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DOMESTIC WATER DEMAND IN RURAL SEMI-ARID NIGERIA

BY

ANTHONY OKON NYONG

A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Doctor of Philosophy

McMaster University

DOMESTIC WATER DEMAND IN RURAL SEMI-ARID NIGERIA

DOCTOR OF PHILOSOPHY (1998) McMASTER UNIVERSITY

(Geography) Hamilton, Ontario, Canada

TITLE: **DOMESTIC WATER DEMAND IN RURAL SEMI-ARID NIGERIA**

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NUMBER OF PAGES: xiv, 184

ABSTRACT

Many rural water projects fail because planners do not understand how local populations relate to, and use domestic water. Although domestic use accounts for about 9% of the consumptive use of water in sub-Saharan Africa, the benefits associated with improved access to it are immense. The study investigated domestic water use in the water-deficient semi-arid Nigeria, using a case study of Katarko. Detailed socio-demographic data known to affect water demand, were compared with aggregate data at the national and regional levels. The high population growth rate, low economic status of the women and the declining water availability present a good recipe for unsustainable water resource development and use in Katarko.

Katarko relies on stream flow, rainfall, ground water and ponds for its domestic needs, with ground water being the only source that can supply perennial water. Distance was identified as the most important factor in the choice of a water source. A tradeoff exists between using good quality water and the effort it takes to obtain it. Using culturally-constructed measures of water quality, the study found that the locals perceive the quality of water they use as higher in the rainy, than in the dry season. Cloth filtration is the preferred method of water purification, followed by the addition of anthill soil, while boiling ranks third.

Multiple regression models were used to study demand in the dry and rainy seasons, when water is scarce and abundant respectively. The levels of explanation provided by the

rainy season and dry season models are 51.2% and 91.1%, respectively. The lower explanatory power of the rainy season model may be an indication of wasteful use when water is abundant. Overall, the results show that although most of the determinants of water demand in both seasons are subject to socio-cultural interpretations, one can approach the management of it with economic principles. Incorporating the socio-demographic variables that affect domestic water demand into projections further reveals how changes in the variables affect future demand. Modeling seasonal variations in demand provides a glimpse of how consumers will adapt their demands to increased water supply.

Geographical accessibility is a major factor in the underutilization of rural water facilities in Nigeria, because facilities are often not optimally sited. This research demonstrates the utility of location-allocation modeling as a decision support tool in siting rural water facilities, where they are accessible to users and yield the highest social welfare returns. The option of either providing new wells that are optimally distributed, or rehabilitating existing wells as requested by the community was examined. The research recommended the provision of a new set of optimal wells, in view of the offsetting benefits associated with them.

The results of the study contribute conceptually and factually to the understanding of domestic water demand in rural areas of developing countries.

ACKNOWLEDGMENTS

I am deeply grateful to my supervisor, Dr. P. S. Kanaroglou, for his patience and constructive criticisms throughout the research. It has been pleasant working with him. I am also grateful to members of my supervisory committee, Dr. Bill Anderson, Dr. Kao-Lee Liaw, Dr. Susan Elliott, and Dr. Ming-Ko Woo, who despite their busy schedules, took time to review several drafts of the chapters. I wish to thank CIDA for the funding for this research, and the University of Jos for granting me a training leave.

Special thanks and appreciation go to my colleagues and friends, too numerous to mention here, who made my stay enjoyable. In particular, I wish to acknowledge the support of Chris, Isaac, Daniel, Charles, Wale, Ephraim, Augustine & Rose, Yetunde, Rifkatu, Norm, Nunoo and the DeMorgans. I am grateful to my Pastor, Reverend Isaac Acheampong and the members of All Nations Full Gospel Church for their prayerful support.

I wish to thank the entire staff of geography department, Joan Parker, Medy, Darlene and Jude. I am grateful to the staff of the GIS lab for letting it be my home these past four years. So, Ron, Dean and Ric, Pat, thanks to you all. My gratitude goes to Dr. Gary Warner, Ms. Cherryll-Ann Jackson, the International Students Advisor, for their support. Aria, for those times we spoke and you nudged me on, and expressed your belief in me, thanks a lot. To all the members of my family whom I love dearly, I say "thanks for the sacrifice".

Finally, I humbly acknowledge God's grace in leading me this far, and the strength to go through this programme.

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PREFACE.

This thesis is presented as a collection of papers. The research papers are:

Chapter 2: Nyong , A. O. and Kanaroglou, P. S. (1998). Socio-demographic characteristics of rural semi-arid Nigeria: Implications for sustainable water development and use. *The Professional Geographer,* submitted.

Chapter 3: Nyong, A. O. and Kanaroglou, P. S. (1998). A survey of domestic water use patterns in rural semi-arid Nigeria. *Society and Natural Resources*, submitted.

Chapter 4: Nyong, A. O. and Kanaroglou, P. S. (1998). Modeling seasonal variations in domestic water demand in rural semi-arid Nigeria. *Environment and Planning A.*

Chapter 5: Nyong, A. O. and Kanaroglou, P. S. (1998).GIS location-allocation approach to siting rural water facilities in northern Nigeria. *The Canadian Geographer,* submitted.

While all the papers were co-authored with the research supervisor Dr. P. S. Kanaroglou, the first author and candidate conducted the actual research involving the problem formulation, literature review, data collection, analysis and writing. Dr. Kanaroglou provided guidance on the direction of the research and reviewed several drafts of each paper.

As with all theses of these nature, several sections are unavoidably repeated, particularly the introductory ones. Variations in style were necessary to satisfy different journals, and are maintained in the thesis.

Chapter One

Introduction

1.1 Background

Although domestic water use accounts for only 9% of the consumptive water use in sub-Saharan Africa (World Resource Institute, 1994), the benefits associated with its adequate supply, such as the effects on health, time savings and greater productivity, are immense (Whittington and Swarna, 1994; Young,1996; Sharma et al.,1996). In recognition of these benefits, successive governments and multinational donor agencies have invested considerable amounts of money toward water projects in rural areas of developing countries. These investments have yielded limited successes and several factors have been identified as responsible for this. They come under the now familiar themes of economic and financial resource constraints, lack of sectoral integration, the lack of community participation and the neglect of women in project planning, inappropriate technology, and weak institutional and implementation capacities (Khan, 1988; Munasinghe, 1990; Kendie, 1992; Koudstaal et al., 1992; Mitchell, 1994; Sharma et al., 1996).

In Nigeria, the failure of rural water projects is of particular concern in the semi-arid region, which is home to 30% of the country's population. Here, water scarcity remains an endemic problem and a continuous threat to survival, creating considerable social, cultural and economic disadvantages. It is a major cause of ethnic and environmental conflicts in the region. Recognizing the failure of past attempts to solve the problems associated with water

scarcity in this region, and the need for alternative strategies, led to the establishment of the Jos-McMaster Drought Research Project in 1993. The goal of the project is to develop community-based, culturally-appropriate and cost-effective strategies for sustainable water development and use in the rural areas of semi-arid Nigeria. For this project to succeed, the following issues should be considered besides the general problems identified earlier.

First, because of the limited water availability in this region, there exists a need to set up policies that will create a balance between population and the local water resource base. The failure of past policies is blamed in part on the limited knowledge of the intricate relationship between population and water resources. Population dynamics determines the growth and distribution of basic needs for domestic water. It is thus the dominant factor in developing regions, especially under arid and semi-arid areas. Traditionally, the search for solutions to the problems of water scarcity has focused on technology, much less on economic instruments and even less on population variables. Where population variables are taken into consideration, analysis is often based on aggregate data at regional or national levels. This broad picture is often insufficient, both on the population side and the development side. It potentially conceals spatial variations in socio-demographic structures, which modify the spatial pattern of demand for domestic water. A good policy should be based on data collected at the micro-level where water development and use are seen through the decision-making process of small group and household economies (Ruddle and Rondinelli, 1983).

Second, water planners often do not take into consideration the social and cultural

inclinations of local water users in the design of water projects. As droughts and long periods of dryness are regular features of the climate of this region, local populations have adapted their water use to varying levels of water availability. They have accumulated valuable information and practices that ought to be incorporated into more formal analyses of sustainable water development (Mabogunje, 1995; Sharma et al., 1996). As not all indigenous practices may encourage efficient water use, building on indigenous knowledge and tradition can only be successful where there is awareness of the problems associated with them, and identification of solutions (Hirji, 1995; Okaru, 1995). Understanding the water use habits of this region could lead to the development of policies that are economically feasible, culturally acceptable and environmentally sound.

Third, the limited water availability in this region, requires that the prevailing supply-oriented approach to rural water development, should give way to one that emphasizes demand management. This requires a better understanding of the preferences and behavior regarding water supply of rural households. (Briscoe and DeFerranti, 1988; Young, 1996). The inapplicability of traditional demand models used in developed countries, has led to the formulation of improved demand models for rural areas in developing countries (Mu et al., 1990; World Bank Water Demand Research Team, 1993; Whittington and Swarna, 1994). These models have primarily concentrated on the factors that govern the choice of rural water sources and the willingness to pay for improved water services. While they provide excellent tools for managing existing demand, they do not address how demand will be affected by the provision of the improved services.

Models that estimate demand as a discrete-continuous process take care of this problem. They characterize how a household decides which water source to use for different purposes, and how much water to use from a particular source. However, this modeling approach has an inbuilt constraint, in that its assumption of an equal choice set among all households is not true in communities in semi-arid Nigeria. Institutional and geographical barriers deny certain people access to some water sources, and all households in the village do not have the same set of water sources from which to choose. Moreover, at the peak of the dry season, the hand-dug well is the only source of water and users do not have a choice about which water source to use for what purpose. Besides these limitations, the model is computational intensive and may not be readily used by local water planners in Nigeria. Adopting a simpler and equally practical approach to estimate demand for improved services before their implementation is pertinent.

Besides considering present demand for water, anticipating future demand and incorporating them in developmental policies is also important. Most often planners do not know the impact of proposed developmental policies on water demand, particular in this region where the pressure on the scarce resource is already acute. Conventional demand projections in Nigeria are based on per capita population units and often exclude socio-demographic variables known to affect domestic water use. Such projections can result in inaccurate demand estimates (Murdock et al., 1991). Besides providing a more accurate estimate of demand, incorporating the determinants of water demand into projections can allow for the conduct of scenario analysis to examine the impact of various national and local

policies on water demand.

Fourth, geographical accessibility is a major factor that hinders the effective use of water facilities. It is documented in literature that water users, particularly women, travel several kilometers daily to fetch water (White et al., 1972; Logan, 1986; Briscoe and DeFerranti, 1988; World Health Organization, 1992; Rathgeber, 1996; Falkenmark, 1994; Sharma et al., 1996). Despite this realization, the selection criteria for the location of water facilities are often not rigorous or need-based. They are often provided in response to specific political or tribal agendas, without considering locations that will be most accessible to users, yielding the highest social welfare returns. Selecting locations that are efficiently and equitably distributed can significantly improve the utilization of rural water facilities (Logan, 1986). Besides, the savings on time that would have been spent traveling to obtain water can be used for more productive ventures.

Developing a better understanding of the relationships between population dynamics, socio-economic development and domestic water, is an indispensable step in formulating related policies. In view of the issues raised above, the goal of this research is to seek a better basic information on water use patterns using a case study of Katarko village, in the semi-arid region of northern Nigeria. The village was selected for this study because it typifies rural semi-arid Nigeria and allowed their women to participate in the project. Because women are the primary users of domestic water, their contribution and participation are important to the success of any rural water project.

1.2 Objectives

The objectives of the study include the following:

1. To show that while data aggregated at regional levels show successes in Nigeria's population policy, they conceal spatial variations in the demographic structure. The study describes the socio-demographic characteristics of Katarko and compares them with those reported at the regional and national levels. The goal is to show how the limited success in Nigeria's population policies can encourage unsustainable water resource development and use in rural semi-arid Nigeria.

2. To examine domestic water use as it relates to the cultural and social norms of rural semi-arid Nigeria. This could enhance the development of economically feasible, culturally acceptable and environmentally sound water development policies in the area. Often, water projects are set up without recourse to how the host population will relate to the new service. This has resulted in situations where facilities are not optimally used because they do not conform with local norms.

3. To develop a domestic water demand function for rural semi-arid Nigeria. With its extremely arid environment and high seasonal water availability, water use may not be subject to the same explanatory criteria as the rest of Nigeria. The study investigates the key demographic, social and cultural variables that affect domestic water demand, and examines how the significance of these variables varies between the rainy and the dry seasons. Modeling domestic water use in the dry season when water is scarce and in the rainy season when it is abundant can also reveal how households will adapt their demands to improved

water services, before they are set up.

4 To assess the implications of including the determinants of water demand into water demand projections. Conventional water demand projections used in Nigeria are based on per capita population units. They do not include other variables known to affect domestic water use. Incorporating these determinants can improve demand projections, and provide the tool for assessing the potential impacts of developmental policies on water demand, before their implementation.

5. To describe the application of location-allocation modeling as a spatial decision support tool to site water facilities in Katarko optimally. Geographical accessibility is identified as a major obstacle to the efficient use of rural water facilities. Providing water facilities at locations that are efficiently and equitably located can encourage their more efficient use, by that justifying the huge investments in providing them.

1.3 Organization of Thesis

Successful application of any strategy to encourage sustainable water development in this region requires, among other things, knowledge of the region's demographic, socioeconomic and cultural characteristics. In addition, one needs to know the anticipated changes in their patterns and trends, as aggregate water consumption patterns may change in response to shifts in these characteristics. Chapter 2 describes the socio-demographic structure of Katarko, and projects its population for the next 30 years. It also highlights the factors that may not encourage sustainability of domestic water use in Katarko.

Chapter 3 examines the pattern of domestic water use in the village. Particular attention is paid to the social and cultural norms of the people and some of their indigenous knowledge system as it applies to domestic water use. Distance to water sources, rather than water quality, is identified as the most important factor that affects domestic water use. The essence of the chapter is to create an awareness concerning possible problems that may be associated with water use habits in the village, and identify possible solutions to them.

In chapter 4, the factors that affect domestic water use in Katarko in the dry and rainy seasons are investigated using multiple regression analysis. The results generally support other studies (White et al., 1972; Mu et al., 1990; World Bank Water Demand Research Team, 1993) that the determinants of domestic water use in rural Africa are subject more to socio-cultural than economic interpretations. Nevertheless, the study finds that the management of it can be approached through economic means.

Considering that distance is the most important factor affecting domestic water use in the village, location-allocation models are used to examine the optimality of existing public wells in Chapter 5. The option of rehabilitating existing wells, as requested by the villagers, is compared with that of providing fresh wells that are optimally located. Although providing fresh wells is more expensive than rehabilitating existing ones, the latter option was recommended in view of the offsetting benefits associated with optimally located wells.

Chapter 6 summarizes the major findings and contributions of the research and presents future research that has emanated from this study.

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Chapter Two

Demographic Characteristics of Rural Semi-Arid Nigeria: Implications for Sustainable Water Development and Use.

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Abstract.

Planning for scarce resources requires careful and detailed demographic and socioeconomic characterization of the user-population at the micro scale. Reliance on aggregate data at regional and national levels, conceals demographic variation and the distribution of demand over space. This paper compares the socio-demographic characteristics of Katarko village in the semi-arid region of northern Nigeria, with those at the national and regional levels. The results show a limited impact of Nigeria's population policy in the village. The high rate of population growth, prevalent level of poverty and illiteracy, particularly among the women, and declining water availability, have strong implications for sustainable water resource development and use in the village.

Key Words. Demographic characteristics, poverty, semi-arid Nigeria, sustainable water use, women.

2. 1 Introduction and Background

In response to the perceived adverse socioeconomic and environmental consequences of rapid population growth, Nigeria launched a National Policy on Population and Development in 1988. The primary goal of the policy was the deceleration in the rate of population growth with a consequent improvement in the standard of living (Federal Republic of Nigeria 1988). Official reports at the national level have recorded gains in population control since the start of this policy. Success at the national level, however, does not reveal the disparities that exist at the regional level. The report of the Nigeria Demographic and Health Survey (NDHS) shows that fertility rates in the south have declined significantly, while those in the north have increased. On the other hand, mortality rates have declined in all the regions, the least decline reported in the north (NDHS 1990). The higher fertility and mortality rates reported in the north are bothersome, especially in the semi-arid zone, which is home to one-third of Nigeria's population. This is because the impact of rapid population growth on the region's fragile resource base is more critical than in other parts of Nigeria.

One resource of concern in semi-arid Nigeria is water. Its scarcity is a pressing problem, creating considerable social, cultural and economic disadvantages. It is a continuous threat to survival. Its impacts are more damaging in rural areas where the population depends largely on natural sources of water for their subsistence. As part of the efforts to combat these negative impacts, successive governments have set up rural water projects in this region to provide sufficient water to meet the needs of its ever-increasing

population. These projects are usually operated under the implicit assumption that water is a free and infinite resource that should be provided at no cost to the users. The sustainability of such projects is usually not considered. This has resulted in several malfunctioning or broken down facilities. The failure of these rural water projects, besides the declining water availability, has called for measures that would improve the efficiency of water use in this region. Consequently, the Jos-McMaster Drought Research Project was established in 1993 with funding from the Canadian International Development Agency (CIDA). The project is involved in developing community-based, culturally-appropriate and cost-effective strategies for sustainable water development and use in the rural areas of the semi-arid northern Nigeria. Additionally, it seeks to enlarge the indigenous capacity for management of the region's water resources.

Successful implementation of any strategy to encourage sustainable water development in this region calls for efforts at creating a balance between population and the local water resource base. This requires, among other things, knowledge of the region's demographic, socioeconomic and cultural characteristics. In addition, one needs to know the anticipated changes in their patterns and trends, as aggregate water consumption patterns may change in response to shifts in these characteristics. Using data aggregated at regional and national levels can conceal spatial variations in socio-demographic structures and may fail to identify unsustainable enclaves that could benefit from immediate population intervention efforts. The thesis of this paper is that while the impacts of population intervention measures are felt less in the north, some places are even worse than are reported at the regional level.

Consequently, population pressure on an already scarce water resource is more severe and the need to encourage and promote its sustainable development and use is very crucial. Immediate efforts should be directed toward identifying areas that are unsustainable, where immediate policies aimed at balancing population growth and resource availability and use can be applied. To achieve this, one has to study data at the micro-level where water development and use must be viewed through the decision-making process of small group and household economies.

This paper describes and explains the socio-demographic characteristics of Katarko, a potentially unsustainable enclave in semi-arid northern Nigeria, and compares these characteristics with those reported at the regional and national levels. Our goal is to show how the failures in Nigeria's population policies can encourage unsustainable water resource development and use in rural semi-arid Nigeria. The paper also suggests measures that can improve Katarko's socio-demographic characteristics, as well as encourage sustainability in water resource development and use. We do not imply that an improvement in the socio-demographic structure alone will guarantee the sustainability of water development projects, as other factors are known to affect it. However, it can be regarded as a step in the right direction.

The first section of the paper describes the study area, providing a geographical setting to the study. This is followed by a description of the research method and data sources. Next, we present the current socio-demographic characteristics of the study area, after which we present the projected population of the village. The purpose of this is to

estimate the growth potential of Katarko within the next three decades. We then discuss the implications of the population characteristics of this village on domestic water use. The paper concludes with a summary of the research findings and directions for future research.

2.2 Study Area

Katarko was chosen as the study site from among several communities visited by the research team. Besides typifying rural semi-arid Nigeria, it was the only village that was willing to allow their women to participate in the project. It is located on latitude 11°33' N and longitude 11°55' E in Yobe state in north-eastern Nigeria (Fig. 2.1). The village occupies an area of approximately two square kilometers and is about 20 km from Damaturu, the Yobe state capital, and 128 km from Maiduguri, the Borno state capital. Despite its proximity to major urban centers, the village has no infrastructure that permits the development of modern sanitary or water supply facilities. Katarko has a hot climate, with yearly temperature extremes ranging from 15°C during the harmattan months (November - February) to about 40°C during the months of April and May. The area experiences two marked seasons, dry and wet, with mean annual rainfall of about 600 mm. The wet season lasts about three months between July and September, while the dry season lasts from October to June. Katarko has a population of 2820 people made up of 1488 males and 1332 females (authors' field work 1996). Rain-fed agriculture and animal husbandry are the main income-generating activities in the area. Groundnut, millet, guinea-corn and maize are the main cash crops while cattle, goats and sheep are the basis of livestock production. The

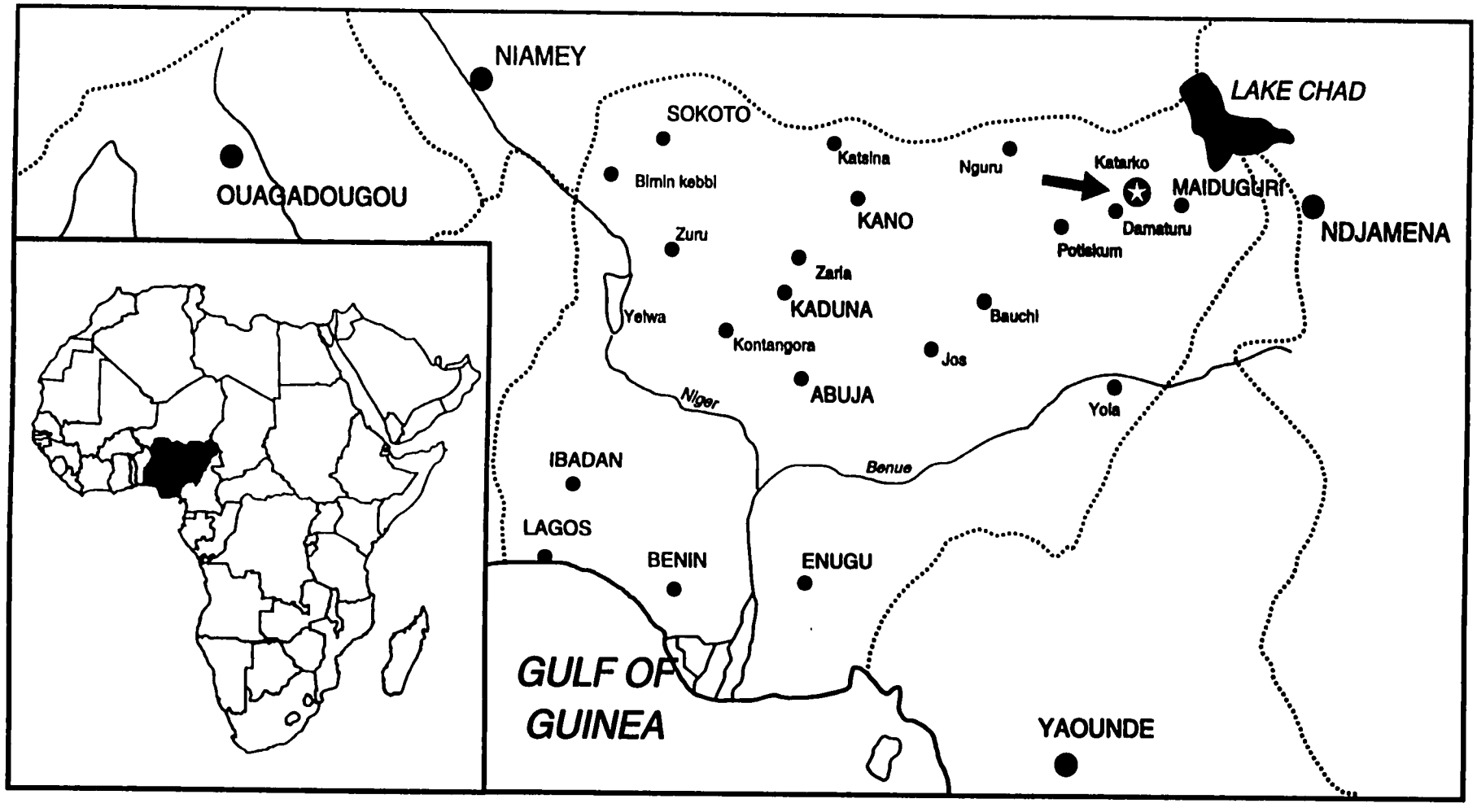

Fig. 2.1: Study area in Nigeria showing major urban centres

village consists of 10 wards, each made up of compounds which form the basic living structure of people bound together by ties of kinship. The main ethnic groups in the village are the Kanuri, Hausa, Fulani, Shuarab and Kare-Kare. Hausa and Kanuri form the main ethnic groups in four wards each, while Shuarab and the Fulani are prominent in one ward each. Katarko came into existence in about 1937, after a colonial officer dug an artesian well in the area (Lee 1995). The implication of this is that the availability of water, which happens to be a scarce resource in the region, aided in establishing the village.

2.3 Research Method and Data Sources

The data for this paper were derived mainly from two face-to-face questionnaire surveys undertaken from June to August 1996 and January to March 1997. Both periods coincide with the rainy and dry seasons respectively. To eliminate the male bias that would result from administering the questionnaires to only household heads who were always men, we also interviewed their spouses.

The survey instrument (Appendix 3) consisted of five sections, each concentrating in one of the following areas: (1) the general characteristics of the household, (2) the economic condition of the household, (3) migration and migration intentions in the village, (4) the relationship of households to water and its use, (5) retrospective information on fertility and mortality history.

Available resources allowed us to sample 250 of the 600 households in the village, representing a sampling fraction of 42%. To ensure proportional representation from all the

wards, a stratified sampling strategy was adopted. The sampling frame was the list of all households in each ward collected during a previous survey (Ihemegbulem 1996). Forty-two percent of the households from each ward were then randomly selected from this list for enumeration. Two hundred women, spouses of the household heads, were also selected for enumeration using the same sampling strategy. Here, the sampling frame was the list of all interviewed household heads.

The instrument was administered by a research assistant and four field assistants (three men and two women), who speak the local languages and English. These interviewers were recruited and trained in May 1996. The culture of the society does not encourage interaction between adult men and women who are not married to each other, so the female assistants administered questionnaires to the women. We anticipated that female respondents would be more open with female enumerators than they would be with male enumerators.

During the first survey conducted in the rainy season, between June and August 1996, all the 250 household heads and 200 women were interviewed. The overall response rate was 100% as no household head or his spouse refused to be interviewed. However, two of the questionnaires from the household heads were unfit for analysis and were discarded. During the second survey, an attempt was made to administer the same questionnaires to the households and women enumerated during the first survey. The main purpose of the second survey was to obtain information on changes in water use patterns between the two seasons. Two hundred and nineteen households were interviewed during the second survey because 29 households interviewed in the first survey had migrated from the village with all their

members. The overall response rate for the second survey was 100%. One questionnaire was found unfit for analysis and was discarded.

2.4 Socio-demographic Characteristics

2.4.1 Characteristics of households and respondents

2.4.1.1 *Household size.*

Based on our sample, household size in Katarko ranges from two to 12 persons, with modal and average household size being five and 4.8 persons respectively. The report of the Nigeria Demographic and Health Survey (NDHS 1990) showed that the average household size in rural Nigeria was 5.6, with north-eastern Nigeria having the largest average household size of 5.8 persons. This shows that the average household size in Katarko is below the reported national and regional averages. Our sample contained no female-headed households. This is common as less than 5% of the households in the north are headed by women, compared to more than 20% in the south (NDHS 1990). A major reason for this is the way by which local communities in the north identify a household head. Katarko, for instance, adopts three methods based on its social organization and customs. The first choice is the person identified by other household members as the one who controls the maintenance of the household and exercises the authority to run the household. Without such an individual, the second option is the person who is the chief earner or supporter of the household's economy. The custom and culture of the village preclude women from owning large farms, by that making it rare for them to be the chief earners in the households. A third choice is the

person who is the oldest male resident in the household.

2.4.1.2 *Sex and age composition.*

The set of pyramids in Fig. 2.2 presents the population composition of Katarko in the rainy and dry season. The ratio of males to females varies with the season. During the rainy season when most of the farming activities take place, the men make up 53.2% of the population, while women account for only 46.8% (Fig. 2.2a). On the other hand, the proportion of males are lower than females (49.1% and 50.9% respectively) in the dry season when little farming activities take place (Fig. 2.2b). This seasonal sex imbalance is a reflection of labor market adjustment in the wider area around Katarko. During the dry season, the young men move out of the village in search of jobs that are unrelated to farming. Accordingly, the proportion of the working age population is lower, particularly among men, in the dry season (50.2%) than in the rainy season (57.4%). This results in higher age dependency ratios in the dry than in the rainy season. The five-year age groups of population in Katarko conform to the pattern of high fertility populations, with many children and young adults. Children below the age of 15 years make up 40.9% of the population in the rainy season (see Fig.2.2a) and 47.7% in the dry season.

