WATER POVERTY INDEX OF SOME SELECTED LOCAL GOVERNMENT AREAS OF EKITI STATE, NIGERIA

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DECLARATION

I solemnly declare that this thesis is an original work of MR. RODIYA. A. A. and that it has not been submitted elsewhere for the award of any degree.

CERTIFICATION

This Thesis Titled "Water Poverty Index of some Selected Local Government Areas of Ekiti State" was written by Rodiya, Afolabi Adeniyi of the Department of Agricultural Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Akure, Ondo State. It was submitted to the Postgraduate School of the University in partial fulfillment of the requirements for the award of Master of Engineering in Agricultural Engineering.

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DEDICATION

This work is dedicated to the Almighty God. The Author and Finisher of my faith and to my beloved sweetheart Mrs. Oreofe Afolabi-Rodiya.

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ABSTRACT

The water poverty index of some selected local government areas in Ekiti State was investigated to identify and evaluate a tool for assessing poverty in relation to water resource availability.

Two approaches: the Composite Index Approach and the Time Analysis Approach were used in calculating water poverty index in Ekiti State using a wide range of data generated from household surveys in ten local government areas out of the existing sixteen local government areas of Ekiti State. The hydrological and hydraulic parameters in the Local Government Areas in Ekiti State were considered as well.

The result obtained shows that using the composite index approach with parameters such as water availability, accessibility to safe water, time taken to access water among others, the Water Poverty Index (WPI) of 20.8, 18.7, and 18.7 were obtained in Moba, Irepodun/Ifelodun and Ado Local Government areas respectively. This is higher than that of Ekiti East, Ise-Orun and Ikere Local Government areas with 10.2, 15.5 and 16.5 water poverty index in that order. This indicates that people in Moba, Irepodun/Ifelodun and Ado Local Government areas experience little stress in accessing safe water when compared with people in Ekiti East, Ise-Orun and Ikere.

In Time Analysis Approach, water poverty index (WPI) of 0.17, 0.32 and 0.33 were obtained in Ido-Osi, Oye and Irepodun/Ifelodun Local Government areas respectively while higher water poverty index of 0.60, 0.57, 0.50 and 0.48 were obtained in Ekiti East, Ekiti South West, Ise-Orun and Ikere Local Government areas respectively. This indicates that Ekiti East, Ekiti South West, Ise-Orun and Ikere Local Government areas are more water stressed in terms of accessibility to safe water.

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CHAPTER ONE

0 INTRODUCTION

Poverty is one of the major problems facing the less developed countries today. overty is generally associated with conditions under which people live. It is usually defined her in absolute or relative terms. There have been divergent views on the definition of verty by different scholars. According to Aliyu (2001) absolute poverty refers to a ndition in which a person or group of people are unable to satisfy their most basic needs in rms of good food, clothing, shelter, footwear, energy, transport, health, education and creation. This shows that poverty affect every aspect of human life, hence the lack of nsensus as its definition.

Today, the evidence of poverty is seen in Nigeria in general and Ekiti State in rticular. The situation is apparent when people are unable to have three meals, unable to ford a decent home, unable to have potable water at home for safe drinking, unable to ford children fees and even, unable to afford medical expenses of the family. According to mison and Lau (1982), it is a situation when the resources of families or individual are adequate to provide a socially acceptable standard of living.

Further, Sen (1983), related poverty to entitlements which are taken to be the various undles of goods and services over which one has command, taking into cognizance, the eans by which such goods are acquired (for example, money and coupons) and the vailability of the needed goods. Yet, other experts see poverty in very broad term, such as eing unable to meet basic needs. These are categorized as physical e.g. food, health care, lucation, shelter etc and non physical e.g. participation and identify.

In Ekiti State, the study shows that poverty manifests in all facets of life; be it social, conomic, political and cultural. It is no gainsaying to note that in Ekiti State, residents, specially at the rural areas are not able to cater adequately for the basic needs of life and the people have limited access to social and economic infrastructures such as portable water and sanitation and consequently, limited chance of advancing welfare capabilities.

Moreover, the situation is manifested in Ekiti State when there are inadequate access to the means of supporting rural development, inadequate access to market for goods and services for the poor, low human capital, destruction of natural resources endowments; and those whose poverty is caused by droughts, storms, floods and pest.

Falegan (2001) sees the situation in Ekiti State as an al embracing definition, when he sympathetically observed that "in the year 2001, you still see women (the most hard-hit and yet most enterprising) carrying pots of water on their heads and walking 5 – 8 km of roads to reach their homes. He sees it as poverty of a vivid dimension. Furthermore, Falegan (2001) sees poverty in Ekiti State beyond mere inadequate resources or lack of knowledge of personal human rights. According to him, poverty includes lack of exposure to the outside world and the new frontiers of human endeavours and application, which make us un-innovative and lack necessary resources to simple basic technology and initiative.

Falegan (2001) reported the steps to take in order to increase water supply. He identifies serous devotion to its provision, maximum community participation in identifying, planning and maintaining low cost water supply system, as well as efficient maintenance, training and technical assistance. The present situation whereby government is using water tankers to distribute water should be discouraged. Instead, sinking of boreholes into various wards across the state should be encouraged.

1.1 OBJECTIVES OF THE STUDY

The objectives of this study are to:

i) Ascertain the extent of water scarcity in some Local Governments in Ekiti State.

ii) Determine the variations in water availability, accessibility to safe water and time spent to access safe water in some selected Local Government Areas of Ekiti State;

iii) Determine the water poverty index for local government areas under study.

1.2 JUSTIFICATION

Ekiti state is naturally endowed. A greater percentage of Ekiti rural dwellers depend on streams and brooks while the urban dwellers predominantly depend on shallow wells for their water supply. However, most of these water sources are untreated and are not easily accessible.

In most cases, lots of household are left without water for weeks most especially during dry seasons when most water supply system have gone below their production capacity. Most streams and brooks serve as the only hope of most inhabitants in Ekiti State and this encourages the spread of diseases such as guinea worm, elephantiasis and cholera.

There is therefore the need to take a critical look at the water scarcity situation of Ekiti State so as to recommend a viable option for water supply to the affected areas.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 IMPORTANCE OF WATER

Water is regarded as the most important natural resource to man judging from its importance and usefulness in all facets of human endeavour. The various uses of water are categorized as follows:

(a) *Commercial Water Use*

Commercial water use includes fresh water for motels, hotels, restaurants, office buildings, other commercial facilities, and civilian and military institutions. Domestic water use is probably the most important daily use of water for most people.

(b) *Domestic Water Use*

Domestic water use includes water that is used in the home every day, including water for normal household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. This accounts for the beneficial use of less than 0.5% of the water accumulated from rainfall (EES, 1990). Although, it represents a small percentage of total rainfall, the successful interception and storage of fresh water for domestic use is highly variable. In some areas, due to limited, seasonal rainfall and limited catchments and storage capacity, aquifers and surface impoundments are depleted. Well failures during the dry season are not uncommon, as shown by the drop of the water level in wells and increased salt water intrusion (Seaman et al., 2000).

(c) *Industrial Water Use*

Industrial water use is a valuable resource to the nation's industries for such purposes as processing, cleaning, transportation, dilution, and cooling in manufacturing facilities. Major water-using industries include Steel, Chemical, Paper, and Petroleum Refining. Industries often reuse the same water over and over for more than one purpose.

(d) ***Irrigation Water Use***

Irrigation water use is water artificially applied to farm, orchard, pasture, and horticultural crops, as well as water used to irrigate pastures, chemical application, crop cooling, harvesting, and for the leaching of salts from the crop root zone. Nonagricultural activities include self-supplied water to irrigate public and private golf courses, parks (Ravnborg, 1999).

(e) ***Livestock Water Use***

Livestock water use includes water for stock animals, feed lots, dairies, fish farms, and other non-farm needs. Water is needed for the production of red meat, poultry, eggs, milk, and wool, and for horses, rabbits, and pets. Livestock water use only includes fresh water.

(f) ***Mining Water Use***

Mining water use includes water for the extraction of naturally occurring minerals; solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. The category includes quarrying, milling (such as crushing, screening, washing, and flotation), and other operations as part of mining activity. A significant portion of the water used for mining, about 32%, is saline.

(g) ***Public Supply Water Use***

Public supply water use refers to water withdrawn by public and private water suppliers, such as municipal water works, and delivered to users for domestic, commercial, and industrial purposes.

(h) ***Thermoelectric Power Water Use***

Thermoelectric power water use is the amount of water used in the production of electric power generated with heat. The source of the heat may be from fossil fuels, nuclear fission, or geothermal. Fossil fuel power plants typically reuse water. They generate electricity by turning a turbine using steam power. After the steam is used to turn the turbines, it is condensed back to water by cooling it. The condensed water is then routed back to the boiler, where the cycle begins again.

2.2 WATER SCARCITY

Water scarcity is commonly defined as a situation where water availability in a country or in a region is below $1000m^3$ per person per year. However, many regions in the World experience much more severe scarcity, living with less than $500m^3$ per person per year, which could be considered severe water scarcity. The threshold of $2000m^3$ per person per year is considered to indicate that a region is water stressed since under these conditions populations face very large problems when a drought occurs or when man-made shortages are created. However, the concept of water availability based on indicators driven from the renewable water resources divided by the total population should be taken with great care (Sullivan et al., 2003). This simple indicator may not be very meaningful in situations where countries make high use of desalination of non-renewable groundwater resources and of wastewater re-use to compensate for their scarcity of renewable water. This may also be true for countries where irrigation water requirements are not large. Water scarcity causes enormous problems for the populations and societies (UNDP, 1997). The available water is not sufficient for the production of food and for alleviating hunger and poverty in these regions, where quite often the population growth is larger than the capability for sustainable use of the natural resources. The lack of water does not allow industrial, urban and tourism development to proceed without restrictions on water uses and allocation policies for other user sectors, particularly agriculture. Natural fresh water bodies have limited capacity to respond to increased demands and to receive the pollutant charges of the effluents from expanding urban, industrial and agricultural uses. In regions of water scarcity the water resources are probably already degraded, or subjected to processes of degradation in both quantity and quality, which adds to the shortage of water. Health problems are commonly associated with scarcity, not only because the deterioration of the groundwater and surface waters favours water borne diseases, but because poverty makes it difficult to develop proper water distribution and sewerage systems. Water conflicts still arise in water stressed areas among local communities and between countries since sharing a very limited and essential resource is extremely difficult despite legal agreements. Poverty associated with water scarcity generates migratory fluxes of populations within countries or to other countries where people hope to have a better life, but where they may not be well received. Last, but not least, water for nature has become a low or very low priority in water stressed zones. Preserving natural ecosystems is often considered a superfluous use of water compared with other uses that directly relate to healthy human life, such as uses in industry, energy and food production. However, the understanding that natural ecosystems, namely the respective genetic resources, are useful for society is growing, and an effort to protect reserve areas is already developing, even in water scarce regions. Regions where water has been always scarce gave birth to civilizations that have been able to cope with water scarcity (Al-Ajmi, and Rahman, 2001). These societies developed organizational and institutional solutions and water technologies and management skills within the local cultural environment that allowed for appropriate water use for domestic, food production and local industrial purposes. Lifestyle and developmental changes during the last decades created new needs for water, provided contradictory expectations on cultural and institutional issues, and led to very strong increases on the demand for water. The existing balances between demand and supply were broken and new equilibria are required, mainly through the use of modern technologies and management tools which must be adapted to the local culture, environment, and institutions (Biswas, 1980). Findings such new equilibria is the challenge for the societies living in water tressed areas, and for professionals in a multitude of scientific and technological domains, hich impinge on the cultural, social and environment facets of water resources.

3 CAUSES OF WATER POVERTY

Water scarcity may result from a range of phenomena. These may be produced by atural causes, may be induced by human activities, or may result from the interaction of oth, as indicated in Table 2.1

able 2.1: Nature and Causes of Water Scarcity in Dry Environments

Vater Scarcity Regime	Nature produced	Man induced
ermanent	Aridity	Desertification
emporary	Drought	Water shortage

ource: (Vlachos and James, 1993)

.3.1 Aridity

Aridity is a natural permanent imbalance in the water availability consisting in low verage annual precipitation, with high spatial and temporal variability, resulting in overall w moisture and low carrying capacity of the ecosystems. Aridity may be defined through limatological indices such as Thornthwaite moisture index, the Budyko radiation index of ryness, or the UNESCO precipitation/evapotranspiration index (Sanderson, 1992). Under ridity, extreme variations of temperatures occur, and the hydrologic regimes are haracterized by large variations in discharges, flash floods and large periods with very low r zero flows.

