AN ASSESSMENT OF SOIL FERTILITY STATUS IN SOME PART OF TOMAS IRRIGATION SITE, KANO

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DECLARATION

I hereby declare that this thesis was written by me and it is a record of my own research. It has not been presented before in any previous undertaking for a higher degree. References made to published literature have been duly acknowledge.

CERTIFICATION

This is to certify that this work has been undertaken by Abdullahi Idris SPS/11/MGE/00016 in the Department of Geography, Bayero University Kano.

APPROVAL

This is to certify that this work has been examined and approved by the Department of Geography, Bayero University Kano.

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DEDICATION

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ABSTRACT

This study assesses nutrient status in some parts of Tomas Irrigation Project, in Kano. The project has been in operation since 1976 about thirty-nine years. Three soil types were identified based on their morphology and selected for the collection of samples; these are Ballauda, Ladi and Tomas. Thirty composite samples were systematically collected from the top (0-30cm) in the sites. Thus, Ballauda, Ladi and Tomas soil types were having 4, 10 and 16 samples respectively. The samples were analyzed for some soil fertility index parameters using the standard routine laboratory tests. In addition, mean values of the soil properties were compared using the Fisher's least significant difference as well as employing critical limits for interpreting levels of soil fertility. The findings indicate high values in Nitrogen (N), Phosphorus (P) and Exchangeable bases like Calcium (Ca), Potassium (K) and Sodium (Na) and these were found to be statistically the same in the three soil units under investigation. Meanwhile a 34% increase in the mean EC values was recorded when compared to Daniel (1985) observations. However, decreases were equally observed in the values of Organic Carbon (O.C), and Cation Exchange Capacity (CEC) and Magnesium (Mg). The increases in these soil parameters under investigations were attributed to both the use of irrigation water and the application of inorganic fertilizer. Therefore, it is recommended that organic manure use be emphasized while it is equally necessary to check and monitor this site with a view to ensuring a nutrient balance.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Global drive for sustainable agriculture involves optimizing agricultural resources to satisfy human needs and at the same time maintaining the quality of the environment and conserving natural resources (FAO, 1989). The establishment of irrigation agriculture is vital to enhance crop production to attain food sufficiency, especially in arid and semi arid regions. The success of soil management to achieve productivity and maintain soil fertility depends on the understanding of how the soil responds to agricultural use and practices (Negassa and Gebrekidan, 2004). Irrigation agriculture could have adverse effects on soil chemical properties, fertility and sustainable productivity if not well monitored. Soil fertility decline has been perceived to be widespread and very common in both rain fed and irrigated fields particularly in sub-Saharan Africa. Its decline is considered as an important cause for low productivity of many soils. It has not received the same amount of research attention as soil erosion, possibly as soil fertility decline is less visible and less spectacular, and more difficult to assess. (FAO, 1989).

In Nigeria, owing to the rapid increase in population and the realization of the need to feed the ever-increasing human and animal population, attention is now focused on the utilization of Fadama lands that was hitherto neglected. This is evidenced in the Federal Government Projects such as the National Fadama Development Project, Fadama I and Fadama II projects. The sustainable exploitation of the Fadama lands is, however, currently hindered by the lack of site-specific information on these soils (Mustapha and Loks, 2005) thereby rendering them prone to abuse and mismanagement. Consequent upon this and in order to achieve Nigeria's goal of food sufficiency through scientific agriculture, the proper understanding of soil fertility status becomes imperative. This will, among others, create an understanding of their outstanding characteristics and constraints, thus ensuring their more rational and economic utilization and guaranteeing greater productivity and sustainability (Mustapha and Fagam, 2007).

1.2 STATEMENT OF RESEARCH PROBLEM

According to Mogue (1991), irrigation allows countries to bring otherwise useless land into production, help increase yields by facilitating the introduction of more productive and high valued crops, and promotes crop intensification by reducing the fallow period and allowing farmers to grow several crops throughout the seasons.

According to FAO (2001), Nigeria is one of the countries with high declining soil fertility. The country was estimated to be losing an average of 24kg nutrients/ha per year (10kg N, 4kgP_{205}, 10kg K_{20}) in 1990 and 48kg nutrients/ha per year in 2000, that is, a loss equivalent to 100kg fertilizers/ha per year. These include fadama lands, as such, there is need for adequate and efficient soil fertility assessment that will provide reliable soil information for sustainable crop production and increase yield. The World Bank (1992) has estimated that it would take about 30 years before the full potential of the Fadama is fully realized in Nigeria.

Knowledge of the soil fertility status within a potential irrigation area is essential for economic and technical reasons. The design of the irrigation scheme itself is dependent on detailed knowledge of soils lying within the irrigable Fadama areas. Studies and information on soil fertility status of Tomas Fadama soils is scanty, therefore, this study was conducted to determine the fertility status and irrigation potentials of these soils. The results of this study will provide soil fertility information within the Fadama lands. As there was no detail investigation into the fertility of the soils of the irrigation area since the inception of the scheme in 1976. Similarly, the lack of monitoring of soils and other variables in the project area since inception and the fact that there was no proper EIA before inception. Consequently, there must have been changes in the nutrient status which need to be ascertained.