2.4.1.3 Education.

Although universal literacy is recognized as a fundamental right and as an explicit development objective, this goal remains elusive in many developing countries, including

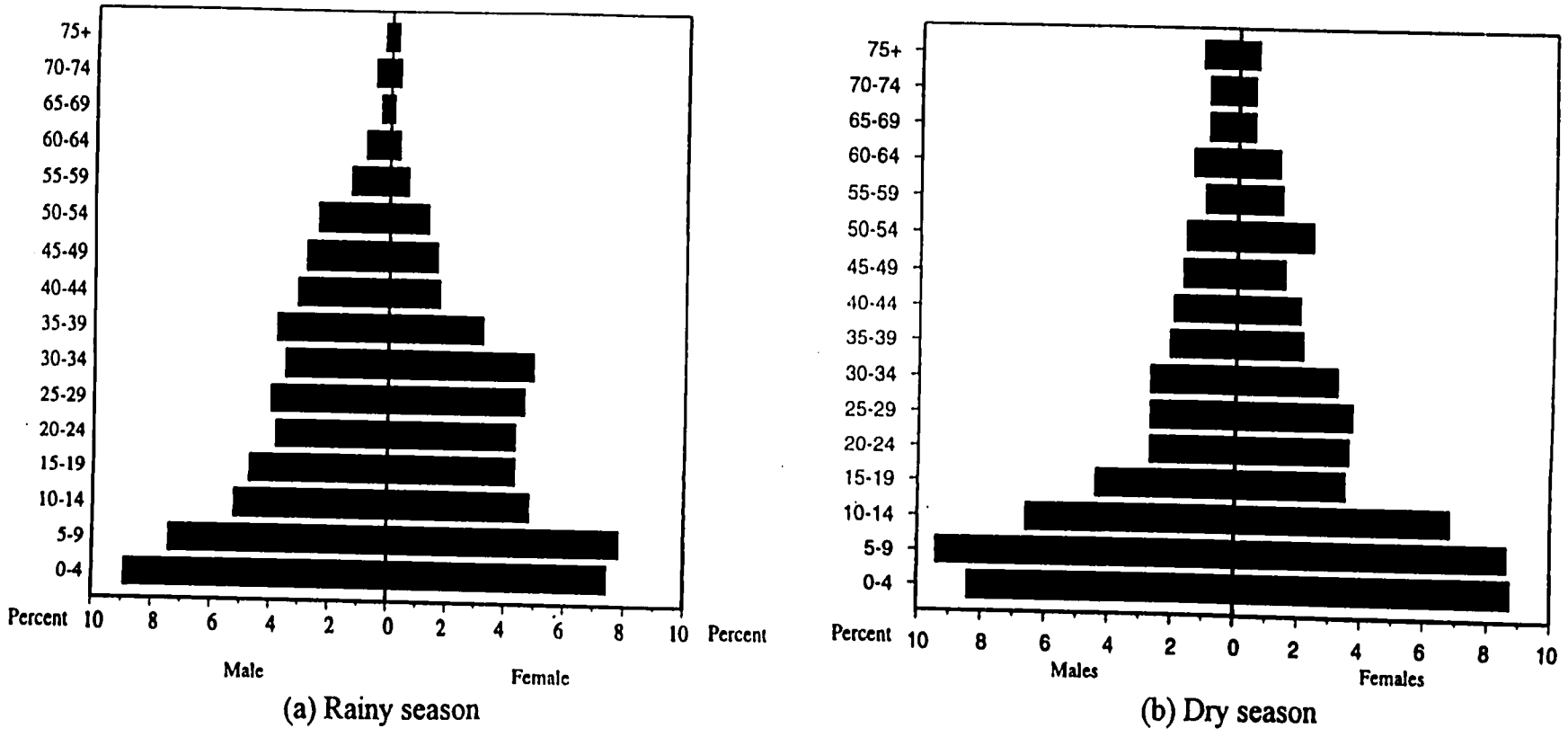

Fig. 2.2: Population composition of Katarko

Nigeria. In 1976, Nigeria adopted a national policy on Universal Free Primary Education, which gave every child the right to free primary education. To serve the needs of migrant pastoral nomads and their children, the government established the National Commission on Nomadic Education in 1989. To complement this effort, the government launched a national mass literacy campaign in 1990 with the purpose of raising literacy. These programs have little impact in Katarko, where an insignificant proportion of the population (1.1% of the males and 0.2% of the females) has completed secondary education. Only 10% of the males and 7.7% of the females have completed primary education. More than 50% of male and 70% of female children aged 5-9 are not enrolled in school (Table 2.1).

Without considering Koranic education, the proportion of males and females in Katarko without any formal education (80.5% and 86.1% respectively), are higher than the national average of 50.2% and 65.2% (NDHS 1990). With Koranic education, only about 35% of the males have not received any education, compared with 67.3% of females in that category. This shows that females are twice as likely to have never attended school as males.

There is a variation in educational attainment among the various tribes in Katarko (Table 2.2). The Kanuris are the most educated, with 34.1% and 30.2% of the males and females having received some form of formal education. Next are the Kare-Kares, with 29.4% and 6.3% respectively. The Shuarabs and the Fulanis have the highest proportion of women (100%) without any formal education.

Table 2.1: Proportion of children of school age enrolled in school in Katarko

(a) Males

Age	None	Koranic School	Some Primary	Primary Completed	Some Secondary	Secondary Completed	Higher	Total	Number of Persons
5-9	52.8	23.6	21.4	1.1	1.1	0.0	0.0	100	89
10-14	25.8	53.2	16.2	1.6	3.2	0.0	0.0	100	62
15-19	8.9	62.5	7.1	14.3	3.6	3.6	0.0	100	56
20-24	21.8	39.1	13.0	23.9	0.0	2.2	0.0	100	46
25-29	10.4	54.2	2.1	22.9	2.1	8.3	0.0	100	48
30-34	14.3	71.4	0.0	9.5	2.4	0.0	2.4	100	42
35-39	21.7	69.6	0.0	8.7	0.0	0.0	0.0	100	46
40-44	24.3	70.3	0.0	5.4	0.0	0.0	0.0	100	37
45-49	14.7	82.4	0.0	2.9	0.0	0.0	0.0	100	34
50-54	17.2	82.8	0.0	0.0	0.0	0.0	0.0	100	29
55-59	13.3	86.7	0.0	0.0	0.0	0.0	0.0	100	15
60-64	20.0	60.0	0.0	10.0	10.0	0.0	0.0	100	10
65+	16.7	83.3	0.0	0.0	0.0	0.0	0.0	100	12
Total	**34.8**	**45.7**	**7.6**	**9.2**	**1.4**	**1.1**	**0.2**	**100**	**526**

(b) Females

Age	None	Koranic School	Some Primary	Primary Completed	Some Secondary	Secondary Completed	Higher	Total	Number of Persons
5-9	70.2	12.8	16.0	1.0	0.0	0.0	0.0	100	94
10-14	52.7	22.8	17.5	7.0	0.0	0.0	0.0	100	57
15-19	53.8	13.5	3.9	26.9	1.9	0.0	0.0	100	52
20-24	65.4	19.2	7.7	7.7	0.0	0.0	0.0	100	52
25-29	54.5	16.4	1.8	25.5	0.0	1.8	0.0	100	55
30-34	67.8	23.7	0.0	8.5	0.0	0.0	0.0	100	59
35-39	71.0	21.0	5.4	2.6	0.0	0.0	0.0	100	38
40-44	85.0	15.0	0.0	0.0	0.0	0.0	0.0	100	20
45-49	89.5	10.5	0.0	0.0	0.0	0.0	0.0	100	19
50-54	77.8	11.1	0.0	11.1	0.0	0.0	0.0	100	9
55-59	87.5	12.5	0.0	0.0	0.0	0.0	0.0	100	8
60-64	75.0	25.0	0.0	0.0	0.0	0.0	0.0	100	4
65+	90.9	9.1	0.0	0.0	0.0	0.0	0.0	100	11
Total	**67.3**	**18.8**	**5.6**	**7.7**	**0.4**	**0.2**	**0.0**	**100**	**478**

Table 2.2: Educational attainment among the tribes in Katarko (percentage)

	Education														Total
	0		1		2		3		4		5		6		
Tribe	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Hausa	13.9	52.4	80.7	41.5	1.1	1.4	3.7	4.8	0.0	0.0	0.5	0.0	0.0	0.0	100.0
Kanuri	25.0	56.6	40.1	13.2	12.5	13.2	16.8	16.2	2.2	0.4	2.6	0.4	0.9	0.0	100.0
Shuarab	81.8	100.0	0.0	0.0	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Fulani	37.3	85.3	55.4	14.7	3.6	0.0	2.4	0.0	1.2	0.0	0.0	0.0	0.0	0.0	100.0
Kare-Kare	35.3	81.3	35.3	12.5	17.6	6.3	5.9	0.0	5.9	0.0	0.0	0.0	0.0	0.0	100.0

Educational Levels.
0 - No Education
1 - Koranic Education
2 - Some Primary
3 - Primary Completed
4 - Some Secondary
5 - Secondary Completed
6 - Higher

2.4.1.4 *Income*

The average annual income of N17,500 (about US$ 180.00) earned by household heads in the village is lower than the national average of N23,500 (US$ 280.00). Although poverty is widespread in Katarko, it is more prevalent among the women. Eighty-four percent of the women earned less than N10,000, compared with only 18% of the men. The reason for the low income among women is that most of them do not participate in the formal labor force. Some of them own small farms where they keep some domestic livestock, like goats and chicken, and control the income from these farms and the sales of such domestic livestock. The income they earn from these ventures is usually small and go into household maintenance. Most of the women work usually in the family farms that are under control of the household heads. Sixty-four percent of the women reported that proceeds from the farms

all go to the household heads, while 27% reported that the household heads shared the money among all male adult household members. Only 9% reported that the money is shared among all adult household members, which includes the women.

2.4.2 Fertility

Katarko has a high crude birth rate of 55 per thousand and a total fertility rate of 7.6, suggesting a population with high growth potential. A major factor contributing to the high fertility rate is the prevalence of early marriages. The earliest age at marriage was 10 years for men and 8 years for women. On average, the age at first marriage was 21 for men and 14 for women. Also, the modal age at first marriage for males was 20 while for females it was 12. At the national level, the female mean age of first marriage in 1981/82 was 18.7 while the figure had dropped to 16.7 in 1991. Usually, the younger the marriage age for women the higher the fertility, since married women are exposed to the risk of conception for a larger portion of their reproductive years. This phenomenon is of strong concern in this village since they have not widely accepted family planning. A typical response during informal discussions on fertility was that "children are gifts from God. He chooses whom He wants to give whenever He wants and one cannot question His providence."

The 15-19 age group has the highest age specific fertility rate for all educational levels except those who have completed primary education (Fig.2.3). The latter group reaches its peak fertility at age 20-24. This phenomenon is related to the patterns of first marriage, as the more educated women delay marriage compared with their less educated

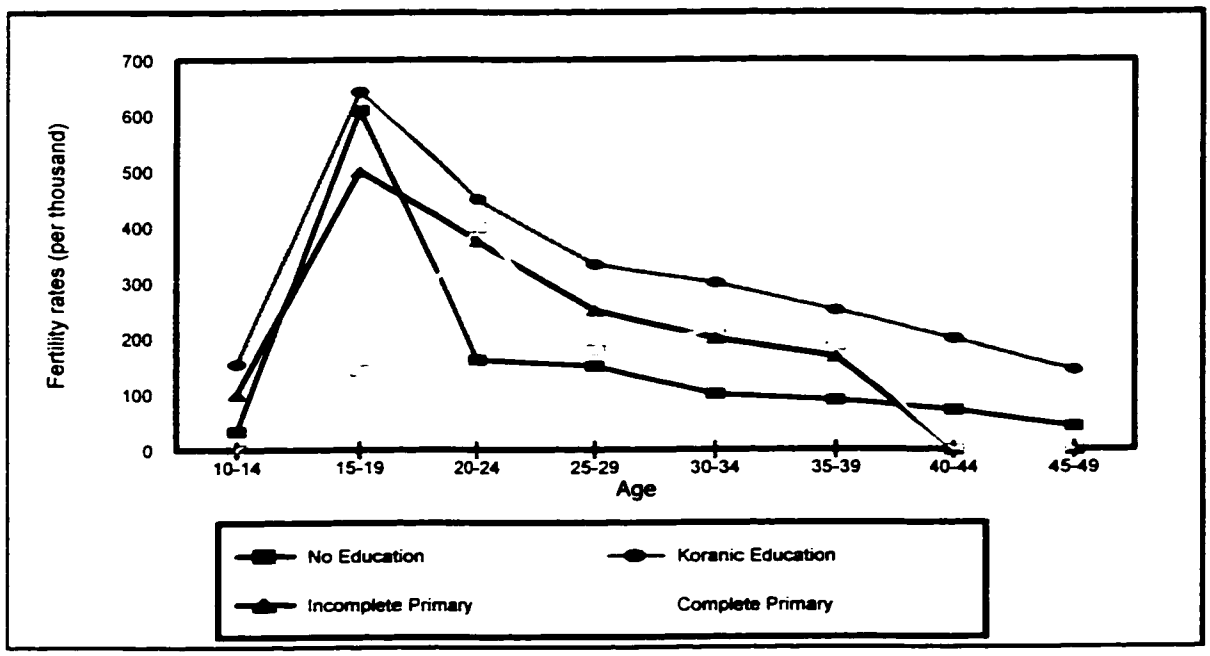

Figure 2.3: Age specific fertility rates by educational levels in Katarko

counterparts.

The effect of education on delayed marriage, and subsequently on fertility, is documented in literature (United Nations 1986; Caldwell et al. 1992; Ainsworth et al.1995; Shapiro 1996). Results from Katarko further support these studies. Women with either no education, Koranic education or incomplete primary education, have the highest fertility rate at the 15-19 age group. Women with only Koranic education consistently have more children across the childbearing age than all the other groups, including those without education. Those with some form of education, but who have not completed primary education, have higher total fertility rates than women with no education. Also, women with only Koranic

education have a higher total fertility rate than women with no education (10.9 and 6.4 respectively). Women who have not completed primary education have a total fertility rate of seven, while women who have completed primary education have the lowest total fertility rate of six.

An examination of general fertility rates among the various tribes in Katarko reveals that the Shuarabs have the highest rate of 300 per thousand, followed by the Hausas at 240.5 per thousand. The Fulanis have 220.8, while the Kare-Kares and the Kanuris have 210.5 and 175 per thousand respectively. Several factors, such as the disparity in educational patterns and child mortality rates may be responsible for this difference in fertility rates. The Shuarabs, besides the fact that none of their women had any formal education, recorded the highest under-five mortality rate. Studies have shown that high levels of child mortality spur parents to have many births (Schultz 1976; Okojie 1991; Maglad 1994).

2.4.3 Mortality

It is generally accepted that female child mortality rates are systematically above those for males in developing countries (D'Souza and Chen 1980; LeGrande and Mbacke 1995). However, Tabutin and Willems (1995), in a comparative study of 62 developing countries, report that males have higher infant mortality rates, while female mortality rates are higher at ages 1-5. In Katarko, both the infant and under-five mortality rates for males are higher than for females. The infant mortality rate for males is 209.3 per thousand, while that for females is 176.4 per thousand. The under-five mortality rates are 85 per thousand and

25 per thousand for males and females respectively. Part of the reason for these high figures might be the outbreak of meningitis in the village, about two months before our survey in 1996. Besides the high incidence of diarrhoea and other killer diseases, the high child mortality rates in Katarko could be attributed to the predominantly young ages of the mothers. Hobcraft (1992), in a study of the impact of fertility patterns on child survival in 18 countries, showed that children born to teenage mothers, especially those under age 18, experience considerable excess mortality before age 5.

Katarko has a high crude death rate of 42.6 per thousand compared with the national average of 14 per thousand reported in 1996 (Federal Republic of Nigeria 1996). Although the crude death rate for males (37.5 per 1000) is lower than that of females (43.9 per 1000) in Katarko, Tables 2a and 2b show that life expectancy at birth is higher for females (42.4) than males (35.8). Women maintain the higher expectation of life throughout the life table except between the ages of 10 and 29, suggesting a high mortality risk of pregnancy and child birth. Based on figures reported for 1995 before the outbreak of the meningitis epidemic, the expectation of life at birth was 38.9 for males and 45.6 for females. These figures are still lower than the life expectancies at birth of 44.5 and 52.5 for males and females, reported at the national level.

Table 2.3a: Abridged life table for males in Katarko

Age	nmx	nqx	npx	lx	ndx	nLx	Tx	ex
Under 1	0.209	0.1823	0.8177	10000	1823	8724	358171	35.8
1-4	0.085	0.2765	0.7235	8177	2261	26602	349447	42.7
5-9	0.005	0.0247	0.9753	5916	146	29213	322845	54.6
10-14	0.003	0.0149	0.9851	5770	86	28633	293632	50.9
15-19	0.002	0.0100	0.9901	5684	57	28277	264999	46.6
20-24	0.000	0.0000	1.0000	5627	0	28135	236723	42.1
25-29	0.007	0.0344	0.9656	5627	194	27651	208587	37.1
30-34	0.005	0.0247	0.9753	5434	134	26832	180936	33.3
35-39	0.005	0.0247	0.9753	5299	131	26170	154104	29.1
40-44	0.016	0.0769	0.9231	5169	398	24849	127934	24.8
45-49	0.000	0.0000	1.0000	4771	0	23855	103086	21.6
50-54	0.030	0.1395	0.8605	4771	666	22190	79231	16.6
55-59	0.052	0.2301	0.7699	4105	945	18165	57041	13.9
60-64	0.000	0.0000	1.0000	3161	0	15803	38876	12.3
65-69	0.100	0.4000	0.6000	3161	1264	12643	23073	7.3
70-74	0.100	0.4000	0.6000	1896	759	7586	10430	5.5
75+	0.142	1.0000	0.0000	1138	1138	2845	2845	2.5

Note:

nmx	=	The annual death rate among people between birthdays x and x+1
nqx	=	The probability that a person at exact age x will die before age x+1
npx	=	The probability that a person at exact age x will survive to age x+1
lx	=	The number of people surviving to their age x birthday each year
ndx	=	The number of people dying each year between exact ages x and x+1
nLx	=	The number living between exact ages x and x+1
Tx	=	The sum of nLx values for all ages x and older
ex	=	The mean years of future lifetime of persons reaching age x

Table 2.3b. Abridged life table for females in Katarko

Age	nmx	nqx	npx	lx	ndx	nLx	Tx	ex
Under 1	0.1760	0.1567	0.8433	10000	1567	8903	424065	42.4
1-4	0.0250	0.0937	0.9063	8433	790	31599	415162	49.2
5-9	0.0050	0.0247	0.9753	7643	189	37744	383563	50.2
10-14	0.0020	0.0100	0.9901	7454	74	37086	345819	46.4
15-19	0.0020	0.0100	0.9901	7380	73	36717	308733	41.8
20-24	0.0180	0.0861	0.9139	7307	629	34960	272016	37.2
25-29	0.0170	0.0815	0.9185	6677	544	32026	237055	35.5
30-34	0.0170	0.0815	0.9185	6133	500	29415	205029	33.4
35-39	0.0260	0.1221	0.8779	5633	688	26446	175614	31.2
40-44	0.0200	0.0952	0.9048	4945	471	23549	149169	30.2
45-49	0.0010	0.0050	0.9950	4474	22	22316	125619	28.1
50-54	0.0000	0.0000	1.0000	4452	0	22260	103303	23.2
55-59	0.0010	0.0050	0.9950	4452	22	22205	81043	18.2
60-64	0.0080	0.0392	0.9608	4430	174	21715	58838	13.3
65-69	0.0500	0.2222	0.7778	4256	946	18916	37123	8.7
70-74	0.1000	0.4000	0.6000	3310	1324	13241	18207	5.5
75+	0.1500	1.0000	0.0000	1986	1986	4965	4965	2.5

Note:

nmx	=	The annual death rate among people between birthdays x and x+1
nqx	=	The probability that a person at exact age x will die before age x+1
npx	=	The probability that a person at exact age x will survive to age x+1
lx	=	The number of people surviving to their age x birthday each year
ndx	=	The number of people dying each year between exact ages x and x+1
nLx	=	The number living between exact ages x and x+1
Tx	=	The sum of nLx values for all ages x and older
ex	=	The mean years of future lifetime of persons reaching age x

A breakdown of mortality by ethnic groups shows that the Shuarabs and the Kare-Kares have the highest under-five mortality rates (333.3 per thousand). The Kanuris have 118 per thousand while the Fulanis and the Kare-Kares have 50 and 44 per thousand respectively. A possible explanation for this variation is found in average educational attainment. The Shuarabs are the least educated tribe in the village, and none of their women has ever been to school (see Table 2.2). Research has shown that a mother's level of education has a strong negative association with child mortality (Hobcraft et al. 1984; United Nations 1985; Adetunji 1995). More educated women probably have easier access to information on nutrition and health care. Panis and Lillard (1995) also believe that education may help in implementing medical advice, such as the use of oral salts to prevent dehydration in case of diarrhoea, which is known to account for 20% of infant mortality in Nigeria.

2.4.4 Migration

The data on in- and out-migration is crucial in assessing the general demographic growth potential of the village. In the first survey, information on out-migration was collected from the stayers. Unfortunately, it was not possible to collect information on households that had already moved out of the village.

2.4.4.1 *In-migration.*

Of the 248 household heads interviewed, 221 (89.1%) were in-migrants. Over two-thirds of the in-migrants came into the village within the last twenty years. The in-migration

generally peaked between 20 and 10 years ago and has reduced significantly within the last 10 years. In-migrations, as documented by Ajaegbu (1995), were largely along ethnic lines and were possibly in response to drought periods in the region. The Fulanis and the Kanuris were the first ethnic groups to migrate into the village. The Shuarabs came in next, followed by the Hausas and the Kare-Kares who came into the village within the past 10 years.

As much as 76.9% of the in-migrant household heads said they came in search of farm work. Katarko had more water than the surrounding areas and as such agriculture was more profitable than in most of the villages they came from. Fifteen percent of the respondents, typically the most recent in-migrants, have considered going back to their villages of origin. Their main reason for contemplating this move is the declining water availability in Katarko.

2.4.4.2 *Out-migration*

During the first survey, we recorded only 3.3% of the sampled population as out-migrants. The 20-24 age group represents the modal class of male out-migrants, while most of the female out-migrants belong to the 10-14 age group (Fig. 2.4). This is not surprising knowing that 72.7% of the female out-migrants went to marry and the average age at first marriage for women is within that age group. Sixty-four percent of the male out-migrants left in search of work in neighboring urban and rural areas. More than 21% of male out-migrants gave education as their reason for migrating, compared with 18.2% of the females. Forty-three percent of those who migrated to the urban centers had completed their secondary

education, compared with 11% of those who migrated to other rural areas. On the other hand, 77.8% of those who migrated to the rural areas had no education. Most of the men who were away during the farming season did not own large farms in the village. They worked as contract-farmers and petty traders outside the village.

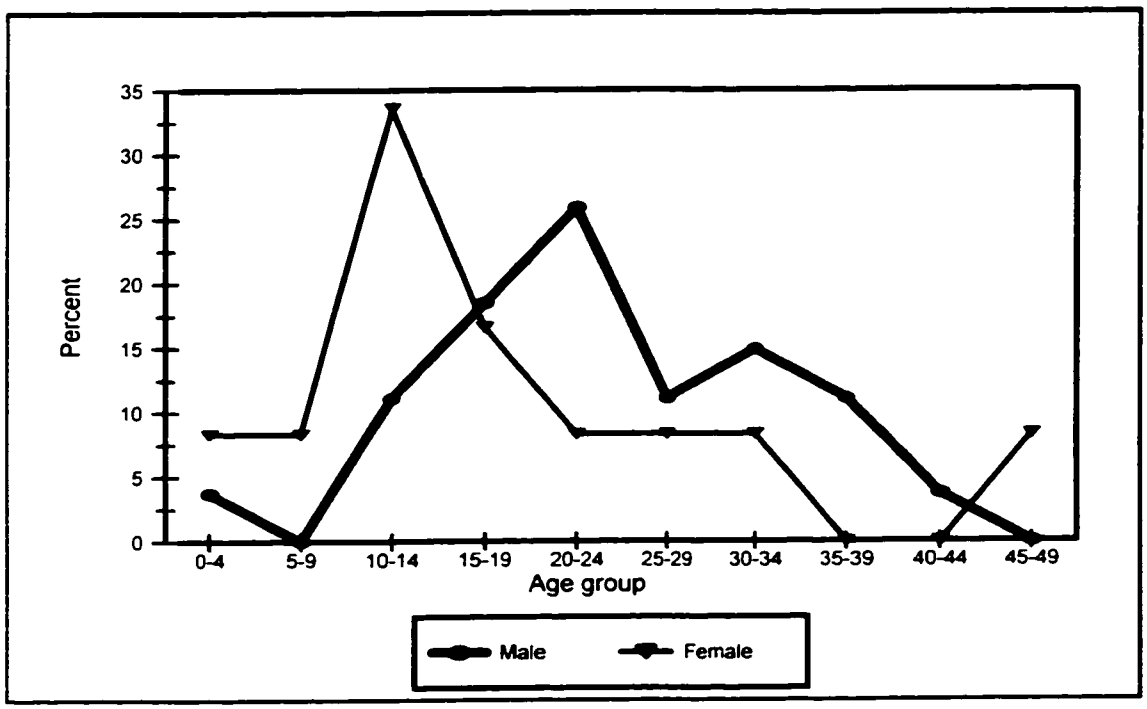

Figure 2.4: Out-migration schedule for Katarko (July/August, 1996)

We observed more out-migrations during the dry season than during the rainy season, and most of these were seasonal circulations. Eleven percent of the households enumerated during the dry season had migrated in search of off-farm season jobs. Two major groups of people move at this time of the year: those who go to other villages for dry season farming,

and the nomadic herdsmen who move their cattle to where they can find pasture. Those who migrate to other rural areas for dry season farming are hired to cultivate and harvest vegetables planted on fadamas[1]. On selling the farm produce, these migrant-farmers are paid with some proceeds from the sales. A common practice is the seasonal migration of entire households, with all members contributing their labor in farming. This was the case of a household that migrated for dry season farming and was traced to its destination.

2.5 Population Projection

The most crucial item among environmental resources in providing livelihood security in tropical and subtropical regions is water (Falkenmark 1994). In the Sahel, in particular, its scarcity is a continuous threat to survival, and the impact is felt more in rural areas, where the population depends largely on naturally occurring sources of water. Past efforts toward mitigating this impact have emphasized the need to increase water availability to meet the ever-increasing demand arising from rapid population growth. The inadequacy of this approach has called for the need to improve efficient water use through demand management. Policies aimed at demand management should not only consider present demands, but also, possible changes in demand that may result from shifts in the demographic structure of the population. Projecting the population of Katarko can reveal possible changes in its composition and serve as a basis for estimating future water demand

[1] This is a Hausa word that refers to flood plains of rivers that are seasonally flooded or have high water tables for all, or a large part, of the year. Their irrigation potentials are exploited during the dry season for the cultivation of vegetables and other crops.

in the village.

We made two types of projections for Katarko, total population projection using the cohort component analysis method, and a household projection using the headship rate method. The latter is important as the household is the primary unit of water consumption, and consumption analysis usually takes place at the household level. We made two projections based on different demographic assumptions. In the first, we assumed that current fertility, mortality and migration rates were carried into the future. In the second projection, we assumed that the government successfully carried out intervention measures and fertility and mortality rates decline throughout the projection period. More specifically, we assumed an increase in life expectancy at birth by 2.5 years and a decline in fertility rates by 0.05 within a five-year period as suggested by United Nations (1989). These estimates are based on the anticipated successes of country-level family planning programs and increasing levels of economic development, where Nigeria is assumed to be entering the second phase of the demographic transition. This stage is characterized by declining fertility and mortality rates, with mortality decline exceeding the fertility decline.

Both projections show that for the next 30 years, the population of Katarko will grow very rapidly (Fig. 2.5). With an improvement in life expectancy at birth, and a decrease in fertility and mortality rates, we expect a 107% growth in the population of this village within the projection period. The enormous growth in absolute numbers is due to the young age structure (see figs. 2.2a and 2.2b) and the resultant built-in demographic momemtum. Failure to anticipate and contain this growth in planning policies will have unexpected severe

consequences on the fragile ecosystem of this region. If the prevailing demographic rates continue into the future, the projected population of the village would have increased by only 54% in 30 years. The lower growth rate is because the high infant mortality rates neutralize the high fertility rates, resulting in a controlled population growth. The problem with this is that the high infant mortality rates encourage higher fertility rates leading to an endless spiral of high fertility and infant mortality rates. This will have a strong negative consequence on the quality of life in the village.