.3.2 Drought

Drought is a natural but temporary imbalance of water availability, consisting of a ersistent lower-than-average precipitation, of uncertain frequency, duration and severity, of npredictable or difficult to predict occurrence, resulting in diminished water-resources vailability, and reduced carrying capacity of the ecosystems. Many other definitions of drought exist (Batini et al., 1999). The U. S Wealth Bureau defined drought (Cancelliere et al., 1995) as a lack of rainfall so great and so long continued as to affect injuriously the plant and animal life of a place and to deplete water supplies both for domestic purposes and the operation of power plants, especially in those regions where rainfall is normally sufficient for such purposes. Generally, these definitions clearly state that drought is mainly due to the break down of the rainfall regime, which causes a series of consequences, including agricultural and hydrological hazards which result from the severity and duration of the lack of rainfall. It is important to recognize the less predictable characteristics of droughts, with respect to their initiation and termination, as well as their severity (Cordery and McCall, 2000). These characteristics make drought both a hazard and a disaster. Drought is a hazard because it is a natural accident of unpredictable occurrence but of recognizable recurrence. Droughts can be a disaster because it corresponds to the failure of the precipitation regime, causing the disruption of the water supply to the natural and agricultural ecosystems as well as to other human activities (Grigg, and Vlachos, 1990).

2.3.3 Desertification

Desertification is a man-induced permanent imbalance in the availability of water, which is combined with damaged soil, inappropriate land use, mining of groundwater, and can result in increased flash flooding, loss of riparian ecosystems and a deterioration of the carrying capacity of the ecosystem.

Soil erosion and salinity are commonly associated with desertification (Anton and Delgado, 2000). Climate change also contributes to desertification, which occurs in arid, semi-arid and sub-humid climates. Drought strongly aggravates the process of desertification by increasing the pressure on the diminished surface and groundwater resources. Different definitions are used for desertification, generally focusing on land degradation, as it is the case of the definition proposed by the United Nations Convention to Combat Desertification:

land degradation in arid, semi-arid and dry sub-humid zones resulting from various factors including climatic variations and human activities. In this definition land is understood as territory and is not restricted to agricultural land since desertification causes and impacts do not relate only with the agricultural activities but are much wider, affecting many human activities, nature and the overall living conditions of populations (FAO, 1990).

However, these definitions need to be broadened in scope to focus attention on the water scarcity issues. When dealing with water scarcity situations, it seems more appropriate to define desertification in relation to the water imbalance produced by the misuse of water and soil resources, so calling attention to the fact that the misuse of water is clearly a cause of desertification. Different definitions are used for desertification, mainly focusing on land degradation and sometimes not referring to water. However, when dealing with water scarce situations it seems more appropriate to define desertification in relation to the water and nature imbalances produced by the misuse of water and land resources, thus calling attention to the fact that desertification, including land degradation, is a cause for water scarcity (Kite, 2001).

2.3.4 Water Shortage

This is also a man-induced but temporary water imbalance including groundwater and surface waters over-exploitation, degraded water quality and is often associated with disturbed land use an altered carrying capacity of the ecosystems. For example withdrawals may exceed groundwater recharge, surface reservoirs may be of inadequate capacity and land use may have changed, revising the local ecosystem and altering the infiltration and runoff characteristics. Degraded water quality is often associated with water shortages and exacerbates the effects of water scarcity. There is no widely accepted definition for this water scarce regime and the term "water shortage" is often used synonymously with water scarcity. However, it is important to recognize that water scarcity can result from human activity, either by over-use of the natural supply or by degradation of the water quality (Allen et al., 1996). This man-induced water scarcity is common in semi-arid and sub-humid regions where population and economic forces may make large demands on the local water resource, and where insufficient care is taken to protect the quality of the precious resource.

2.3.5 Aridity and Drought Water Scarcity

In terms of water management, regions having dry climates due to natural aridity are often not distinguished from drought prone areas. This rough approximation of definitions can be misleading in water management. In arid regions rainfall is low all the year around and is particularly lacking during the dry season, which may last for several months (Vlachos and James, 1993). The natural vegetation and ecosystems may be of the desert or steppe type in arid zones, or of savannah and chaparral types in semiarid zones. Rain-fed agriculture is uncertain in arid climates, but is generally viable under semiarid conditions, especially when the use of rainfall is maximized, as for winter grain and fodder crops. However, to achieve higher yields and to produce vegetables and food and fiber cash crops in these climatic conditions, irrigation is required. Irrigation in arid and semi-arid zones has been practiced for millennia, supporting ancient civilizations in very densely populated areas of the world. Peoples and nations in arid areas developed appropriate skills to use and manage water in a sustainable way (Bocco et al., 1994). These included measures to avoid waste of water, the adoption of technologies appropriate to the prevailing conditions, making successful use of water for agriculture and other productive activities, and the development of institutional and regulatory conditions that largely influenced the behaviour of rural and urban societies (Wilhite and Glantz, 1987). These adaptations to live with limited water availability also included measures and practices to cope with extreme scarcity conditions when drought aggravate the limited water supplies. In the civilizations that survived, the present conditions correspond to an integration of a strong cultural heritage with modern management engineering, social and institutional practice to respond to the challenges of development. This integration is not yet totally satisfactory due to the contradictory forces of progress, and thus innovative thinking is required to make development sustainable. Water scarcity due to drought needs appropriate approaches. To successfully cope with drought there is a need to understand the characteristics and consequences of those phenomena which make water scarcity due to drought very different from that caused by aridity. Dealing with water scarcity situations resulting from aridity usually requires the establishment of engineering and management measures that produce the conservation and perhaps the seasonal augmentation of the available resource (Wilhite and Glantz, 1987). On the other hand, droughts require the development and implementation of preparedness and emergency measures. A difference in the perception of drought does lead to the adoption of different definitions, which do not have general acceptance, nor have worldwide applicability, as reviewed by Wilhite and Glantz (1987). The controversies over perceptions of drought, and the consequent defining of them and their characteristics, do not help decision and policy makers to plan for droughts. Lack of clearly agreed definitions makes it difficult to implement preparedness measures, to apply timely mitigation measures when a drought occurs, or to adequately evaluate drought impacts. Several authors point out that scientist, engineers, professionals and decision-makers often do not agree on whether to regard drought as a hazard or as a disaster. As stated by Grigg and Vlachos (1990), this difference in perception is one of the central problems of water management for drought. As discussed above, drought is a hazard and a disaster. It is a hazard because it is a natural incident of unpredictable occurrence, and it is a disaster, because it corresponds to the failure of the precipitation regime, causing disruption of water supply to the natural and agricultural ecosystems as well as to human and social activities (Jones, et al., 1981). The perception of the hazardous nature of dependence on precipitation and water availability depends on the climatological, meteorological and hydrological regimes of the affected region, as well as on the severity of the effects. In humid climates a short period without rainfall may be considered a drought, while in an arid or semiarid environment a dry period with the same duration could be considered normal. The characterization of a drought using indices is also controversial and often contradictory. It is common that agronomists use the word drought to define a water stress condition affecting crop growth and yield. Drought could then be characterized by a crop-water stress index. Short duration dry periods in agriculture are not considered to be drought in this publication, but are defined as dry spells. These are characteristic of sub-humid temperature and tropical climates, and may cause relatively long periods of low soil moisture for introduced agricultural activities. However, they have less impact on natural ecosystems and on other human activities. Some authors prefer to adopt an operational definition that distinguishes between meteorological, agricultural, and hydrological droughts (Arnell, 1989). These usually focus on the indicator variable of prime interest, which could be the precipitation (meteorological drought), soil moisture (agriculture drought), stream flow discharges or groundwater levels (hydrological drought and groundwater drought). Alternative definitions result from the complexity of the hydrological process that controls the temporal and spatial distribution of rainfall via the various paths within the large-scale hydrological cycle and the global circulation of the atmosphere. In certain regions, where water supplies mainly depend upon river diversions, when dealing with a regional drought it may be necessary to consider not only precipitation but also stream-flow. However, stream flow is also a dependent variable, controlled by the current and antecedent precipitation. In many cases, where the river discharges are regulated by dams and other hydraulic structures, the drought definition may need to be more a reflection of the river management decisions than of the natural supply. Thus, the use of precipitation or stream-flow data may not be sufficient to characterize droughts at the local scale, but the definition may need to reflect the supply conditions at the river basin scale. The interdependence between climatic, hydrologic, geologic, geomorphic, ecological and societal variables makes it very difficult to adopt a definition that fully describes the drought phenomena and the respective impacts. Meteorologists and hydrologists have developed indices, which depend on hydrometeorological parameters or rely on probability. Several drought studies e.g. Yevjevich et al., (1983) and Wilhite et al., (1987) give examples of these indices. The definition adopted herein accommodates a variety of conditions and corresponds to the concepts of both hazard and disaster. That definition also allows a clear distinction between drought and the other water scare regimes defined above (Vlachos and James, 1983).

Among other characteristics, aridity is very often associated with:

i) Population growth that is above the capacity of support of the available natural resources, water in particular;

ii) High pressure on natural resources, producing their progressive degradation;

iii) Strong competition for water for human, economic, and social uses, more recently including those of a recreational and leisure nature;

In arid areas water is a limiting resource for development, particularly for agriculture and food. They are also vulnerable and with fragile natural ecosystems. Also, in this area the soil resource is often degraded by erosion and salinity hazards, which are aggravated by poor agricultural and water management. Poverty and low educational levels of the populations also threaten development in such areas.

Therefore, the sustainable use of water resources under aridity, implies the effective adoption and implementation of integrated land and water resources planning and also the improvement of water distribution and irrigation systems to achieve an increased service performance, which would induce efficient water use and production.

The climatic conditions commonly present in regions of water scarcity are associated with low and irregular rainfall, high temperature and high evaporation. It is also common that meteorological and rainfall measurement systems are rarely well developed in areas affected by water scarcity. At best, in these arid areas, the main climatic parameters are monitored at synoptic stations which have a very low spatial density. Poor levels of observation worsen the problem since it leads to inadequate management of the small quantities of water available. The delimitation of arid and semi-arid regions of the world has been described in the Map of the World Distribution of Arid Zones (Rodier, 1993). This delineation is primarily based on a bio-climatic aridity index, the P/ETP ratio (where P is the mean value of annual precipitation, and ETP is the mean annual potential evapotranspiration). The three zones are the "hyper-arid" zone (P/ETP < 0.03), the "arid" zone (0.03 < P/ETP <0.20) and the "semi-arid" zone (0.20 < P/ETP/0.50). In addition to these criteria, temperature is taken into account based on the mean temperature of the coldest and the hottest month of the year. Consideration is also given to the rainfall regimes (dry summers, dry winters) and to the position of the rainfall period in relation to seasonal temperatures.

2.3.6 Rainfall Variability in Time and Space

Rainfall quantities and the pattern of their occurrence vary considerably in different climate regimes. In general, the lower the annual rainfall amounts the greater their variability from one year to another. In semi-arid and arid regions the rainfall is irregular and unreliable. In these regions, the rainfall variability and spatio-temporal differences are very pronounced. Many hydrological and hydrometeorological studies give evidence of such behaviour (Nicholson, 1993). Most of the world's arid and semi-arid regions have climatic regimes in which precipitation is characterized by some or all of the following (WMO, 1994):

i) One, rarely two, short rainy season, followed by long and often hot dry periods;

ii) Short rainy periods, rarely more than two days, unevenly scattered throughout the season;

iii) Violent showers, having high rainfall intensity and large spatial variability over a small area even at a scale of $10km^2$,

iv) Irregular inter-annual rainfall depths and great local differences that often render the usual statistical tools in climatology ill-adapted, e.g. dissymmetric or multi-modal frequency/probability histograms.

Lack of rainfall has varying significance in the different climatic regimes in the world. In some of the arid zones, there may be several years in which no measurable precipitation occurs and the flora and fauna are adapted to these normal desiccating conditions. In other arid areas, where very little rainfall occurs, the deficiency of the rainfall below the normal results in serious water shortages requiring a number of measures to be taken. Low annual amounts of rainfall in a region may result from its geographical location relative to the general circulation of the atmosphere, its location on the lee-side of a mountain range, or absence of a topographic height that would favour the formation of precipitation from clouds passing over it. This has a bearing on the surface runoff that is generated, and on the quantities of water that may be recharging the ground water systems (NWRC, 2000). At the same time, the occurrence of rainfall in short and infrequent outbursts creates flash floods, which do not provide sufficient opportunity for water to infiltrate to ground water systems.