1.3 AIM AND OBJECTIVES

The aim of this study is to assess soil properties that will help to evaluate the soil fertility status under three land facets in the Tomas River Project Kano.

The objectives are:

i. To identify the different land facets and associated management practices.

ii. To determine the morphological and key physical and chemical properties of the identified land facets so as to assess their characteristics.

iii. To evaluate the fertility status of the soil units studied by use of (Yusuf, 2002) soil fertility ranking model.

iv. To make recommendations based on the findings.

1.4 JUSTIFICATION OF THE STUDY

Owing to the declining soil fertility and productivity of agricultural land has made efficient management of Nigerian soils imperative. Therefore, assessing the nutrient status of soils in the Tomas Irrigation project area will shed more light on these soils and the agricultural lands. The research findings will be useful for better planning and management of the irrigated soils in the project area than waiting to investigate serious cases of soil deterioration as it is the case in most Nigerian irrigation projects (Maurya 1982; Olofin 1983; 1984 and Essiet (1984).

However, it's noteworthy that, irrigation project is costly to initiate and to maintain. It should be sustainable in order to continue to manage the project. Therefore, understanding of the soil parameters of the study area is the major contribution of this research.

1.5 SCOPE OF THE STUDY

The Tomas Irrigation Project is estimated to be about 2,500 hectares. The upper and middle terraces which comprise of Ballauda and Ladi series covers 2000 hectares. While the Tomas series is 400 acres (160 hectares). These statistics refer to farm plots owned by the Kano State Government and do not include those of Private Ownership (KRIP Report, 2009). The Tomas irrigation site is further subdivided by virtue of its irrigation facilities into distributory canal (I, II and III), field channel and field ditches in that order. And the study covers these areas.

Soil properties are key to sustainable irrigation farming. And soil fertility index such as texture, pH, organic matter content, CEC, exchangeable bases, Available phosphorus, Nitrogen etc, are important soil chemical properties influencing nutrient availability and retention in soils. Thus these properties are expected to help in assessing the fertility status of the soils of these areas.

Ponnamperuma (1976) reported that organic matter content ranging from low to high cannot be used to make yield prediction in an irrigation project because land development will likely disturb the top soil organic matter content.

FAO (1986) found out that the value of Cation Exchange Capacity (CEC) exceeding 8/cmol kg-1 soil reflects soils that are capable of satisfactory production under irrigation.

1.6 STUDY AREA

1.6.1 Location and Extent

The study area is situated in Makoda Local Government Area of Kano State. The projects falls within Dambatta/Makoda and comprise of a total of fourteen villages. The Tomas irrigation project is owned by the Kano State Agricultural and Rural Development Authority (KNARDA).

The Tomas River is one of the three rivers (the other two are Gari and Jakara rivers), which drain and occupy about 4,921 square kilometer of the upland areas situated north and east of Kano city. The river is part of the drainage system of the Chad basin and is located in Kano –Daura road, serving as a bridge over the Tomas water flow at Galoru village.

The study area which is part of down stream of Tomas dam is located east and west of the Kano –Daura road about 56km North of Kano city, the state capital, and is between latitude 12^0 20' and 12^0 30'N and longitudes 8^0 30' and 8^0 40'E (figure 1). The area falls within Dambatta and lies within 3-6 kilometers of Dambatta town. The whole project area is estimated to be about 2,500 hectares which was put under gravity irrigation.

1.6.2 Background of Tomas Irrigation Project

The Tomas irrigation Project was commissioned in the year 1975-76 for town water supply, fisheries, recreation, navigation and wildlife (Dam data book, 1976). The design capacity of the scheme was 2500 hectares. However, the present capacity of the irrigation scheme is 620 hectares (KRIP Report, 2009). This is further divided between State Government acquisition and the other part owned by private individuals, this is to minimize cost on the project and ensure maximum returns on investments.

The Tomas river irrigation project is estimated to cost N10,610, 608 (Ten million six hundred and ten thousand six hundred and eight) as of 1976 .This includes the cost of construction of the entire canal and distributory system and all the associated works, the cost of the land development, construction of road and buildings for management and maintenance staff. Tanko (2009) carried out soils suitability classification for rice production in Tomas where an interim report was submitted in furtherance of the state government target to boost rice production.