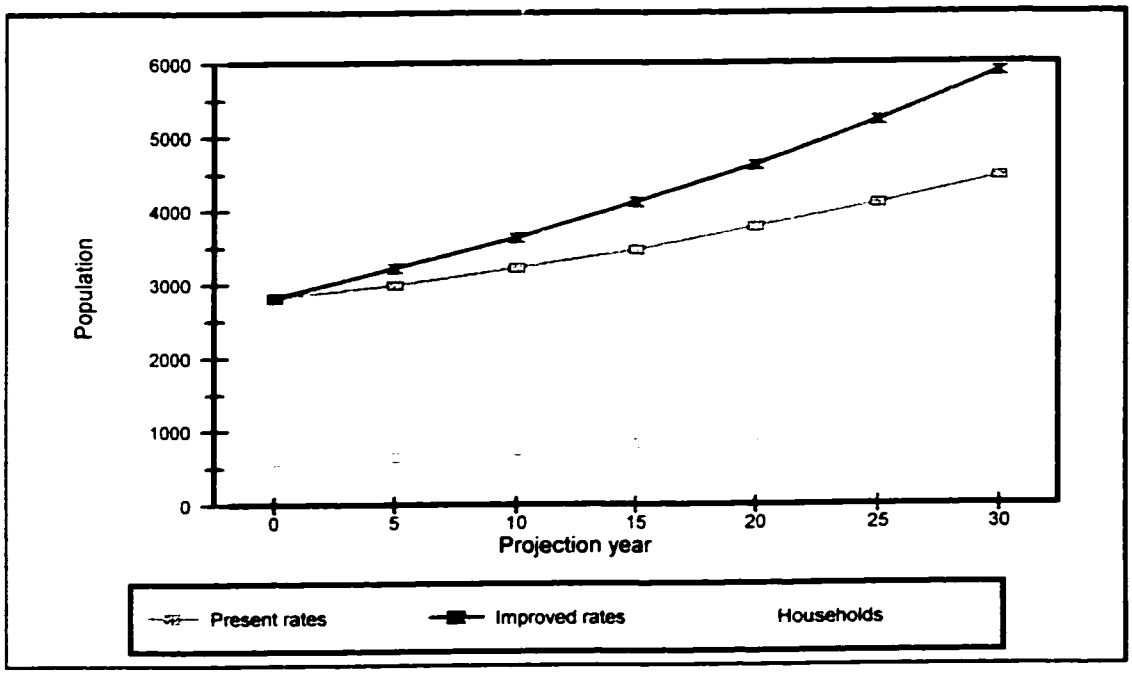

Figure 2.5: Population projections for Katarko

We have shown in section 4 the limited impact of Nigeria's National Population Policy on the demographic structure of Katarko. In view of this, the goal of realizing the

United Nation's assumptions of a declining fertility and mortality rates, and an increase in life expectancy at birth, may not be readily achievable. The limited success of Nigeria's population policy in the village can be attributed to the inadequacy of contraceptive use as a sole population intervention measure in rural Nigeria. Najam (1996) has argued that rapid population growth is not a clinical but a developmental problem and as such, family planning must be regarded as an integral part of the new models of sustainable human development. If fertility is to be lowered in this village, population intervention efforts should not be divorced from other developmental measures that can improve the quality of life. For instance, despite Katarko's proximity to two large cities, it does not have any dispensary or clinic, neither does it have any modern amenities such as toilets or pipe-borne water. The absence of these basic facilities may contribute to the prevalence of diarrhoea in the village (see Nyong and Kanaroglou 1998a). Providing these essential facilities can reduce infant and child mortality by more than 50% (WHO 1992), and may consequently reduce the desire to have many children. This could break the cycle of high fertility and mortality rates, and improve the quality of life in the village. Seeing the prospect of realizing the United Nation's estimate would then be easier, than it is now.

To provide a glimpse of the impact of any successful population intervention measures on water use in Katarko, we did a household projection with the assumption that fertility and mortality rates declined throughout the projection period. The number of households is expected to more than double in 30 years (see Fig. 2.5), from 600 to 1230. We also expect that the number of households headed by people younger than 50 years of age

will increase from 431 to 754 within the same period. Households with six or more persons are also expected to increase from 178 to 357 at the end of the projection period. The increase in the number of large households obviously has a strong implication on water use. In a study by Nyong and Kanaroglou (1998b), they found that household size correlates positively with domestic water consumption, and with wasteful water use in Katarko.

Whatever the projection assumptions, it is certain that population growth will lead almost certainly to water scarcity as population pressure on water will rapidly increase. Falkenmark (1994) has observed that this type of situation could make access to an adequate amount of water, needed as a lubricator of socioeconomic development, ever more difficult. Although reducing population growth could alleviate the pressure on the region's scarce water resources, other socio-demographic characteristics of the population need to be improved to ensure the sustainable development and use of the resource. We now turn to examine the implication of the socio-demographic pattern of this village on sustainable water development and use and the measures one can adopt to improve them.

2.6 Implications for Sustainable Water Use.

It is pertinent to stress that this study focuses on domestic water use. Although it accounts for only 9% of consumptive water demands in sub-Saharan Africa (World Resources Institute 1994), the benefits associated with improved and adequate supply of domestic water, such as the effects on health, time savings and greater productivity, cannot be overstated. These factors directly affect the quality of life in this village. Therefore,

planning for its sustainable development and use is important, particularly in a water-deficient environment like the semi-arid zone of Nigeria. Since the publication of the Brundtland Report, *Our Common Future* in 1987, sustainability has generally been identified as the overriding framework within which water planning, management and development should occur (Sharma et al. 1996). Despite this, considerable ambiguity still exists regarding sustainable development, both at the conceptual and operational levels (Mitchell and Shrubsole 1994).

While recent years have witnessed a wide-range of discussions regarding what sustainable development is overall, Gupta and Hyma (1995) have identified four key elements that promote sustainability of water supplies in a rural community in Bali. These are reliability of systems, human capacity development, local institutional capacity, and cost. These elements integrate into the concept of sustainable development the principles of economics and other indigenous cultural and social practices systems that traditional societies have used to balance rapid population growth and sustainable resource use over the years. Building on Gupta and Hyma's ideas, sustainable water resource development and use, for purposes of this paper implies that water resources should be harvested within regeneration capacity using appropriate technology, with equitable access among all users. Also, that water-related infrastructures are maintained to provide a continued yield, without degrading its quality. It does not follow that practices appropriate in Bali are necessarily transferable to Katarko, but they can provide a framework on which one can assess the sustainability of proposed water resource development in our study area. In considering the

impact of Katarko's socio-demographic structure on sustainable water resource development and use, we pay particular attention to the women. This is because the experiences of the last decade have shown that women's involvement is necessary for successful implementation, continued operation, and maintenance of rural water systems.

Whatever the definition of sustainable development one adopts, a common theme that emerges when considering the concept of sustainability is the continued support of human life through the ongoing satisfaction of basic needs (Mitchell and Shrubsole 1994). Meeting these needs are primarily tied to the pressures of human populations. We do not assume that the population and natural resource equation can be treated as a one-to-one relationship. Direct demographic pressures interact with direct economic and technological impacts - which themselves have some demographic elements as well - and are mediated by sets of interacting variables (Falkenmark 1994; Oever 1994; Stolnitz 1996). Accordingly, the influences of demographic variables cannot be ignored. Rapid population growth resulting from high fertility rates, compounded by poverty and low human capacity development, poses a tremendous threat to the sustainable use of water resources in Katarko. The population growth projected for Katarko raises concern as the limited water availability in the region puts a limit on the population that can be supplied at a minimum acceptable per capita level. As noted by Falkenmark and Suprapto (1992), rapid population growth in water-scarce regions translates to increasing population pressure on an already vulnerable resource. For instance, average household water consumption in Katarko in the dry season is 125 liters per day, wholly from groundwater sources. In 30 years, projected domestic water demand

would increase to 150,000 liters per day. Considering that this constitutes only 9 percent of total consumptive, expected total consumption will be about 1.7 million liters per day. With too many people mining the finite and scarce water resource of this semi-arid region. we could be seeing a sure recipe for unsustainable water development and use.

We have shown that poverty is pervasive in Katarko and it can be a major obstacle to fertility decline. It is doubtless that it can also reduce the population's capacity to use water resources sustainably. There are strong and obvious associations between poverty and the quality of life. The poor usually have a much lower life expectancy and a high infant mortality, and have limited access to education and health care. As seen in our study village and supported by literature, these factors drive the need to have large families. The World Health Organization (WHO) also observes that the poor suffer more from communicable diseases and a higher proportion of their lives is spent in poor health (WHO 1992). These also contribute to a low human capacity development that is essential to sustainable development. One principle of the Rio Declaration from the Earth Summit held in 1992 is that the eradication of poverty is an indispensable requirement for sustainable development (United Nations Conference on Environment and Development 1992). Because of this, we argue that the key to improving the socio-demographic structure of this village, and encourage sustainable water development and use, is to improve its local economic and social base, particularly that of the women.

The relationship between poverty and marital fertility in sub-Saharan Africa is little understood. It is argued that rural people in developing countries are not poor because they

have many children but that they have many children because they are poor (Caldwell and Caldwell 1977; Najam 1996). A man with many children in Katarko does not necessarily see those children as a burden in terms of the number of mouths he has to feed. He sees them as assets in terms of the number of hands available for farm work. The inability of the people to afford farm credits and modern equipment makes farming, the major occupation in this village, labor-intensive. This contributes to the prevalence of polygyny in Katarko, as women provide the much-needed labor for farm work.

Research has shown that the culture of polygyny helps to maintain a high fertility level and lowers the social status of the women (Boserup 1985; Timaeus and Graham 1989; Hayase and Liaw 1997). A low social status among women deprives them of the self-confidence and competence they require to undertake tasks that might be expected of them. This is particularly so considering that the educational attainment of the women is much lower than that of the men in Katarko. We believe that polygyny, and its resultant negative effects can be reduced by addressing the factors that encourage the practice, such as the need to provide farm labor. If household heads could afford labor-saving farm equipment, it would reduce the need for many wives and children. This reinforces the argument that the solution to the problem of high fertility rates in developing countries can be found in the solution to poverty (Mahbub-ul-Haq 1994).

Although the women provide the bulk of the farm labor in Katarko, they do not own large farms of their own. They work in family farms controlled by the household heads and less than 10% of these women share from the proceeds from these farms. Most of the women

depend on their husbands for subsistence and household maintenance. The lack of economic independence among the women serves as an obstacle to fertility decline in the village. Locoh (1992), cited in Sonko (1994 p. 408) supports this view by stressing that:

> "where women are involved in agricultural production, have almost no say in decision-making, where their status is low and they have to depend on their husbands, the objective conditions that encourage the population to have many children will always persist."

The positive association between poverty and sustainable resource use is well-documented in the literature (Redclift 1987; United Nations Sudano-Sahelian Office 1994; Schnaiberg and Gould, 1994). The poor are largely concerned with their immediate livelihoods and it is the enlightened rich who give priority to sustainability. The perspective of the poor is at variance with that of most economists and ecologists, placing satisfaction of needs and the avoidance of risk before sustainability. Similarly, the time horizon of the poor is shorter as they probably cannot afford to take a long-term view at resource degradation. Consequently, they value the future much less than the present, and mining resources in the short run may be a perfectly rational and justifiable strategy to ensure family survival.

Considering that women are the principal users of domestic water, their poverty has a greater and extensive effect on all matters relating to water use. We argue that if the prevailing poverty and low social status among the women continues, one may not see Katarko moving in the path of sustainability in its water projects. Kendie (1992) has observed that the poverty of women contributes to limiting the choice of drinking water

sources to those nearest home, regardless of quality. Where this happens, those water sources become over-exploited, resulting in water scarcity, not because the water is unavailable at some distance away from their homes but that the water becomes inaccessible. Another area where the effect of poverty of women is particularly felt is in the sustainability of water resource projects. Briscoe and DeFerranti (1988), argue that men in most rural areas of developing countries do not value improved water services as women do, and as such, have few incentives to carry out repairs. Where the women in Katarko, the primary users, are not able to pay for water services, it will inhibit the development of a sound financial practice that is fundamental to sustainability. When this happens, we expect to see a large number of broken-down water facilities, that already characterizes the study region. In a recent study in Ghana, Kendie (1996) found that the poor economic conditions of women largely accounted for the continuing difficulties at instituting the utilization of hand-pumps as drinking water sources and their sustainable operations.

For sustainable resource development and use to become a reality, Farvar and Glaeser (1979) argue that giving priority to the livelihoods of the poor is necessary. However, they go on to question how this priority can be pursued at the local level while the effect of international development systematically 'marginalizes' them? Despite the possible influences of national and international economic policies on small rural communities, we believe that short-term local economic incentives can improve the economic base of Katarko. This view is shared by Chambers (1986), who argues that even short-term improvements at the local level can yield phenomenal long-term results, as short term improvements in living

create conditions for later livelihood-intensive use of the environment that is sustainable.

Improving the economic base of Katarko may appear difficult, but successes recorded by other communities show that this can be done. A similar community in Ghana faced with a similar dilemma developed an ingenious way of raising their economic base, by first raising the economic status of the women. The women formed cooperative farming groups where they utilized their labor and pool of capital to cultivate a large rice farm, selling the products on the market and to the state (Dei 1994). The success of the cooperative farms gave the women access to government extension services and farm credit. They made repeated financial contributions toward community projects. Water wells that were previously abandoned were revived and maintained from proceeds from these cooperative farms. In this way, the women were able to revive the economy of the village. The economic success of the women and their financial independence led to the improvement in the nutritional status and health of the household members, particularly the children. A follow-up study in this village showed that infant mortality rates had fallen and so did the fertility rates. The lesson learned from this village can be applied in Katarko, where the adoption of measures to ensure women's economic independence can reduce the high fertility and mortality rates, and encourage sustainable water resource development and use.

2.7 Conclusion

The primary objective of this paper was to present the demographic and social structure of Katarko, a drought-prone village in north-eastern Nigeria, based on detailed

primary data collected in the rainy and dry season. The gains reported in population control at the national level since the start of the National Population Policy in 1988 are not reflected in the village. Fertility and mortality rates in Katarko are consistently above the reported national and regional averages. With a total fertility rate of more than seven, it is expected that the population of this village will grow very rapidly and may not experience any significant decline in the nearest future. The limited success in population intervention measures calls for alternative strategies for population control. Efforts should be made to improve the quality of life in the village and reduce the high incidence of child mortality. Where serious measures are taken for a sustained reduction in child mortality, the fertility rates will eventually follow. Sustaining the reductions in fertility rates requires policies that remove the economic necessity to have large families. One way of achieving this is to improve the local economic base and social status of the women.

The high rate of population growth and the pervasive poverty in this village may not encourage sustainable water resource development and use. Efforts should be made at creating a balance between population and the local water resource base in the village, and indeed, the entire region. Rather than adopting a general national population policy where spatial imbalances in the population-resource relationships are overlooked, critical ecological zones should be identified and efforts intensified at population intervention in such zones. In view of the critical impact that rapid population growth has on the limited water resources in the semi-arid region of Nigeria, we recommended that relevant population policies be adopted to alleviate the pressure on this finite and rapidly-depleting resource.

In view of the above, some areas for further research have emerged. There is clearly a need to understand how local populations in this region relate to, and use domestic water. How they adapt their water use habits to periods of abundance and scarcity will provide a useful insight in developing an efficient coping strategy to reduce the impact of water scarcity during periods of drought. Another key area of research is to examine the impact of Nigeria's development policies on water demand in this region. How will the outcomes of these developmental policies affect water availability and use? A third important issue is the examination of the barriers that hinder the effective utilization of existing water sources in the village. These important issues will be addressed in the course of the wider research of which this paper is a part.

Acknowledgements.

The financial assistance of the Canadian International Development Agency (CIDA) and research support by the University of Jos, Nigeria, are gratefully acknowledged. We thank Susan Elliott, Bill Anderson and Kao-Lee Liaw for their very helpful comments and suggestions on earlier drafts of this paper. We would like to thank Jasper Dung for research assistance.

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Chapter Three

A Survey of Household Domestic Water Use Patterns in Rural Semi-Arid Nigeria

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Society and Natural Resources

Abstract

This paper presents the pattern of domestic water use in Katarko, with the aim of improving the understanding of how local communities in the Sahel relate to water. Contrary to popular belief that women are the primary water collectors in rural sub-Saharan Africa, we show that the gender of primary water collectors depends on the custom and culture of the local community. Our results reveal a tradeoff between using good quality water and the effort it takes to obtain it. This, with poor sanitation and unhygienic water handling practices, may explain the high incidence of diarrhoea in the village. The preferred method of water purification is cloth-filtration, followed by the addition of anthill soil, with boiling ranking third.

KEY WORDS: Domestic water use, Nigeria, rural households, semi-arid regions, women.

3.1 Introduction and Background

Although domestic water use accounts for only 9% of consumptive water demands in sub-Saharan Africa (World Resources Institute, 1994), limited water availability to satisfy this need is a major concern in the semi-arid zone of northern Nigeria. Consequently, its efficient management is important to maintain the health and well-being of the people, particularly in the rural areas. This is because of the neglect of the rural areas in the provision of amenities and infrastructure. For instance, official figures show that 100% of Nigeria's urban population in the mid-80s had access to safe water (UNICEF, 1990), while only 36% of the rural population was served in 1992 (Federal Republic of Nigeria, 1994). This figure may be lower as studies have shown that official figures for the number of people adequately served, particularly in rural areas, often overestimate by as much as 70% the number actually served (Briscoe and DeFerranti, 1988; World Health Organization, 1992). Besides the lack of a standard definition of "access", the inclusion of underutilized facilities in the assessment of coverage is blamed for the inflated figures.

The underutilization of rural water facilities is blamed in part by the fact that engineering and technical considerations principally guided their design and implementation. Attention was not paid to the cultural and social inclinations of water usage in the host communities. Supporting this criticism, Rathgeber (1996), argues that water planners in developing countries usually assume that households and other social groups in rural communities will change their water use habits to accommodate and take advantage of improved water supply. They fail to recognize that newly available water may not be used

optimally because it does not conform to the existing norms of such social groups. Before providing new rural water facilities, it is expedient that water planners should understand existing water use habits of the local population, and how they may adapt their use to the new facility.

The semi-arid zone is characterized by two seasons, a short rainy season and a long dry season. The rainy season is usually accompanied by flash floods and water is abundant, compared to the dry season. Besides the intra-annual water variability, this zone has experienced periods of severe droughts and over the years, local populations have adapted their water use to these varying levels of water availability. They have accumulated valuable information that ought to be incorporated into more formal analyses of sustainable water development (Mabogunje, 1995; Sharma et al., 1996). Recent successes of World Bank sponsored rural water projects in several sub-Saharan African countries have been attributed to their being built upon indigenous knowledge and traditions (Hirji, 1995; Okaru, 1995). As not all indigenous practices may encourage efficient water use, building on indigenous knowledge and tradition can only be successful where there is awareness of the problems associated with existing patterns of water use and identification of solutions.

With a view to contribute to this awareness, we present the result of a study of household domestic water use patterns in Katarko, a rural community in the semi-arid region of north eastern Nigeria. We examine domestic water use as it relates to the cultural and social norms of the village. Our goal is to contribute factually and conceptually to a growing body of knowledge on domestic water use by rural African households. In this paper,

domestic water use includes cooking, drinking, washing dishes, bathing, washing clothes, house cleaning, ablution, backyard gardening and serving few household domestic livestock. Specifically, the paper addresses the following questions:

1. What sources of water are available to serve domestic household needs in Katarko in the rainy and dry seasons and what factors influence a household's choice of a particular source?
2. Who are the main water collectors in this community and what role does culture play in determining this?
3. What strategies do households employ in adapting to water availability in Katarko?
4. What are the adverse health implications of the existing patterns of water use in this village?

The rest of the paper starts with a description of the study community. This sets the context of the physical and social characteristics of Katarko, which was chosen as the study community. Besides typifying rural semi-arid Nigeria, it allowed their women to participate in the project. This is followed by a description of the method of data collection and a discussion of the results. The paper concludes with a summary of the findings and highlights areas for further research. This paper is part of a larger research investigating the consequences of rapid population growth on water availability and use in northern Nigeria.

3.2 Study Community

Katarko is on latitude 11°33' N and longitude 11°55' E in Gujba local government

area of Yobe state in north eastern Nigeria. It is located at about 20 km from Damaturu, the Yobe state capital and about 120 km from Maiduguri, the Borno state capital (Fig. 3.1). Although the village is so close to large urban centers, it lacks modern amenities such as pipe-borne water, electricity, clinic or modern toilet facilities. It is characterized by a short rainy season that lasts about three months between the months of July and September, and a long dry season that is hot and dusty and lasts from about October to June. Mean annual rainfall is less than 600 mm and the mean monthly temperatures range from 65° F in the coldest month to 90° F in the hottest. With such high temperatures, evapotranspiration is very high, up to 1650 mm per annum resulting in severe soil dessication (Ajaegbu, 1995; Ogezi et al., 1996).

Katarko essentially lacks relief as it is situated on the gently undulating and monotonous plain of the Chad basin. Its elevation ranges between 384 and 391 meters above sea level with an average slope of less than 0.03°. As noted by Tarhule (1997), the lack of relief, low rainfall, and few rivers produce a low drainage density in the area. The village is drained by river Annuma, a seasonal tributary of River Gongola, which flows through the southern part of the village in a southeast-northwest direction.

Katarko has a rapidly growing population of about 3000 inhabitants, with an average household size of 4.8 persons. Poverty is pervasive in the village and the mean annual income in 1996 was about N17,500 ($180 U.S.) per household. The village is divided into 10 wards, each with a ward head who reports to the village head. The wards are culturally homogenous with each ward being occupied mainly by one ethnic group. The main ethnic

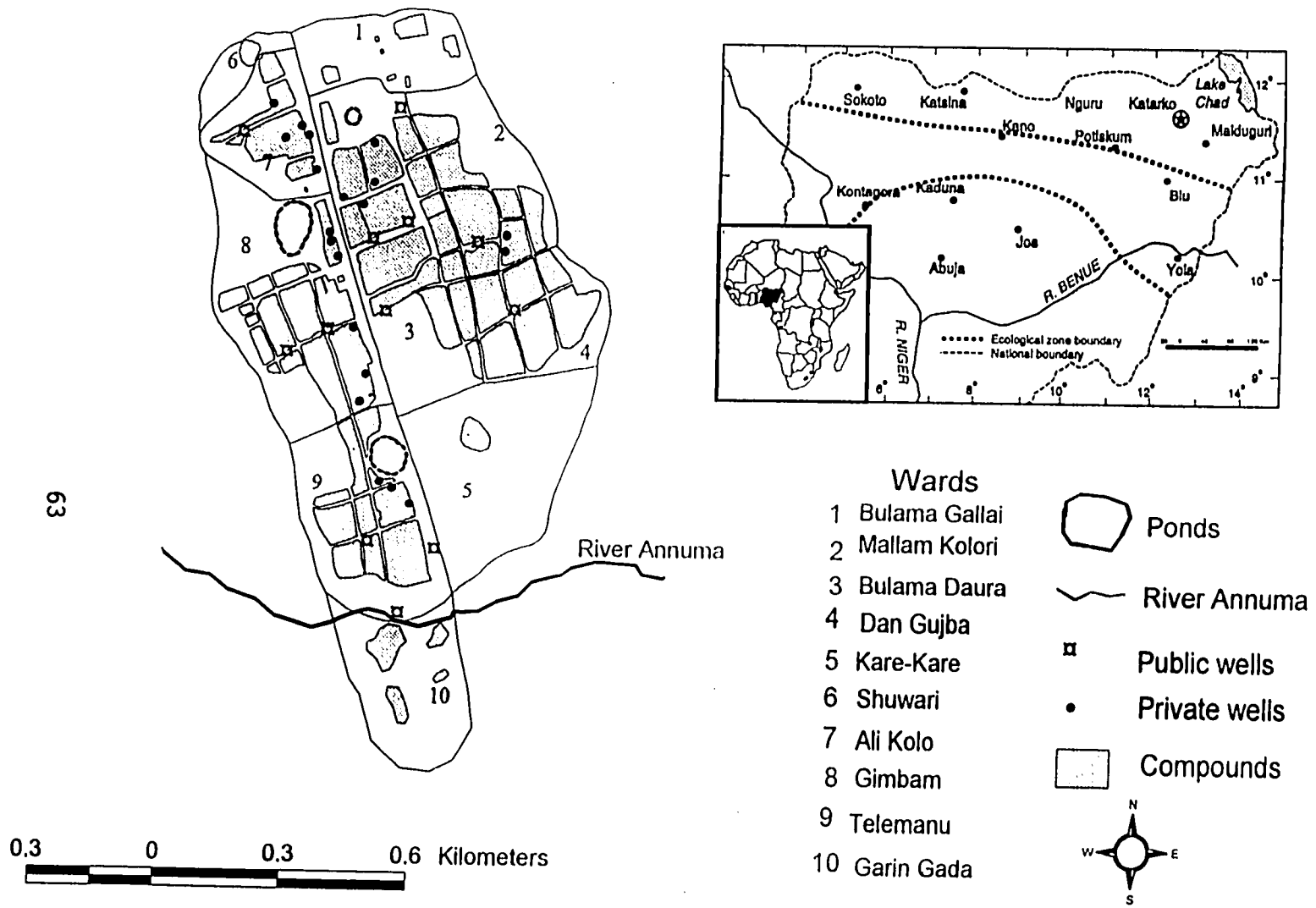


Fig. 3.1: Location of Katarko Village

groups in the village are Kanuri, Hausa, Fulani and Shuarab. While the Kanuris and the Hausas engage primarily in sedentary agriculture, the Fulanis and the Shuarabs are primarily nomads. History has it that the village came into existence when a water well was dug in the area in 1937 (Lee, 1996). This well was built by the then colonial administration and served as a watering point for animals. The first settlers arrived in the village about two years after the well was built. The existence of the well and the availability of water from it led to further subsequent movements of people into the village to settle. This implies that water, which has become a scarce resource, was instrumental to the establishment of the village.

3.3 Methods of Data Collection

The data for this paper were collected from two face-to-face questionnaire surveys undertaken in the rainy season (June to August 1996) and the dry season (January to March 1997). The survey instrument (Appendix 3)contained both closed and open-ended questions. Responses from the latter provided insight to the interpretation of the closed-ended questions. In a bid to clarify any other inconsistencies, informal discussions were held with the respondents. Based on the experience gained during the pretest, the final questionnaire was organized into five sections. The first section solicited information on the socio-demographic characteristics of the households. Section B contained questions that aimed at assessing the economic condition of the household, which is well-known to have a direct impact on water use habits. In section C, we collected information on migration and migration intentions in the village. Section D concentrated on how households relate to, and

use water, while the last section collected retrospective information on the fertility and mortality history of the household.

Two hundred and fifty households (representing a sampling fraction of 42%) were selected for interviewing. To ensure proportional representation from all the wards, a stratified sampling strategy was adopted. The sampling frame was the list of all households in each ward collected during a previous survey (Ihemegbulem, 1996). Forty-two percent of the households from each ward were then randomly selected from this list for final enumeration. Although the household is our primary unit of observation, we are aware that women are the prominent users of water at home, thus, their participation in water use studies is important. In view of this, we administered the same questionnaire to household heads (who in all cases were men), and their spouses. Obtaining information from men and women on the same issues provided gender perspectives and helped in assessing the reliability of the responses from the survey. Two hundred women were selected for interviewing using the same sampling strategy. Here, the sampling frame was the list of all interviewed household heads.

The instrument was administered by a research assistant and four field assistants (three men and two women), who speak the local languages and English. These interviewers were recruited and trained in May 1996. The culture of the society does not encourage interaction between adult men and women who are not married to each other, so the female assistants administered questionnaires to the women. It was anticipated that female respondents would be more open with female enumerators than they would be with male

enumerators. During the first survey conducted in the rainy season between June and August 1996, all the 250 household heads and 200 women were interviewed. The overall response rate was 100% as no household head or his spouse refused to be interviewed. However, two of the questionnaires from the household heads were found unfit for analysis and were discarded.

The main purpose of the second survey, conducted in the dry season between January and March 1997, was to obtain information on changes in water use patterns between the two seasons. An attempt was made to administer the same questionnaires to the households and women enumerated during the first survey. Two hundred and nineteen households were interviewed in the second survey because 29 households interviewed in the first survey had migrated from the village with all their members. The overall response rate for the second survey was 100%. One questionnaire was found unfit for analysis and was discarded.

3.4 Results and Discussion

3.4.1 Sources of water for domestic uses

Katarko relies entirely on natural sources of water through Rainfall, surface water, including water from ponds and river Annuma, and ground water. Because of seasonal variations, these sources of water are not available to the village always. The timing of the availability of the various water sources is presented in Figure 3.2. Rain water is only available during the 3-4 months of the rainy season. Occasionally, flash floods occur during the rainy season but the extra water provided is lost through runoff and evapotranspiration.

During the rainy season, water collects as ponds in three borrow pits excavated to provide laterite for the construction of the Damaturu-Biu road that runs through the village. These open ponds contain stagnant and murky water and serve as breeding grounds for parasites and related diseases. These ponds serve as a major source of water for livestock, bathing and cleaning during and shortly after the rainy season, before they dry out. Another major source of domestic water is River Annuma, a tributary of River Gongola. It is a seasonal river and flows between July and October. Water from river Annuma, when available, is used for all forms of domestic activities. Groundwater in the village exists in two types of aquifers: a deep aquifer and alluvial aquifer (Tarhule and Woo, 1997).

The village has 33 permanent hand-dug wells spread across it, which draw water from the deep aquifer. Twenty-one wells are privately owned and are found within the confines of the compounds. The others are communally-owned and were constructed either by the government or by the collective effort of the community. These wells are outside the compounds where they are accessible to everybody in the village. Their depths vary between 8 m in the south-western part of the village, and 30 m in the northeast. Most of them dry up completely or their yields reduce very drastically at the peak of the dry season, with less than 30% of them serving the community at this time.