It is important to have good rainfall measurements for a sufficiently long duration and of adequate spatial distribution for the appropriate assessment, planning and management of the water resources at a regional level. The need for observed rainfall time-series, both for analysis of water availability and forecasts in the long and medium term, is the requirement most often expressed by development planners and decision-makers. This requirement is currently not usually satisfied in regions suffering from water scarcity. It is therefore necessary to strengthen observation networks for planning and operational purposes and to allow research on rainfall variability and spatial differences (WMO, 1994). The rainfall measurement in a given location provides point information usually only valid for the area attributed to that rain gauge. A large number of such observation points would be needed for arid and semi-arid regions to provide meaningful information due to the exhibited peculiarities of spatial variation of rainfall in these areas. The knowledge of climate and precipitation is inevitably based on the development and maintenance of such an observing network system in the long term WMO, 1994. A drought is usually considered to be a period in which the rainfall consistently falls short of the climatically expected amount, such that the natural vegetation is affected, and availability of water for other uses is severely limited. A drought in low rainfall regions could be devastating and disastrous since the already limited existing quantities of water in such an area could not suffice to cope with the situation. Thus, drought has widely different connotations according to location and likely consequences (Cancelliere et al., 1995). The intervening periods between rainfall events – dry spells – in regions where aridity prevails are normally quite long and, with the usually high existing potential evaporation, create soil moisture deficiencies, which have to be recovered before runoff will be initiated or there will be infiltration to the aquifers. Thus, in these areas, the effect of a rainfall event on runoff generation and aquifer recharge is reduced compared to the effects of similar events in temperate regions, where rainfall occurs more regularly (Cordery, and Curtis, 1984).

2.4 EVAPORATION

Evaporation and evapotranspiration are important in assessing water availability and must be considered in water resource planning and management. Water evaporates from soil water and groundwater, vegetation canopies, natural and man made lakes and ponds, streams, and canals and wet surfaces. Evaporation and evapotranspiration are the object of many papers and books, mainly relative to observation and computational procedures (Demissie, and Stout 1988; Allen et al., 1996), including the use of satellite information (Jones et al. 1981). The discussion here focuses on the particular aspects of evaporation that are of vital concern in arid and drought prone regions and that affect water availability and demand in these regions. Evaporation affects the quantity of effective rainfall, the yield of river basins, the storage in surface reservoirs, the yield of aquifers and especially the consumptive use of water by crops and natural vegetation. Some of the more important factors affecting evaporation are:

- Solar radiation, being the main source of energy affecting evaporation. Solar radiation varies with latitude and season, being generally higher for low latitudes, where its seasonal variation is smaller than at higher latitudes. The net available radiation also depends on the reflectivity of the surface (albedo), the rate of long wave radiation from the earth's surface and the transmission characteristics of the atmosphere.
- Temperature of both the air and the evaporative surface, which is also dependent on the major energy source, the solar radiation. As a consequence of the energy balance, the surface temperature increases when more solar energy is available and a larger fraction of that energy becomes sensible heat. Conversion of energy to sensible heat is enhanced when only a small fraction of the available energy is used for evaporation. The surface temperature decreases when the evaporation rate increases and higher surface temperature occurs when the evaporation surfaces become dry.
- Vapour pressure deficit (VPD) of the air, which corresponds to the amount of water vapour that can be absorbed by the air before it becomes saturated, has a large controlling effect on the evaporation. More evaporation can be expected in inland areas where the air tends to be drier, than coastal regions where the air is damp due to the proximity to the sea.

- Wind speed above the evaporating surface. Wind represents a major driving force to replace the air layer adjacent to the surface which has been wetted by the evaporated water vapour, with dry air having a higher VPD. As water evaporates, the air above the evaporating surface gradually becomes more humid until it becomes saturated and can hold no more vapour. If the wet air above the evaporating surface is replaced with drier air the evaporation may proceed. Evaporation is greater in exposed areas that enjoy plenty of air movement than in sheltered localities where air tends to stagnate.

Other factors have a generally broader scale influence on evaporation. The prevailing weather pattern, referring to the atmospheric pressure, affects evaporation. The edge of an anticyclone provides ideal conditions for evaporation mainly when some air movement is operating in conjunction with the high air pressure. Low atmospheric pressure is usually associated with damp unsettled weather in which the air is already well charged with water vapour and conditions are not conducive to enhance evaporation. The nature of the evaporating surface, which may modify the wind pattern, may also influence evaporation. Over a rough irregular surface, friction reduces wind speed, but has a tendency to cause turbulence so that, with an induced vertical component in the wind, evaporation may be enhanced. This influence is often associated with the effects of topography on the nature of evaporative surfaces, the energy balance and the weather variables that determine evaporation. Evaporation is necessarily dependent on the water availability at the evaporating surface.

Evapotranspiration from natural or agricultural vegetation depends upon the availability of water in the soil and the capability of plants to extract this water, which may be retained at high soil water tension. Thus, evapotranspiration is controlled by soil moisture content and the capacity of the plants to transpire, which is conditioned by the climatic demand of the atmosphere. A large amount of the water that is precipitated in a region is returned to the atmosphere as vapour through evaporation from wet surfaces and through transpiration from the vegetation. The water scarcity experienced in regions with low rainfall and long summer dry – spells is exacerbated by high evaporation and transpiration demand. Evaporation is difficult to control. Development of ground water reservoir and artificial ground water recharge can reduce evaporation losses. At the same time, proper design of dams located in topography that would store water with minimal free surface area would be advisable. However, such favourable locations are few. In arid zones, not only are evaporation losses important themselves, but high evaporation tends to encourage salinity problems. In such regions, water and soil salinity tend to be high due to the concentration of salts in the soil and aquifer following continuous high rates of evaporation. The resulting saline marshlands, salt-lakes, sabkhas, saline soils and brackish and saline waters, add to the problems of regions with water scarcity conditions.

2.5 WATER QUALITY

In temperature zones the blending of large quantities of surface runoff tends to maintain reasonable water quality standards. These large quantities of water are absent from arid and semi-arid climates. The result is that the reduced flows are laden with increased amounts of salts leached from the soil profiles and the groundwater, which is then enhanced by the very high evaporation. Furthermore, fertilizers and pesticides from agricultural activities that find their way to the groundwater and stream flow appear in increased concentrations in those water bodies due to the low recharge and the low discharges in the streams. Effluents from urban and industrial areas significantly add to the problem, mainly affecting the quality of stream flows. The fact that floods are sudden and are highly charged with sediments worsens the water quality problems (United Nations, 1992). The harsh evaporative environment in areas of low rainfall adds to the amount of salts present in surface waters. The high temperature and the addition of salts and nutrients to surface water bodies easily create conditions of eutrophication, which largely affect water quality and the riparian ecosystems. Groundwater quality in regions of water scarcity is often very low. The contribution of ground water to surface runoff often increases the salts present in the surface flows. Water quality degradation, which affects surface and groundwater, often results from man made water shortages and is a cause of desertification. When high quality water becomes contaminated with salts, charged with untreated municipal and industrial effluents containing toxic substances and heavy metals, that water becomes unavailable and there is pressure to explore and exploit other sources of water. Consequently, water becomes scares or the degree of water scarcity is increased. If the degradation of water quality can be reversed after appropriate management, which is more likely to be possible with surface water, the water shortage problem may be overcome. If reversal of that degradation requires long term measures, such as are more likely for groundwater, then a desertification process may have been installed. Recovering the quality of groundwater to an exploitable condition in areas of very limited recharge and high demand pressure may be a task for several generations or may be impossible. Considerable attention must therefore be placed on avoidance of man-induced water scarcity, which can mainly be combated through protection, preservation and good management of the resources.

2.5.1 Water Quality Deterioration

Over-exploitation of aquifer that are in contact with the sea or other water bodies of inferior quality may result in the deterioration of the aquifer's water quality. A drop of the water table below the level of the sea disturbs the existing equilibrium and seawater propagates inland rendering the groundwater useless for irrigation or domestic supplies. This process takes some time. Therefore, it is not unusual to lower the water table to levels below the sea level for limited periods of time, varying from months to years, depending on the local hydrogeological conditions. This is common in arid and semi-arid regions where major recharge events do not occur annually, but at irregular time intervals (Beomonte and Neri, 1986).

However, continued over-exploitation, may create irreversible conditions for the quality of the ground water. In the same way, if groundwater of inferior quality exists in the same area as an exploited aquifer may invade if the aquifer is over-used. Wells and groundwater galleries may have to be abandoned if invaded by water of inferior quality unless some form of treatment is introduced before water use. Repeated use of low quality water may seriously damage agricultural soil, vegetation, and animal biodiversity and may cause human health problems (Rosegrant, 1995). Over-exploitation of aquifers during periods of water scarcity causes much steeper hydraulic gradients towards wells. These conditions favour increased groundwater contamination from the ground surface especially if the area is agriculturally developed (Redondo, 2001). This quality deterioration could become quite serous and affect the use of groundwater for drinking purposes. The pollutants that cause the most concern are nitrates and to a lesser extent pesticides, heavy metals and organic compounds. Outbreaks of disease may occur as people use unprotected, traditional sources or sources invaded by inferior quality groundwater. In general, scarcity of water causes the search for and development of new sources of water and as the scarcity worsens so does the quality of water considered acceptable for use (Al-Nakshabandi et al., 1997).

2.6 ECONOMIC AND SOCIAL IMPACT OF WATER POVERTY

The quest for water in areas of water scarcity or under a prolonged drought episode results in intensive groundwater extraction. This increased groundwater pumping entails and is associated with many undesirable environmental impacts that in turn lead to serious economic consequences. Capital investment in well construction and pumping plant may be totally lost if the well runs dry, unless it can be deepened. Larger capital investment will be required for wells of increasing depth. Additional costs will be incurred where yields decrease and escalating recurrent costs will be associated with pumping from ever-greater depths. The same apply in the case of intrusion of water of inferior quality with the consequent abandoning of wells. Great economic and social costs are associated with the abandoning of wells, particularly in minor aquifers, when they become dry or their use becomes prohibitive due to deterioration of water quality. Costs refer to the need to develop other water sources and to changes in the economic activities which were relying on the use of that groundwater. Large economic costs are also associated with measures to re-establish equilibrium where the unbalanced exploitation of aquifers led to such deterioration. Social costs are also associated with the restrictions that have to be imposed on small farmers, who are often poor, when access to irrigation water has to be limited. The abandonment of the area by populations migrating to locations where they expect to have better life conditions constitutes a major impact of over-use of groundwater. When springs dry out in rural areas, rural populations are obliged to increase their time investment in collecting water from distant locations, often in conflict with other villages that were previously using that source (Attia, 1998).

Economic and social costs are also very high when the over-use of aquifers, coupled with uncontrolled land uses, facilitates the contamination of aquifers, so making them inappropriate for domestic and other high quality-requirement uses. Then quite costly water treatment to free water from nitrates, heavy metals and other substances have to be practiced, leading to higher costs for the water delivered to users. Social costs are particularly evident when poor urban and peri-urban populations need to search for other water sources. In the case of degraded surface wells and springs in rural areas, villagers need to search for new sources at some distance, demanding additional time and increasing competition and sometimes conflicts with others. Large economic and social costs also accrue from land subsidence produced by lowering of water tables. Roads, houses and other infrastructures may be highly affected when uneven ground conditions occur due to differential land subsidence. Costs are associated with the repair of houses and buildings, roads and hydraulic infrastructures. Surface water conduits may have to be totally rebuilt. Additionally, economic activities may be very much disturbed causing serious problems for poor families.

The environmental costs of wetland diminution and landscape change are high but very difficult to assess in economic terms. Impacts are more evident when rare vegetation and animal species are endangered, when nesting conditions for migratory birds are affected, or when the "green" landscape constitutes an almost unique ecosystem in an arid or semi-arid zone. Economic consequences are easier to be evaluated when human populations make use of such oases or natural green areas. The environmental impact of any groundwater management plan on wetlands and riparian ecosystems depending on groundwater should be taken into account. Moreover, the added benefits from the recovery of such ecosystems, together with the economic and social impacts as referred above, should be considered when performing any costs-benefit analysis on the improvement of the groundwater quantity and quality in any deteriorated area.