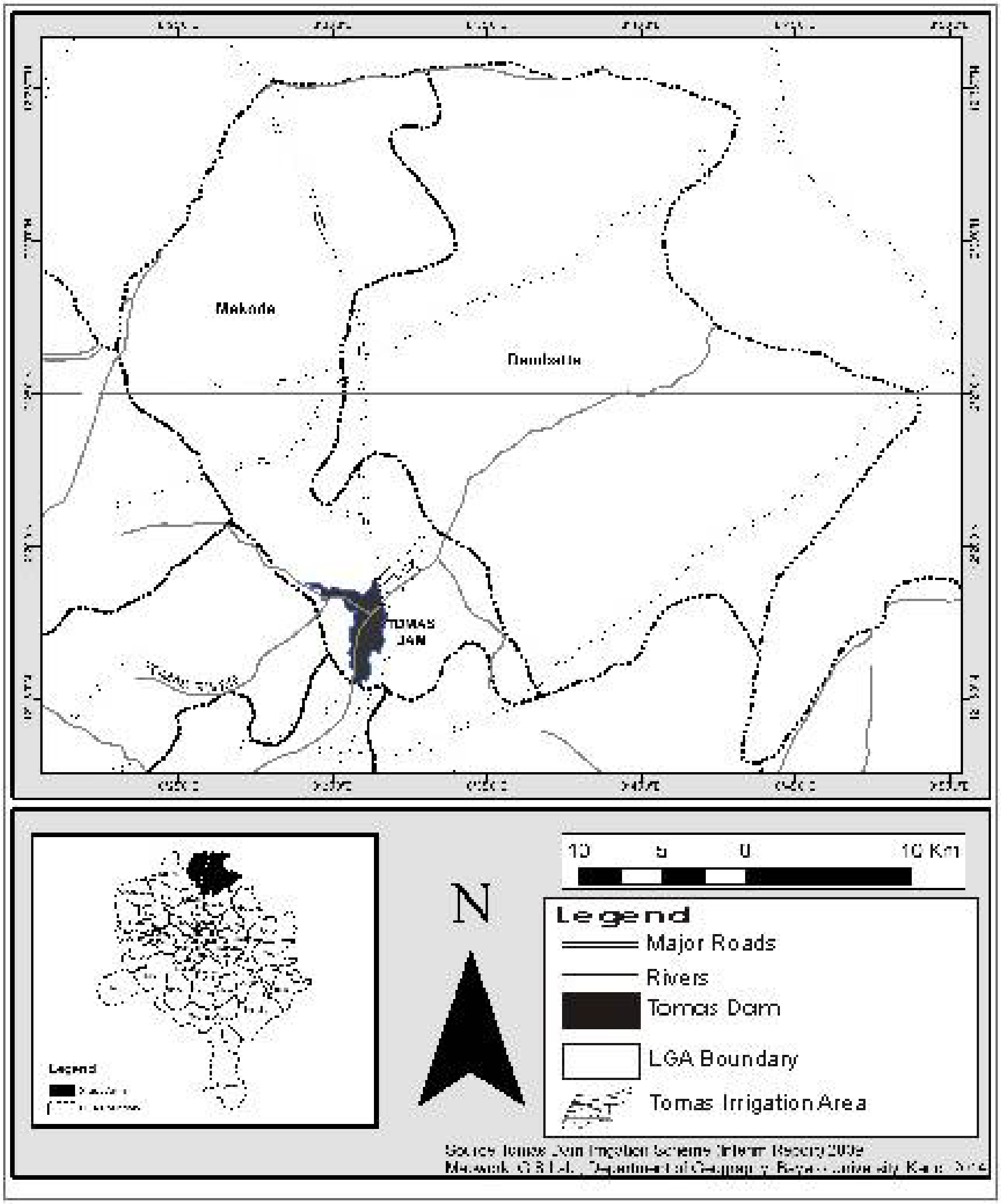

FIG. 1: TOMAS IRRIGATION DAM PROJECT

1.6.3 Vegetation

The natural Vegetation of Kano is the savanna type, typically Sudan savanna which is composed of a variety of trees scattered over a wide area of grass lands. The trees are characterized by broad canopies and rarely exceed 20m tall. The tallest grass grows not longer than 1.5m and they dry during the dry seasons (Sanchez et al. 1985).

In Tomas irrigation area, the vegetation found include *Tamarindus Indica* (Tsamiya), *Azadirachta indica* (Darbejiya) *Swietenia macrophylla* (mahogany), *diospyros mespiliformis* (Kanya), *Anogeissus leicarpus* (Marke), *Borrasus aethiopum* (Giginya) (Ahmad, 2003). Similarly, we have grasses like dumar rafi, bunsurur fagge, tumpapiya and kuduji etc. All grasses were controlled by the application of herbicides before cultivation however 'kuduji' which is a resistant grass defy herbicidal control and affects crops like guinea-corn, maiwa and pearl millet. Researches are ongoing to find solution to the problem.