Wells that draw water from the alluvial aquifer are seasonal and are dug in the flood plain and bed of river Annuma after the river has dried up. The quality of water from them is usually very poor. During the peak of the dry season, they serve as the only water sources

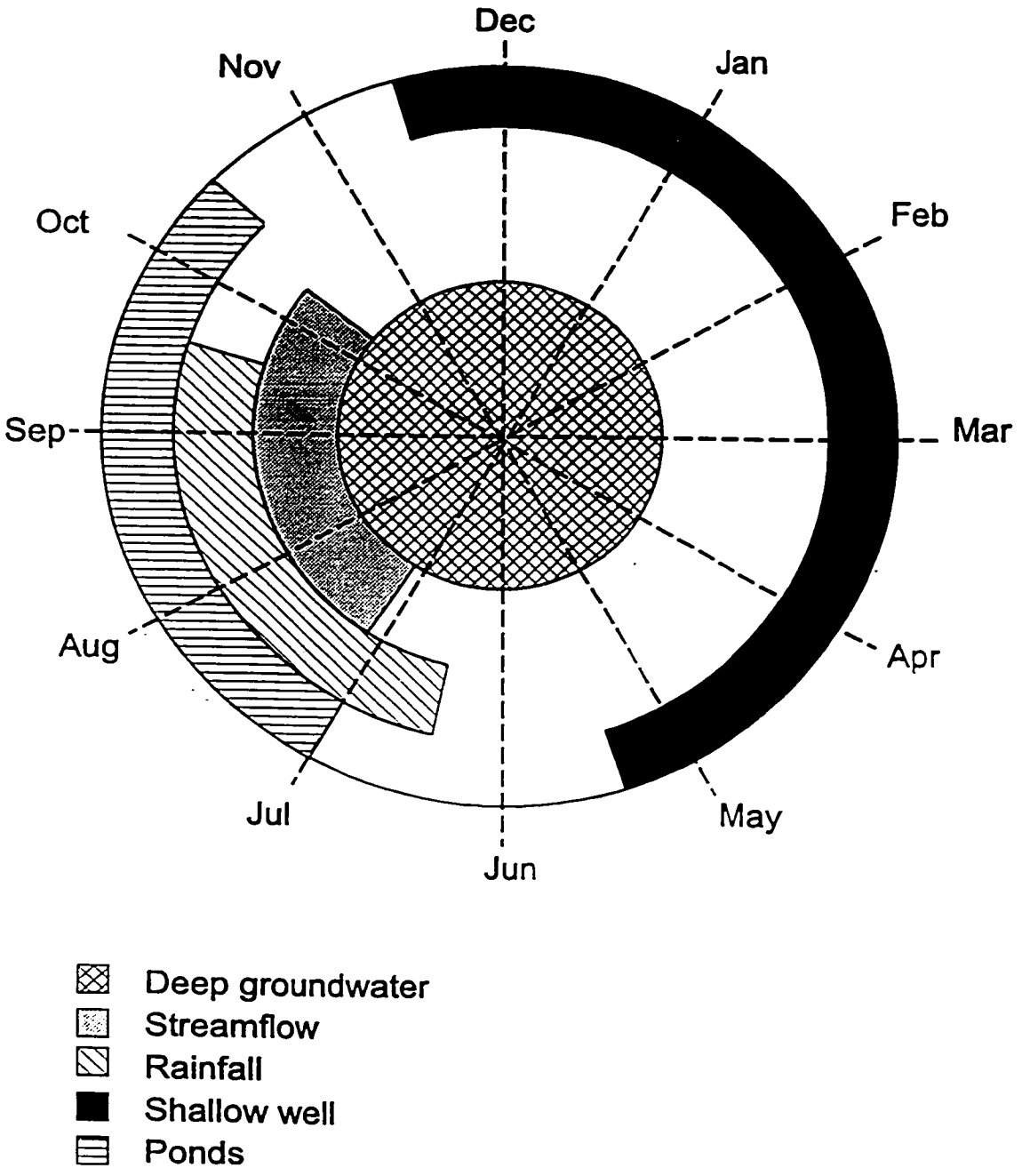


Fig. 3.2: Timing of availability of sources of water in Katarko
(Source: Adapted from Tarhule and Woo, 1997)

for domestic activities. They vary in depth between three and four meters and are communally-owned along ethnic lines and associations, with some restriction on their use. Households that do not have access to private wells, and live far away from the public wells generally purchase water from vendors, or travel about 8 km to Gujba town to obtain water.

3.4.1.1 *Factors that influence the choice of water sources*

Although the various sources of water are available to the village at different times of the year, our survey shows that households had preferences for particular sources. In response to a question on the most important factor that influenced which source a household used, 61% of the respondents mentioned proximity to the home. Seventeen percent preferred sources that were well-kept and maintained, 11.5% preferred sources used by fewer people, while less than 8% considered the quality of water. People were three times more likely to use a particular source of poor quality water that was closer to their homes than good quality water at a farther distance. This tradeoff between water quality and the effort to obtain the water is presented in Table 3.1. People who lived farther away from any water source settled for water of less quality than those who lived close to water sources.

In an attempt to identify barriers to the use of certain water sources in the village, about 66% of the respondents did not use sources that were far from their homes. Some of them commented that after spending a long and hard day on the farm, the last thing they wanted to do was walk long distances to fetch water. As a result, they settled for water

Table 3.1. Proportion of households (%) by distance to water sources and quality of water used in Katarko in the dry season

Distance	Water Quality			Total
	Bad	Good	Very Good	
Less than 100 m	0	11.5	15.9	27.4
100 to less than 500 m	0	18.8	9.6	28.4
500 m to 1 km	2.8	15.6	2.8	21.2
Greater than 1 km	17.9	4.6	0.5	23
Total	20.7	50.5	29.4	100

sources close to home, no matter the quality of water from them. About 23% indicated poor water quality, while 12% mentioned institutional and social constraints. Because of a long-standing feud between the Hausas and the Fulanis, none of these tribes used wells in wards dominated by each other. Also, some shallow wells were dug by specific ethnic and social groups like the water vendors' association and non-members were not allowed to use them.

Considering that geographical accessibility is the main factor in the choice of a water source, we now compare the distance people travel to fetch water in the two seasons. In the rainy season, about 38% of the households obtained their water within 100 m of their homes compared with 16% in the dry season. Also, 23% of the respondents traveled more than one km to fetch water in the dry season, compared with only 4% in the rainy season.

3.4.2 Household water use

3.4.2.1 *Differences in perception of water availability*

Inequity in access among households can lead to differences in the way each household perceives water availability in the village. This difference in perception has crucial relevance for their reactions when expectations cannot be met, and can influence household water use patterns. To investigate this variability, respondents were asked to assess the availability of water in the village to meet their domestic needs, on a three-point scale that ranging from scarce through adequate to abundant. In the dry season, 69% considered water scarce in the village, 27% felt it was adequate, while 4% considered it abundant. Even in the rainy season when water is plentiful, 30% of the households still considered it scarce, 34% said it was adequate, while 36% reported that the water in the village was sufficient to meet their domestic needs. A chi-square test (p=0.000) shows a positive association between household perception of water availability and the seasons. This confirms the local population's awareness of the variability in water availability between the rainy and dry season.

3.4.2.2 *Quantity of water used for domestic activities*

The daily household domestic water use in Katarko as derived from our sample ranged from 37.5 liters per day (lpd) to 737.5 lpd in the rainy season and from 19.2 lpd to 288 lpd in the dry season. About 37% of the households used more than 250 lpd in the rainy season, while only about 29% used less than 150 lpd, the minimum recommended by the

World Health Organization (Dieterich and Henderson, 1963). In the dry season, the proportion that consumed less than 150 lpd increased to 67%, while those that used more than 250 lpd reduced to about 5%. The mean household domestic water consumption in the rainy season is 215.4 liters per day (lpd) while that in the dry season is 125.4 lpd. To examine statistically whether domestic water consumption is significantly different in both seasons, mean water consumption was compared using the difference of means test. The result shows that the difference is statistically different ($F = 3.42$; $p = 0.05$).

Although the World Health Organization considers 150 lpd as the minimum quantity of water rural households need to maintain basic hygiene, we attempted to find out if this agrees with the local community's situation and experiences. Responses to a question that asked respondents to suggest the quantity of water they consider sufficient for them, showed a seasonal variation in the quantities. In the rainy season, 62% of the respondents suggested between 300 lpd and 200 lpd, 27% mentioned quantities that ranged between 200 lpd and 100 lpd, while 8% and 3% suggested between 50 lpd and 100 lpd, and less than 50 lpd respectively. All the households that indicated between 200 lpd and 300 lpd contained more than 6 persons. In the dry season, the quantity of water households considered as sufficient had reduced significantly. Only 15% cited quantities between 200 and 300 lpd, 56% between 200 lpd and 100 lpd, 23% between 100 lpd and 50 lpd, while 6% mentioned quantities that were less than 50 lpd. This implies that the availability of water plays a strong role in how much water that households consider sufficient. Although some households used more than 700 lpd in the rainy season, none of them suggested amounts that much. This is an indication

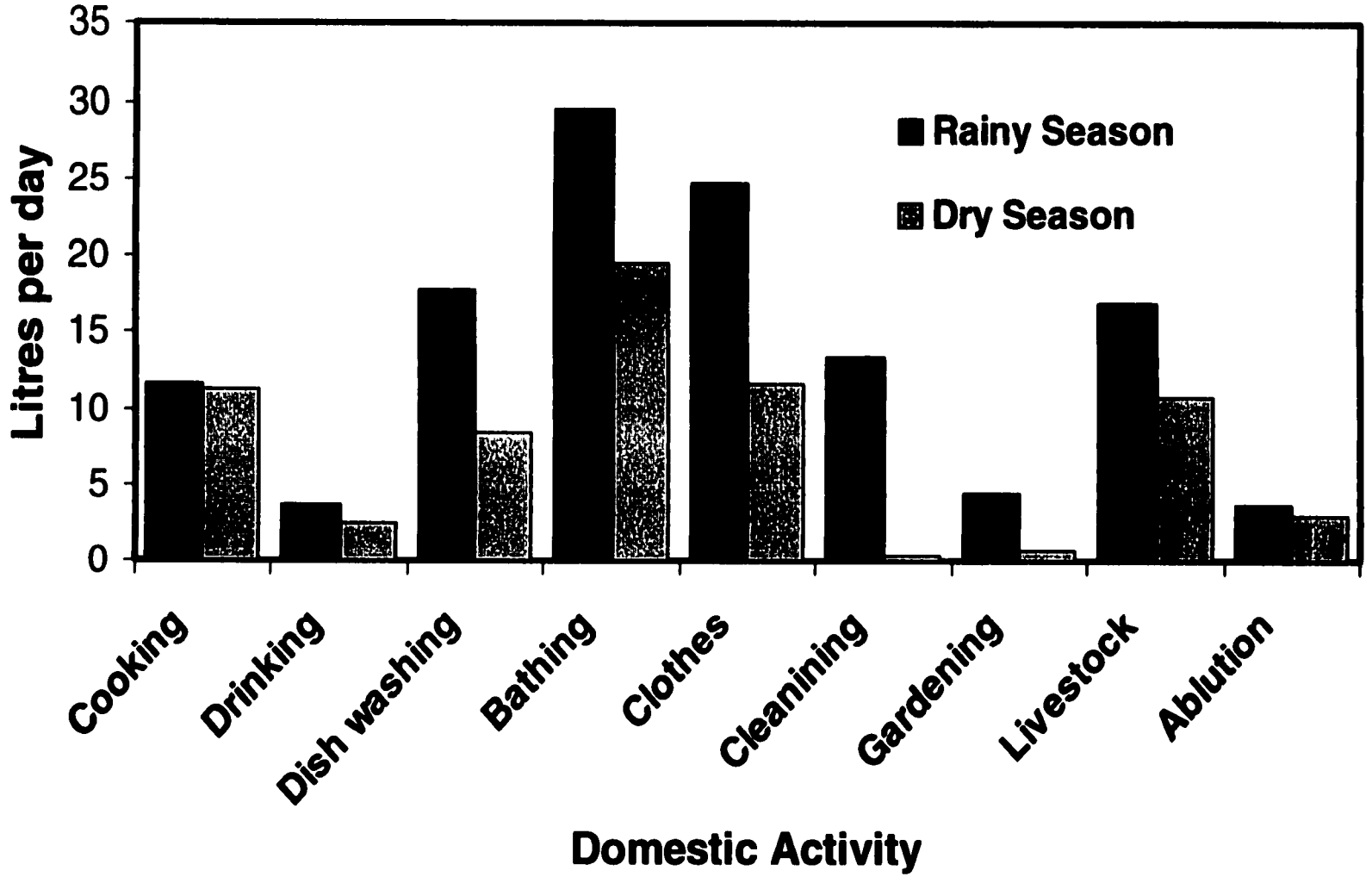
of wasteful water use when water is abundant.

In the rainy season, some domestic activities such as washing of clothes and bathing were done both at home and in-stream and measuring correctly the quantity of water used for each of these activities was difficult. With the quantity of water respondents used for bathing and washing of clothes off-stream, and the frequency they carried out these activities, we deduced how much water those activities consumed daily. Seasonal variations in the quantity of water used for domestic activities that the respondents consider as necessary, such as cooking, drinking and ablution, were small (Fig. 3.3). Domestic activities that pertain to cleanliness and hygiene showed marked seasonal variations in water use. In the rainy season, households generally used about twice as much water for dish washing, clothes washing and bathing, than during the dry season.

3.4.2.3 *Coping strategies*

The reduction in the quantity of water that households use for different activities in the dry season is an indication of their adjustment to water scarcity. The impacts of water scarcity are more acute during periods of droughts that occur frequently in this region. In an attempt to understand household coping strategies, respondents were asked to mention water-use activities that they normally give up at such times. Besides showing household coping strategies, this information can also reveal some unpleasant consequences of acute water scarcity in Katarko. More than 30% said they would first give up household cleaning, while about 23% and 21% said they would forego washing their clothes and having their baths

Katarko: Domestic water use by activities



respectively. This confirms the near absence of household cleaning activities in the dry season (see Fig. 3.3).

During the dry season, some respondents stated that they had their bath about twice a week. Most of them generally pointed that they did not consider this bad as ablution served to reduce the need to have a complete bath every day. Others mentioned that because they do not engage in any farming activities in the dry season, they did not consider themselves dirty. Informal discussions with some children revealed that not bathing in one week was common.

3.4.2.4 *Water handling practices*

To reduce the frequency of traveling to fetch water, all the households store domestic water at home. Generally, water is stored in earthen pots that range in size between 20 and 40 liters and are covered at the top with a plate (Plate 3.1). Sometimes the pots are wholly or partially buried in the ground in the open part of the compound, usually at the backyard, to keep the water cool during the hot dry season. Keeping these pots outside further introduces the possibility of dust particles and dirt being blown into the pots if they are not properly covered. Usually, a cup is used to fetch the water from these pots and the same cup is used by everybody in the household. These cups are not handled hygienically as we recorded instances when a cup would fall into the pot and someone would have to dip her or his hand into the pot to retrieve the cup. This poor water handling practice further introduces the possibility of contaminating the stored water.

Plate 3.1: Earthen pots used in storing domestic water in Katarko

With such poor water handling practices, the longer water is stored before the pots are emptied and cleaned, the greater the risk of contamination. In the rainy season, about 84% of the households stored water that lasted less than three days while the remaining 16% stored water that lasted between three and seven days. In the dry season, about 65% of the households stored water for less than three days. Twenty-one percent stored water for up to one week while as much as 14% stored water that lasted more than one week. This reveals a greater chance of using contaminated water in the dry season than in the rainy season.

Regarding water purification and treatment, a Participatory Rapid Appraisal exercise in the village revealed several methods in use by the community. These include cloth filtration, adding alum, adding coal ash, boiling, adding anthill soil, and adding fermented milk. Most of the respondents mentioned the use of cloth filtration, followed by the addition

of anthill soil. Boiling of water ranked the third preferred method of purifying water. Considering that boiling water is generally recommended as the most efficient method in rural areas, finding it out why it ranked third in Katarko would be instructive. Although some of these methods of water purification seem absurd, one cannot dismiss them because they challenge conventional western knowledge. Subjecting these methods to detailed laboratory investigations may lead to informed decisions on culturally-acceptable and medically-efficient water treatment efforts in the community.

3.4.2.5 *Perception of water quality*

Defining acceptable standards of drinking water for communities in rural areas of developing countries has not been unanimous. Many studies consider the setting of water quality standards the sole responsibility of experts or planners because of the technical nature of many issues relating to it. However, Sheat (1992) has stressed the importance of acknowledging the perception of the water users. He argues that perception may very well become more important than reality, especially when it comes to the quality of drinking water. Among local people, this perception is based on their indigenous knowledge and should be taken seriously. As noted by Gonzalez (1995) among these people, this knowledge has rules of thumb, usually based on qualitative observations of their daily lives and the surrounding natural environment. It is therefore pertinent that rural water development projects, if they are to be optimally used by the local people, should meet their 'standards' of quality. These standards can only be known through the understanding of their culturally

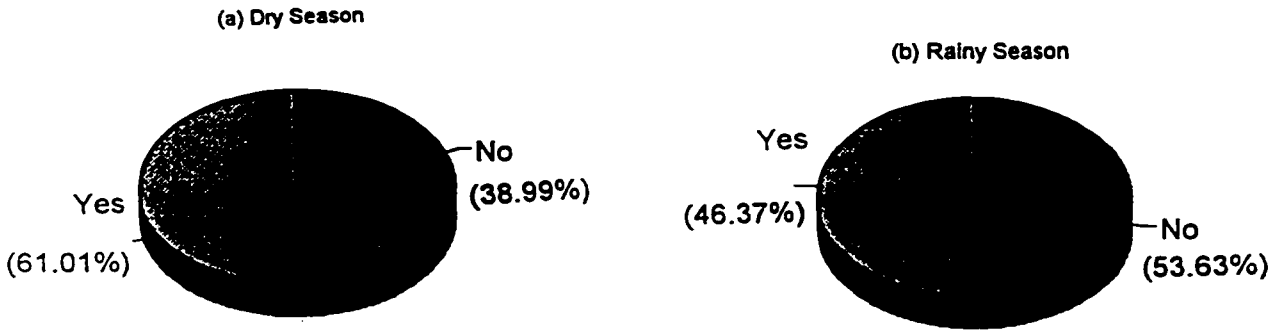
constructed concepts and definitions.

Respondents were asked to indicate how they perceived the quality of water they used, on a three-point scale, ranging from bad through fair, to good. This scale was designed by the community leaders and us during the pretest, using yardsticks that are relevant to the experiences of the village. Such yardsticks include color, odor, taste, clarity, presence of foreign objects, slime, and the feel on the hand. For instance, they believe that good water from the well is usually cold. In the rainy season, only about 1.0% of the households perceived their water quality as bad, about 63% perceived it as fair, while about 36% perceived it as good. In the dry season, more than 50% of the households perceived the quality as bad, compared with less than 20% that perceived it as good.

3.4.2.6 *Some health implications*

We have shown in previous sections that water scarcity makes washing and personal cleanliness difficult and infrequent. This and the poor quality of water, compounded by poor water handling practices, may contribute to the prevalence of diarrhoea in the village. The incidence of diarrhoea within one month preceding each interview in the rainy and dry seasons are presented in Fig. 3.4. As expected, the number of households that had diarrhoea in the dry season was more than that in the rainy season (61% and 46% respectively). Among households that recorded the occurrence of diarrhoea, the frequency of occurrence in the dry season was more than that in the rainy season. In the dry season, about 53% of the households had diarrhoea three or more times within the month preceding the survey,

Figure 3.4 Occurrences of diarrhoea



compared with about 38% in the rainy season (Fig. 3.5). The incidence of diarrhoea in this village, even in the rainy season when water is abundant, is an indication that improvements in water supplies alone cannot eliminate the problem. Improvements in water supply have to be accompanied by health education to change hygiene and water handling and storage practices.

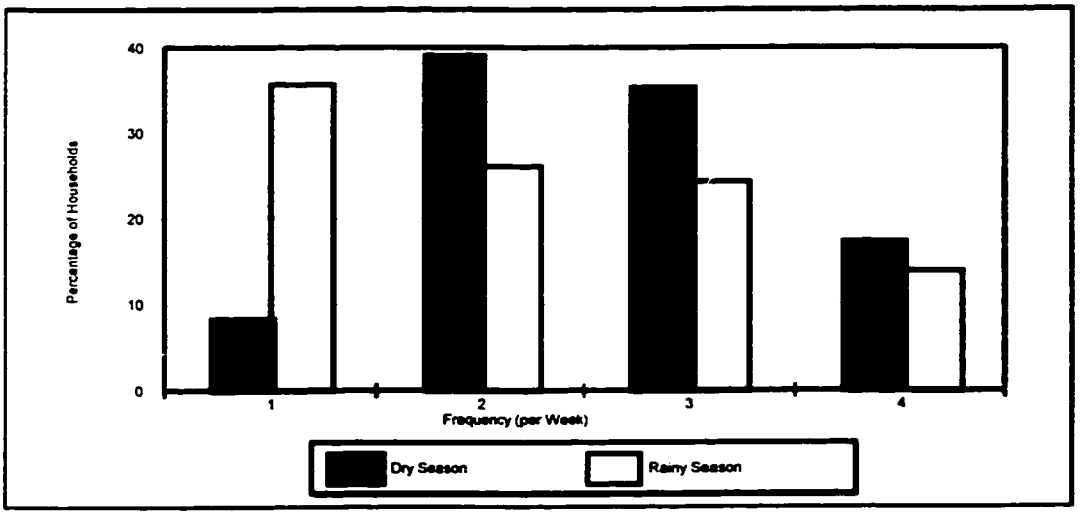


Fig. 3.5: Frequency of occurrences of diarrhoea in Katarko

3.4.2.7 *Principal water collectors*

It is a generally-held opinion that females are the main water collectors in rural areas of developing countries. Our survey showed that women were the main collectors of domestic water in only 48% of the households. A breakdown of the gender of main water collectors by ward and the predominant ethnic group in each ward is presented in Table 3.2. Females are the main water collectors in wards where Kanuri is the predominant ethnic group. In Hausa-dominated wards, females account for less than 30% of the water collectors. Among the Hausas, the *purdah* system is strictly observed, where women are kept in seclusion from men and are not allowed to go out to fetch water or engage in any other work outside the home. The association between ethnicity and gender of primary household water collectors is proved here by a statistically significant ($p = 0.000$) χ^2 test. This shows that culture and custom play an important role in determining who fetches water in any particular locality. Although local custom and culture determine the gender of the primary water collectors, the fact remains that women are the main users of domestic water, and the primary beneficiaries of improved domestic water supplies. This has important implications for the provision of water supply schemes in the village. If they are to be efficiently and effectively used by the intended beneficiaries, efforts should be made to either breakdown or accommodate the barriers that hinder the women from having access to them.

3.4.2.8 *Water vending activities*

More people reported purchasing water from vendors in the dry season (37.6%) than

in the rainy season (18.8%). A breakdown of vendor patronage by wards shows that households in wards that are further away from the stream (and consequently, the shallow wells) used the services of water vendors more than those in wards that are closer. A further

Table 3.2: Household level primary adult water collectors in Katarko

Ward	Major Ethnic Group	Male	Female	No of Households
Bulama Gallai	Kanuri	2	7	9
Mallam Kolori	Hausa	25	5	30
Bulama Daura	Kanuri	17	35	52
Dan Gujba	Hausa	17	3	20
Kare Kare	Kare Kare	6	2	8
Shuwari	Shuarab	3	2	5
Ali Kolo	Kanuri	8	16	24
Gimbam	Kanuri	9	23	32
Telemanu	Fulani	19	9	28
Garin Gada	Hausa	7	3	10
Total		113	105	218

analysis reveals that richer households used the services of vendors more than the poorer ones. Fifty-eight percent of households that earned more than N90,000.00 ($1100.00 U.S.) per annum purchased water from vendors, compared with only 25% that earned less than N10,000 (US$ 120.00). Some respondents did not use the services of water vendors because they saw water as a free resource from God and considered it unethical to sell the commodity. The issue is not only that of the cost of purchasing water, but ethics. A need exists therefore to educate the people that water is a scarce and finite resource and has a cost

that, as much as possible, should be borne by the users.

The finding concerning vendor patronage shows clearly that demand management in this community can be approached with economic principles. Contrary to the prevailing practice where water is provided free on the assumption that users cannot afford to pay for its use, improved services can be provided on a cost recovery basis. These services can often replace vendors and provide households with more economical and convenient supply at the same price as they pay to vendors. The finding that richer households patronize the services of vendors more than their poorer counterparts, shows that an improvement in the economic status of the households can improve their willingness to pay for water. In view of this, we believe that there ought to be a change in the way rural water projects are set up in a poor community like Katarko. Rural water projects should be tied to those that improve the economic status of the users, if a sound financial practice that encourages sustainability is to be developed.

3.5 Summary and Conclusions

A major reason for the unsustainability of rural water projects in Africa is the fact that they are often designed without recourse to the circumstances of the population they are intended to serve. Water planners are known to assume wrongly that local populations will adapt their water use habits to newly-provided facilities. This obviously has resulted in many underutilized facilities. The design of water systems needs to be based on an analysis of local problems that assesses which combination of actions would make the best use of resources.

In this study, we have shown how a local community in semi-arid northern Nigeria uses and relates to domestic water, highlighting some problems that are associated with their water use habits.

Overall, the results of our findings can be summarized as follows. First, geographical accessibility is the most important barrier to the source of particular sources of water in Katarko. People are more likely to use water from more accessible sources no matter the quality of water from those sources. Second, besides geographical accessibility, the research identified the existence of institutional barriers to the use of certain water sources. The Fulanis and the Hausas do not use water sources in each other's domains. Also, Hausa women are kept in seclusion and are not allowed to interact with men and strangers, and are therefore excluded from the use of public wells. If these cultural practices cannot be accommodated, ways should be sought on how they can be broken down so that these women can use improved water sources in the village. Third, contrary to popularly-held opinion, women are not the principal water collectors in Katarko. Local customs and culture affect the gender of principal water collectors in any community. Fourth, households adapt to the scarcity in the dry season by reducing the quantity of water they use for activities that pertain to cleanliness and hygiene. In periods of drought when water is very scarce, these activities are eliminated. This, with poor water handling practices contribute to the prevalence of diarrhoea in the village, particularly in the dry season.

Although unclean domestic water is a prime source of infectious diseases such as diarrhoea, it is also known that insufficient availability of water also hampers people's

efforts to practice good personal and domestic hygiene. Research has suggested that, even when potentially negative health effects of poor water quality and sanitation systems are known to local populations, not much consideration is given to decisions regarding proper water use (Rathgeber, 1996; Whittington et al., 1994). Without a health education campaign to improve hygiene and water handling practices in Katarko, one may not see any meaningful result in the health benefits that are usually associated with improved water supplies.

Results of our study suggest some areas of further research. First, considering that distance is the most important factor influencing the choice of water sources in Katarko, where should one establish improved water facilities in the village to minimize travel distance for all potential users? Past decisions on location of water facilities in Nigeria have been driven by technical considerations without considering the preferences of potential users. Maintaining this practice implies that we may continue to witness several underutilized facilities as people are unwilling to travel long distances to obtain water. Second, there is a near absence of conservation practices in the village. A previous study by Adelakun and Olumodeji (1996) revealed that more than 71% of respondents admitted that they had never been instructed on the cautious use of water, and therefore do not consciously practice any form of conservation. Developing economically feasible, culturally acceptable and environmentally sound ways of increasing water availability in the dry season through conservation in the rainy season, is important. This will reduce the stress of searching for water during the dry season. A good place to start this in this community would be to educate people on the ways and benefits of water conservation.

Acknowledgments

The financial assistance of the Canadian International Development Agency (CIDA) and research support by the University of Jos, Nigeria, are gratefully acknowledged. We thank Susan Elliott, Bill Anderson and Kao-Lee Liaw for their very helpful comments and suggestions on earlier drafts of this paper. We would like to thank Jasper Dung for research assistance and Rick Hamilton for producing some of the final figures.

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Chapter Four

Seasonal Variations in Domestic Water Demand in Rural Semi-Arid Nigeria

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Prepared for submission to

Environment and Planning A

Abstract

Multiple regression models were used to study domestic water demand in the dry and rainy seasons rural north-eastern Nigeria, when water is scarce and abundant respectively. The determinants of domestic water demand in both seasons are not identical. Modeling seasonal variations in demand provides a glimpse of how consumers will adapt their demands to increased water supply. The overall levels of explanation provided by the rainy season and dry season models are 51.2% and 91.1%, respectively. The lower explanatory power of the rainy season model may be an indication of wasteful use when water is abundant. Our findings show that although most of the determinants of water demand in both seasons are subject to socio-cultural interpretations, one can approach the management of it with economic principles. Incorporating the determinants into water demand projections further reveals how changes in the variables affect future demand.

4.1 Introduction

The increasing difficulty in meeting the demands for water in Nigeria has drawn attention to it as a valuable and finite resource that requires proper and wise management. However, the emphasis, like in most developing countries, has been on managing its supply to serve the needs of the ever-increasing population (Koudstaal et al., 1992). The limited success of this supply-oriented approach, particularly in rural areas, has led water planners to consider alternative measures that will increase the efficiency of water use. Although there are many reasons for the limited success of past rural water supply programs, it is generally agreed that a better understanding of household water demand will contribute to more economical and effective programs (Mu et al., 1990; Young, 1996).

During the last decade, the realization of the inapplicability of traditional demand models used in developed countries, for assessing village water demands in developing countries has led to the development of water demand models for rural areas in developing countries (Briscoe et al., 1990; Whittington et al., 1990; Mu et al., 1990; World Bank Water Demand Research Team, 1993). Most of these studies have used revealed preference and contingency valuation methods to examine households' willingness-to-pay for improved water services. Cairncross and Kinnear (1992) and Whittington and Swarna (1994) have discussed the major problems associated with these methods. Both approaches emphasize consumers' willingness to use or pay for an improved water service, with little consideration on how the introduction of the new service will affect consumption.