2.7 WATER POVERTY REDUCTION PROCESSES

2.7.1 Fog-Capturing, Water Harvesting, Cloud Seeding, and Water Transfers

Dew, mist and fog generally make only a small contribution to precipitation in water scarce regions. However, they can be responsible for peculiar vegetation ecosystems in arid or semi-arid areas. Several physical processes influence the occurrence of these ecosystems.

Agnew and Anderson (1992) refer to the importance of fogs in several coastal areas in Namibia, Oman and Peru. Fog collection is used in isolated arid areas, in mountains and islands where the occurrence of fog is common but rainfall is rare. Ancient examples of fog capturing have been found in the Negev, the so-called "dew mounds", and in Crimea, these ones constituted by piles of rocks named "aerial wells" (NAS, 1974). Modern examples are reported by Agnew and Anderson (1992) for Peru, Oman and the Negev. Several case studies are described in Schemenauer and Bridgman (1998), namely the use of fog collectors in Chile and Peru coastal villages and in the islands of Cape Verde, located offshore of the Sahel zone of Africa, fog-harvesting in Namibia, Oman, the Negev and Canary Islands. Particular attention is given to the chemical composition of fog water in view of its use by humans, animals and ecosystems in dry areas Schemeanauer and Bridgman (1998). Fog capturing is achieved by means of appropriate screens that favour the coalescence of the small fog droplets to create larger drops with enough dimensions to flow down by gravity into collectors. Fog screen collector design is described by Handy, (2001). The amount of water collected every day is small and depends on the properties of the air masses passing over the collection sites. The reliability of fog capturing is associated with the frequency of fog occurrence. When fog occurs nearly everyday, a water yield of 3l/day/m^2 of collector net may occur as in Mexico. In general, fog capturing is only feasible for human consumption for small populations living in such areas, and for drinking of animals, mainly those grazing on high pasture lands where frequent fogs favour vegetation despite the lack of rains. Reviews of fog capturing by natural vegetation and its impacts on ecosystems in dry African regions are presented in Schemenauer and Bridgman (1998). Rainwater harvesting, or simply water harvesting (WH), has been practised for millennia in the Negev and in Petra, Jordan, by the Nabateans. Prinz (1996) refers to water harvesting structures in Jordan from 9000 years ago and in southern Mesopotamia as early as 4500 BC. Rainwater collection was a common practice in the Roman cities of North Africa and the Near East. Water harvesting for agriculture is an ancient practice common in Mexico. Tunisia, the Arabian Peninsula, Afghanistan, Pakistan, India and the Sahel countries, among others. New developments are being introduced in areas where WH was not traditional such as the arid Northeast Brazil, or where social changes require new approaches, such as the Sub-Saharan Africa (Reij and

Critchley, 1996). Roof-top rainwater harvesting, commonly associated with water collection from impermeable areas surrounding the households, plays a major role for making water available for domestic uses and animal drinking in a large variety of rural environments throughout the World. However, care is required to keep stored water in cisterns free from contamination by animals and sewage water. Drinking water has to be boiled before consumption and filtering is commonly also required. WH for animal drinking is commonly achieved by collecting runoff into small reservoirs created by excavation or using small earth dams. Animals should not have direct access to the stored water to avoid contamination by excreta. Appropriate drinking facilities should be used such as drinking fountains connected to the reservoir by a pipe. WH for crops varies from one region to another according to the indigenous knowledge, land form, soil type, runoff intensity and the crops to be irrigated. Generally, distinction is made among: inter-row WH, where water collection is made in the location where it is used; micro-catchments WH, where rain is collected in part of the area and is infiltrated in the downstream cropped zone; macro-catchments WH, where runoff water is collected in large areas to be stored in earth dam reservoirs or tanks to irrigate the downstream fields; and floodwater diversion systems, also called spate irrigation systems, where appropriate structures in the river bed divert the flood runoff in a controlled manner to the nearby cropped fields.

Another traditional process for capturing water in arid zones is groundwater harvesting. This term is used to make a distinction from modern groundwater exploitation, which is mainly with tube wells. It includes dug-wells, which capture quite shallow groundwater and keep being the basic water supply system in many arid or semiarid areas of Africa and West Asia, horizontal hand made wells, which are commonly in use in many parts of the world, and the qanats. The latter are horizontal tunnels that tap the water in an alluvial fan and transport it to the surface where it is used without any pump or other lifting equipment. The qanats are a heritage of the Persians, who developed them about 3000 years ago. Qanats are used for irrigation in arid zones of Iran, Pakistan, Afghanistan, Xinjiang in West China, the Arab Peninsula, and North Africa. Water is transported underground for several kilometers, in many cases 10 to 20km. Qanats are composed of dug or horizontal wells for capturing the water, a tunnel having a series of vertical shafts used for digging out the excavation debris and for respiration, and the downstream diversion structures that provide for the distribution of waters into different canals. Qanat systems are of great importance. Modernization of these systems is desirable but careful approaches have to be used, regarding both the structural and the management aspects. A recent analysis on qanats in Oman, locally called aflaj, is provided by Al-Marshudi (2001), who pays particular attention to the traditional organization aspects as key for maintenance and operation.

Weather modification has been an objective of research for a long time but a success reported in the literature is limited. Essentially, it consists in using aircrafts to bomb the clouds passing over an arid area with substances such as ice, frozen carbon dioxide and silver iodide, which may serve as nuclei for condensation and coalescence of rain drops. When large enough, these drops could fall to the ground. This method for rainfall augmentation is called cloud seeding. Results show that wet air masses must be cold enough that the formed water particles are in the form of ice crystals that coalescence to be large enough to create drops which can reach the ground as rain. In most low-lying arid areas, wet air masses are not as large, cold or frequent as in mountainous areas. There, cloud seeding could be effective, but these are often unpopulated regions and benefits to the populations can result only from augmentation of runoff due to that increased rainfall. Nevertheless, as reported by Khouri et al., (1995), during the 1980 drought in Morocco, cloud seeding over the Atlas mountains increased the rainfall by 10 to 15%, which caused runoff that could be stored in small dams downstream, and contributed to alleviation of the drought.

Water transfers from one basin to another have not been discussed much until recently. The idea is mostly concerned with long distance transfer of water from basins in a humid or semi-humid zone to another basin in a semiarid environment. A typical example is the Grand Canal in China, for which construction started in the Qin Dynasty, around the year 400 B.C. Its main purpose was navigation but it also served to transfer water from the Yangtse River to the north across the lower reaches of the Yellow River and the Huai River. New water transfers are currently planned to import water from the Yangtse basin to the municipal areas of Beijing and Tianjin and for irrigation and municipal uses in the lower Yellow River and Huai River basins. One of these projects is essentially an update of the Grand Canal system but focuses on the South to North Water transfer. Several water transfer projects are operating in various parts of the world. This is the case for the Tajo – Segura transfer from Central Spain to the semi-arid south Mendiluce, (1986); the Basento – Bradano system in south Italy (Beomonte and Nery, 1986); the transfer of water from the Colorado river to irrigate the arid southern California and to supply the Los Angeles and San Diego areas, and in Western Australia the 700 km pipeline that transports water from south of Perth to Kalgoorlie. Another example is the Snowy Mountains Schemes in Australia, where the coastal flowing Snowy river water is turned inland to provide for irrigation and generate hydropower. In this case power generation pays for the works and irrigation water is put into the inland rivers at no net cost. Although, water transfer is a rational way for increasing water availability in areas where water scarcity is evident demand largely exceeds the available supply, several factors contribute to a decline in interest in water transfers. They may contribute to an unbalanced regional development since the excess demand in the water importing area may not be fully in balance with its overall ecological potential. Similarly, the water exporting region may not receive all the investments and policy measures that could help it to develop better (Rhoades et al., 1992). These issues are of course questionable, but they give rise to political, cultural and social attitudes opposed to inter-basin water transfers. More important are the recognizable environmental impacts on the basin from where water is transferred due to the consequent decrease in river flow, particularly during the low-flow period, with detrimental effects on the river ecosystems and biodiversity. The environmental impacts in the water importing areas due to quick growth of irrigation areas, urbanization, and other activities that affect the fragile ecosystems in the water scarce regions may be less evident, but they occur. Finally, costs associated with inter-basin transfers are very high because distances to be covered the large, compensatory measures are costly and environmental control measures are quite demanding. Water transfers are usually only feasible when the water transferred has high value, such as for large population survival and high value industry. Appropriate evaluation and implementation of measures that provide for the sustainable development of both the areas exporting and importing water are required. Biswas, (1980) presents an updated discussion on these matters. Water transfers should go together with the implementation of water conservation and saving measures since the corresponding increase in availability does not turn the importing area one of water abundance. In many areas, the reallocation of water rights may be an alternative or a complementary measure to water transfer (Chaturvedi, 2001). This reallocation generally relates to the water value and may be easily performed when a water market can be implemented.

2.8 WATER MANAGEMENT

2.8.1 Water Saving in Domestic Application

Domestic water use can be classified under indoor and outdoor uses. In a typical household having outdoor facilities, nearly 50% of the water use is for the garden (Ohlsson, and Appelgren, 1998). Water uses in commercial and services buildings are considered herein together with the domestic ones since they are similar, they are very often located in the same neighbourhood or distribution sector, and water measures are common. Also, common are water uses for hotels and restaurants (IFAD, 2002).

A few years ago, as much as 35% of indoors water use could be accounted for by toilets, 30% by showers, and 20% by clothes washing (Falkenmark, and Widstrand, 1992). Nowadays, there is a slight change: 33% concern showers and bath, 24% are relative to toilet flushing and 22% to laundry water use. The main attention must be given to the following types of water uses:

a) **Toilets:** Traditional toilets use 16 to 20 litres per flush, which means an average of 80 to 100 litres per day capita. Leaks from the toilet reservoir are the most common system losses in domestic water use, occurring in 15% of cases.

Water saving in toilets may be achieved by using several means such as:

i) Toilets with a reduced reservoir, such as 6 litres per flush,

ii) Toilets with double discharge, one producing larger flushes, the other a smaller flush.

iii) Placing containers or bags filled with water in the tank of traditional large volume toilets to reduce its capacity; however, the toilet's siphoning effect may be reduced

iv) Changing to longer discharge siphons in traditional toilets, which reduces water flushes.

v) Toilets having flushes controlled by the pressure in the mains or a pressure regulation device, so that volumes of water discharged may be near 6 litres per flush.

vi) Special toilets such as with pressure within the tank equals the difference in levels between the free surface of the main water tank and the surface of the toilet tank, or biological toilets or incinerators, which degrade faecal matter in deposits located below and turn it into fertilizer.

vii) Toilets where leaks are easy to detect and repair or toilets less susceptible to leaks such as pressurized tanks without the conventional fittings, and models that substitute siphons for new design fittings.

b) **Showers and Bathing:** Showers take second place in domestic water demand. Water savings include;

i) Using shower-head designs that limit the discharge not to exceed fixed values such as 10l/min.

ii) Using flow or pressure limiting devices to reduce shower discharges to target values,

iii) Reducing the time for showering,

iv) Preferring shower to immersion bathing,

v) Controlling leaks in shower fixtures, such as those caused by worn gaskets or loose nuts, which are simple to repair.

c) **Basin Taps:** Several water saving may be applied in water use from taps in bath rooms and kitchens;

i) Flow reduction by using aerators, which add air to the stream and disperse it, increasing the spread and the washing efficiency, reducing flow as much as 6%,

ii) Flow reduction by using pressure control devices when the pressure is too high,

iii) In hand washing basins, use of valves with sensors that activate the water flow only when the hands are placed beneath them, or use of valves for limited flow time in hand washing basins, caring about keeping taps closed when not being required, such as keeping them closed while soaping the hands and opening again to wash, or wash teeth using a glass of water, not flowing water.

iv) Use of tap valves easy to close and re-open that make it easier to have water flowing only when it is necessary.

v) Dish washing in a basin, not with flowing water,

vi) Controlling leaks in tap fixtures such as caused by worn gaskets or loose nuts.

d) **Washing Machines:** Water savings in these machines can be achieved by:

i) Loading the washers with the appropriate weight of clothes, using the water levels necessary for efficient operation; some modern machines may require less water when half charged.

ii) Using washers that require less water, front loading washers can use up to half the amount of water (up to 50% of the hot water and 33% of the detergent) required by tub or top loading washers; modern washing machines have reduced water use, by up to 25% in comparison with traditional models;

iii) Follow instructions of the manufacturer on selecting the programmes since they may have different water and energy demands.

e) **Dish Water:** Water savings concern:

i) Selection of the machines that requires less volume of water to perform the same operations; some modern machines use about one third that of old models.

ii) Load the machines to full capacity; modern dishwashers have somewhat reduced demand when half charged.

iii) Follow instructions of the manufacturer on selecting the programmes since they may have different water and energy demands.

f) **Control of Indoor Leaks:** Leaks in pipes, plumbing fixtures and toilets are very frequent and may be difficult to detect. One way to solve the problems is to use leak-proof fittings and other materials whose specifications correspond to pressures to be used as well as to the temperature of the water. Hot water pipes and plumbing often leak. After installation of the pipes, a test must be performed to check joints and valves before walls are closed. Safety valves must be installed for easy repair operations.