1.6.4 Climate

The climate of Kano State (Dambatta inclusive) is the tropical wet and dry type denoted as Aw by koppen. The temperature is averagely warm to hot throughout the year at about 25^0C+/-7^0C (Olofin and Tanko, 2002). The monthly rainfall distribution over the Kano region is characterized by one peak (single maximum) which is usually attained in August (Buba, 2009).

In the study site, mean yearly rainfall is around 854mm which was distributed within 64 rainy days and this was concentrated in the month May-June to September-October. However, a sunshine hour for the whole season (2011) ranges between 2-12 hours (IITA, 2011).

1.6.5 Geology

Geologically, the Tomas irrigation area is composed of rocks of relative resistance to weathering. Base on the feasibility studies conducted by Haskoning Engineering Consultant (1976), it reported that, the area lies within the basement complex comprising of pre-cambrian igneous and metamorphic rocks overlain by a mantle of soils of variable thickness.

Due to the nature of the geology (Basement Complex) with sedentary or drifted materials, the area varies in terms of the amount of water that can be found both on surface and underground. The surface water is minimal because the nature of the geology permits easy percolation of water down the ground.

1.6.6 Relief and Drainage

Physiographically, Dambatta falls within the lowest relief unit of Kano and consists of plains developed essentially on igneous and metamorphic rocks known as basement complex structure (Haskoning, 1976). The surface drainage is made up of individual streams such as Gari and Tomas which drain the northeast and north of Kano eastwards. The Tomas River is part of the drainage area of the Chad basin. The Babbarruga Dam is located just upstream of the existing road and bridge, while the potential area for irrigation stretches on either bank of the Tomas River downstream of the dam.

1.6.7 Hydrology

In the basement complex area of Kano, the USDI (1968) identified two hydrological area as the upland and lowland area. The upland area comprises of river Kano, Challawa and Gaya. While the lowland comprises of River Gari, Tomas and Jakara. Runoff coefficient at the lowland is of (4.0-9.6%).The mean unit runoff is similarly lower in Gari (0.39 to $0.63 m^3 s/km^2$) than in upland ($1.45\text{-}1.77 m^3 s/Km^2$). Peak discharge is also higher in upland because of the higher rainfall and larger catchments. Peak unit runoff varied from ($0.07\text{-}0.14 m^3 s/km^2$) in the upland to (0.01-0.03 $m^3 s/km^2$) in the Gari area (Ahmed et al. 1989).

1.6.8 Soils

FAO/UNESCO genetic classification classified the soils of the basement complex part of northern Nigeria as ferruginous tropical soils. These are kaolinitic and iron dominated tropical soils. They are well matured red and brown soil of the savannah (Yusuf, 2010).

The study area is a plain of low relief with gentle undulating topography. It lies within the basement complex overlain by a mantle of soils of variable thickness. Reports on feasibility studies carried out in the area classified the soils under three different soil series, namely; Tomas, Ladi and Ballauda (Haskoning Engineering Consultants, 1976). The Tomas series are found in the lower terrace, Ladi in the transitional belt and Ballauda series in the predominantly higher terrace. Similarly, owing to the sandy nature of the soils, infiltration is high and the percentage of surface run off is of the order of 10% (Haskoning, 1976). The area does not have any ground water potential for irrigation.

1.6.9 Irrigation Farming in Tomas

The Tomas irrigation dam project has about nine interfluves named after the surrounding villages notably among which are Babbarruga, Rimi, Sabon ruwa, Maitsidau, Satame, Kwatsauri, Shiddar, Shantake, Wailare.

An area of 6000 acres is proposed to be developed along the left bank of the river through gravity irrigation. The gravity system includes a 13.9miles long main canal which supplies water directly to 22 distributaries (blocks) from three right storage reservoirs fed from the main canal which was consequently divided into DCI, DCII and DCIII. The water flow is further facilitated by the provision of field channels and ditches to the crop land (WRECA, 1976).

A semi subsistence level of farming is carried out in the study area. The dry season farming commences from September-April of each year. With crops like pepper, onions, maize, tomatoes, water melon and occasionally wheat on cultivation. However in the wet season cultivation extends from June-September except in some small depressional areas where availability of moisture during the dry month permits cultivation of crops like sugarcane and some vegetables.

However, upon completion of the dam and project, it was expected to achieve a maximum cropping intensity of 178% in wet and 78% in the dry season (Haskoning, 1976).

1.6.10 Population

The 2009 projected population figures for the study area (NPC, 2009) was 68,207. These comprises of the 14 villages surrounding the study area some of which are Wailare, Rimi, Satame, Galoru, Maitsidau, Babbarruga etc. The population of the study area is predominantly peasants farmers, mainly smallholders and petty economics activities. During the rainy season, farmers cultivate crops like millet, guinea-corn, rice, groundnut, cowpea and soybeans etc. Similarly, at the onset of dry season, the land is prepared for crops like pepper, tomatoes, rice, maize, water melon etc. Cropping potential in the various soil type is a function of soil texture, water holding capacity and residual moisture. Farmers equally engage in off-farm activities like poultry keeping, fishing, livestock rearing etc. To supplement income during lay-out period of non –agricultural activities.

