numbers of people in the state. The study also showed that the methodology and techniques of Management Science (Operations Research or Operational Research) could assist in analyzing policy issues.

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