2.8.2 Water Conservation and Water Saving in Industrial and Energy Uses

Water conservation in industry and energy production mainly refers to the managerial measures and user practices that aim at preserving the water resources, essentially by combating the degradation of its quality. Water saving should be adopted in every managerial measure or user practice that aims at limiting or controlling the water demand and use for any specific process, including the avoidance of water wastes and the misuse of water. In general, industrial processes and related support services have a large demand for water but, very often, the non-consumed fraction is very high and is returned to nature or to sewage systems. However, industrial demand is much smaller than the agricultural demand, particularly in arid and semi-arid regions where it is of the same order of magnitude as the domestic demand except in tourist areas. On the other hand, in developed and industrialized regions, it largely exceeds the domestic demand. The great importance of the industrial water uses also result from the fact that they occur in populated areas, and are in direct competition with domestic uses, and very often are supplied by the same urban networks. The volumes and quality of water required by the industry vary with the type of industry and process. Similarly, the non-consumed fractions and the quality of effluents are also very different. Moreover, the same industry has different requirements for the quality of water to be supplied, and produces effluents with different quantities, which may require different treatment processes. Water recycling and reuse are the main water saving processes in industry. Recycling consists in utilizing water in the same process as it was originally used. The physical and chemical properties of the water may change after being used, requiring some simple treatment before being used again. Water reuse consists of using treated water after its use in a different process where it cannot be utilized again.

Water for energy production is generally not consumed, as for hydropower, though for evaporative cooling larger consumption is involved. However, in the latter case the disposed water may have higher temperature than required for some uses, including for nature in river ecosystems. Water uses can be grouped in various ways in relation to water conservation and water savings. The following are further considered:

a) **Temperature Control:** Water is used for both heating and cooling. The former usually involves the generation of steam in boilers that burn coal, oil, gas or waste products. Cooling processes employ the circulation of cold water through cooling towers, pipes or pools. Water conservation and savings concern, among others, the following issues:

i) Heating processes are generally in closed circuits and do not require high quality water, but mainly that the water does not produce detrimental residuals. The amount of residuals admissible depends upon the frequency and processes applied to clean the boiler. Treated water, inclusive of previous industrial uses, may be used. For steam production the recovery of water by condensation may be expensive but may be justified when water is scarce and could be reused.

ii) Cooling requires water that has low temperature and is non corrosive or is not likely to attack the equipment or materials with which it is in contact. After cooling, the temperature of the water is elevated but can be recovered by open air-cooling and aeration, or be directly reused such as for greenhouse heating. Evaporative cooling tower consume quite large amounts of water. Evaporation losses are generally higher when cooling is practiced in pools.

b) **Manufacturing Processes:** Industrial processes requiring water are very diverse. Among the more important, water conservation and saving opportunities are:

i) Incorporation in the product, as is the case for drinking and food industries: extremely good quality water is required. The non-consumed fraction is small and may be added to reusable effluents.

ii) Water used in physical extraction processes, such as in the vegetable oil industry, must be of high quality. However, effluents usually have too many organic inclusions but can often be reused for irrigation, such as the effluents from sugar mills.

iii) Chemical extraction processes are used, the water quality requirements are related to the chemicals utilized, the type of raw material, and the type of manufactured product. Generally, water savings relate to changes in the processes and water conservation to the treatment of effluents, as is the case for the paper industry. Textile dyeing requires huge amounts of water and reuses is limited due to difficulties in removing the dye. Water conservation in this industry depends upon further developments in research relative to that specific water treatment problem, such as is being pursued in China.

i) Washing raw food materials requires high quality water, which may be reused for cooling, heating or indoor washing if the size of the industry is large enough to reuse the water. Otherwise, effluents may be treated for external reuse.

ii) Washing raw non-food materials generally do not require high quality water such as in the mining industry. Recycling may be adopted when effluents mostly carry materials in suspension, which could be easily filtered. In this case, sedimentation ponds may be used for final treatment. Water used for transportation of materials, in pipes or channels, requires variable water quality according to the nature of material to be transported, being generally high water demanding. Water demand is reduced when mechanical transport is adopted, and when recycled water could be used. Water is also used for cooling equipment such as in wood and stone cutting and polishing industry. Water quality requirements relate then to not having materials in suspension nor corrosive chemical components. Generally, water savings depend on advances in the equipment itself. Effluents often require extraction of sediments produced during the processes of cutting and polishing the materials.

In the construction industry water uses include incorporation in the product such as in concrete and other masses, cooling of stone and mosaic cutting equipment, and earth compaction. Non-saline water should be used. Water savings mainly concern the control of leaks from tanks and pipes utilized, and care in handling them to avoid unnecessary wastes.

c) **Power Generation:**

i) Water energy can be directly used to generate electrical energy by running turbines, so the water used is not consumed. However, water storage is often required, which may create a competition with other uses when the stored water could be used by other sectors. This problem can only be solved under a water conservation perspective when water resources are planned and managed at the basin scale adopting an integrated perspective, which needs to include allocation of the resource under competitive demand and multiple uses of stored water from reservoirs.

ii) When reservoirs are required for energy production, losses by evaporation occur, as well as deep percolation. The latter is mainly controlled at construction. Evaporation losses are extremely difficult to control since the application of chemicals in the water surface may affect aeration of the water and are often detrimental for other uses, such as fish production, human consumption and recreational and environmental uses, which are common in these reservoirs.

i) Water is used in thermoelectric and nuclear plants for cooling. A large fraction of the water used is consumed because it vaporizes, while another fraction is recovered by condensation and returned to nature, preferably after lowering its temperature. It could also be reused for heating in a different activity, such as greenhouse heating.

d) **Washing:** A large variety of industrial residuals and other materials accumulate every day on the floors of industrial installations and buildings, as well as dust on the industrial equipment. Cleaning by washing is common. Water savings may be achieved is several ways:

i) Using dry cleaning machines when residuals and the floor are mostly non wet.

ii) Using water cleaning machines, which require less water and detergent than water cleaning with a hose.

iii) Separating heavily polluted washing effluents, such as with oils, from less polluted effluents. The first may not be reused while the latter may be reused in washing the floor.

ii) Dry clean outside areas such as sidewalks and parking lots.

2.8.3 Water Conservation in Dryland Agriculture

Dryland agriculture, also called dry farming or rainfed agriculture, is crop production without irrigation. Crop water requirements are satisfied by the rainfall occurring during the crop season. However, distinction should be made between rianfed agriculture in areas where rainfall is abundant, in humid and temperate climates, and crop production in water scarce regions where rainfall is low and erratic in quantity and temporal distribution and evapotranspiration largely exceeds precipitation during much of the year. The terms dryland agriculture and dry farming apply to the latter.

Dryland agriculture is traditionally practiced in water scarce when rainfall during the rainy season is sufficient for the crop to develop and produce. Yields are commonly lower than for irrigated agriculture and vary in a large range from one year to the other, following the trends in the temporal variation of precipitation. The use of water conservation practices is usually required for successful crop production under water scarcity conditions. Water conservation in dryland agriculture may assume quite different facets and include the selection of crops that are less affected by rain water deficits, the adoption of cropping practices that favour the ability of crops to escape water stress, and soil management practices that help to conserve water in the soil for crop use. A recent review has been produced by Shin and Salas (200). In semi-arid and arid conditions and when drought occurs the water deficit periods during the crop season may be quite large, and supplemental irrigation and water harvesting become part of dry farming practices.

Typically, the term water conservation in dryland agriculture is used for the technologies which aim to improve the amount of water infiltrated and stored in the soil. However, it is used here to include other technologies that improve the water productivity of the crops, i.e. the yield quantity produced per unit quantity of water. In fact, by increasing water productivity the water use is improved and the resulting demand for water may be better controlled and, in certain cases, the demand for other water uses may be better satisfied.

CHAPTER THREE

3.0 METHODOLOGY

3.1 LOCATION

Ekiti State is located between longitude 4°45' East of Greenwich Meridian and between latitude 7°15' and 8°5' North or Equator. It lies south of Kwara and Kogi states as well as east of Ogun state. It is bounded in the east and in the south by Ondo state. The state which has a population of about 1.75 million (1996 on creation) is mainly an upland zone, rising above 250m to the mean sea level. It lies within the area underlain by metamorphic rock of the basement complex. It has a generally undulating land surface with a characteristic landscape that consists of old plains broken by step-sided out-crops dome rocks that may occur singularly or in groups of ridges.

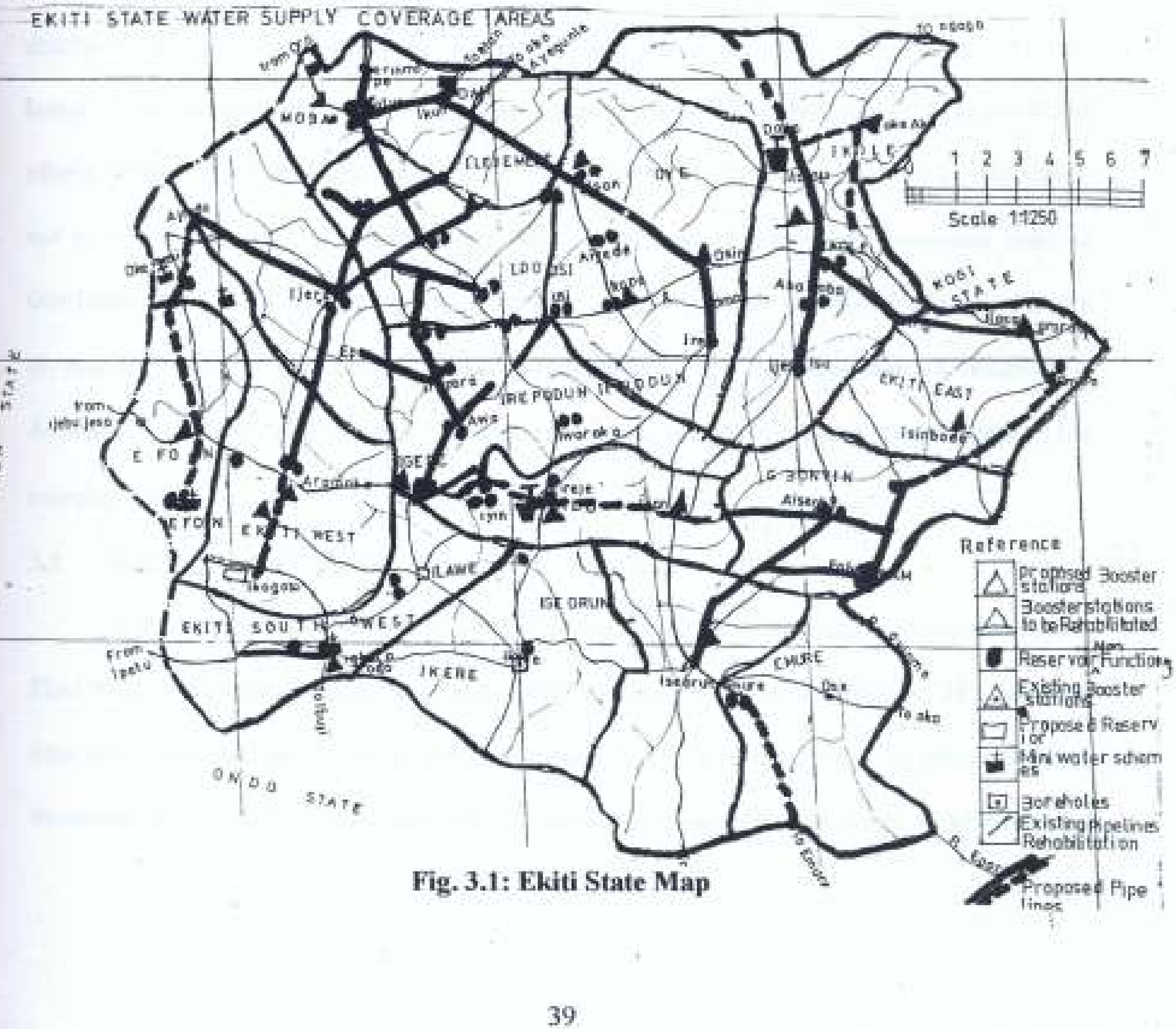

Fig. 3.1: Ekiti State Map

The state enjoys tropical climate with two distinct seasons. These are the rainy season (April – October) and the dry season (November – March). Mean air temperature ranges between 21 and 28°C with high humidity. The South – Western wind and the North – East trade winds blow in the rainy and dry (Harmattan) seasons, respectively. Tropical forest exists in the south, while the guinea savannah occupies the northern peripheries. Several rivers run through the state of which the most important ones are Era, Osun, Ogbese and Oni.