1:6:11 Land Use and Management

The land of the Tomas Irrigation project belong to the Kano State Government. So allocation to farmers was irrespective of their former ownership status. And land preparation and water supply charges are according to the size of a farmers plot. A farmer may not necessarily be on the same plot year-in-year-out as allocation are subject to rotation. Land preparation is done manually and the implements used include traditional hoes and cutlasses. Farm size is on the average 264 square metres per plot. Labour is supplied by male members of the family.

The rain-fed upland area that is traditionally cultivated by the local farmers is another management system in the study area. It corresponds to the higher terrace of the physiographic units. Under this system, land preparation begins at the commencement of the rains (May-June). It is carried out with the aid of traditional implements like the hoe or in some cases tractors. However, due to the absence of grasses and shrubs, little or no clearing is carried out before tillage. Planting may be done without tilling the land, or after the ridges have been prepared. Planting is done with the aid of the long-handle hoe used for digging shallow holes in the soil.

Seeds are then dropped into these holes and covered up with soil. Crops gown are mainly sorghum, millet, groundnut and maize.

The farm plot arrangement is the basin type in all the irrigated areas. This basin type allows for water to be retained within each basin for effective infiltration and control of erosion resulting from over-flow. Also, the direction of the water-flow from one basin to another can be controlled by the farmer using a shovel to pack soil for opening or blocking the basin. Average size of the basins is 16 square meters. The basin pattern is combined with the ridge and furrow as a pattern of cultivation. Crops grown during the dry season include tomatoes, pepper, onions, water melon, pumpkin, beans, sugar-cane, maize and rice. However, a mixture of vegetable crops is being practiced. For instance, a plot might be used for pepper, onions and tomatoes or maize, tomatoes and pepper. The advantage of this crop mixture include increased returns per hectare, increased return per man-hour, a more efficient use of scarce land and a short growing season, it also ensure insurance against the failure of any one crop and the reduction in losses from diseases, insects and weeds (Jones and Wild, 1979). Fertilizers being applied include NPK at ratio of 15:15:15, Urea and Superphosphate.

CHAPTER TWO
LITERATURE REVIEW

2.1 SOILS AND LIVELIHOOD IN AFRICA

Soil are critical to agriculture and therefore to food security and livelihoods. Over the last decade, there has been growing concern about the fertility of soils and consequently the sustainability of land use. Many studies some of them very influential suggest that soils are rapidly degrading in large parts of sub-Saharan African. Sanchez et al. (1997) stated that soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capita food production in sub-Saharan Africa. Olderman et al (1991) estimated that 17% of the almost 3 million hectare of cultivated land in Africa is seriously degraded. Degradation of the other lands is certainly at stake, but not yet that visible. Soil degradation seems to be more important in the Sudano sahelian region of West Africa and in some countries in East Africa, like Ethiopia, Somalia and Kenya.

Stoorvogel and Smaling (1990) have analyzed the nutrient balances for different cropping systems in sub-Saharan Africa. The nutrient balances include, on one hand, major nutrient inflows from rainfall, organic manure, mineral fertilizers, symbiotic nitrogen fixation and sedimentation, on the other hand, nutrient outflows through harvested produce and losses due to erosion, leaching etc. They concluded that soil nutrient depletion is quite severe in sub-saharan Africa. Estimates of net losses were of the order of 10kg N, 4kg P_20_5 and 19kg K_20 ha-^{1} year-^{1}. Extrapolating these results over space and time (Sanchez et al. 1997) one can calculate that an average of 66kg N ha-^{1}, 75kg P ha-^{1} and 450kg K ha- ^{1} has been lost during the last 30 years from about 200 million ha-^{1} of cultivated land in 37 African Countries. These estimates are more or less confirmed by a similar study executed by IFDC (Baanante and Henao, 1999). In this study, they concluded that, in the semi arid, arid and sudano-sahelian areas that are more densely populated, soils lose 60-100 kg of Nitrogen, phosphorus and potassium (NPK) per hectare each year.

2.2 CONCEPT OF SOIL FERTILITY

Soil fertility has been defined by numerous authors. Soil fertility is usually seen as equivalent to the capacity of the soil to supply nutrients to the plants. Similarly, it is seen as the ability of a soil to supply essential elements for plant growth without a toxic concentration of any element (Foth, 1990). Moreso, it can also be seen as the inherent capacity of the soil to supply nutrients to plants in adequate amounts and in adequate proportions. It also refers to the amount of nutrients available to the soil and function of soil structure and porosity (Brady, 1974). Wild (1996) defined soil fertility as the capacity of soil to support crop being grown. According to Henry (1965), the fertility of the soil is the quality that enables a soil to provide the proper nutrients in proper amount, and proper balance; which enable the growth of specified plant when temperature and other factors are favourable.