Addressing this shortcoming, Whittington and Swarna (1994) have advocated the use

of a discrete-continuous decision process to model village water demand, as rural African households usually obtain water from several sources. The model characterizes how a household decides which water source to use for different purposes and how much water to use from a particular source. Some of its underlying assumptions limit the use of this model in our research. First, it assumes that a household only uses one source of water for a particular domestic activity. In the dry season, the only source of water available in our study community is the hand-dug well and water from it is used for all domestic activities. Second, the model assumes that all households have the same water sources available from which to choose. Evidence exists that cultural barriers deny some local groups access to some water sources in this village, as such, all households do not have the same choice set.

This paper attempts to contribute to the understanding of domestic water demand in rural areas in three ways. First, although several studies have investigated water demand in Nigeria, they have focused on the large urban centers in the south (Akintola and Areola, 1980, Ayoade, 1981; 1987; Anyadike and Ibeziako, 1987). In contrast, the rural areas in the Sahelian belt of the north have received little attention. With its extremely arid environment and high seasonal water availability, water use may not be subject to the same explanatory criteria as the rest of Nigeria. Understanding water demand behavior in this region is important as it is home to a third of Nigeria's population, and its limited water availability is a major source of environmental and ethnic conflicts. Second, studying water demand in the rainy and dry seasons, when water is abundant and scarce respectively, can reveal how households will adapt their demand to the introduction of improved water services. We

hypothesize that the determinants of water demand when water is abundant are different from those in times of scarcity. In addition, we statistically test for the factors that explain the discrepancy in domestic water use between the rainy and dry seasons. Third, the regularly-used projections in Nigeria are based solely on per capita usage of water (Ayoade, 1987) and cannot assess the impact of changes in socio-demographic, cultural and economic variables on water demand. This research incorporates the determinants of water demand into water demand projections to evaluate how demand may change with different developmental and demographic scenarios.

The results presented in this paper are based on primary data collected from two surveys, over a period of about eight months. This research is part of a larger study aimed at investigating the impact of population growth on domestic water use in the semi-arid region of northern Nigeria. Our specific objectives are:

- To investigate the key demographic, social and cultural variables that affect domestic water demand in rural northern Nigeria, and to examine how the significance of these variables varies between the rainy and the dry seasons.
- To assess the implications of including the determinants of water demand into water demand projections.

The structure of the paper is as follows. In the next section we present the study area and the field procedures, after which we discuss the sources of water for domestic activities in Katarko. The results of the analysis are presented in the next section. Results reveal that the determinants of water demand are not identical in the rainy and dry seasons, and the

overall level of explanation provided by the dry season model is higher than that of the rainy season model. We then discuss the implications of changes in socio-demographic, cultural and economic variables on water demand projections. A comparison of water demand projections that include key socio-demographic variables with those based solely on per capita usage of water shows that the latter may underestimate demand. The paper concludes with a summary of the main points and directions for future research.

4.2 Study Area and Field Methods

4.2.1 Study area

Water scarcity is a pressing problem in the semi-arid region of northern Nigeria. It remains a source of suffering and a constraint to rural development, as its impacts are more pressing in the rural areas. The failure of past rural water development projects in providing effective strategies for managing the scarce water resources of this region, led to the establishment of the Jos-McMaster Drought Research Project in 1992. With funding from the Canadian International Development Agency (CIDA), the project aims at developing and implementing strategies to optimize rural water use and strengthen indigenous capacity for coping with water scarcity. Katarko village was chosen from several communities that the research team visited during a regional search for a suitable study site. Besides typifying rural semi-arid Nigeria, it allowed the women to participate in the research. In view of the fact that women are the prominent users of domestic water in rural Nigeria, their contributions are important to the success of any water development project.

Katarko is located on latitude 11°33' N and longitude 11°55' E in Yobe state in north-eastern Nigeria (Fig. 4.1). It occupies an area of approximately two square kilometres and is about 20 km from Damaturu, the Yobe state capital, and 128 km from Maiduguri, the Borno state capital. Despite its proximity to major urban centres, the village has no infrastructure that permits the development of modern sanitary or water supply facilities. The climate is hot, with yearly temperature extremes ranging from 15° C during the harmattan months (November - February) to about 40° C during the months of April and May. The area experiences two marked seasons, dry and rainy, with mean annual rainfall of about 600 mm. The rainy season lasts about three months between July and September, while the dry season lasts from October to June.

Katarko has a population of 2820 people made up of 1488 males and 1332 females, with an average household size of 4.8 persons (Nyong and Kanaroglou, 1997). The level of educational attainment in the village is low. Half the sample population has not received any formal education and females are twice as likely to have never attended school as males. About 10.0% of the males have completed primary education compared to 7.7% of the females. An insignificant proportion of the population (1.1% of the males and 0.2% of the females) has completed secondary education. Poverty is widespread, with average annual income of household heads of US$180.00 (the national average is US$ 280.00). The main income generating activity in the area is rain-fed agriculture and animal husbandry.

The village is made up of 10 wards, each with a ward head who reports to the village head. The wards are made up of compounds which form the basic living structure of people

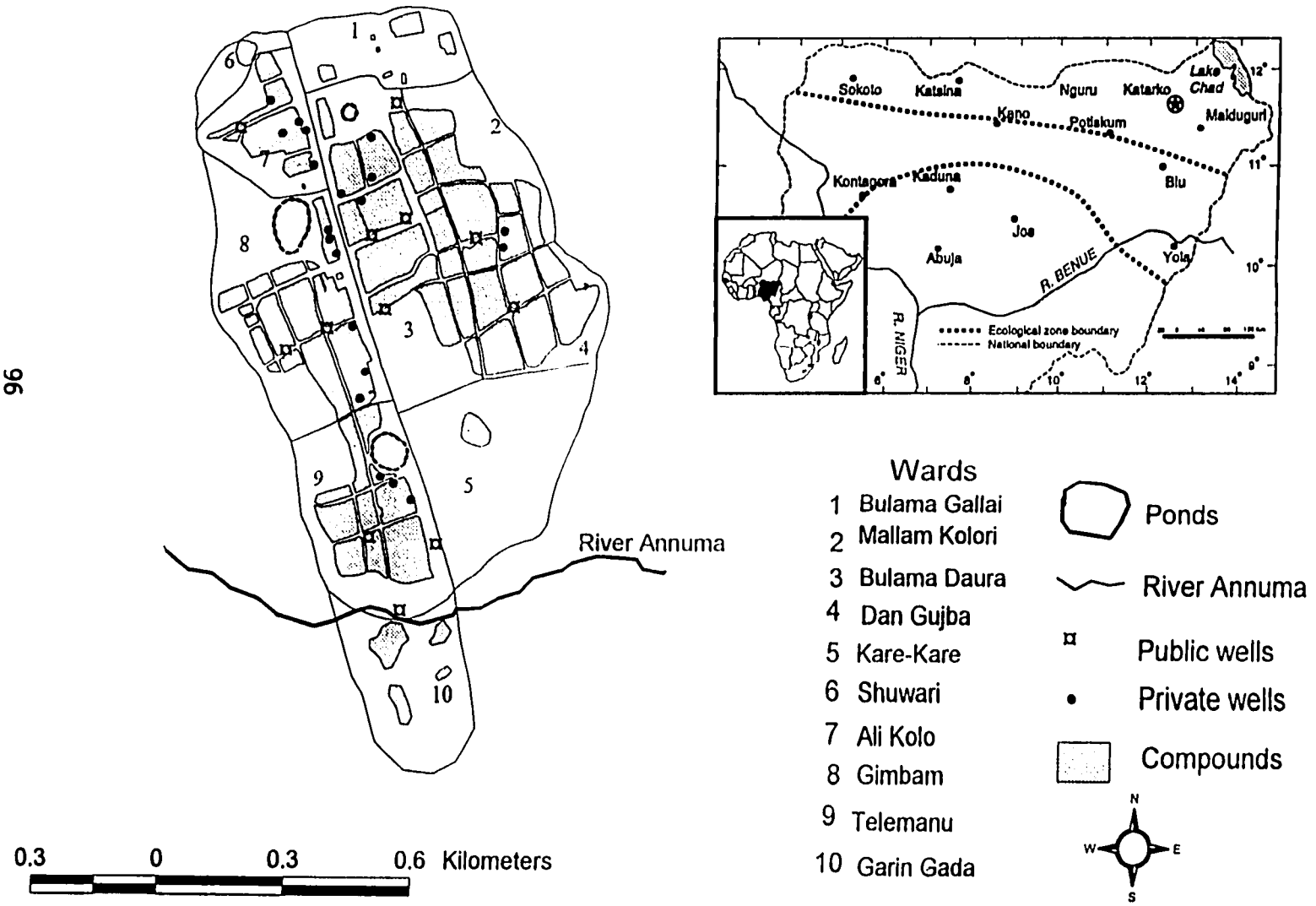


Fig. 4.1: Layout of Katarko village

bound together by ties of kinship. The main ethnic groups in the village are Kanuri, Hausa, Fulani, Shuarab and Kare-Kare. The Hausas and the Kanuris are the main ethnic groups in four wards each, while the Shuarabs and the Fulanis are prominent in one ward each.

Historically, the village came into existence in about 1937, after a colonial officer dug an artesian well in the area (Lee, 1995). The existence of the well and the availability of water from it led to further subsequent movements of people into the village to settle. According to Ajaegbu (1995) most of these migrations were in response to the droughts during 1941-42 and 1963-64. The Kanuris came in first, while the Hausas, the Kare-Kares and the Shuarabs are the most recent migrants into the village. With the growth of this village, more wells were dug to serve the needs of the growing population. Despite that, the village no longer enjoys abundance of water as it did previously. The rapid population growth has led to overexploitation of the water resource. In addition, unfavorable climatic conditions, such as the combination of declining mean annual rainfall and high evaporation, have contributed to compounding the problem of water scarcity.

4.2.2 Field methods

The data for this paper were derived mainly from two face-to-face interview surveys undertaken between June and August 1996 and January to March 1997, which coincide with the rainy and dry seasons respectively. Although the household is our primary unit of observation, we are aware that women are the prominent users of water at home and in the fields, and their participation in water demand studies is important. To eliminate the male

bias that would result from interviewing only household heads who in all cases were men, we administered the same questionnaire to their spouses. Obtaining information from both men and women on the same issues provided gender perspectives and helped in assessing the reliability of the responses from the survey. In a bid to clarify any other inconsistencies, informal discussions were held with the respondents. The survey instrument contained both closed and open-ended questions. With the closed-ended questions, respondents could only select answers from among a given list, while they could provide their own answers to the open-ended questions. Responses from the latter provided insight to the interpretation of the closed-ended questions.

The survey questionnaire consisted of five sections. The first section solicited information on household characteristics such as the names and ages of all household members, their relationship to the household head, their educational levels, ethnicity and occupation. Section B contained questions that aimed at assessing the economic condition of the household, which is well-known to have a direct impact on water use habits. The purpose of section C was to collect information on migration and migration intentions in the village. Section D concentrated on how households relate to, and use water. The last section aimed at collecting retrospective information on the fertility and mortality history of the household.

Available resources allowed us to sample 250 of the 600 households in the village, representing a sampling fraction of 42%. To ensure proportional representation from all the wards, a stratified sampling strategy was adopted. The sampling frame was the list of all

households in each ward collected during a previous survey (Ihemegbulem, 1996). Forty-two percent of the households from each ward were then randomly selected from this list for final enumeration. Two hundred women, spouses of the household heads interviewed, were also selected for enumeration using the same sampling strategy. Here, the sampling frame was the list of all interviewed household heads.

The instrument was administered by a research assistant and four field assistants (three men and two women), who speak the local languages and English. These interviewers were recruited and trained in May 1996. The culture of the society does not encourage interaction between adult men and women who are not married to each other, so the female assistants administered questionnaires to the women. It was anticipated that female respondents would be more open with female enumerators than they would be with male enumerators.

In the first survey conducted in the rainy season, all 250 household heads and 200 women were interviewed, with an overall response rate of 100%. However, two of the questionnaires from the household heads were found unfit for analysis and were discarded. In the second survey, conducted in the dry season, we attempted to administer the same questionnaires to the households and women enumerated in the first survey. The main purpose of the second survey was to obtain information on seasonal changes in water use. Two hundred and nineteen households were interviewed during the second survey because 29 households interviewed in the first survey had migrated from the village with all their members. The overall response rate for the second survey was 100%. One questionnaire was

found unfit for analysis and was discarded.

4.3 Sources of Water for Domestic Uses

Although Katarko is close to large urban centers, it lacks modern amenities like electricity and pipe borne water. It relies entirely on natural sources of water through rainfall, ponds, stream flow and ground water, for all its domestic needs. Katarko does not have any system in place to integrate these sources into a unified complementary system. These sources of water are not available to the community throughout the year. Rain water is only available between July and September. Mean annual rainfall in Katarko is about 600 mm, with mean monthly values ranging between 200 mm in August and 10 mm in October. A large inter-annual and a steady temporal decline characterize rainfall in this region, which adversely affect water availability through the other natural sources.

During the rainy season, water collects as ponds in borrow pits dug to provide laterite used to build the Damaturu-Biu road that runs through the village. These ponds are open and contain stagnant and murky water, serving as breeding grounds for parasites and diseases. They are a major source of water for livestock, bathing and cleaning during and shortly after the rainy season, before they dry out through evaporation. Another major source of domestic water is River Annuma, a seasonal river that flows between July and October. During the flow-life of this river, it provides water for all domestic activities.

Groundwater exists in two types of aquifers: an alluvial aquifer at a depth of about 3-4 m, and a deep aquifer whose depth starts at 8.0 m (Tarhule and Woo, 1997). The village

has 21 private and 12 public wells spread across the entire village, which draw from the deep aquifer. These wells are all hand-dug and are not deep enough to supply water all year through, particularly in the dry season, when the water level is very low. At this time, the villagers abandon these wells for the shallow wells, which exploit the alluvial aquifer. These wells are seasonal and are dug in the flood plain of river Annuma after it has dried up. The exploitation of the shallow aquifer begins in December but withdrawals for domestic use increase as the dry season progresses. The quality of water from these wells is usually poor and the only alternative is to travel about 8 km to the neighboring town of Gujba to fetch water.

4.4 Results

4.4.1 Descriptive analysis of seasonal water use

It is a generally-held opinion that females are the main water collectors in the rural areas of developing countries. This is not true in rural northern Nigeria as local customs and religion influence the gender of major water collectors in a household. In Katarko, only 48% of the households sampled have women as the principal water collectors. This figure varies among the different tribes in the village. Women are primarily responsible for water collection among the Kanuris, while among the Hausas, females account for less than 30% of the water collectors.

A seasonal variation exists in the distance that households travel to obtain water, with households traveling longer distances in the dry than in the rainy season. About 73% of the

households collect their water within 500 m of their homes in the rainy season, while only about 42% of the households do that in the dry season. There is also a seasonal variation in households' self-reported perception of the quality of water they use. More households perceive the quality as better in the rainy season than in the dry season. In the rainy season, only about 1.0% of households perceive their water quality as bad, about 63% perceive it as fair, while about 36% perceive it as good. In the dry season, more than 50% of the households perceive the quality as bad while only about 20% perceive it as good.

The number of households who patronize water vendors also varies according to the season. Only 18.8% of the households purchase water from vendors in the rainy season, compared with 37.6% in the dry season. Besides the seasonal variation, there is also a spatial variation in vendor patronage. Households in wards that are farther away from the river and shallow wells, patronize the services of water vendors than those in wards that are closer to the shallow wells. A breakdown of water use by wards shows that households in wards that are closer to the river, and consequently, the shallow wells, generally use more water in both seasons, than households in wards that are farther away (Table 4.1).

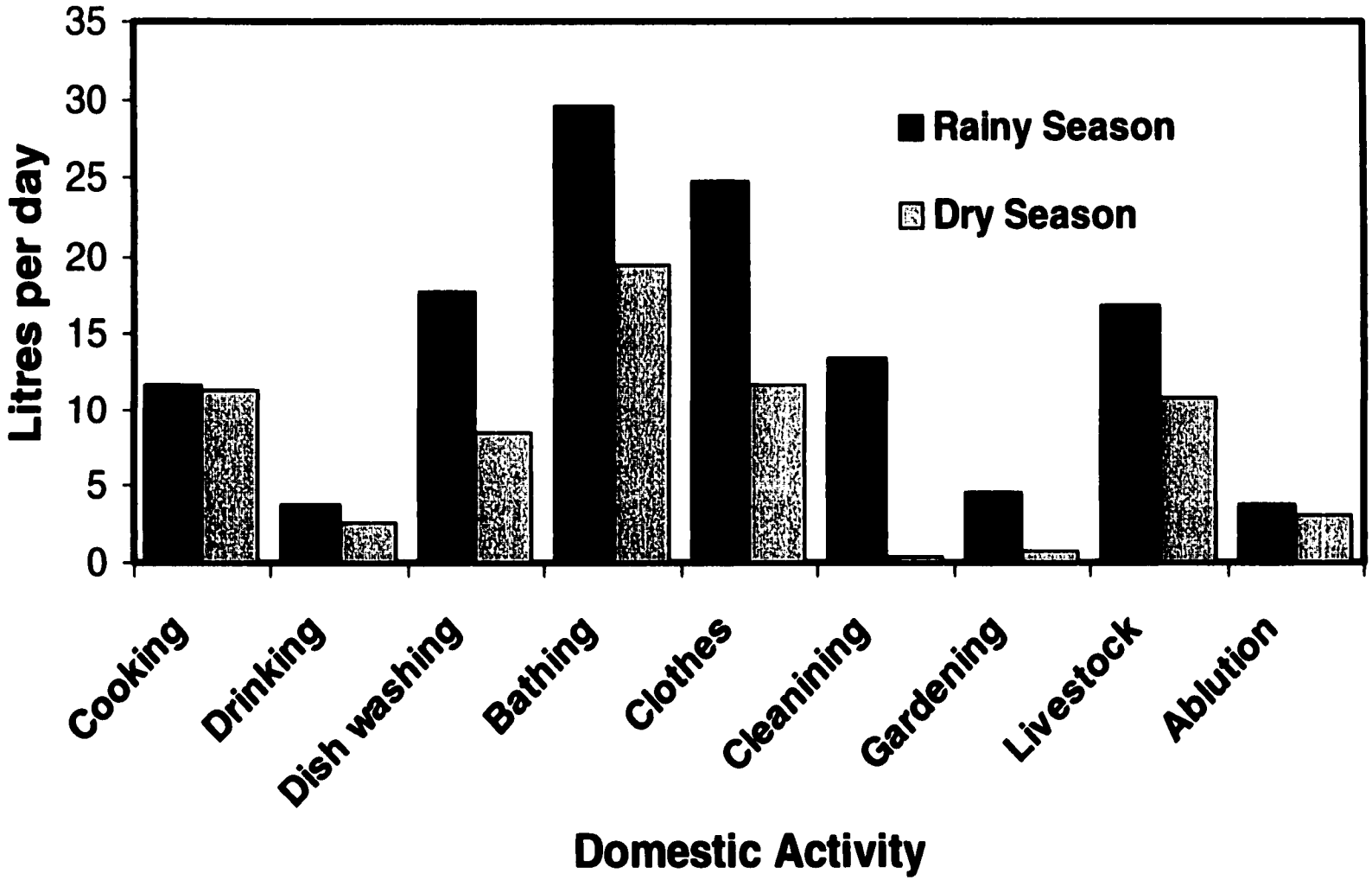
Figure 4.2 shows the quantity of water that households use for different domestic activities in both season. The quantity of water used for necessary domestic activities such as cooking, drinking and ablution does not vary much between the seasons. In contrast, considerable seasonal variation exists in the quantity of water used for activities that pertain to cleanliness and hygiene. In the rainy season, households use about twice as much water for activities such as dish washing, clothes washing and bathing, than during the dry

Table 4.1: Average household daily water use by wards (liters)

Wards	Distance from river (m)	Rainy Season	Dry Season
Garin Gada	120.0	256.6	154.1
Telemanu	335.0	248.2	138.7
Gimbam	580.0	189.0	134.9
Kare-Kare	770.0	205.1	120.4
Dan Gujba	882.0	196.6	128.3
Ali Kolo	920.0	182.6	129.6
Bulama Daura	1005.0	184.7	124.1
Mallam Kolori	1050.0	187.8	122.0
Shuarab	1115.0	167.3	115.4
Bulama Gallai	1280.0	170.8	103.3

season. This low level of personal hygiene has adverse health implications, such as the high incidence of diarrhoea recorded in the village (Nyong and Kanaroglou, 1998). The average quantity of water that households use for domestic activities ranges between 37.5 and 737.5 liters per day (lpd) in the rainy season and between 19.2 and 288 lpd in the dry season. The mean household domestic water consumption in the rainy season is 215.4 lpd while that in the dry season is 125.4 lpd. This difference is statistically significant ($F = 3.42$; $p = 0.05$). The next section of this paper analyzes the factors that explain this seasonal difference in water use.

Katarko: Domestic water use by activities



4.4.2 Result s of multivariate analysis

The previous subsection has shown that domestic water use is dependent on several social, demographic, economic and cultural characteristics of households. Also, water use is dependent on the distance from water sources and the quality of the water. In this subsection we explore the relative significance of all these factors in explaining the variability in household domestic water use, both for the dry and rainy season. For this purpose we estimate regression models for each season. We also estimate a model of the difference in water use between the two seasons, as a function of independent variables. The latter model aims at identifying the characteristics of households that explain differences in their water consumption patterns between the rainy and dry season.

Regression analysis assumes that errors are normal and homoscedastic. A normal probability plot and histogram of residuals from an initial run of the regression model indicated a positively skewed distribution. To correct this problem, we tried several monotonic transformations of the dependent variable, the square root yielding the best results. We applied the log transformation to household size to linearize its relationship to the dependent variable. Although 52 explanatory variables were used in the models, a full description of the significant ones is presented in Appendix 1.

4.4.2.1 *Dry season domestic water use*

Estimated parameters of the model of the dry season water use are presented in Table 4.2. The fit of the model is quite good with an adjusted R-square of 91.1%. Most of the

variables are highly significant and of the right signs: nativity, compound well, water quality, log of household size and the number of adult women in the household have positive effects, while distance and vendor patronage have negative signs.

From the results presented in Table 4.2, we learn the following. First, natives use more water than non-natives. Water is becoming increasingly scarcer in the village and natives have been there when water was generally in abundance and have probably not adjusted their demands to the present water situation in the village. It could also be that non-natives are more frugal with water since they have moved in reaction to water scarcity elsewhere. Second, the more the number of adult women in the household the more water that household uses. This is expected as women are the principal users of domestic water in rural areas. Third, in terms of education, households whose heads have completed primary education, use more water than households whose heads have no education. We expect that more educated households are better informed of the health benefits of using sufficient water. Fourth, households that purchase water from vendors use less than those who do not. Finally, residents in wards that are closest to the river and consequently, the shallow wells use more water than those in wards that are farther away from the river (See Table 4.1). Besides measuring the relative locations of the households, the ward variable captures other cultural factors and attitudes that affect water use that are not captured by ethnicity. Although each ward is culturally homogenous and occupied by a major ethnic group, ethnicity was not a significant explanatory variable.

Other intuitive inferences that can be drawn from our results are: (1) domestic water

Table 4.2: Results of multivariate analysis of domestic water demand

Explanatory Variable	Dry Season		Rainy Season		Seasonal Difference	
	Coef.	t-score	Coef.	t-score	coef.	t-score
Constant Term	9.131	23.20	8.378	12.82	11.364	10.72
Nativity (ref.: non-natives)						
natives	0.374	1.86			-3.073	-4.25
Compound Well(ref.: no well)						
Well in Compound	0.424	2.34			-5.033	-7.91
Water Quality (ref.: Bad)						
Fair	0.495	2.27			-1.939	-3.77
Good	1.101	4.33			-2.841	-4.42
Distance travelled to fetch water (ref,: [Dist1] Less than 100 m)						
100m to less than 500 m (Dist2)	-1.311	-7.79	-0.58*	-1.06	0.6753*	0.23
Between 500 m and 1 km (Dist3)	-2.471	-12.04	-1.597	-3.54	4.174	7.02
Greater than 1 km (Dist4)	-4.031	-14.60	-3.758	-5.31	5.031	6.78
Use of water vendors (ref.: Does not use vendors)						
Uses vendors	-0.408	-3.36				
Ward (ref.: Bulama Galai)						
Mallam Kolori	0.629	2.28	-0.297*	-0.30		
Bulama Daura	0.903	4.86	0.641*	0.52		
Ungwar Dan Gujba	0.681	3.25	-0.159*	-0.15		
Ungwar Kare Kare	1.334	3.59	-1.05*	-0.82		
Mallam Kolori	0.1151*	0.47	-0.361*	-0.843		
Ali Kolo	-0.1638*	-0.50	0.204*	0.841		
Gimbam	1.220	6.46	0.943	1.88		
Telemanu	1.374	7.34	2.034	4.03		
Garin Gada	1.377	4.74	1.903	4.54		
Log of Household Size	1.186	6.41	9.107	10.34	5.488	5.41
Adult women in household	0.244	2.88	0.298	1.69		
Occupation (ref.: Traders)						
Civil servants			-4.186*	-1.54		
Artesians			-4.986*	-1.62		
Farmers			6.230	2.39		
Education (ref.: No education)						
Koranic Education	0.026	0.17				
Primary not completed	-0.003	-0.01				
Primary completed	0.423	2.12				
Secondary not completed	0.282	0.46				
Secondary completed	0.221	0.36				
Summary Statistics:						
Adjusted R-Square	91.100		51.200		77.000	
F-Statistics	124.180		51.090		41.350	
P-value	0.000		0.000		0.000	

*Not significant at the 10 percent level

use decreases significantly with distance from a water source. (2) Households that perceive the quality of water as good use more water than households that perceive it as poor. (3) Households that have wells in their compounds use more water than households without wells in their compounds. From the results, we can deduce that apart from the cost-benefit analyses of convenience and water quality, social and cultural factors are important in explaining domestic water use in a rural context. The finding that water demand responds to vendor patronage that has a price element attached to it, shows that although cultural and demographic factors influence water demand in this village considerably, one can approach the management of it with economic principles.

4.4.2.2 *Rainy season domestic water use*

The independent variables are identical to those included in the dry season model, and the results of the test of the model is summarized in Table 4.2. The rainy season model explains only 51.2% of the variability in daily domestic water use. The lower explanatory power suggests that other factors not captured by our explanatory variables are at work in influencing domestic water demand. It could also suggest the possibility of indiscriminate domestic water use, where the abundance of water in this season with almost no cost attached may encourage its wasteful use.

While the determinants of water demand in the dry and rainy season are generally different, three variables are common to both seasons. These are the log of household size, number of adult women in the household and distance. A difference of means test showed

that the parameters of these variables are significantly different in both seasons. The log of household size is most significant (t=115.6, $p < 0.005$), followed by the distance variables (Dist2, t = 37.8, $p < 0.0005$; Dist3, t = 28.57, $p < 0.0005$; Dist4, t = 12.6, $p < 0.005$). The parameter for the variable representing the number of adult women in the household is significant at the 10% level.

Having seen that the individual parameters of the models in both seasons are significantly different, we now proceed to compare the results of both seasons. All the significant variables have the right signs. Like the dry season model, the effect of distance is negative and significant. The effect of log of household size is positive and significant. The variable representing the number of adult women in the household has the expected sign and is significant at the 10% level. Occupation of the household head affects domestic water use only in the rainy season. Farmers use more water than the other occupations. We expect that after farm activities, farmers will take their baths and wash their clothes more frequently than those engaged in the other occupations, hence the high water consumption among them.

4.4.2.3 *Seasonal discrepancy in domestic water use*

To consolidate the findings in the previous two sections, we turn now to examine the factors that explain the discrepancy in domestic water use between the rainy and dry season. In this analysis only households sampled in both seasons are included. The result of this model is presented in Table 4.2. Six significant variables explain 77.0% of the seasonal variation in domestic water use.

We have already discussed the effect of distance on within-season variability in domestic water demand in the previous sections. From the previous models we know that distance negatively affects the quantity of water used for both the rainy and dry seasons. The between-season model shows that households that obtain water at distances that are greater than 1.0 km exhibit greater discrepancy than those who obtain it within 100 m of their homes. The positive sign here shows that controlling for other factors, the discrepancy in water use between the rainy and dry season increases with distance.

Households that have wells in their compounds display less discrepancy in water use than those without wells. Considering that households that have wells in their compounds use more water than those without wells, the low variability suggests a sustained high water use in both seasons among those with wells in their compounds. Other things being equal, non-natives are associated with greater seasonal discrepancy in water use than natives. In the rainy season, the difference in water use between the natives and non-natives is not significant. In the dry season when water is scarce, non-natives who probably moved into the village because of water scarcity in their origins are more frugal with their water use than the natives. Natives, on the other hand, do not significantly adjust their demands to the water availability in the dry season as do the non-natives. This explains the greater seasonal discrepancy in water use among non-natives. The way households perceive their water quality also contributes to the seasonal variation in domestic water use. The quality of water as reported by the households, is higher in the rainy season than in the dry season. Households that perceive the quality of their water as good in the dry season, record less

discrepancy than those who perceive the quality of their water as poor. This shows that the lower the quality of water as perceived by the households in the dry season, the lower the quantity of water they use when compared with the rainy season, when the quality is higher. The effect of household size is also significant. The larger the household size, the bigger the differences in domestic water use. This suggests that larger households probably use more water than they need in the rainy season because water is abundant. In the dry season when water is scarce, they reduce consumption to suit availability.