3.2 DATA COLLECTION ON WATER POVERTY IN EKITI

Ten thousand questionnaires were randomly distributed to household in the sampled local government areas. One thousand questionnaires each were distributed to local government areas visited (Irepodun/Ifelodun, Ido-Osi, Ekiti south-west, Ise-Orun, Ikole, Ikere, Ado, Oye, Moba and Ekiti East local government areas). The questionnaires were so distributed to reflect what could be obtainable from the considered local government areas. Some of the components considered in the composition of the questionnaire include among others: source of water, water availability, time taken to access water, access to safe water, use to which water is put in the households, occurrences of water borne diseases such as diarrhoea, cholera, typhoid and others. Oral interviews were also conducted where necessary to ensure thorough administration of questionnaires. The questionnaire is detailed in Appendix 1. Two local government areas were visited per day to ensure effectiveness of the exercise.

3.3 WATER AVAILABILITY

Water availability data were collected from the 10 sampled local government areas of Ekiti State. Respondents were to report water availability or non-availability. The collected data were subjected to statistical analysis using MS Excel to determine the mean, standard deviation and variance of the number of respondents that indicated water availability and non-availability. The cumulative of the number of respondents that supported water availability and non-availability were determined.

3.4 ACCESS TO SAFE WATER

This component of the water poverty index estimates the number of respondents that have access to safe water and those that cannot access safe water. Percentage of households in the sampled local government areas with access to water source that are protected was also estimated. In this contest, protected water simply means supplied that were made to prevent pollution of water by animal and other contaminants. These data were obtained from the household survey.

Water supply through pipe-borne water system and boreholes were considered safe while those from streams, brooks, lakes and shallow wells were considered unsafe water.

3.5 TIME TAKEN TO ACCESS SAFE WATER

Time taken to access safe water includes the time taken to get to the source of water supply and queuing. This component was estimated using two types of data:

i) Households with pipe-borne water supply were assumed to spend a nominal 2 minutes to collect water; and

ii) For households without pipe-borne water supply, the average of the total time spent to access water was estimated by multiplying together the average time spent in each trip by an individual of the household with the total number of people from each household that fetches water during the day.

3.6 WATER POVERTY INDEX (WPI)

Two methods were adopted in the estimation of water poverty index of the sampled local government areas. They are the Conventional Composite Index Approach and the Time Analysis Approach. The method of WPI estimation from the two approaches are discussed below:

3.6.1 Conventional Composite Index Approach

The conventional composite index approach was constructed from a series of variables which capture the essence of what is being measured. This was carried out at a local level, using locally determined values and parameters. The various components of the WPI using the composite index approach include:

i) Water availability

ii) Access to safe water

iii) Clean sanitation, and

iv) Time taken to collect domestic water

The water poverty index WPI using the composite index approach was estimated from the following relationship.

$$WPI = w_a A + w_s S + w_t (100-T) \qquad 3.1$$

Where,

- A = adjusted water availability expressed as percentage. This was calculated on the basis of ground and surface water availability related to ecological water requirement and basic human requirements, plus all other domestic demand, as well as the demand from agriculture and industry. The value of A is dependent on the seasonal variability of water availability.
- S = the population with access to safe water and sanitation expressed as percentage;
- T = the index (e.g. between 0 and 100) to represent time and effort taken to collect water, for the household (for example, from the proportion of population that have access to water at home or near the home). (100 – T) is the structure used to take account of the negative relationship between the time taken to get water and the final level of the WPI;

- W_a, w_s and wt are the weights given to each component of the index so that $w_a + w_s + w_t = 1$. Since A, S and T are all defined to be between 1 and 100, and w_a, w_s, and w_t are between 0 and 1, to produce a WPI value of between 0 and 100. The formula was therefore modified as follows:

$$WPI = 1/3 (w_a A + w_s S + w_t (100 - T) \quad 3.2$$

The weight w_a, w_s and w_t attached to the composite index method in this research are 0.5, 0.25 and 0.25, respectively following the method of Sullivan et al., (2002). These coefficients were multiplied with parameters A, S and T as indicated in equation 3.2 and WPI computed.

3.6.2 Time Analysis Approach

The WPI was calculated using household data from the survey carried out in 10 local government areas of Ekiti State.

The following data were computed from the survey:

- Time (minutes) taken to collect water from the main source, including the queuing time in the wet and dry seasons;
- Volume of water (litres) collected in each trip respectively by women, men and children in the household;
- Number of women, men and children gathering water respectively in trips one, two and three or more of the day.

All the above were used to estimate:

i) The total time spent by a household collecting water in a day; and

ii) The total volume of water available for a household in a day.

The time spent by the household in a day to collect water was calculated by multiplying time spent per person collecting water by the total number of people collecting water in all trips.

The total volume of water was obtained by summing together the total amount of water fetched by women, men and children. The total amount of water fetched by women was estimated by multiplying the volume of water collected in each trip by the total number of women carrying water in a day. The same procedure was adopted for men and children.

Also, the time spent by households with pipe-borne water supply was estimated. It was assumed that the average time spent per head collecting water is 2 minutes and the volume of water per head per day was provided by the local water authorities. For the households with pipe-borne water supply, the total time and volume of water were not calculated as these were assumed the same across the members of the household.

The index of water poverty was estimated under the Time Analysis Approach as follows:

$$WPI = \frac{T}{V}\left(ml^{-1}\right) \qquad 3.3$$

Where:

T is the total time in (minutes) spent per household in a day to collect volume V of water in (litres). The more time a household spends in collecting a given volume of water, the higher the opportunity cost.

The time-volume index (minutes/litre) was calculated simply by dividing the total time (minutes/day) by the total volume of water (litres/day). This index tells how many minutes a household has spent collecting each litre of water. The higher the index, the worse off is the household.

3.7 STATISTICAL ANALYSIS

Data collected from the questionnaires were tabulated and analyzed statistically to find the means, standard deviation, variance and skewness of the collected data. Also, analysis of variance (ANOVA) was carried out to determine the level of significant difference in the time spent in getting water and the access to safe water in the sampled local government areas. Comparative analysis was also carried out on two approaches to determine which of the method is most suitable for the local government areas under consideration.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 WATER AVAILABILITY, ACCESSIBILITY AND TIME TAKEN TO ACCESS SAFE WATER

4.1.1 Water Availability

Table 4.1: Water Availability in Sampled Local Government Areas

Local Government	Number of Respondents (%)	
	Available	Not Available
Irepodun/Ifelodun	72	28
Ido-Osi	60	40
Ekiti South-West	65	35
Ise-Orun	69	31
Ado	60	40
Moba	70	30
Ikole	62	38
Ikere	55	45
Oye	70	30
Ekiti-Ekiti	54	46
Mean	63.7	36.3
STD	±6.5	±6.5

Table 4.1 gives the statistical representation of water availability, in percentage obtained from the distributed questionnaires to sampled local government areas. High water availability was observed in Irepodun/Ifelodun, Moba, and Oye local government areas since over 70% of the respondents claim water availability. However, Ikere and Ekiti-East local

government areas suffer the lowest water availability considering the 55 and 54 percent of the respondents that indicated water availability. Ado-Ekiti, the capital city of Ekiti state is only a little above average in terms of water availability with only 60% of the respondents that claimed water availability.

The cumulative statistics of water availability and non-availability across the local government areas considered is presented in Figure 4.1. The cumulative of respondents that enjoy water availability from the local government areas is higher than the cumulative of respondents without water availability.

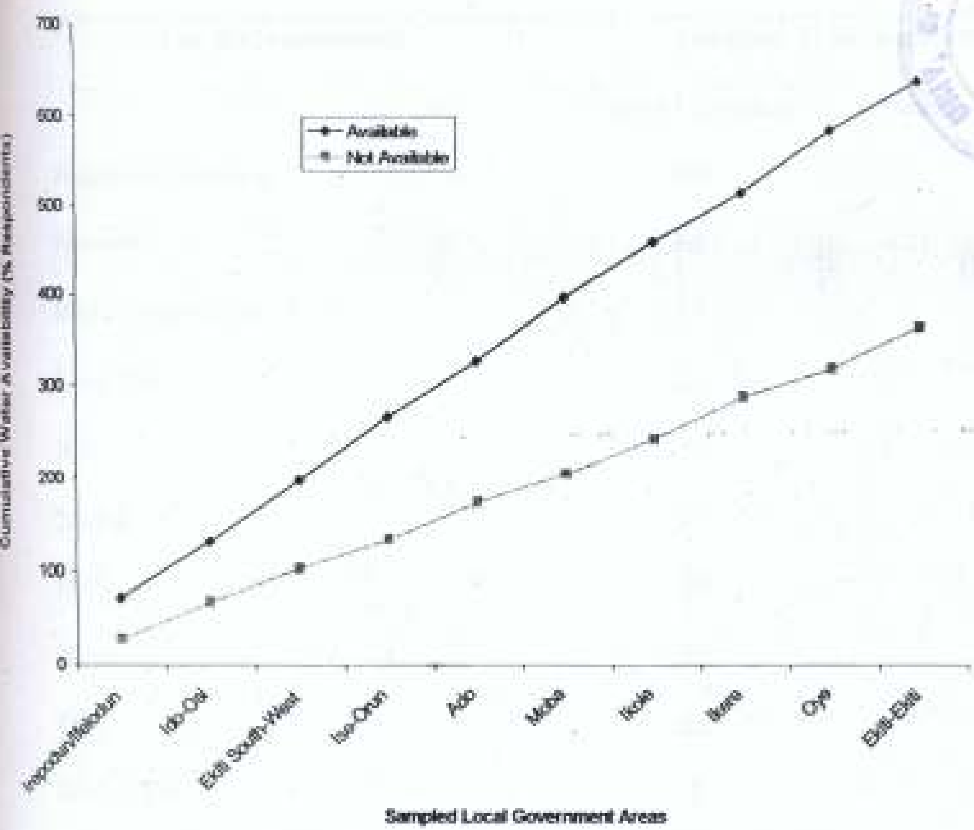

Figure 4.1: Cumulative Statistics of Water Availability from Sampled Local Government Areas

4.1.2 Accessibility to Safe Water

The result obtained from the respondents on accessibility to safe water from the research locations is presented in Table 4.2. Despite the abundant water availability in the sampled local government areas, accessibility to safe water was considerably low. Water supply through pipe borne water system and boreholes were considered safe and respondents that indicated such sources are considered to have access to safe water while water supply from streams, brooks, lakes, shallow wells and springs were considered unsafe water and respondents that indicated such sources were considered to have no access to safe water.

Table 4.2: Accessibility to Safe Water in Sampled Local Government Areas

Local Government	Number of Respondents (%)	
	Access safe water	Cannot access safe water
Irepodun/Ifelodun	48	52
Ido-Osi	66	34
Ekiti South-West	37	63
Ise-Orun	22	78
Ado	56	44
Moba	66	34
Ikole	40	60
Ikere	52	49
Oye	63	37
Ekiti-Ekiti	8	92
Mean	45.8	54.2
STD	±19.6	±19.5
Variance	383.3	383.3
Skewness	–0.9	0.9

Accessibility to safe water is least in Ekiti East, Ise-Orun, Ekiti South-West and Ikole local government areas. The problem of accessibility to safe water were significantly high in all the sampled local government areas but Ekiti East is at the extreme as 92% of the respondents indicated no access to safe water. The means of respondents that signified access to safe water and no access to safe water are 45.8% ($\pm$19.6) and 54.2% ($\pm$19.5), respectively. However, inhabitants of Ido-Osi, Ado, Moba and Oye Ekiti relatively enjoy better accessibility to safe water as 66, 56, 66 and 63% respectively, of the respondents from these local government areas indicated good access to safe water.