Many factors are responsible for the quality of any given soil which include agro-climatic, hydrogeology and cropping/cultural practices (NASS, 1993). Although it is difficult to measure (Cannon and Winder, 2004) nevertheless it still needs to be assessed regularly because nearly all land uses depends on healthy soil functions (USDA, 2002). The necessity for regular investigation of soil in order to assess its quality is further heightened because of the simple fact that, land use and management can change the capacity of the soil to function (Karlen, 1997; USDA, 2002).

Farmers perception of soil fertility are not limited to the soils nutrient status. Fertility is assessed through outcomes such as crop performance and yield and includes all soil factors affecting plant growth. In fact, the farmers' interpretation of soil fertility reflects the definition of soil productivity used by the international soil science society (ISSS). The ISSS describes it as the capacity of a soil in its normal environment to produce a specified plant or sequence of plants under a particular system of soil management (ISSS, 1996). In their critical analysis of how farmers in different settings classify and manage soil. Talawar and Rhoades (1997) also found that farmers see soil fertility as a multi-faceted concept. It include factors such as the soils capacity for sustainable productivity, its permeability, water holding capacity, drainage, tillage and manure requirements, and how easy it is to work.

2.3 INDIGENOUS KNOWLEDGE AND SOIL FERTILITY

Expert knowledge; farmers and other users of the land have expert knowledge about their soil. Palada et al. (1987) emphasized that the indigenous agricultural knowledge systems developed by certain cultural or ethnic groups could help meet subsistence goals within our ecosystem context. This knowledge has been passed on through generation, and therefore has become refined into system which is compatible with natural resources and relevant ecological processes (Richard, 1985). Indigenous knowledge is expected to help in the design of low-cost approaches for the conservation of the environment and for the development of long-term sustainable farming system. A close integration of modern and traditional practices appears to be a more effective approach to the management of land use systems (Omotayo and Musa, 1999). Okafor (1986) suggested that the ingenuity of small-scale farmers could be capitalized upon further to introduce technical innovations into their farming system that would help ensure an adequate food supply system.

Using indigenous agricultural knowledge, development workers may become good technical consultants for participatory research and development projects and easily disseminate information and modern agricultural techniques. Integrating farmers' knowledge into project planning facilitates the generation of new technologies with a high likelihood of adoption. Comparison of the farmers knowledge with scientific information can benefit the transfer of technologies to other regions. Such knowledge needs to be recorded for offering solutions to future ecological problems which we have not had seen. The centre for indigenous knowledge resources have made efforts to gather such knowledge into a data base (Quiroz, 1996; Warren 1995) or other forms of documentation (Raji, 1991).

2.4 IRRIGATION FARMING IN SUB-SAHARAN AFRICA

Africa has vast agricultural potential. It has 23% of the world's land of which less than 25% is cultivable and not more than 5% is irrigated (Viet, et al. 1995). At least 65% of the economically active population of Africa is currently engaged in agriculture. Irrigation occupies 2-5% of the cultivable land. This has increased particularly in the Western part of the continent in the third quarter of the 20th century. However, it is observable that agricultural output per hectare is substantially higher on irrigated land than non-irrigated land. In addition, irrigation has made higher and more reliable yield possible (Worlf, 1995) as crops can be planted more than once in the tropics in a year, apart from the bigger and reliable yield as against yearly cultivation, which is often at the mercy of the seasonal rainfall as observed by the Sokoto-Rima River Basin Development Authority (SRRBDA. 1984).

According to Shanan (1987), when irrigation is introduced to a piece of land, it affects soil aeration, soil moisture, soil micro-organism, soil organic matter content, soil pH and soil texture including soil temperature. All these will invariably affect the level of exchangeable bases and extractable Copper, Iron, Manganese and Zinc in the soil. It should be noted that these soil nutrients are required for plant growth some in large quantities as the case of cations and micronutrients in small quantities.

2.5 IRRIGATION FARMING IN NIGERIA

Many studies have been carried out on various aspects of irrigation in Nigeria: Nwa (1981), Sangari (1991) examined the cost effectiveness of irrigation scheme in northern Nigeria. Olofin (1984), Olu and Yusuf (1999) studied environmental impact of Tiga and Bakolori schemes respectively. Musa (1992) did examine the changing policy horizon for irrigation in Nigeria emphasizing the institutional approach to irrigation development and operation. Daniel (1985) examined the significance of post implementation monitoring of land development projects in Tomas irrigation project in Kano State and observe the translocation of some soil nutrient elements. Jega (1987) looked at the extent of state intervention in irrigation project (Bakolori) and the change in the organization of production and social relation. Apart from the fact that these studies were carried out in the northern part of the country, none of them except Daniel looked at the soil properties and the implications on crop production particularly in sub-humid environment.