4.5 Water Demand Projections

A third goal of this paper was to determine the implications of changes in socio-demographic, cultural and economic variables on water demand. Projecting water demand based only on per capita use ignores the effects of these factors, which we have shown affect water demand significantly. Population data to project water demand were derived by: (1) projecting household population of Katarko using the headship rate method, and (2) projecting the total population using the cohort component method based on a life-table constructed for the village (Nyong and Kanaroglou, 1997). We derived the initial age and sex structure of the population, mortality, fertility and migration, from demographic data obtained from the two surveys reported in section 2. In the projections, we assumed an increase in life expectancy at birth by 2.5 years and a decline in fertility rates by 0.05 within a five-year period as suggested by United Nations (1989).

To project water demand for the different socio-demographic groups, it was first

necessary to determine average water use for household groups with different characteristics. The socio-demographic characteristics we used included average household size, total number of households, the number of adult women in a household, nativity, and educational levels of household heads. Other variables were the existence of wells in compounds, perceived water quality, distance to water sources, and vendor patronage. To have a sufficiently large number of respondents with each characteristic to estimate water demand, the socio-demographic variables were reclassified into fewer categories. For example, distance to water sources was categorized into near (less than 500 m) and far (greater than 500 m). Education was dichotomized into: (a)those who had either no education, Koranic Education, or incomplete primary, and (b) those who had completed primary schooling and higher. Water quality was divided into good and bad, while vendor patronage retained its original categories used in the multivariate analysis. The number of adult women in a household was dichotomized into small (less than 4) and large (4 or more). The average household size and the number of adult women in a household were derived from the population projection. The results of water use projections for 10 years in Katarko are presented in Table 4.3. These results apply to the entire village and not to the sampled population.

The surveys revealed that daily water use in the rainy season was 71.8% more than that in the dry season (129240 lpd and 75240 lpd respectively). Based only on per household water use and assuming that there is no improvement in the water service, we estimate that daily domestic water demand in 10 years will be about 97060 lpd in the dry season. With an

improvement in water services, we postulate that demand will resemble that of the rainy season and could increase from 97060 lpd to 166720 lpd. This implies that with an improved water service in this community, households are likely to use approximately 70% more water than what they would use if the current water situation in the dry season continued into the future. We could generalize that if water availability in Katarko increases to the same level with that in the rainy season, total domestic water demand would more than double in 10 years (from 75240 lpd to 166720 lpd). We do not assume that the only reason for the difference in water consumption between the rainy and dry season is water availability. There are other factors such as the differences in activities that people are engaged in during the two seasons. Besides this, some socio-demographic variables discussed in the preceding section contribute to this seasonal discrepancy in demand. However, the rainy season demand presented here could provide a glimpse of an anticipated increase in demand that may result from an increase in water availability.

Including socio-demographic and cultural determinants of water demand into the projections sheds additional light to future water consumption in the area. In the projections, we have conservatively assumed that present household water use patterns would remain constant throughout the projection period. Projecting demand based on household size yields estimates that are very comparable to those based on per household water use. The dry season estimate is lower (less than 1%) while the rainy season estimate is higher (2.8%) than the estimates based on per household water use. Projecting water demand based on the number of adult women in a household shows an increase of 4890 lpd (5.0%) in daily

Table 4.3: Water Demand Projections for Katarko (litres per day)

	0 year	10 years	Projection Difference	
			Quantity	Percent
Projected Number of Households	600	774		
Average Household Size	4.6	5.31		
Per Household water use projection				
Dry Season	75240	97060		
Rainy Season	129240	166720		
Difference*	54000	69660		
	72%	72%		
Projection by household size				
Dry Season	74902	97238	178	0.2
Rainy Season	130538	171308	4588	2.8
Difference*	55636	74070		
	74%	76%		
Projection by existence of well in compound				
Dry Season		98802	1742	1.8
Rainy Season		168276	1556	0.9
Difference*		69474		
		70%		
Projection by Distance to water source (within 500 m)				
Dry Season		109652	12592	13.0
Rainy Season		169974	3254	2.0
Difference*		60322		
		55%		
Projection by Water Quality		98456	1396	1.4
Projection by number of adult women in household		101950	4890	5.0
Projection by education of household head		100692	3632	3.7
Household size, adult women in household, education of household head.		102230	5170	5.3
Distance to water source and quality		113266	16206	16.7
Patronage of water vendors		94514	-2546	-2.6
Distance to water source, quality and vendor		109811	12751	13.1

Difference* is the disparity between the rainy and dry season consumption associated with any variable in any particular projection year

Where the season is not specified, projection values refer to the rainy season consumption

Projection difference is the difference between the values obtained from projection based only

demand, assuming there is no improvement in water supply.

An important process in policy design is the appraisal of its impact before implementation, using the *with and without* principle (Young, 1996). This principle holds that policy appraisal should contrast the "state of the world" as it would be with the policy, to the "state of the world" without the policy. An important implication of the principle is that project evaluation is not adequately accomplished by comparing conditions before the project with conditions after its implementation. The water demand projection we have developed can be used as a tool to appraise the impacts of some of Nigeria's developmental policies on water demand before they are carried out.

In 1976, Nigeria adopted a national policy on Universal Free Primary Education, which gave every child the right to free primary education. To complement this effort, a national mass literacy campaign was launched in 1990 to boost literacy in Nigeria. To serve the needs of migrant pastoral nomads and their children, the National Commission on Nomadic Education was established in 1989. The major target of all these policies has been to provide every Nigerian a minimum of six years of primary education. The impact of the success of this policy on water demand can be evaluated by incorporating education in the water demand projection. In our previous models, we found that education affects water demand in Katarko. Those who had completed primary education used more water than those who had not. If every household head in Katarko completes primary education in the next 10 years, daily domestic water demand would increase by 3632 lpd (3.7%). If other things remain constant, the combined effect of education, household size, and number of adult

women in a household increases water demand by 5170 lpd (5.3%).

The recognition of the central role of good quality water to the well-being of individuals led to the declaration of the 80s as the International Drinking Water Supply and Sanitation Decade. The main object of this policy was to make good quality drinking water accessible to every individual in rural communities. The effect of this policy on demand can also be assessed using our projection model. If the present quality of water is made accessible to this community such that households obtain water within 500 m of their homes, domestic water demand will increase by 3524 lpd (2.0%). If besides making water accessible, the quality is improved such that all households perceive the quality of their water as good, domestic water demand will increase by 16206 lpd (16.7%).

The effect of price introduction on water demand can also be examined. If every household paid the equivalent of what it pays to vendors, demand would decrease by 2.6%, and making good quality water available within 500 m of users' homes at a nominal price, reduces the demand from 113266 lpd to 109811 lpd, a decrease of 3.0%. Besides this, knowing how much households pay to vendors is an indication of how much they would be willing to pay for an adequate water supply if it were made available to them.

The water supply in this village is unreliable and individuals have taken to digging wells in their compounds in a bid to be self-sufficient in water. Digging private wells in this community is expensive and above the means of most households. We observed during the field survey that one reason that out-migrants remit money back home is so that the household can dig a private well. If every household digs a private well, domestic water

demand will increase by 1742 lpd (1.8%).

Although these values do not seem high, the extremely arid nature of this region poses an important question: Can the water supply of this village meet these future demands? In view of the rapid population growth experienced by this village, the prevalent levels of poverty and the limited water availability, we may speculate that one cannot meet this demand at the long run. Water planners must incorporate demand management in their overall water development policy for this region, particularly before the introduction of an improved service. One step toward achieving this is by correctly estimating future water demand, particularly for yet-to-be-introduced water services.

4.6 Conclusion

This study has investigated the determinants of domestic water demand in rural north-eastern Nigeria in the rainy and dry seasons. Not all the factors that explain dry season water use are significant in explaining rainy season water use. The fit of the rainy season model is lower than that of the dry season, with an adjusted R-square of 51.2% and 91.1% respectively. The lower explanatory power of the rainy season model could portray some level of wasteful use because of the abundance of water in that season. Overall, the results of the entire analysis are broadly supportive of the proposition that domestic water demand in rural areas of developing countries is subject to socio-cultural interpretations. From a theoretical perspective, these findings are consistent with Rathgeber's (1993) contention that local people's customs, culture, intergroup relation, social organization, gender relations and

social structure have direct bearing on issues of water use.

Although cultural and demographic factors influence water demand in this village considerably, the management of it can be approached with economic principles. A strong support for this is provided by the statistically significant negative relationship between vendor patronage and domestic water demand. In a poor rural community like Katarko, it is often assumed that people will not pay for water use and that generating sufficient revenue from water sales to maintain the water supply and management system is unlikely. The activities of water vendors in this village show that people are willing to pay for water services. It also reveals how much they are willing to pay for water supply if it were made available to them. Research has shown that improvements in the quality of water supply and in its availability are usually possible at relatively low costs (WHO, 1992; Sharma et al., 1996). In such communities a proper piped water system can often replace the vendors and provide these households with more economical and convenient supply at the same price as they previously paid to vendors.

Modeling water use behavior in the rainy and dry seasons in Katarko has revealed how households adjust their water use behavior to water availability. We do not assume that increasing water availability in this village to the level in the rainy season will necessarily lead to a doubling of the demand. This is because some rainy-season specific activities also contribute to the large domestic water consumption in that season. However, the rainy season demand presented here could provide a glimpse of anticipated increases in demand with an increase in water availability. Policy issues on domestic water projects in rural areas of

developing countries should not only emphasize the need to understand what improvements in their water services people really want and are willing to pay for. They should also pay attention to how the improved water services will be used once they have been provided.

With the limited water availability in this region, it is imperative that water planners should pursue policies that aim at managing both present and future demands. In this paper, we have shown that excluding the socio-cultural factors that explain as much as 90% of the variability in domestic water use clearly underestimates demand. We have also shown that incorporating these variables into demand projections, one can assess the impact of proposed development projects on domestic water demand.

In view of the above, a number of areas for further research have emerged. At the peak of the dry season, only water from the deep aquifer is available to this community and most of the wells that draw from this aquifer are not deep enough to supply water at these times of the year. The scarce resources of the village can only permit the provision of a few facilities capable of supplying water perennially. Research should investigate where facilities should be sited such that they are accessible to the population in the most efficient manner.

The physical presence of a water facility in this village does not guarantee equal access to it by the entire community. A previous study has shown that cultural barriers deny some local groups access to some water sources in this village (Nyong and Kanaroglou, 1988). Examining these barriers with the view to suggest how they can be broken is important. These important research issues will be addressed in the course of the wider research for which this paper is a part.

Acknowledgements

We wish to thank CIDA for the financial support in the preparation of this paper, and the University of Jos, Nigeria for providing the research support. We are grateful to the village head of Katarko, all the community leaders who contributed to the preparation of the questionnaire and the entire Katarko community for their cooperation during the research. We also wish to acknowledge the contributions of our research assistant, Jasper Dung for acting as the interpreter between the field assistants and myself. We are grateful to Drs. W. Anderson, K-L. Liaw and S. Elliott for reviewing earlier versions of this manuscript.

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Appendix 1: The Explanatory Variables

The key demographic, social and cultural variables used in our models to explain the variability in domestic water use in rural north eastern Nigeria are:

Household size: We expect that larger households would use more water than smaller households. However, the relationship between household size and water use is curvilinear and as such household size was transformed using a log transformation.

Education: This is a polytomous variable and is specified to have six categories: (0) No education; (1) Koranic education only; (2) primary school not completed; (3) primary school completed; (4) secondary school not completed; (5) secondary school completed. "No education" served as the reference class. It is hypothesized that more educated households are better informed about the health implications of poor sanitary practices and as such will use more water than the less educated households.

Occupation: This is a polytomous dummy variable with four categories: (1) Farming; (2) Trading; (3) Artisan; (4) Civil servants. Trading was the reference category. In a previous study it was found that more water is used for bathing and clothe-washing than for other domestic activities (Nyong and Kanaroglou, 1997). We hypothesize that farmers wash their clothes and take their baths more often, farming households use more water than those engaging in other professions.

Nativity: This is a dichotomous dummy variable that identifies whether the respondent is a migrant or a native-born, with two categories: (1) native born, (0) non-native, with non-native as the reference category. We hypothesize that natives use more water than non-

natives. The water in the village is becoming scarcer and household heads who were born in the village have been accustomed to the situation when water was abundant and as such use more of it.

Ward: Katarko village is divided into 10 wards for administrative reasons. Each ward is made up of compounds occupied by people bound by ties of kinship and consanguinity. Each ward is culturally homogenous, occupied by one major ethnic group, the member of which migrated into the village approximately the same time. This variable is used to capture salient cultural differences that are peculiar to the wards. We expect that water use is not homogenous across all the wards and that culture is a strong factor affecting water use. It is specified as a polytomous variable with 10 categories: (1)Bulama Gallai; (2) Mallam Kolori; (3) Bulama Daura; (4) Ungwar Dan Gujba; (5) Ungwar Kare-Kare; (6) Shuwari; (7) Mallam Ali Kolo; (8) Gimbam; (9) Telemanu; (10) Garin Gada. Bulama Gallai served as the reference ward. Among other things, we expect that households living in wards located closer to the river will use more water than households in wards that are far from the river.

Adult women in the household: Previous studies have found that households with more adult women use more water than households with few adult women (White et al, 1972, Mu et al, 1990). We expect that households with more adult women in the household will use more water than those with fewer adult women. This variable is an interval-level variable and was entered directly into the regression equation.

Compound well: This is a dichotomous dummy variable that measures the availability of a well within the compound where the household lives. The variables are: (0) No well in

compound; (1) Has well in compound. We expect that households that have wells in their compounds will use more water than households that do not have wells in their compounds.

Water Quality. This self-reported variable measures the way households perceive their water quality. It is an ordinal variable with three categories: (1) bad; (2) fair; (3) good. During the pretest of our questionnaires and with the help of community leaders, we came up with local indices that conveyed these different levels of quality to the respondents. We hypothesize that households that perceive their water quality as good use more water than those who perceive otherwise.

Water Distance: This variable measures the distance that households travel to fetch water. It is an ordinal variable with four categories: (1) less than 100 m; (2) 100 m to less than 500 m; (3) 500 m to less than 1 km; (4) more than 1 km. We expect that households who live closer to water sources will use more water than those who live further away from water sources.

Water Vendors: This is a dichotomous dummy variable identifying those who use the services of water vendors. The categories are: (0) Does not buy water from vendors; (1) Buys water from vendors. We expect that households that buy water from water vendors are likely to use less water than those who do not.

Chapter Five

GIS Location-Allocation Approach to Siting Rural Water Facilities in Northern Nigeria.

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Submitted to

The Canadian Geographer

Abstract

Because water facilities are often provided in response to political and tribal agendas, their selection criteria are neither rigorous nor need-based. This paper demonstrates the utility of location-allocation modeling as a decision support tool in siting rural water facilities, using a case study of Katarko in northern Nigeria. Using the *p*-median constrained model, we show that existing public wells are neither efficiently nor equitably distributed. We examine the option of either providing new wells that are optimally distributed, or rehabilitating existing wells as requested by the community. We recommend the provision of a new set of optimal wells, in view of the offsetting benefits associated with them.

5.1 Introduction

A large proportion of the rural population in developing countries is without access to improved potable water supplies, despite the huge investment in water supplies within the last two decades (Mu et al, 1990; World Bank, 1995, Mutemba, 1995; Young, 1996; Sharma et al., 1996). While sufficient attention has been given to institutional problems that limit the success of rural water schemes, such as financial resource scarcity, problems in institutional coordination and decentralization, legal and political hindrances, the lack of community participation and the neglect of women in project planning, the inadequacy of linkage of type of technology selected to the management capacity of the community, the problem of cost recovery, and the lack of criteria to measure the success of rural water supply projects (Kendie, 1996), the problem of geographical accessibility is often overlooked. This is an oversight as it is commonly-known that water users, particularly women, travel several kilometers daily to obtain water for domestic activities (White et al., 1972; Briscoe and DeFerranti, 1988; Falkenmark, 1994; Rathgeber, 1996).

The problem of geographical accessibility is partly explained by the fact that selection criteria for the location of facilities are neither rigorous nor need-driven. This is the case in Nigeria where, without a rural water development plan, water projects are often provided in response to political and tribal agendas. Where such plans exist, they are often guided by engineering and technical considerations, paying little or no attention to the spatial distribution of water demand.

The purpose of this paper is to illustrate how location-allocation (LA) models can be

used as a spatial decision support tool for rural water planning, using a case study from Katarko in northern Nigeria. Besides typifying rural semi-arid Nigeria with its endemic water scarcity, the village allowed its women to participate in the research. This is crucial as women are the main users of domestic water in rural areas and their participation is important to the success of any water resource project.

This study differs from existing African applications of the model in the following ways: First, LA models have primarily been used in Africa to assess the location of public health facilities (Stock, 1982; Okafor, 1983; Ayeni et al, 1987; Oppong and Hodgson, 1994; Oppong, 1996). The application of LA models to other sectors of the economy has received little attention. One important sector in which the use of LA models is relevant is the water sector. The failure of past rural water schemes has generated fresh initiatives to ensure that a large number of rural households have access to good quality water, efficiently and equitably within the next decade (Sharma et al., 1996). The location of water facilities to achieve these objectives lends itself well to the LA approach. Second, existing studies employ continuous space models, where accessibility is measured in euclidean distance. Their assumption is that walking, which is the main mode of travel in rural areas, is continuous and takes place freely. What they miss is that rural people use well-established footpaths and roads that should be modeled as networks. From a practical viewpoint, the continuous space model is limited because of the absence of constraints on locational possibilities (Hansen et al., 1985; Goodchild and Noronha, 1987). Consequently, we have structured our model in discrete space where distances are measured on a road network and

facility locations are restricted to the vertices of this network. Finally, existing studies have used population as proxy for demand. We estimated detailed demand using multiple regression models. Since other factors besides population numbers affect natural resource use, we believe that our demand estimates will produce better LA results.

The organization of the rest of the paper is as follows. We begin with a description of the village of Katarko, providing a geographical setting for the study. This is followed by a review of its sources of domestic water. Next, we present the formulation of the p-median with maximum distance constraint model (from now on called the p-median constrained model), and describe the methodology used in the study. We then discuss our findings and conclude with a highlight of the main points. This research is part of a wider study investigating the relationship between population and domestic water use in rural northern Nigeria.

5.2. Characteristics of the Study Area

Katarko is on latitude 11°33' N and longitude 11°55' E in Yobe state in north eastern Nigeria (Fig. 5.1). It occupies an area of approximately two square kilometers and is about 20 km from Damaturu, the Yobe state capital, and 128 km from Maiduguri, the Borno state capital. Despite its proximity to major urban centers, the village lacks modern sanitary and water supply facilities. The climate is hot, with yearly temperature extremes ranging from 15°C during the harmattan months (November - February) to about 40°C during the months of April and May. Katarko experiences two marked seasons, dry and wet, with mean annual

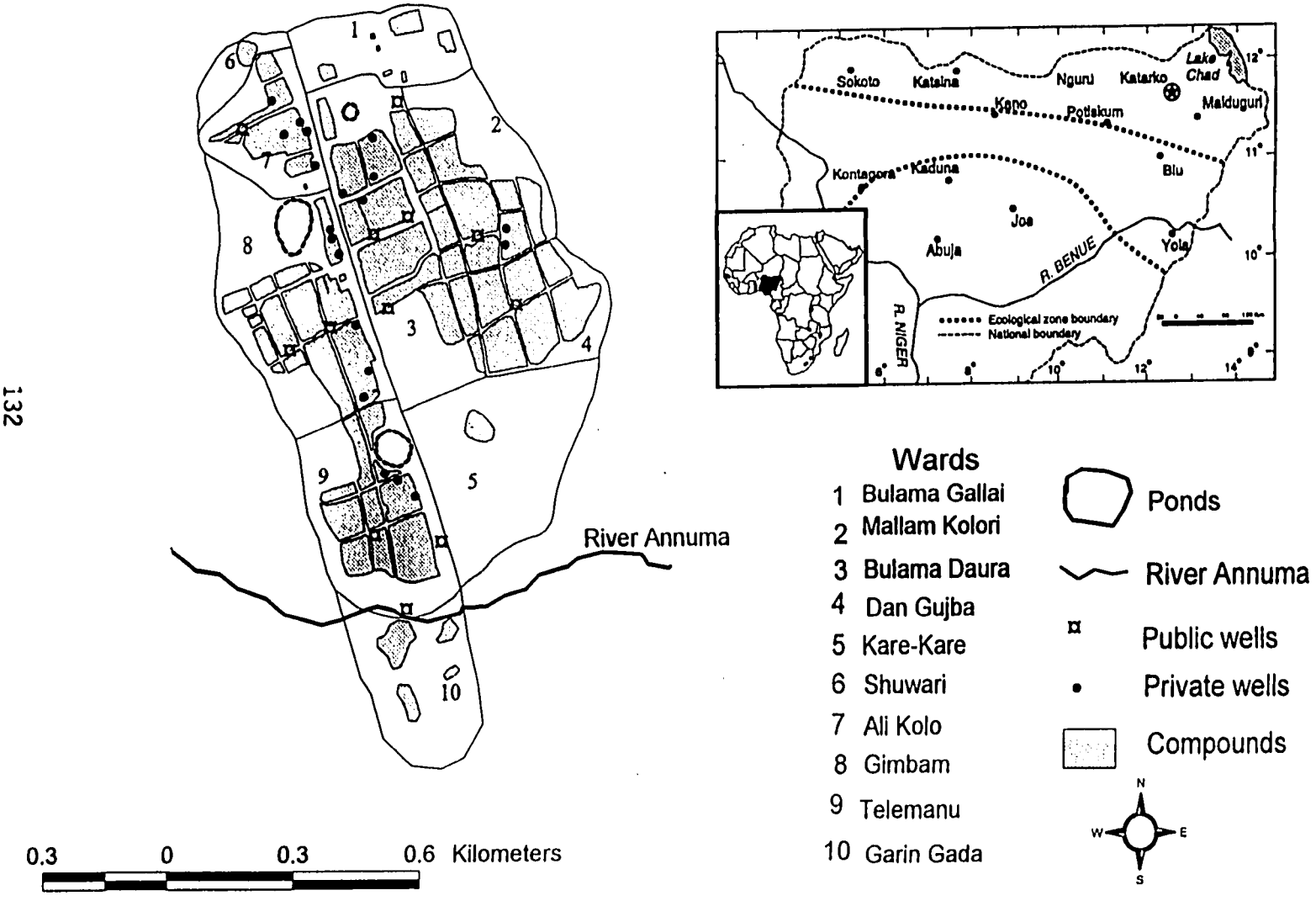


Fig. 5.1: Study area showing wards and water sources

rainfall of about 600mm. The wet season lasts about three months between July and September, while the dry season lasts from October to June.

Katarko has a population of 2820 people made up of 1488 males and 1332 females (Authors' fieldwork, 1996). Household size ranges between 2 and 12 persons, with an average of 4.8 persons. Rain-fed agriculture and animal husbandry are the main income generating activities in the village. Poverty is widespread, with average annual income of household heads of N17,500.00 (US$180.00), compared with the national average of N25,000.00 (US$ 280.00). Ninety-six percent of the women and 75% of the men earn an income less than the national average. Educational attainment in the village is low with only 10% of the males and 7.7% of the females having completed primary schooling. Katarko is made up of 10 wards, and each ward consists of compounds that form the basic living structure of people bound together by ties of kinship (See Fig. 5.1). The main ethnic groups in the village are Kanuri, Hausa, Fulani, Shuarab and Kare-Kare. The Hausas and the Kanuris form the main ethnic groups in four wards each, while the Shuarabs and the Fulanis are prominent in one ward each. About 90% of the household heads are immigrants, with 80% having come in search of farm work because of the previously abundant water supply in Katarko. Historically, the village came into existence in about 1937, after a colonial officer dug an artesian well in the area (Lee, 1995). The existence of the well and the availability of water from it led to attracting more settlers into the village. Over the years, many private and communal wells have been provided to serve the needs of the growing population.

Different decision structures have guided the provision of the communal wells.

Besides the well provided by the colonial administration in 1937, two others were provided recently by the government through the water programs of the Directorate for Foods, Roads and Rural Infrastructure, and the Better Life for Rural Women Project. Their locations were arbitrarily selected by politicians in the Local Government Administration. The remaining 9 wells were provided through communal efforts. The decision to dig a well is usually initiated by a ward head who seeks approval of the village head and his ruling council. Once the approval is obtained, the location of the well, which has to be on public land, is at the discretion of the ward head. None of these permanent wells is deep enough to supply perennial water.

5.3 Sources of Domestic Water

Katarko relies entirely on natural sources of water through rainfall, ponds, stream flow and ground water, for all its domestic needs. The timing and availability of water from these sources vary throughout the year. Rain water is only available between July and September. Mean annual rainfall is about 550 mm, with mean monthly values ranging between 10 mm in October, and 200 mm in August (Tarhule and Woo, 1997). A large inter-annual and a steady temporal decline characterize rainfall in this region, and adversely affect water availability through the other natural sources. In the rainy season, water collects as ponds in borrow pits dug to provide laterite used to build the Damaturu-Biu road that runs through the village. These ponds are open and contain stagnant and murky water, serving as breeding grounds for parasites and diseases. They are a major source of water for livestock,

bathing and cleaning during and shortly after the rainy season, before they dry out through evaporation. Another major source of domestic water is River Annuma, a seasonal tributary of Gongola River, that flows between July and October. During its flow-life, the river provides water for all domestic activities. Groundwater is the only source that can provide water perennially in the village. It exists in two types of aquifers: an alluvial aquifer and a deep aquifer. The alluvial aquifer is shallow and occurs at a depth of between 3.0 and 4.0 m, while the deep aquifer occurs from a depth of about 8.0 m (Tarhule and Woo, 1997).

Katarko has 33 permanent wells (21 private and 12 public), which draw from the deep aquifer (see Fig. 5.1). The private wells are found within the compounds of the households who own them and are not available to the public. On the other hand, the public wells are found outside the walls of the compounds, where access to them is unrestricted. At the peak of the dry season when the water level is at its lowest, the deep wells are abandoned for the shallow wells that exploit the alluvial aquifer. These wells are seasonal and are dug in the flood plain of river Annuma after it has dried up. Although their use begins in December, withdrawals for domestic use increases as the dry season progresses. The quality of water from them is usually poor and the only alternative is to travel about 8 km to the neighbouring town of Gujba to fetch water.

Undoubtedly, the limited access to good quality water, particularly in the dry season, has severe negative impacts on the quality of life in Katarko. In view of the failure of past attempts to improve the water situation in this village, and the surrounding areas, the Jos-McMaster Drought Research Project was established, with funding from the Canadian

International Development Agency (CIDA). The goals of the project include the improvement of existing water supply schemes to reduce the incidence of water-borne diseases, the augmentation of present supplies, and the establishment of new facilities at locations that would yield the highest social welfare returns. Recent successes of rural water supply schemes in sub-Saharan Africa show that these ideals can only be achieved when communities determine their priorities and assume responsibility, authority, and control over improvements in and operation of water facilities (World Bank, 1991; 1995). This underscores the fact that sustainability of water projects requires that the users should be provided with what they want and are willing to pay for and maintain.

In a recently-concluded Participatory Rapid Appraisal in Katarko (Jos-McMaster Drought and Rural Water Use Research Project, 1998), the villagers identified access to good quality water as their greatest need. They suggested that existing public wells should be rehabilitated, and handpumps installed in them. Considering financial resource constraints, not all the public wells can be rehabilitated simultaneously. Any decision on which wells to rehabilitate will raise the issue of efficiency and equity. These criteria make for a useful application of the *p*-median constrained model, where the objective is to maximize efficiency while accounting for equity.

5.4 The Model

The best-known and most commonly-used of the location-allocation models is the *p*-median problem. Its objective is to determine the location of a given number of

uncapacitated facilities, p, so that the total distance traveled is minimized. It is formulated as (ESRI, 1997):

$$Minimize\ Z = \sum_{i=1}^{n} \sum_{j=1}^{m} W_i\ d_{ij}\ x_{ij}$$

Where:

j = candidate facility location

n = the number of demand locations

m = the number of candidate facility locations

p = the number of facilities to locate

W_i = weight at demand node i

d_{ij} = shortest distance between demand location i and candidate j

subject to the following constraints:

$$\sum_{j=1}^{m} y_j = p \qquad (1)$$

$$\sum_{j=1}^{m} x_{ij} = 1,\ \forall\ i \qquad (2)$$

$$y_j \geq x_{ij},\ \forall i,j \qquad (3)$$

$$y_j = 0\ or\ 1,\ \forall_j \qquad (4)$$

$$x_{ij} = 0 \text{ or } 1, \ \forall_{i,j} \qquad (5)$$

Constraint (1) restricts the number of facilities to p; (2) ensures that every demand location i is served; (3) ensures that node i can assign to j only if there is an open facility at j (if x_{ij} = 1, then y_j = 1); (4) is the facility site location decision variable (y_j = 1, if facility is located at site j, 0, otherwise), while (5) is the allocation decision variable (x_{ij} = 1, if demand location i is served by facility at site j, 0, otherwise).