The cumulative statistics of accessibility to safe water across the various local government areas sampled is presented in Figure 4.2. The plot showed an upward rise in cumulative accessibility and none accessibility to safe water from the sampled local government areas with Ekiti East being worst hit.

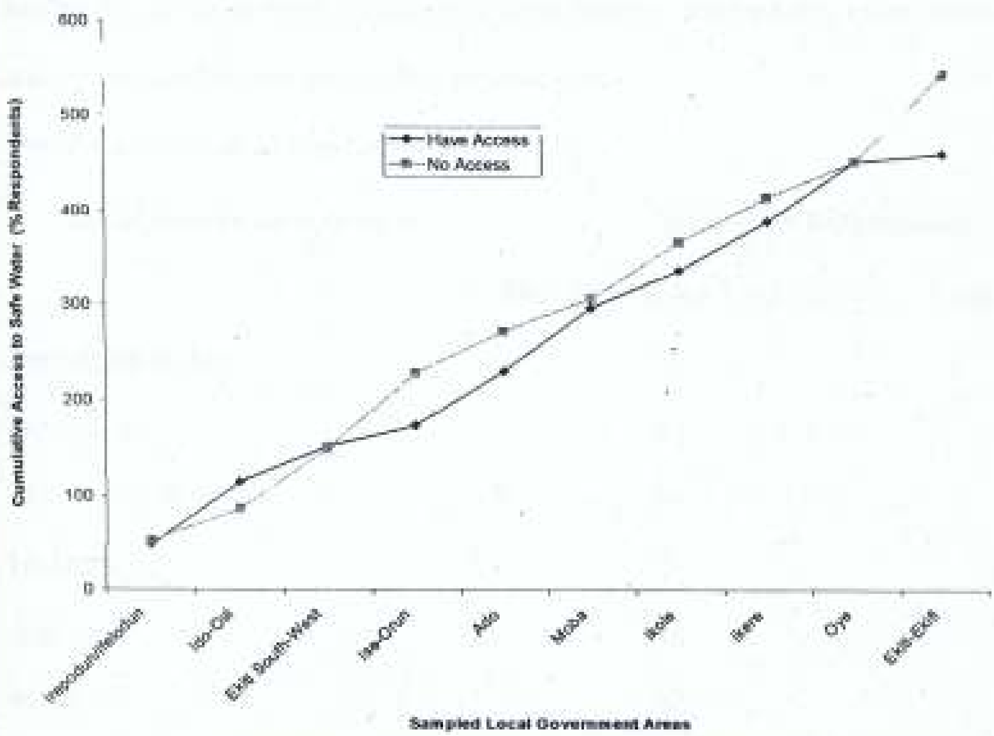

Figure 4.2: Cumulative Statistics of Accessibility to Safe Water

4.1.3 Time to Access Water

Table 4.3 shows the percentage of the respondents that indicated shortest and longest possible time to access water from the various sources. Shortest possible time is only applicable to those respondents that have pipe borne water in their domain and it has been assumed that they spend approximately 2 minutes to access water. Though, water availability is on the high side in Oye local government area, it takes longer time to access water as only 15% of the respondents admitted that it takes short time to access water. In Oye local government area, municipal water supply is local at some distances away from many homes that access it and in most cases, lots of the inhabitants have to queue up to access this important natural resource. Ekiti East local government area is predominantly poor in terms of accessibility to safe water and time taken to access water. Water supply from Ekiti East is mostly from streams, brooks and shallow wells located some distances away from residential houses. On the other hand, Irepodun/Ifelodun local government area enjoys water availability and access water within the shortest possible time.

Table 4.3: Time to Access Safe Water

Local Government Area	Number of Respondents	
	Shortest Possible Time (%)	Long time (%)
Irepodun/Ifelodun	32	68
Ido-Osi	30	70
Ekiti South-West	54	46
Ise-Orun	26	74
Ado	48	52
Moba	44	56
Ikole	35	65

Ikere	36	64
Oye	15	85
Ekiti-Ekiti	6	94
Mean	32.6	67.4
STD	18.4	18.4
Variance	337.1	417.7
Skewness	0.03	–0.5

The cumulative statistics of time taken to access water in the various local government in shown in Figure 4.3. Statistical analysis of the time spent in getting water in all the sampled local government areas showed that the least variance (8.0) between the number of respondents that fetch water in the shortest possible time and those that spent longer time to access water occurred in Moba local government area. The highest variance (3872) was observed in Ekiti East local government area.

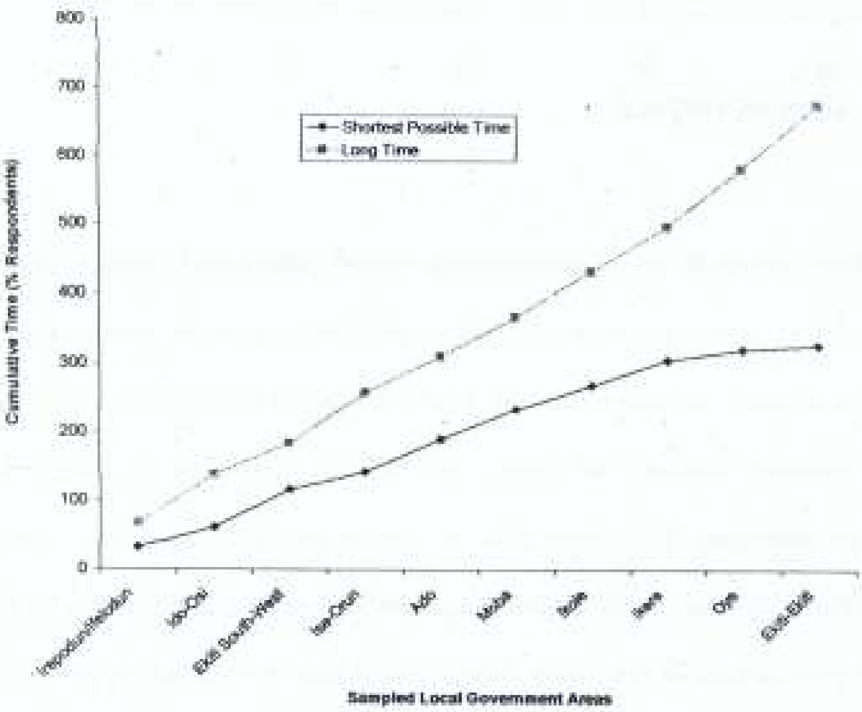

Figure 4.3: Time to Access Water in the Sampled Local Government Area

Normal probability plot of the number of respondents that access water within the shortest possible time is shown in Figure 4.4. The plot showed a high correlation value (0.98) between the percentage respondent that indicate shortest possible time and the sample percentile.

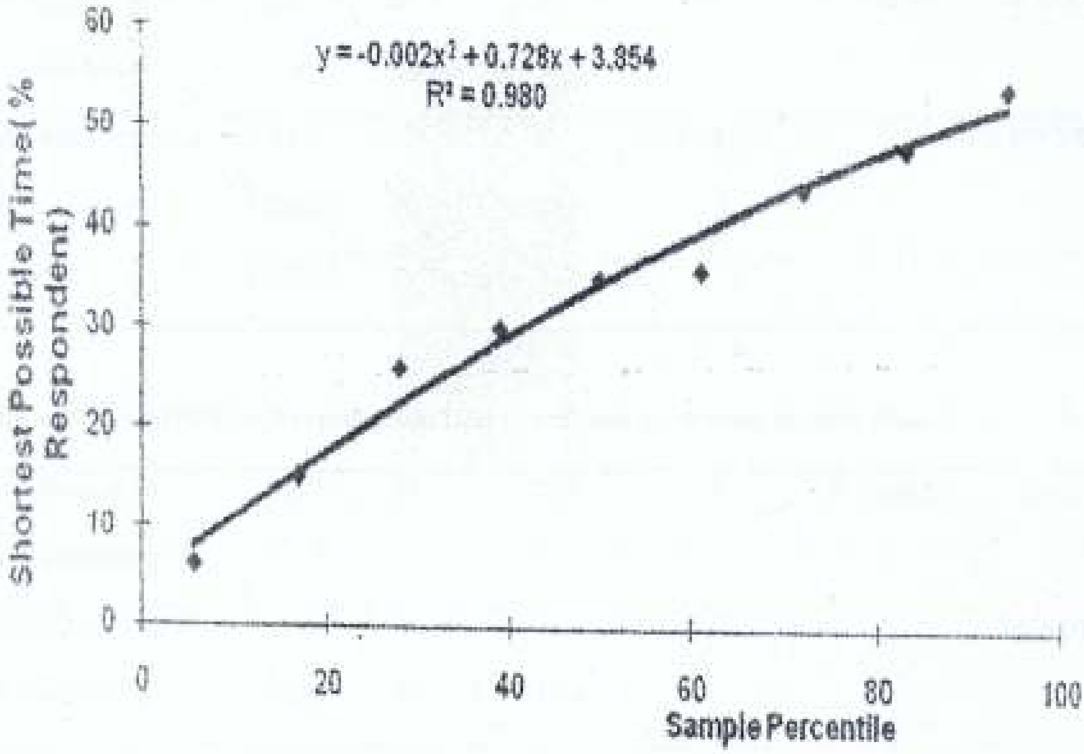

Figure 4.4: Normal Probability Plot of Respondents under Shortest Possible Time

Analysis of variance (ANOVA) of the time spent in getting water showed that the difference between respondents that access water at the shortest possible time and at a long time is significant at P(0.05((Table 4.4). Also, the variance between the number of respondents that have/have not access to safe water and sanitations is least (8.00) in Irepodun/Ifelodun local government area and analysis of variance shows that the difference between the respondents that have access to safe water and those that have no access to safe is highly significant at 5% level (Table 4.5).

The three parameters (water availability, accessibility to safe water and time taken to get water) have been used as a framework for estimating indicators of sustainable water supply (Simon, 1999), and as a measure of poverty (Gills et al., 1987).

Table 4.4: ANOVA of the Time Spent in Getting Water

Source of Variance	SS	df	MS	F	P – value	F crit
Between Groups	45	9	5	0.004861	1	3.020383
Within Groups	10286	10	1028.6			
Total	10331	19				

Table 4.5: ANOVA of Respondents that have/have no Access to Safe Water

Source of Variance	SS	df	MS	F	P – value	F crit
Between Groups	0	9	0	0	1	3.020383
Within Groups	7174	10	717.4			
Total	7174	19				

4.2 WATER POVERTY INDEX (WPI) USING THE COMPOSITE INDEX APPROACH

Results of water poverty index using the composite index approach is shown in Table 4.6. Among all the local government areas sampled, Moba has the highest water poverty index of 20.83 (index point) which is an indication that Moba community experiences the lowest degree of water stress. Ekiti East local government which has the least water poverty index of 10.17 (index point) experiences the highest degree of water poverty when compared with all other local government sampled. It was also observed that some local government like Oye, Ikole and Ise-Orun though experience water stress but not as intense comparatively with that of Ekiti East local government which has the lowest water poverty index (10.17).

Table 4.6: WPI Using the Composite Index Approach

Local Govt. Area	Water Availability	Access to Safe Water	Index of Time Spent in water Collection	WPI
Weight	0.5	0.25	0.25	
Irepodun/Ifelodun	72	48	68	18.7
Ido-Osi	60	66	70	18.0
Ekiti South-West	65	37	46	18.4
Ise-Orun	69	22	74	15.5
Ado	60	56	52	18.7
Moba	70	66	56	20.8
Ikole	62	40	65	16.6
Ikere	55	52	64	16.5
Oye	70	63	85	18.2
Ekiti East	54	8	94	10.2

In the composite method, the higher the value of WPI, the lower the degree of water stress.

Moba, Irepodun/Ifelodun and Ado local government ranked highest in WPI among the local government areas sampled and therefore enjoys accessibility to safe water without much time waste. Ido-Osi, Ekiti South-West and Oye local government areas closely follow in the WPI ranking. However, water stress is felt mostly in Ekiti East, Ise-Orun, Ikole and

Ikere local government areas. The mean WPI of the sampled local government areas is 17.16 (±2.85) under a standard error of 0.9 and sample variance of 8.14.

4.3 WATER POVERTY INDEX FROM THE TIME ANALYSIS APPROACH

The result of water poverty index from the time analysis approach is presented in Table 4.7. Ekiti East local government area among all the sampled local government areas has the highest water poverty index of $0.6ml^{-1}$ and hence experiences the highest water stress. The water poverty index of Ekiti East is almost twice the values of WPI in Irepodun/Ifelodun, Ado, Moba and Oye Ekiti local government areas. Ido-Osi local government areas as least affected by water poverty, the water poverty index being very low ($0.17ml^{-1}$).