In the Tomas Irrigation sites, land facets were subdivided into three toposequence on basement complex rock and the soil-landscape was level to gently undulating with dominant slopes of 0-4 degree (Haskoning, 1976). It was found that soils along the toposequence were friable and thin and these include Ballauda, Ladi and Tomas. The Tomas series is named after the Tomas river while the Ladi and Ballauda series are named after the nearest villages to where the soil series predominates. Infiltration is high because of the soils sandy nature and percentage of surface run-off is only 10-15 (Haskoning, 1976).

2.6 IRRIGATION FARMING AND SOIL PROPERTIES

According to Stern (1979), irrigation includes any process other than natural precipitation which supplies water to crops, orchards, grass or any other cultivated plant. However, Gordon (1980) viewed irrigation as all those practices that are adopted to supply water to an area in order to reduce the length and the frequency of the period in which lacking in of soil moisture is the limiting factor to plant growth. It also serve as insurance against drought and to provide a cooling effect on the soil environment for plant growth and development, so, irrigation is aimed at improving and raising the productivity of soil resources.

The principle, according to Hudson (1975), is that the environment is characterized by fair to good soils but poor and unreliable low precipitation as it is the case in dry and semi-dry lands affects farming. Irrigation tries to meet additional water requirement of crops during the dry season. In other words, the irrigation system is aimed at increasing and improving agricultural yield, particularly in moisture-deficient environments. Rosegrant et al. (2002) report that irrigation has been a key to achieving food security in many parts of the world.

The expansion and improvement of the irrigation system over the years has been a major factor in helping global food supply to keep up with, and even surpass the global growth in population. In the 20th century, irrigated cropland expanded greatly in many parts of the world. Irrigated areas world wide doubled during the first half of the 20th century, rising to 94 million hectare in 1950. A continued growth has brought the world's total irrigation areas to about 240 million hectares. Today, at least one-third of the global harvest comes from the 16% of the world's cropland that is irrigated (Technical centre for Agriculture (CTA), 2001).

However, irrigation leads to significant changes in soil condition, some of which are long lasting and not all of which may be beneficial in agricultural terms. Briggs et al. (1993) observed that this is evident especially in semi-arid and arid regions, where water used is of poor quality. Barrow (1993), explained that irrigated soils suffers suffusion (washing out of soluble salts).

Sometimes the whole clay content is washed down the profile by irrigation, causing the soil texture to change. And this reduces its resistance to compaction and causes deterioration of crumb structure.

2.7 PRODUCTIVITY FUNCTION OF SOILS

Soils cover most land of the earth, but regarding their service for human, they are limited and largely non-renewable resource (Blum, 2006). On the globe, about 3.2 billion hectares are used as arable land, which is about a quarter of the total land area (Davis and Masten, 2003). Total agricultural land covers about 40-50% of the global land area (Smith et al., 2007).

The development and survival of civilizations has been based on the performance of soils to provide food and other essential goods for humans (Hillel, 2009). Global issues of the 21st century like food security, demand of energy and water, climate change and biodiversity are associated with the sustainable use of soils (Jones et al; 2009). Feeding about 10 billion people is one of the greatest challenges of our century. Borlaug (2007) stated: the battle to alleviate poverty and improve human health and productivity will require dynamic agricultural development.

Handling of soils by societies must be in a sustainable way in order to maintain the function of all global ecosystem (Hillel, 2009). This includes the use of soils by agriculture for high productivity (Lal, 2009 Walter and Stutzel, 2009). Soils have to provide several ecological and social function (Blum, 1993; Jones etal; 2009). Based on a definition of Blum (1993) one of the six key soil function is food and "biomass production" as a main soil function which must be maintained sustainably. He call this the "Productivity Function" the productivity function is related to the most common definition of soil quality as "the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain plant and animals productivity, maintain or enhance water and air quality and support human health and habitation (Karlen et al; 1997). Based on this definition, the objective comes close to the assessment of agricultural soil quality.

Firstly, agricultural soils have to be used sustainable to maintain their productivity potential long term. Secondly, natural soil functions (habitat, nutrient cycling, biofiltering) are not only the domain of soils in natural protected areas. Agricultural soils have to fulfill their natural functions too, e.g provide or support ecosystem services (Foley et al; 2005).Assessing the productivity function is not restricted to specific land use concepts with regards to management intensity. It embraces the capacity of soil for low input and organic farming approaches. This is hinged on the hypothesis that, a growing community of land users and stakeholders has to achieve a high productivity without any significant definite long-term impact on soils and the environment. Therefore, a standardized methodology for assessing the productivity function of the global soil resources consistently over different spatial scales will be demanded by a growing international community of land users and stakeholders for achieving high soil productivity in the context of sustainable multifunctional use of soils.