The p-median problem optimizes the efficiency of a network of facilities by placing them where most of the demand points are, tending toward those with a high weight. The model is best suited for private sector problems where the goal is to minimize transportation cost. Although this model is commonly used for public sector problems, researchers have questioned the suitability of the model for locating public facilities (Hansen et al., 1985). This is because minimizing the total distance traveled may favor, sometimes to a considerable extent, demand points clustered in population centers, to the detriment of those that are spatially dispersed. To provide equitable solutions with respect to individual accessibility, the p-median with maximum distance constraint model is solved by imposing a distance constraint to ensure that no individual travels more than a pre-specified maximum distance to their closest facility. When this happens, facilities may move away from the weighted center of demand, toward outlying demand points. This causes an increase in the total distance traveled, with an obvious loss in efficiency, but a gain in equity. The

formulation of the model is the same as the *p*-median problem with an additional constraint to ensure that no demand travels further than a specified distance *S*. The extra constraint ensures that at least one facility is within distance *S* of each demand location *i* and is given as:

$$x_{ij} \cdot d_{ij} \leq S, \ \forall i, \ \forall j \qquad (6)$$

When $d_{ij} > S$, the corresponding x_{ij} cannot have a value of 1, which means that facility *j* cannot serve demand point *i*. For the purposes of this paper, we make use of the model that is available within the network module of ARC/INFO (version 7.1.2) which implements the Teitz and Bart's (1968) site-substitution heuristic algorithm.

The algorithm begins with a starting solution, the user's random assignment of facility locations. A chosen candidate that is currently not a temporary center is substituted for each temporary center in the starting solution. The chosen candidate is then switched with a temporary center if the total weighted distance can be reduced. The temporary center to be removed is the one that, upon replacement by the chosen candidate, yields the greatest decrease in the total weighted distance. Replacement results in a new set of temporary centers. A second non-center is then chosen for substitution, and the process is repeated until all candidates have had a chance to be substituted and no candidate replacement yields a decrease in the total weighted distance. The temporary centers then become the chosen

centers and the heuristic ends.

5.5 Model Implementation

5.5.1 Data

Studies have identified data limitation as a major obstacle to the use of location-allocation models in developing countries (Phillips, 1990; Rondinelli, 1990). In Nigeria, for instance, digital spatial databases are not available while topographic maps are obsolete, and are usually on a scale that is unusable for detailed planning activities. Detailed demand data for facilities are virtually nonexistent. Consequently, data for this research were collected through primary field surveys between 1993 and 1997. The topographic map of the village, came from a detailed survey of the village in 1993 (Nyong, 1994). It was digitized and coverages were created in ARC/INFO for subsequent analysis.

We collected detailed demographic and water demand data through two sample surveys of the village from May to August 1996 and January to March 1997. The two periods coincide with the rainy and dry seasons when water is abundant and scarce respectively. Available resources allowed a sample size of 250 households, representing 42% of the population. Because all the household heads in the village are men and in view of the importance of the contribution of women, we also interviewed 200 spouses of the household heads. The respondents were selected using a stratified random sampling strategy to ensure a proportional representation from all the wards. Based on the experience gained during the pretest, the final questionnaire was organized into five parts (Appendix 3), each

concentrating in one of the following areas: (1) the general characteristics of the household, (2) the economic condition of the household, (3) household migration activities, (4) households use of water (5) retrospective information on fertility and mortality history. In the first survey, all 250 household heads were interviewed and 2 questionnaires were unfit for analysis and were dropped. In the dry season survey, 219 household heads were interviewed as 29 of those interviewed in the first survey had temporarily migrated from the village with their entire households. One questionnaire was dropped from the analysis as it contained inconsistent information.

5.5.2 The network

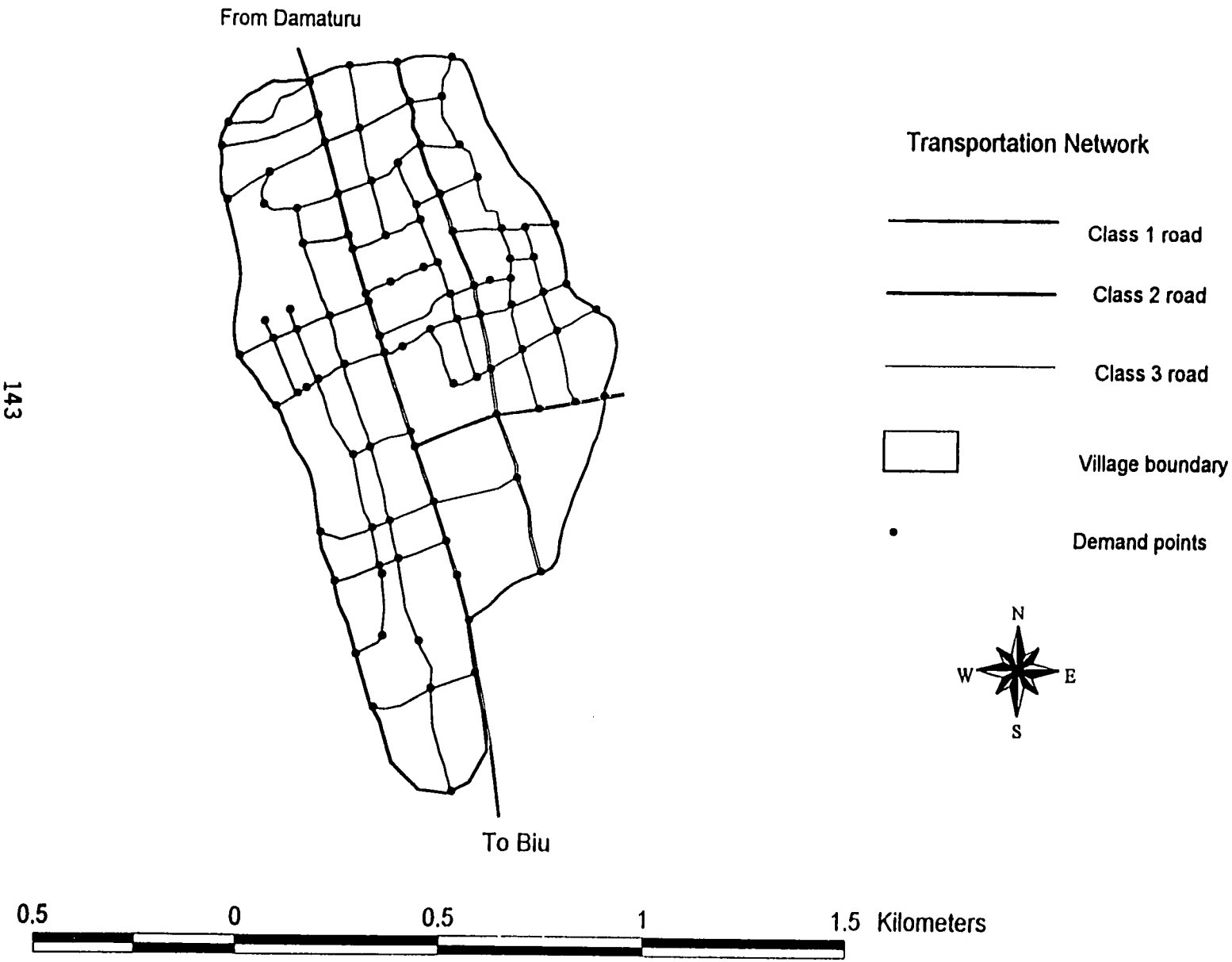
Roads in Katarko can be grouped into three classes (Fig. 5.2). The first class is the tarred road that runs through the village, linking Damaturu, the state capital, to Biu. Class 2 roads are the dirt-surfaced feeder roads, while class 3 roads are the many footpaths in the village. As walking is the main mode of travel to obtain water in the village, walking speed is considered uniform, so that the transformation of distance into time is not useful. Also, the village has a gentle topography (with an average slope of 0.33°), so we have no cause to think that unevenly distributed difficult terrain might impose additional impedances on specific geographic areas. We structured the LA model in discrete space where facility locations and demand centers are limited to nodes on the network, because the villagers travel on this network to obtain water.

A previous study (Nyong and Kanaroglou, 1998) has shown that daily household

water use varies significantly from one ward to another. In view of the potential implications of spatial differentials in water use, we estimated demand separately for each ward using multivariate statistical models (see the discussion on this in the next section). Since simply locating demand at the vertex of a road network nearest to the centroid of each ward would be simplistic and crude, we opted for a more detailed geographical configuration of demand. After estimating the total demand for each ward, we computed the demand for road segments within each ward. We excluded from the analysis, roads that are farther away from the built-up part of the village, and therefore away from the demand weights, and do not provide direct access to public wells. This ensured that a disproportionately large weight was not assigned to a long road segment that passes through a sparsely populated section of a ward having a high average demand weight. The demand on each road segment was then assigned to the respective nodes of the segments, resulting in a set of 97 demand points (see Fig. 5.2).

The set of potential supply points *j* includes the current 12 public wells plus locations selected from among the demand points after eliminating dead-end points or tips of the road network. This is because no optimal location can be found in the set of non-majority dead-end points (Benguin et al, 1992). This choice resulted in 77 candidate supply sites.

Fig. 5.2: Network of roads, demand and supply points



5.5.3 Demand

In this study, we estimate domestic water demand from multiple regression analysis, which we believe is closer to actual demand than that obtained using population. Although we obtained average household water consumption for each ward during the surveys, multiplying that by the population of each ward would conceal the effect of other factors other than population numbers that affect domestic water demand. Using regression analysis, we were able to control for these factors. Before we discuss the results of the regression models, we first present the results of our sample surveys in Katarko. It will provide a framework for the interpretation of the regression results. Domestic water use, in this paper, includes drinking, cooking, clothe-washing, house cleaning, bathing, ablution, watering backyard gardens and serving few domestic livestock. The quantity of water that households use for these activities in the rainy season is significantly different from that in the dry season. It ranges between 37.5 and 737.5 liters per day (lpd) in the rainy season and between 19.2 and 288 lpd in the dry season. Average household water use in the rainy season is almost double that in the dry season (215.4 lpd and 125.4 lpd respectively).

Sixty-one percent of the respondents indicate distance as the most important factor in their choices of water sources. Seventeen percent use particular sources because they are well-kept and maintained, while less than 12% prefer sources used by fewer people. Surprisingly, only about 8% of the respondents consider water quality a major factor. People are three times more likely to use sources of poor quality water that is closer to their homes, than good quality water at a farther distance. The distance households travel to obtain water

varies in both seasons. About 40% of the households collect water within 100 m of their homes in the rainy season, while only 16% does so in the dry season. More than 23% of the respondents travel farther than one km to fetch water in the dry season, compared with only 4% in the rainy season. Water vendors are a prominent source of water, and the number of households who purchase water from them varies according to the season. Only 18.8% purchase water from vendors in the rainy season, compared with 37.6% in the dry season. Besides the seasonal variation, a spatial variation exists in vendor patronage. Households in wards that are farther away from the river and shallow wells patronize the services of water vendors than those in wards that are closer.

We now go on to discuss the estimation of water demand using regression analysis.The methodology we adopted is similar to that used by Benguin et al. (1992). In the analysis, we employed three categories of independent variables - demographic, economic and attitudinal - that are documented in literature to affect water demand (White et al., 1972, Murdock et al., 1991, Mu et al., 1990). Specific variables that define and measure these categories of independent variables (Appendix 2) were obtained from our sample surveys and their means and standard deviations are contained in Table 5.1. All variables were checked and transformed where necessary to ensure that the distribution of residuals approximates normality. The dependent variable is the daily household domestic water use in each ward in the dry season.

The number of households sampled in Shuwari, Kare-Kare and Garin Gada wards were too few for any meaningful multivariate statistical analysis. As a result, Shuwari was

Table 5.1: Descriptive statistics of explanatory variables

Variable Name	Definition	Village n = 219		Ali Kolo n = 23		Dan Gujba n = 24		Bulama Daura n = 41		Gimbam n = 25		Mallam Kolon n = 28		Telemanu n = 26		Shuarab/ Bulama Gallai n = 25		Kare-Kare/ Garin Gada n = 27	
		Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D
LOGHSIZE	Variable indicating the natural log of number of persons in the household	1 47	0 48	1 63	0 34	1 33	0 52	1 46	0 51	1 41	0 44	1 65	0 45	1 45	0 53	1 40	0 46	1 36	0 41
Education																			
EDUC0	Dichotomous variable indicating if the person has been to school or not	0 20	0 40	0 15	0 37	0 29	0 46	0 19	0 40	0 13	0 35	0 07	0 26	0 28	0 46	0 54	0 52	0 11	0 31
EDUC1	Dichotomous variable indicating if the persons highest education is Koranic school	0 64	0 48	0 75	0 44	0 50	0 51	0 44	0 50	0 77	0 43	0 89	0 31	0 59	0 50	0 46	0 52	0 89	0 10
EDUC2	Dichotomous variable indicating if the person has some form primary education	0 04	0 19	0 10	0 31	0 08	0 28	0 04	0 19	0 00	0 00	0 00	0 00	0 06	0 25	0 00	0 00	0 00	0 00
EDUC3	Dichotomous variable indicating if the person has completed primary education	0 10	0 30	0 00	0 00	0 13	0 34	0 25	0 44	0 10	0 31	0 04	0 19	0 06	0 25	0 00	0 00	0 00	0 00
EDUC4	Dichotomous variable indicating if the person has some secondary education	0 01	0 01	0 00	0 00	0 00	0 00	0 04	0 19	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
EDUC5	Dichotomous variable indicating if the person has completed secondary education	0 10	0 10	0 00	0 00	0 00	0 00	0 04	0 19	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
NATIVES	Dichotomous variable indicating if the person was born in the village	0 11	0 31	0 00	0 00	0 13	0 34	0 37	0 49	0 07	0 25	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
HWOMEN	Variable indicating the number of women in the household aged 12 and above	1 65	0 89	1 65	0 75	2 00	1 14	1 63	0 91	1 33	0 55	1 46	0 69	2 06	1 08	1 54	0 88	1 42	0 69
YESWELL	Dichotomous variable indicating the existence of a private well in the compound	0 17	0 37	0 15	0 37	0 17	0 38	0 06	0 24	0 37	0 49	0 18	0 39	0 19	0 40	0 15	0 38	0 11	0 32
Water Quality																			
QUALITY1	Dichotomous variable indicating if the respondent perceives the quality of water he/she uses as poor	0 21	0 41	0 10	0 31	0 21	0 41	0 19	0 40	0 17	0 38	0 25	0 44	0 28	0 46	0 15	0 38	0 26	0 45
QUALITY2	Dichotomous variable indicating if the respondent perceives the quality of water he/she uses as fair	0 50	0 50	0 45	0 51	0 50	0 51	0 56	0 50	0 57	0 50	0 50	0 51	0 44	0 50	0 54	0 52	0 42	0 32
QUALITY3	Dichotomous variable indicating if the respondent perceives the quality of water he/she uses as good	0 29	0 46	0 45	0 51	0 29	0 46	0 27	0 45	0 27	0 45	0 25	0 44	0 28	0 46	0 31	0 48	0 32	0 48
Water Distance																			
DIST1	Dichotomous variable indicating if the respondent's usual water source is less than 100 m from the home	0 01	0 12	0 45	0 51	0 33	0 48	0 33	0 47	0 30	0 47	0 25	0 44	0 22	0 42	0 15	0 38	0 11	0 32
DIST2	Dichotomous variable indicating if the respondent's usual water source is bewteen 100 m and 500 m from home	0 28	0 45	0 25	0 44	0 33	0 48	0 23	0 43	0 37	0 49	0 25	0 44	0 25	0 44	0 38	0 51	0 26	0 45
DIST3	Dichotomous variable indicating if the respondent's usual water source is bewteen 500 m and 1 0 km from home	0 28	0 45	0 15	0 37	0 21	0 41	0 13	0 34	0 13	0 35	0 32	0 48	0 25	0 44	0 31	0 48	0 32	0 48
DIST4	Dichotomous variable indicating if the respondent's usual water source is farther than 1 0 km from home	0 21	0 41	0 15	0 37	0 13	0 34	0 31	0 47	0 20	0 41	0 18	0 39	0 28	0 46	0 15	0 38	0 34	0 48
FETCHF	Dichotomous variable indicating if the primary water collector in the household is female	0 48	0 53	0 15	0 37	0 66	0 48	0 32	0 47	0 17	0 38	0 42	0 50	0 72	0 46	0 31	0 48	0 26	0 45
YESVEND	Dichotomous variable indicating if the respondent usually buys water from a vendor	0 08	0 28	0 20	0 41	0 46	0 51	0 69	0 47	0 37	0 49	0 25	0 44	0 38	0 49	0 23	0 44	0 26	0 45

n = number of households sampled

Table 5.2: Results of Ordinary Least-Squares Regressions of Household Water Use for the Wards in Katarko

Variable	Wards							
	Ali Kolo	Dan Gujba	Bulama Daura	Gimbam	Mallam Kolori	Telemanu	Shuarab/Bulama Gallai	Kare-Kare/ Garin Gada
Intercept	148.25	198.05	139.63	118.48	90.89	159.99	76.90	75.88
LOGHSIZE							5.85*	
Education (reference category = EDUC0)								
EDUC1		13.25			30.47**		9.69*	
EDUC2		66.74*			6.23			
EDUC3		3.37						
EDUC4								
EDUC5								
NATIVES		-55.45*		28.84*				
HWOMEN		14.31**					12.03*	31.32*
YESWELL	36.31*	71.93*	39.46*				55.23*	
Water Quality (reference category = QUALITY1)								
QUALITY2			1.96	44.20*	4.96	7.73	9.36*	32.63*
QUALITY3			24.66*	70.29*	49.21*	44.20**	19.10*	72.26*
Distance (reference category = DIST1)								
DIST2	-7.53	-12.61	-43.33*	-35.23*	-32.60**	-31.29	-12.75*	-35.288
DIST3	-43.75**	-125.53*	-67.49*	-62.71*	-49.77*	-58.79*	-27.22*	-47.81*
DIST4	-78.57*	-103.77*	-126.7*	-79.20*	-83.20*	-84.44*	-30.11*	-60.37*
YESVEND		-50.61*					-5.82*	
FETCHF	65.09*			25.63*			17.66*	
Adjusted R^2	0.82	0.93	0.90	0.92	0.90	0.83	0.98	0.96

* = significant at the 5 per cent level
** = significant at the 10 per cent level

merged with Bulama Gallai, and Kare-Kare and Garin Gada wards were merged for the multivariate analysis of demand. The merged wards had similar characteristics. Eight multiple regression models were used to estimate dry season water demand in the village. We chose the dry season demand because we are interested in planning for the dry season rather than the rainy season.

The levels of explanation provided by the models for each ward range from 81.6% to 99.6% (Table 5.2). Overall, the results of the analysis broadly support the proposition that the determinants of domestic water demand in rural Nigeria are subject more to socio-cultural, than economic interpretations.

Table 5.3: Demand estimates for the wards in Katarko

Ward	Total No. of Households	Total Population	Water Demand (lpd)
Bulama Gallai	23	95	2440
Mallam Kolori	80	343	10380
Bulama Daura	135	617	15943
Dan Gujba	52	269	6349
Kare-Kare	19	96	2231
Shuwari	14	48	1543
Ali Kolo	78	336	10112
Gimbam	92	445	12525
Telemanu	79	438	11276
Garin Gada	28	138	4316
Total	600	2825	77115

Average household demand was estimated for every ward using significant explanatory variables in the models. This was multiplied by the number of households in each ward to obtain the total demand for the ward (Table 5.3).

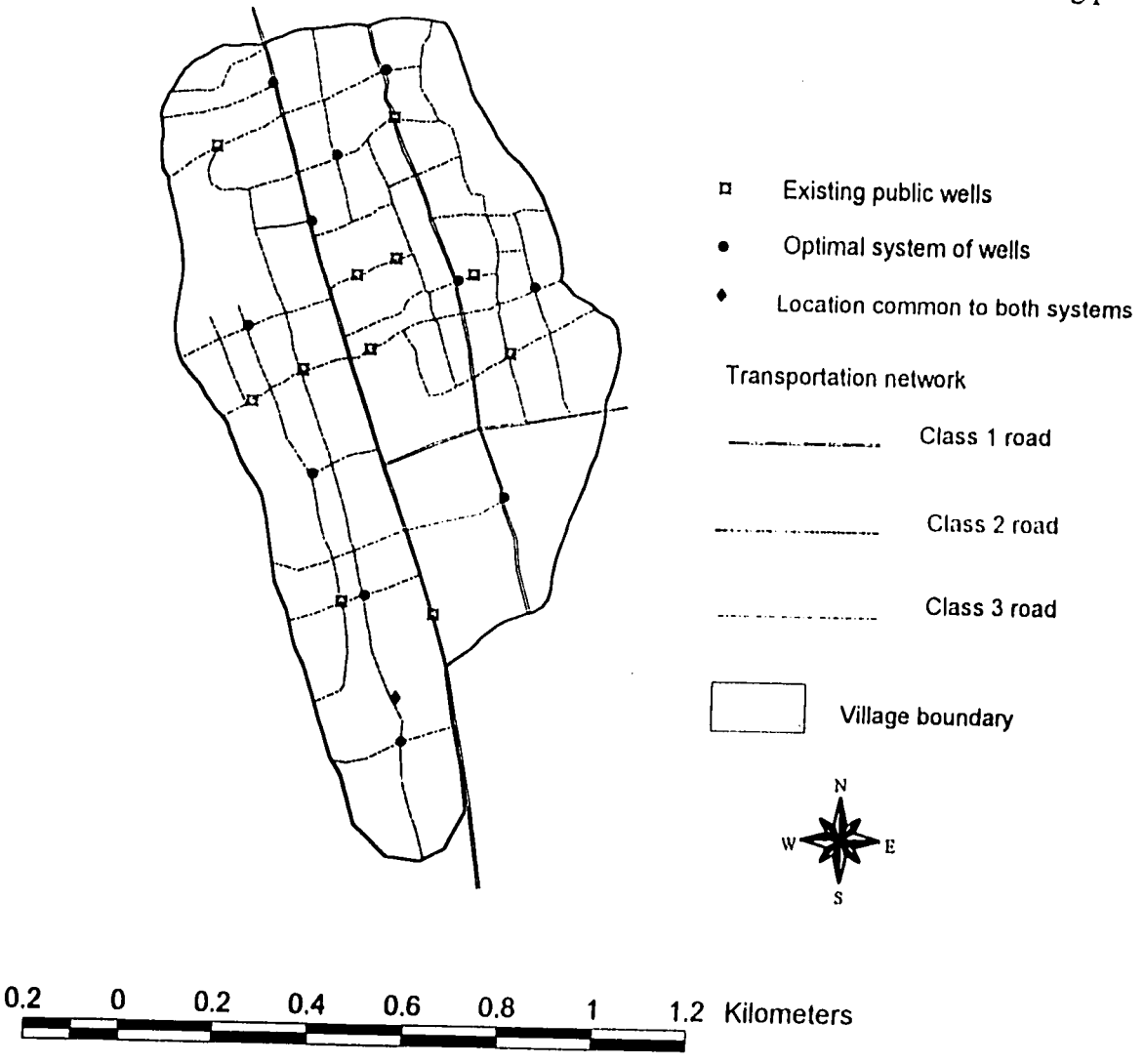
5.6 Results and Discussion

5.6.1 Evaluation of the location of existing wells

The first objective of this paper is to evaluate the optimality of existing public wells in Katarko. To do this, we solved two LA problems for 12 wells and compared their distribution with that of existing wells. First, we solved the ordinary *p*-median problem, where the objective is to maximize efficiency by minimizing average distance, only one existing well was included in the optimal 12. Next, we used the *p*-median constrained model, and at a maximum distance of 400 m when total demand is covered, only one existing well (different from the first) was selected. We can infer from these results that the location of the wells in Katarko cannot be explained by any of these models that maximize either efficiency or equity.

Next, we compared existing public wells with an optimally located set of 12 wells selected using the *p*-median constrained model. The location of existing wells and the optimally located wells are shown in Figure 5.3. In Table 5.4, we compare the efficiency of the system of existing wells using Average Weighted Distance (AWD), and equity using the furthest travel distance (FD). The AWD and the FD in the existing system are 131% and 251% more than in the optimal system. From these results, we can infer that the existing

Fig. 5.3: Optimal set of wells and existing public wells



system of wells is not as efficiently or equitably distributed, compared with an optimal system.

Table 5.4: Location-Allocation Results

	Optimal System		Existing System	
Number of wells	Average Weighted Distance	Furthest Distance	Average Weighted Distance	Furthest Distance
1	468.0	594.9	930	1424.6
2	370.7	481.7	761	1263.7
3	289.9	407.1	664.6	1070.5
4	242.0	349.9	587.3	839.5
5	241.3	305.2	494.4	684.6
6	197.7	270.4	456.7	684.6
7	184.6	236.4	414.2	684.6
8	166.9	203.5	380.2	628.1
9	157.6	184.5	373.7	628.1
10	145.3	175.2	349.5	597.7
11	140.3	169.6	328.4	597.7
12	138.6	166	319.9	582.2

In view of financial and material constraints, the next issue that we considered was the number of wells that will provide the greatest coverage, at the shortest imposed distance constraint. We are aware that the set covering model is best-suited to solve this type of problem, but the commercial GIS package we used does not have this model. Therefore, we did a sensitivity analysis using the *p*-median constrained model and our results are acceptable

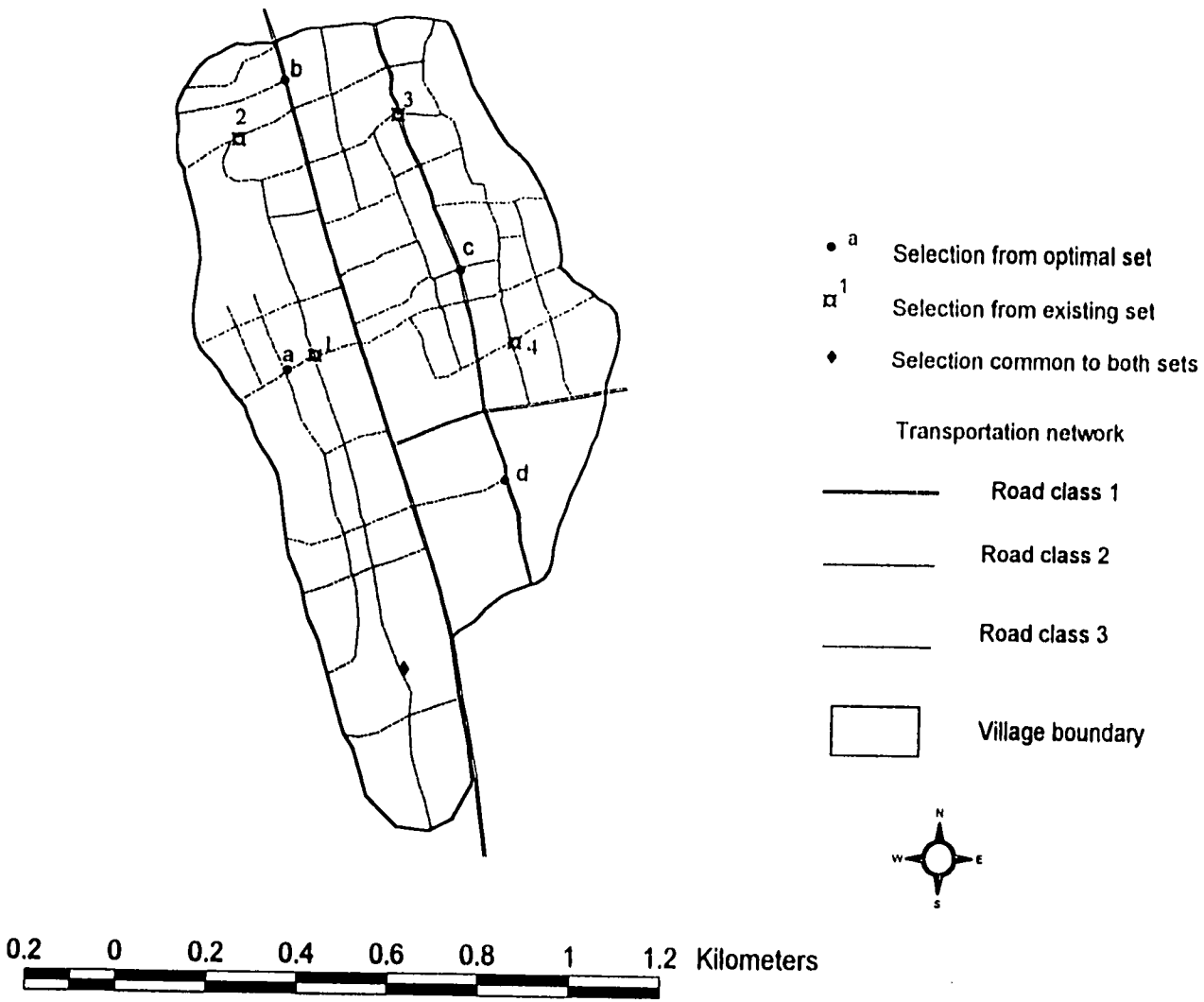
and intuitive.