Table 4.7: WPI Using the Time Analysis Approach

Local Govt. Area	Time taken to Access Water	Total Volume (Litres/Head/Day)	WPI
Irepodun/Ifelodun	50	150	0.33
Ido-Osi	35	200	0.17
Ekiti South-West	72	125	0.57
Ise-Orun	90	180	0.50
Ado	40	125	0.32
Moba	40	120	0.33
Ikole	55	125	0.44
Ikere	72	150	0.48
Oye	65	200	0.32
Ekiti East	90	150	0.60

The two approaches predicted well the water poverty levels of the considered local government areas. The composite and time analysis approaches predicted Ekiti East local government area as the worst in terms of water poverty. Irepodun/Ifelodun, Ido-Osi and Moba local communities were predicted by the two approaches stand to be fair comparatively with other local government areas considered. Correlation analysis carried out on the two approaches shows a slightly high correlation (r = 0.63) at P = 0.05. The coefficients allocated to each of the parameters used in the composite approach may probably have resulted into undesirable variations in the WPI and therefore may requires some adjustment to facilitate a better correlation between the two approaches.

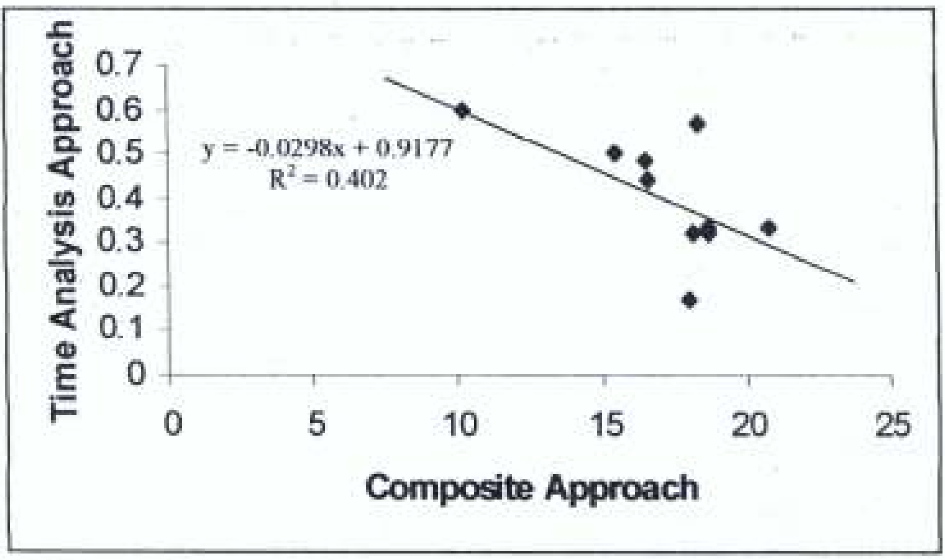

Figure 4.5: Correlation between Composite and Time Analysis Approaches for WPI determination

However, considering the ease of computation and ease of interpretation of data, the time analysis approach is preferably better. The time analysis approach considered the time to access water as one of the most important factor that determines the water poverty level of the communities under consideration.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The importance of water in the daily activities of man cannot be over-emphasized. Hence, the determination of the variability in availability of this important natural resource is paramount to improve living standard and the economic growth of any society. The study was aimed at determining water availability, accessibility to water and the time taken to access water in some selected local government areas of Ekiti State.

Based on the result obtained, the following conclusions can be drawn:

i) Sufficient water was available for the inhabitants of the visited local government areas during the period of the study;

ii) Despite the appreciable quantum of water that were scattered around local governments like Ise-Orun, Oye and Ekiti, time taken to access safe water supply is very high;

iii) Ekiti South-West, Ise-Osun, Ikole and Ekiti East among the local government areas sampled were characterized by poor accessibility to safe water supply;

iv) Ekiti East was most disadvantaged in terms of portable water supply and timelines to access safe water and therefore suffers the highest water poverty;

v) The composite and time analysis approaches are both suitable for the estimation of water poverty as the two approaches showed a reasonable goodness of fit ($r = 0.63$) in the predicted water poverty index; and

vi) The time analysis approach is mostly appropriate for the study are as it takes into consideration the total time spent to access safe water supply.

5.2 RECOMMENDATIONS

From the findings and results of this study, the following recommendations are suggested:

i) There is urgent need for government and non government organizations (NGO) to put efforts together at minimizing the very deplorable water situation of some of the local government areas visited;

ii) Direct sinking of boreholes should be encouraged especially in the rural areas of the sampled local government. The boreholes should be located at short distances and close to the residence of the communities;

iii) Although re-orientation should be carried out to discourage the inhabitants of rural areas from indiscriminate consumption of water obtained from streams, lakes and brooks;

iii) To encourage economic development and better standard of living, there is the need for government and other private bodies to locate very good water sources. This will alleviate the hardship people pass through especially during the dry season and as well encourage irrigation agriculture and fish farming all year round.

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APPENDIX 1: QUESTIONNAIRE

WATER POVERTY INDEX IN EKITI STATE

Information to be collected from household respondent

Note: Information and data collected from this questionnaire are strictly for academic purpose and not for the distribution of amenities or any political purpose.

GENERAL INFORMATION

Name of Respondent: ……………………………… Position in household…………………

City/Village: ……………………… Local Govt………………………….State……………

Gender of Adult respondent who gather water

Male [ ] Female [ ]

1) How many adults and children normally live in your household?

Adult [ ] Children [ ]

2) What is your source of gathered water for your household in the DRY SEASON?

(a) Pipe (Private) [ ] (b) Pipe (Public) [ ] (c) Borehole (Private) [ ]

(d) Borehole (Public) [ ] (e) Well (Public) [ ] (f) Well (Private) [ ]

(g) Natural Pond [ ] (h) Spring [ ] (i) Stream [ ]

(j) River [ ] (k) Water truck [ ] (l) Water vendor [ ]

3) If you pay for water from your main source, do you feel it is affordable for your household? Yes [ ] No [ ]

4) How long (in minutes) does it usually takes to collect water from your main source, during a single trip including queuing time, during the dry season? [ ]

5) What is the quality of water you gather from your main source in dry season?

Good	Fair	Poor

6) How reliable is your main water supply in the dry season?

Very reliable	
Reliable	
Not reliable	
Sometimes dries up completely	

7) How many adult in your household have matriculated from school [ ]

8) Are you aware of the presence of a formal water user association/committee in your community?

9) Are you aware of organizations outside your community responsible for water supply? Yes [ ] No [ ]

10) Has any member of your household participated in water use and/or hygiene related training programme? Yes [ ] No [ ]

11) How many times over the last year, has anyone in household had diarrhea or been ill due to contaminated water? Many times [ ] Occasionally [ ] Never [ ]

12) How many of the following durable products are used in your household? (Give number of each)

Bicycle [ ] Motor Vehicle [ ] Washing Machine [ ] Cooker [ ]

Television [ ] Radio [ ] Electric Fan [ ] Fridge [ ]

Power Supply [ ] Gardening Tools [ ]

APPENDIX 2

CALCULATION OF WATER POVERTY INDEX USING TIME ANALYSIS APPROACH

Water Poverty Index WPI $= ⅓ [(W_aA + W_sS + W_t (100 – T)]$

Where A = Adjusted water availability (%)

S = Population with access to safe water

T = Index to represent time taken to collect water

The percentage of respondent that indicate longest possible time

$W_a = 0.5$, $W_s = 0.5$ $W_t = 0.25$

1) Irepodun/Ifelodun

A = 72, S = 48 T = 68

WPI = ⅓ [(0.5 x 72 x (0.25 x 48) + 0.5 (100 – 68)]

= ⅓ (36 + 12 + 8)

= ⅓ (56)

= 18.67 (Index Point)

2) Ido-Osi

A = 60, S = 66 T = 70

WPI = ⅓ [(0.5 x 60 + (0.25 x 66) + 0.25 (100 – 70)]

= ⅓ (30 + 16.2 + 7.5)

= ⅓ (54)

= 18.00 (Index Point)

3) Ekiti – South West

A = 65, S = 37 T = 46

WPI = ⅓ [(0.5 x 65 + (0.25 x 37) + 0.25 (100 – 46)]

= ⅓ (32.5 + 9.25 + 13.5)

$= ⅓ (55.25)$

$= 18.42$ (Index Point)

4) Ise-Orun

A $= 69$, S $= 22$ T $= 74$

WPI $=$ $⅓ [(0.5 \times 69 + (0.25 \times 22) + 0.25 (100 - 74)]$

$= ⅓ (34.5 + 5.5 + 6.5)$

$= ⅓ (46.5)$

$= 15.5$ (Index Point)

5) Ado

A $= 60$, S $= 56$ T $= 52$

WPI $=$ $⅓ [(0.5 \times 60 + (0.25 \times 56) + 0.25 (100 - 52)]$

$= ⅓ (30 + 14 + 12)$

$= ⅓ (56)$

$= 18.67$ (Index Point)

6) Moba

A $= 70$, S $= 66$ T $= 56$

WPI $=$ $⅓ [(0.5 \times 70 + (0.25 \times 66) + 0.25 (100 - 56)]$

$= ⅓ (35 + 16.5 + 11)$

$= ⅓ (62.5)$

$= 20.83$ (Index Point)

7) Ikole

A $= 62$, S $= 40$ T $= 65$

WPI $=$ $⅓ [(0.5 \times 62 + (0.25 \times 40) + 0.25 (100 - 65)]$

$= ⅓ (31 + 10 + 8.75)$

$= ⅓ (49.75)$

= 16.58 (Index Point)

8) Ikere Local Government

A = 55, S = 52 T = 64

WPI = ⅓ [(0.5 x 55 + (0.25 x 52) + 0.25 (100 – 64)]

= ⅓ (27.5 + 13 + 9)

= ⅓ (49.5)

= 16.5 (Index Point)

9) Oye

A = 70, S = 63 T = 85

WPI = ⅓ [(0.5 x 63 + (0.25 x 63) + 0.25 (100 – 85)]

= ⅓ (35 + 15.75 + 3.75)

= ⅓ (54.5)

= 18.17 (Index Point)

10) Ekiti East

A = 54, S = 8 T = 94

WPI = ⅓ [(0.5 x 54 + (0.25 x 8) + 0.25 (100 – 94)]

= ⅓ (27 + 2 + 1.5)

= ⅓ (30.5)

= 10.17 (Index Point)

APPENDIX 3

CALCULATION OF WATER POVERTY INDEX USING TIME ANALYSIS APPROACH

WPI $= {}^{T}/_{V}$ (ml^{-1})

Where WPI = Water Poverty Index

T = Total time (minutes) spent per households in a day to collect water

V = Volume of water (litres)

1) Irepodun/Ifolodun

T = 50mins, V = 150litres

WPI = ${}^{T}/_{V} = {}^{50}/_{150} = 0.33ml^{-1}$

2) Ido-Osi

T = 35mins, V = 200litres

WPI = ${}^{T}/_{V} = {}^{35}/_{250} = 0.17ml^{-1}$

3) Ekiti – South West

T = 27mins, V = 125litres

WPI = ${}^{T}/_{V} = {}^{75}/_{125} = 0.57ml^{-1}$

4) Ise-Orun

T = 90mins, V = 180litres

WPI = ${}^{T}/_{V} = {}^{90}/_{180} = 0.50ml^{-1}$

5) Ado

T = 40mins, V = 125litres

WPI = ${}^{T}/_{V} = {}^{40}/_{125} = 0.32ml^{-1}$

6) Moba

T = 40mins, V = 120litres

WPI = ${}^{T}/_{V} = {}^{40}/_{120} = 0.33ml^{-1}$

7) Ikole

T = 55mins, V = 125litres

WPI = $^{T}/_{V} = ^{55}/_{125} = 0.44ml^{-1}$

8) Ikere Local Government

T = 72mins, V = 150litres

WPI = $^{T}/_{V} = ^{72}/_{150} = 0.48ml^{-1}$

9) Oye Local Government

T = 65mins, V = 200litres

WPI = $^{T}/_{V} = ^{65}/_{200} = 0.32ml^{-1}$

10) Ekiti East Local Government

T = 90mins, V = 150litres

WPI = $^{T}/_{V} = ^{90}/_{150} = 0.60ml^{-1}$