We have shown that both the AWD and FD decrease as the number of facilities increases, for both optimal and existing wells (Table 5.4). In both systems, the decrease is rapid up to the point when 5 wells are selected, beyond which the decrease is marginal. Changes in AWD and FD between 1 and 5 wells in the existing system show a decrease of 87.1m and 148.0 m per well respectively. Between 6 and 12 wells, there is a marginal decrease of 19.5 m and 14.6 m respectively per well. In the optimal system, marginal decreases in AWD and FD per well, for up to 5 wells, are 56.7 m and 57.9 m. Beyond 5 wells, marginal decreases are 8.4 m and 14.9. m respectively. By the formulation of the model, the FD presented in Table 5.4 corresponds to the distance at which coverage is achieved. We can see that beyond 5 wells, the benefit derived from every additional well in terms of efficiency, equity, and coverage is minimal. The 5 wells selected from the optimal and existing systems are presented in Figure 5.4.

5.6.2 Rehabilitation or new construction

It is generally agreed that an important recipe for the sustainability of rural water projects is to provide what users want and are willing to pay for. Although the village, due to financial constraints, has proposed the rehabilitation of existing wells, we examine the implications of either rehabilitating existing, or providing new wells that are optimally located. Undoubtedly, providing new wells is more expensive than rehabilitating existing ones. Opting for the 5 optimal wells selected by our model implies the construction of 4 new

Fig. 5.4: Comparison of optimal wells and existing wells chosen for rehabilitation



ones, as only one existing well is selected by the algorithm. Because the villagers provide the labor for the construction of the wells and the Jos-McMaster Drought Research Project installs the handpumps, the difference in the cost of either rehabilitating existing wells or digging new ones is minimal. Nonetheless, we believe that the benefits derived from a more efficient set of wells could offset the extra cost of providing them.

Choosing 5 wells from the optimal set, we have shown that coverage can be achieved at 305.2 m, with AWD of 241.3 m (Table 5.4). In the existing system, coverage is achieved at 684.6 m, a 124% increase in coverage distance. AWD in the existing system is larger than that of the optimal system by 105%. A comparison of the demand covered at various imposed distances provides a perspective on the demand that will remain unserved if people choose not to travel more than certain distances to use the facilities (Fig. 5.5). In the existing system, people will travel about twice the distance in the optimal system to have the same level of coverage. In terms of efficiency, equity, and coverage, the obvious choice is to select from the optimal set. If the villagers are made aware of the offsetting benefits associated with the optimal set of wells, we are certain they would opt for them, rather than rehabilitate existing inefficient wells.

Besides these, other factors support our recommendation that the optimal wells should be provided, rather than rehabilitate existing wells. First, there is the possibility that the rehabilitated wells may be underutilized, considering that households may be unwilling to travel on average 500 m to use them. An optimal set of wells will lead to a more efficient use of water with all the benefits associated with access to improved water sources. Second,

research has shown that where people spend much time in search of water, it reduces the time they would spend on other productive and income-generating activities (Briscoe and DeFerranti, 1988). The loss of potential income resulting from this has negative impacts on the sustainability of rural water projects.

If, on the other hand, the villagers are unwilling to dig 4 new wells, we examine the option of reducing this number. In Fig. 5. 4, optimal well **a** is about 100 m from existing well 1. Substituting the optimal well for the existing well increases AWD by 7%, to 241.3 m, and FD to 338.6 m, and increase of 11%. If this option is chosen, we compromise the extra effort required to provide an additional well, for a loss in equity and efficiency.

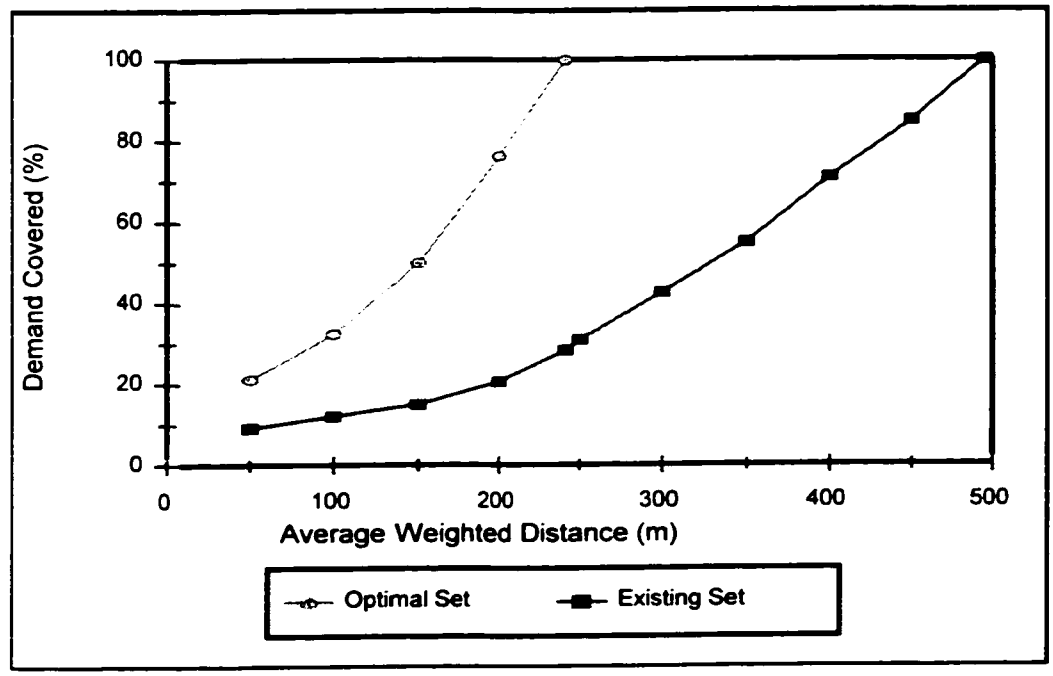


Figure 5.5: Comparison of demand covered by rehabilitating 5 existing wells versus providing 5 optimal wells.

5.6.3 Assessment of coverage criteria

Although the need to make water accessible to everybody is recognized, there is considerable ambiguity in the threshold distance within which a person is considered as served. Nigeria adopts coverage criteria for rural water supply systems developed by official agencies such as United Nations and World Health Organization. According to these agencies, having water within 100 m of a house is often considered the minimum standard by which a person can be considered covered. An important question that one may ask is: How realistic and achievable is this criterion in poor rural communities? Meeting the above definition of coverage requires that local water planners should know the number of water facilities required, and the resultant financial implications. For instance, if this definition is to be adopted in Katarko, establishing water facilities at all potential supply sites cannot provide coverage at 100 m (Table 5.5). Local water planners will need to define the distance within which a person can be considered served, and locate water facilities in a way that reduces this distance as much as possible. Thus, they need to formulate water development goals bearing in mind their limited financial and material resources.

Location-allocation modeling can provide insight on decision alternatives, trading off resource inputs against alternative locational outcomes, and even in defining or refining the locational objectives. For instance, after evaluating the implications of providing coverage using a specific water supply system, local planners may decide to provide a combination of facilities. Research has shown that standposts cost roughly half as much to build as house connections, per head. Besides the cost factor, those who use standposts consume less than

half as much as those with house connections (WHO, 1992). The need to set up cheaper systems that reduce consumption is crucial in this community, considering the prevalent poverty and limited water availability.

Table 5.5: Coverage at 100m from water source

Number of wells	Proportion of demand covered (%)	Number of wells	Proportion of demand covered (%)
77	97.9	10	58
60	97.2	9	50.2
50	96.4	8	46.3
40	94.9	7	41.8
30	91	6	38.8
25	88.3	5	32.4
20	77.2	4	20.4
15	70.5	3	15.3
12	65.6	2	10.5
11	63.7	1	3.5

5.7 Conclusion

Sustainability is a major focus of water resource projects in developing countries, and an important requirement is that water facilities should be located where people will use them, and be willing to pay for them. Inaccessibility contributes to the underutilization of rural water facilities, and may lead to an unwillingness by users to pay for them. When this happens, the water projects may not generate sufficient revenue to maintain the water supply

and management system. It is therefore important that water facilities should be sited where they are accessible to the users and yield the highest social welfare returns.

A major issue that this paper addressed was where to locate water facilities in Katarko that would efficiently and equitably serve the needs of the village. Although the village, due to financial constraints, has proposed the rehabilitation of existing public wells, we evaluated the optimality of these wells and found that they are neither efficiently nor equitably distributed. We compared the benefits of providing new wells that are efficient and equitably distributed, and rehabilitating existing wells. Although rehabilitating existing wells is cheaper, we recommend the provision of new and optimally-located wells considering the offsetting benefits associated with them. Moreover, considering that distance is a major factor in the choice of water sources in Katarko, the rehabilitated wells may remain underutilized if the distance to them is beyond what people are willing to travel.

We are aware that overcoming geographical inaccessibility may not guarantee access to everybody, as institutional barriers are also known to deny some people access to water facilities in Katarko. However, we see it as a solution to one part of the problem. Investigating the factors that are responsible for institutional inaccessibility is important to provide solutions that will break down such barriers to the optimal use of water facilities.

Finally, it should be borne in mind that this is a case study and the results depend on the characteristics of Katarko, and may not be applicable to other rural areas. However, the paper has shown that location-allocation models can be used as a decision support system for water resource planning in rural Nigeria.

Acknowledgments

This research was supported by a grant from the Canadian International Development Agency (CIDA). We are grateful for the research support we received from the University of Jos, Nigeria. We would also like to thank Bill Anderson for his helpful comments.

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Appendix 2: Explanatory variables for estimating domestic water demand in Katarko

Variable	Definition
LOGHSIZE	Variable indicating the natural log of number of persons in the household
Education	
EDUC0	Dichotomous variable indicating if the person has been to school or not
EDUC1	Dichotomous variable indicating if the persons highest education is Koranic school
EDUC2	Dichotomous variable indicating if the person has some form primary education
EDUC3	Dichotomous variable indicating if the person has completed primary education
EDUC4	Dichotomous variable indicating if the person has some secondary education
EDUC5	Dichotomous variable indicating if the person has completed secondary education
NATIVES	Dichotomous variable indicating if the person was born in the village
HWOMEN	Variable indicating the number of women in the household aged 12 and above
YESWELL	Dichotomous variable indicating the existence of a private well in the compound
Water Quality	
QUALITY1	Dichotomous variable indicating if the respondent perceives the quality of water he/she uses as poor
QUALITY2	Dichotomous variable indicating if the respondent perceives the quality of water he/she uses as fair
QUALITY3	Dichotomous variable indicating if the respondent perceives the quality of water he/she uses as good
Water Distance	
DIST1	Dichotomous variable indicating if the respondent's usual water source is less than 100 m from the home
DIST2	Dichotomous variable indicating if the respondent's usual water source is between 100 m and 500 m from home
DIST3	Dichotomous variable indicating if the respondent's usual water source is between 500 m and 1.0 km from home
DIST4	Dichotomous variable indicating if the respondent's usual water source is farther than 1.0 km from home
FETCHF	Dichotomous variable indicating if the primary water collector in the household is female
YESVEND	Dichotomous variable indicating if the respondent usually buys water from a vendor

Chapter Six

Summary and Conclusion

6.1 Major Findings

Water scarcity is a major problem in the semi-arid region of northern Nigeria, and its impact is felt more in rural areas that depend solely on naturally occurring sources of water for their domestic needs. Although domestic water use accounts for only 9% of consumptive water demands in sub-Saharan Africa, the benefits associated with its improved and adequate supply, such as the effects on health, time savings and greater productivity, cannot be overstated. These factors directly affect the quality of life in any community. The failure of past-supply oriented approaches to provide better access to good quality water through engineering and technical considerations has drawn attention to the need for alternative approaches. For any water development project to succeed in this region, a need exists to create an awareness of water resources challenges, issues, and opportunities, between policy makers and users. In creating this awareness, one has to understand behavioral and cultural norms and use them appropriately to engender the right responses in the target groups. Besides, this knowledge is needed to change perceptions and create a sense of communal responsibility for a scarce resource at both societal and policy making levels. This research has added to this knowledge, conceptually and factually, by investigating the factors that affect domestic water use in rural semi-arid Nigeria, using a case study from Katarko. The following conclusions can be drawn from the thesis:

1. Katarko has a high potential for population growth, with a total fertility rate 7.6, where women with only Koranic education had the highest rate of 10.9. Infant and child mortality rates are high in the village. Contrary to generally-accepted views, mortality is higher among males than females, except during the reproduction years, suggesting a high mortality risk of pregnancy and child birth. If population intervention efforts succeed in this village and fertility and mortality rates decline, Katarko will experience an enormous growth (107%) in absolute numbers in 30 years due to the young age structure and the resultant built-in demographic momemtum. On the other hand, if present demographic patterns continue into the future, the population will grow by only 54% within the same period. The lower figure is because the high population growth will be moderated by high infant mortality rates, which will fuel each other in an endless spiral, having a negative impact on the quality of life in the village.

2. Poverty is pervasive in the village, with women affected the most. They do not own large farms but work usually on household farms controlled by men. Although educational attainment is low, the gender disparity in access to education is high. While more than 50% of male and 70% of female children aged 5-9 are not enrolled in school, females are twice as likely to have never attended school as males. The lack of economic independence among the women serves as an obstacle to fertility decline, and sustainable water resource development in the village.

3. Both geographical and institutional barriers hinder the effective use of water

resources in this area. People were three times more likely to use water sources of poor quality that were closer to their homes than good quality water at a farther distance. In the dry season when water is scarce, households adapt their water use by progressively eliminating water use activities that pertain to cleanliness and hygiene. The poor water quality and poor sanitation may be responsible for the high incidences of diarrhoea in the village.

4. While sufficient attention has been given to institutional barriers that hinder effective water use, the problem of geographical accessibility has been ignored. The locations of existing wells in Katarko are not optimal, and are neither efficiently nor equitably distributed. Consequently, some of them are not used effectively because they are far away from the intended users. The utility of location-allocation models as a spatial decision-support tool in establishing rural water projects has been demonstrated. Although, due to financial constraints the village has proposed the rehabilitation of existing wells, the provision of fresh wells that are optimally located is recommended. This is in view of the offsetting benefits associated with them.

5. Contrary to popular belief, women are not the principal water collectors in the village, as the local custom and culture affect the gender of the person that plays this role. Among the Hausas, where the purdah system is enforced, women are kept in isolation and do not interact with other men and are therefore denied access to public water from sources used by other men.

6. The study showed that the determinants of water demand in the dry season are

different from those in the rainy season. The results suggest a possibility of wasteful water use in the rainy season when water is abundant. Overall, the results support other studies that show that domestic water demand in rural Africa is subject more to socio-cultural, than economic interpretations. However, activities of water vendors prove that water management in the village can be approached using economic means.

7. Modeling seasonal domestic water use can provide a glimpse of how local populations will adapt their demands to improved water availability. Domestic water consumption in the rainy season is almost twice that of the dry season. If an improvement is made such that water availability is at the level of the rainy season, we might expect household water use to double.

8. Conventional water demand projections used in Nigeria are based on per capita population. They do not incorporate factors known to affect domestic water demand. This study has shown that excluding these factors consistently underestimates demand. Also, the inclusion of these factors can enable the evaluation of the impact of developmental policies on water demand before they are implemented.

6.2 Future Research

The findings enumerated above contribute significantly to the understanding of domestic water demand in rural areas. The study has shown that population numbers and attributes affect domestic water use. It has also shown how households adjust their demands to varying levels of domestic water availability. While it is known that the relationship

between population and resources is not unidirectional, the exact interaction between them is not known. While this study emphasized domestic water demand, it is important to investigate how population dynamics affect intersectoral and intrasectoral competition for water. This will enable one to understand how the conceivable alternative outcomes of that competition will in turn affect population dynamics. This is necessary in setting up developmental policies that may aim at sustainable population development, where a balance is maintained between population growth and local water resource base of the area.

Appendix 3

DOMESTIC WATER DEMAND IN RURAL SEMI-ARID NIGERIA:

A CASE STUDY OF KATARKO VILLAGE, YOBE STATE.

QUESTIONNAIRE

INTERVIEWER

_____

FIELD ASSISTANT

_____

HOUSEHOLD ID./WARD

_____

DATE

_____

A: General Characteristics of Present Household members

MEMBERS OF HOUSEHOLD	RELATIONSHIP	GENDER	AGE	MARITAL STATUS	RELIGION	ETHNIC GROUP	OCCUPATION	EDUCATION
Q1. Can you list the names of all persons of your household who usually live here beginning with the head of the household?	**Q2.** Relationship to the head of the household Spouse [1] Son [2] Daughter [3] Mother [4] Father [5] Brother [6] Sister [7] Other [8]	**Q3.** Is this person male or female? Male [1] Female [2]	**Q4** How old is she/he (age in completed years)?	**Q5.** What is his or her current marital status? Single [0] Married [1] Widowed [2] Separate [3]	**Q6.** What is her or his religion? Christianity [1] Islam [2] Other [3] (Specify) _____ _____	**Q7.** What is his or her ethnic group? Hausa [1] Kanuri [2] Shuarab [3] Fulani [4] Other [5]	**Q8** Occupation Farmer [1] Trader [2] Artesan [3] Civil servant [4] unemployed [5] Other [6] (Specify)	**Q.9** What is the highest level of schooling completed? None [0] Koranic [1] Incomplete Primary [2] Complete Primary [3] Incomplete Secondary [4] Complete Secondary [5] Post Secondary [6] Other (specify) [7]
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

B. Socio-Economic Activities.

1. Did you do any of these activities in the past 12 months? Yes/No	No [0] Yes [1]	Hours per day	Months per Year	Did you earn any income from this activity No [0] Yes [1]	Cash income per month
Working in paid employment					
Farm work for Family					
Work in garden					
Work with animals					
Food Processing					
Handicrafts					
Cooking, washing clothes, cleaning house, etc					
Petty Trading					
Any other business bringing in cash					
Gathering firewood					
Fetching water					
Caring for Children					

2. How much did you earn last year?
   [1] less than N 10,000.00
   [2] N10,000 - N29,999
   [3] N30,000 - N59,999
   [4] N60000 - N89,999
   [5] Above N90,000
   [9] Don't know

3. How much did you spend to buy food in the last one month?

   _____

4 When you sell a crop who does the money go to?
   [1] All to household head
   [2] Shared between all adult household members
   [3] Shared between all male adult household members
   [4] Spent on an agreed item for general benefit (e.g school fees, house repairs, etc)

5. How would you rate your general economic condition?
[1] not adequate [2] just adequate [3] more than adequate

C. Migration

C1 In-Migration

1. Were you born in this village
[1] yes
[0] no; ***{if 'yes' Skip to Section C2}***

2. When did you come to this village?
[1] 0 - 9 years ago
[2] 10 - 19 years ago
[3] 20 - 29 years ago
[4] 30 - 39 years ago
[5] 40 years ago and above

3. From where did you come to this village?
[1] a village [2] a town [3] other

4. With who did you come to this village?
[1] parent(s)
[2] son or daughter
[3] other relation
[4] alone.

6. Why did you come to this particular village?
[1] education
[2] to look for work
[3] to get married
[4] availability of water here
[5] other

7. Have you ever considered going back to where you came from?
[1] yes
[0] no

8. Why?

_____

_____

_____

C2. Outmigrants

Q1. List the members of your household that are not living with you at this moment.	**Q2.** Relationship to the head of the household Spouse [1] Son [2] Daughter[3] Mother [4] Father [5] Brother [6] Sister [7] Other [8]	**Q3.** Where does this person live? [1] town [2] village [3] other	**Q4.** How far is this from here [1] < 5 km [2] 5-10 km [3] 11-50 km [4] 51-99 km [5] 100-99km [6] > 200 km	**Q5.** Why did this person go there [1] education [2] to look for work [3] to get married [4] poor amenities here [5] flee from drought here [6] other _____ _____ _____ _____	**Q6.** How often does this person come home? [1] weekly [2] 2 times every month [3] monthly [4] 3 months [5] 6 months [6] yearly [7] does not come home [8] Other(specify)	**Q7.** When this person comes home how long does he/she stay before going back? [1] < 3 days [2] 1 week [3] 2 weeks [4] 1 month [5] 3 months [6]>3 months	**Q8.** What is the religion of this person [1] Christ. [2] Musl. [3] Other	**Q9.** Was this person married at the time he/she left? [1] Yes [0] No	**Q10.** How old was this person when he left home	**Q11.** In what year did this person leave home?	**Q12.** What was the highest level of education attained by this person before he left? [0] None [1] Koranic [2] Incomplete primary [3] Complete primary [4] Incomplete Secondary [5] Complete Secondary [6] Post-Secondary [7] Other (specify.....)

C3: Transfers to out-migrants:

1. How much money did these persons take when they left this household?
   [1] less than N1000
   [2] N1000 - N2999
   [3] N3000 - N4999
   [4] above N5000
   [5] None. ***{If 'none' skip to question 3}***

2. What was the main source of that money?

Personal savings	[1]
Household savings	[2]
Gift from relatives/friends	[3]
Loan from moneylender	[4]
Sold or pledged land, house or household assets	[5]
Other (specify)	[6]

3. (a) Have you or any member of this household ever sent money or goods to these persons?
   Yes [1]
   No [0] ***{If 'No' skip to Section C4}***

   (b) Who sent money or goods?
   [1] Spouse
   [2] Son
   [3] Daughter
   [4] Mother
   [5] Father
   [6] Brother
   [7] Sister
   [8] Other (Specify)_____

(4) Name of Migrant	(a) In the past 12months how much money has been sent to these persons	(b) Apart from money, what goods if any have been sent to these persons in the past 12 months	(c)Considering the money sent in the past 12 months, what was your main purpose in sending the money? [01] help pay for his/her consumption [02] school fees [03] pay travel cost [04] productive investment there [05] purchase of goods to be sent back [06] other (specify)_____

C4: Transfers from Out-Migrants:

1. Do these persons send back any money or goods to you or other members of the household?
   [1] Yes [0] No ***{If 'No' Skip to C5}***

2. To whom has money been mainly sent?
   [1] Spouse [6] Brother
   [2] Son [7] Sister
   [3] Daughter [8] All household
   [4] Mother [9] Other (specify)_____
   [5] Father

3.

Name of Migrant	(a) How long after leaving did this person first send money?	(b) How much money has this person sent within the last 12 months	(c) How regularly Does this person send money [1] Monthly [2] At least two times a year [3] Yearly [4] Mainly when requested [5] Other	(d) Considering money received in the past 12 months, for what did this person intend it to be used for? (Give up to three uses in order of importance) [1] Buy land [2] Sink well [3] Rent land [4] Buy farm implements [5] Buy pesticides, fertilizers, seeds, etc [4] Pay for schooling of household members [5] Pay off debts [6] Pay for move/migration of other household member [7] improve land [8] Other (specify)	(e) For what was that money actually used? (Give up to three uses in order of importance) (Code as in 3d)	(f) Apart from money, has this person sent or brought any goods for you or for any other member of the household? [1] yes [2] No If no Skip to C5	(g) What have been the main items received in the past twelve months?	(h) What was the approximate monetary value of all the items received in those 12 months?

C5: Potential Migrants

1. Are you intending to move to live or work outside this village?

[1] Yes [2] No. {If 'yes' Skip to Question 3, if 'No' answer Q.2 and Skip to **E**}.

2. What are your reasons?

[1] Have family ties
[2] Lack of education
[3] Old age
[4] Cannot leave the family land
[5] Generally satisfied with life here
[6] Other (specify)

3. When do you think you will leave

[1] Within three months
[2] Three to six months
[3] Six months to one year
[4] One to two years
[5] Two years or more
[9] Don't know, not sure

4.(a) Would you take your family with you when you migrate?

[1] Yes [0] No {If 'No' skip to 4(c)

(b) Whom would you take with you?

[1] Spouse
[2] Children
[3] Parents
[4] Brothers/sisters
[5] Other (Specify)_____

(c) What are the main reasons?

[1] Will bring them later after finding work
[2] It is expensive
[3] Might lose land/property here
[4] Family already settled here
[5] Other (Specify)_____

5. For how long are you likely to stay away

[1] Less than three months
[2] Three to six months
[3] Six months to one year
[4] One to two years
[5] Two years or more
[9] Don't know, not sure

6. Why do you intend to leave this village? (Circle up to three)

[1] No work here
[2] To get education for self
[3] To get married
[4] Poor farm yields

[5] Lack of amenities here [6] Lack of water
[7] Escape from farming [8] Other (specify)

7. Which of these reasons is the most important?

_____

8. Have you decided where you would want to migrate to?
[1] Yes [2] No {If 'No' Skip to Section E}

9. What is this place?
State_____
Local Government Area_____
Village or Town_____

10. Have you lived in that place before?
[1] Yes [2] No

11. Have you any friends or relatives there?
[1] Yes [2] No

12. What are your main reasons for choosing that place? (Circle up to three)
[1] Better job opportunities
[2] More educational and health facilities there
[3] Physical environment better there (fertile soil, good climate, etc)
[4] More amenities there (pipe-borne water, electricity, etc).
[5] Other (Specify) _____

13. Do you own farm land?
[1] Yes [2] No

14. What is the size of your farmland?_ (Hectares)

15. What was the average income you made from farming during the last farming season?

[1] Less than N10,000 [2] N10,000 - N39,999 [3] N40,000 - N59,000 [4] N60,000 - N89,000 [5] Over N90,000.

16. Compared to the season before the last, has this amount increased or decreased?
[1] Increased [2] Decreased [3] No difference

17. What do you think is responsible for this?

_____

_____

E. Water Use.

1. What is/are the major source(s) of your domestic water supply?
   - Well [1]
   - River [2]
   - Tanker, truck or other vendor [3]
   - Rainwater [4]
   - Other (Specify)_____ [5]

2. Why are the other sources listed in Q1 not being used?
   - Far from home [1]
   - Have to pay to use them [2]
   - Social or institutional restraint [3]
   - Not available all the time [4]
   - Other (specify)_____ [5]

3. Why do you use that (those) particular source(s)?
   - Well-kept and maintained [1]
   - Reliable [2]
   - Close to home [3]
   - Allows me to socialize [4]
   - Used by fewer people [5]
   - Good quality [6]
   - Other (specify)_____ [7]

4. Do you have a well in your compound?
   Yes [1] No [2]

5. How do you perceive the quality of the water from the source(s) you use?
   [1] Good [2] Fair [3] Bad

6. Who fetches water for the household

Name	Gender [1] male [2] female	Age	Size of Container

7. How far do they travel to fetch water?

Less than 100m	[1]
100m to less than 500m	[2]
500m to less than 1.0 km	[3]
1.0 km to less than 2 km	[4]
Greater than 2.0 km.	[5]

8. How long (time wise) does it take to make one trip?

Less than 10 mins	[1]
Between 10 mins and 30 mins	[2]
Between 30 mins and one hour	[3]
Greater than one hour.	[4]

9. How many trips do they make in a day to fetch water?

One trip	[1]
Two trips	[2]
Between three and five trips	[3]
More than five trips	[4]

10. What domestic activities do you use water for? (List the activities and the quantities used)

Activity	**Frequency** [1] 3 times daily [2] once daily [3] about 3 times a week [4] about once a week [5] every two weeks [6] about once a month [7]less than once a month	**Source of water** [1] well [2] river [3] vendor [4] rainwater [5] other	**Quantity per use** (in litres)
cooking			
drinking			
washing dishes			
bathing			
washing clothes			
general cleaning of house			
backyard gardening			
small livestock			
Ablution			

11. Do you consider this quantity of water sufficient for you?
[1] Sufficient [2] Not sufficient

12 How much water do you consider sufficient for your household needs?

_____

13. If there is no water, list 5 of the activities listed in Q.10 which you would give up (List in the order that you would give them up)

[a] _____
[b] _____
[c] _____
[d] _____
[e] _____

14. Does your household buy water from water vendors?
[1] Yes
[2] No [If 'No' Skip to Q.16]

15. How often do you buy this water in a week?_____

16. How much do you spend on the average to buy water in a week?_____

17. Do you store water in the house?
[1] Yes
[0] No [skip to Q.19]

18 What do you use to store this water? (**Request to see the container and estimate its size**) _____

19. How long does this stored water last?
[1] Less than one week
[2] between one week and two weeks
[3] between two weeks and one month
[4] more than one month

20. When there is no water in the house, who is usually held responsible?
_____

21. Why?
_____
_____
_____

21. Has there been any family feud as a result of water in this household?
[1] Yes [2] No. {If 'No' go to Q.23}

22. What was the nature of the feud?
_____
_____
_____
_____
_____
_____
_____
_____

23. Has any member of your household suffered from diarrhoea within the past one month? [1] Yes [2] No

24. If 'yes', how many times has this occurred within the same period? _____

F: Contextual Information.

1. How would you describe the water situation in this village?
   [1] Very scarce [2] Scarce [3] Sufficient [4] Abundant

2. Why do you think so?

_____
_____
_____
_____
_____
_____
_____
_____
_____

3. How would you describe the amount of rainfall in this community: In most years is it
   [1] excessive [2] adequate [3] not adequate

4. And how was it in the past 12 months?
   [1] excessive [2] adequate [3] not adequate

5. Do you have farm under irrigation?
   [1] Yes [2] No {If 'No' Skip to 7}

6. What proportion of your farms is under irrigation?
   [1] Less than a half [2] More than half [3] All

7. Have you experienced any major drought in this community in the past 10 years?
   [1] Yes [2] No {If 'No' Stop}

8. In what year(s)?

_____
_____
_____
_____

9. When the droughts occured could you describe to me what you did to cope with the situation?

10. Do you belong to any cooperative or community organization in this village?
[1] Yes [2] No {If 'No' Stop}

11. Name the organization(s)

12. During those droughts, did you receive any assistance from such organizations?
[1] Yes [2] No.

13. What was the nature of the assistance that you received?