2.7.1 Soils and their Constraints to Plant Growth

Soils are components of terrestrial ecosystems. The productivity of these systems is controlled by natural factors and by human activity. Most important external natural factors are solar radiation, influencing temperature and evaporation, and/or precipitation (Lieth, 1975).

Thus, natural constraints to soil productivity can be classified into three major groups. The first group include the thermal and moisture regimes of soils. Plants require appropriate soil temperature and moisture for their growth (Murray et al, 1983; Lavalle et al; 2009). For most soils, thermal and moisture regimes are directly dependent on climatic condition. They define the frame for limitations like drought, wetness, or a too short vegetation period limiting the productivity (Fischer et al; 2002).

The second group of restrictions includes other internal soil deficiencies mainly due to an improper substratum limiting rooting and nutrition of plants. These include shallow soils, stoniness, hardpans, anaerobic horizons, or soil with adverse chemistry such as salinity, solidity, acidity, nutrient depletion or contamination which may cause severe restrictions to plant growth or the utilization of biomass (Louwagie et al; 2009).

The third groups include topography, sometimes considered as an external soil property, preventing soil erosion and providing accessibility by human and machinery (Fischer et al; 2002; Duran Zuano, 2008). Meanwhile there seems to be an interaction between natural constraints to soil productivity and societal factors.

Historically many countries with poor soils tended to be poorly developed. This has led to accelerated soil degradation. Currently, in developing countries, about two thirds of soils have severe constraints to agriculture. Their low fertility (38%), sandy or stony soil (23%), poor soil drainage (20%) and steep slopes (10%) are the main limits to productivity (Scherr, 1999).

2.8 METHODS OF SOIL FERTILITY ASSESSMENT

Traditionally, soil science has used several qualitative measures of science properties like soil colour and field texture. Soil mapping also has qualitative aspects including the delineation of mapping units.

However, qualitative approaches have greatly contributed to our knowledge on soil resources and form the base for what can be called expert knowledge system. This knowledge ensures that the merits of the farmers' indigenous soil knowledge are better integrated into agricultural development programs, since the use of the farmers soil classification in extension and on-farm research facilitate the dialogue between farmers and extensionist/researchers.

Meanwhile, the soil science literature is flooded with short-term observation, by which transient phenomena can be missed or misinterpreted (Pickett, 1991). In general, observations made over a long period allow more regions analysis. However, long-term observation also imply large time steps, it may mask what has happened during the period of observation. Therefore, the best approach is long-term monitoring with relatively short time steps (Hartemink, 2003).

Also the soil property chosen and the technique used for its analysis affects the assessment of soil fertility decline. Changes in the microbial population occur within hours or days, whereas a significant different change in CEC may require years of cultivation between the measurements.

A related problem is that some soil parameters fluctuate during the day or between season and detecting changes may therefore be confounded with the natural variability.

Also, farmers and other users of the land have expert knowledge about soils; which is loosely described as indigenous soil knowledge or ethnopedology (Barrios and Trejo, 2003; Krasilnikov and Tabor et al, 2003) indigenous soil knowledge has different characteristics from knowledge gained by the scientific study of the soil. More so, farmers empirical knowledge is not soil process or data oriented but yield or management oriented (Bouma, 1993).

Nevertheless, farmers' knowledge can be instrumental in selection of sampling sites or for additional information and various examples in literature exist where such information was used to investigate long-term changes in soil fertility.

2.9 MEASURED CHANGE IN SOIL CHEMICAL PROPERTIES

Two different approaches have been used to monitor soil chemical properties. First, soil nutrient dynamics can be monitored over time at the same site which is called chronosequential sampling (Tan, 1996) or type 1 data (Sanchez et al; 1985) changes in a soil chemical property under a particular type of land-use overtime. Usually, the original level is taken as the reference level to investigate contamination by comparing soil samples collected before the intensive cropping period with recent samples taken from the same locations (Lapenis et al. 2000). Type 1 data are useful to assess the sustainability of land management practices in the tropics (Greenland, 1994b) but few data set exist because they require long-term research commitment and detailed recordings of soil management and crop husbandry practices (Hartemink, 2003).

In the second approach to investigate changes in soil chemical properties, soil under adjacent different land use system are sampled at the same time. This is called biosequential sampling (Tan, 1996), type II data (Sanchez et al; 1985) or "Sampling from paired sites" in the soil science literature from Australia (Bramley et al; 1996; and Garside et al. 1997). It has also been named the "space-for-time" method (Pickett, 1991) and the "inferential method (Ekanade, 1988). The underlying assumption is that the soil of the cultivated and uncultivated land are the same and that differences in soil properties can be attributed to differences in land-use and management.

Obviously, this is not always the case; the uncultivated soil may have been of inferior quality and therefore not planted. Also, spatial variability may be confounded with changes over time (Sanchez et al; 1985) other confounding factors are differences in clay content, soil depth, or unknown history of land-use.

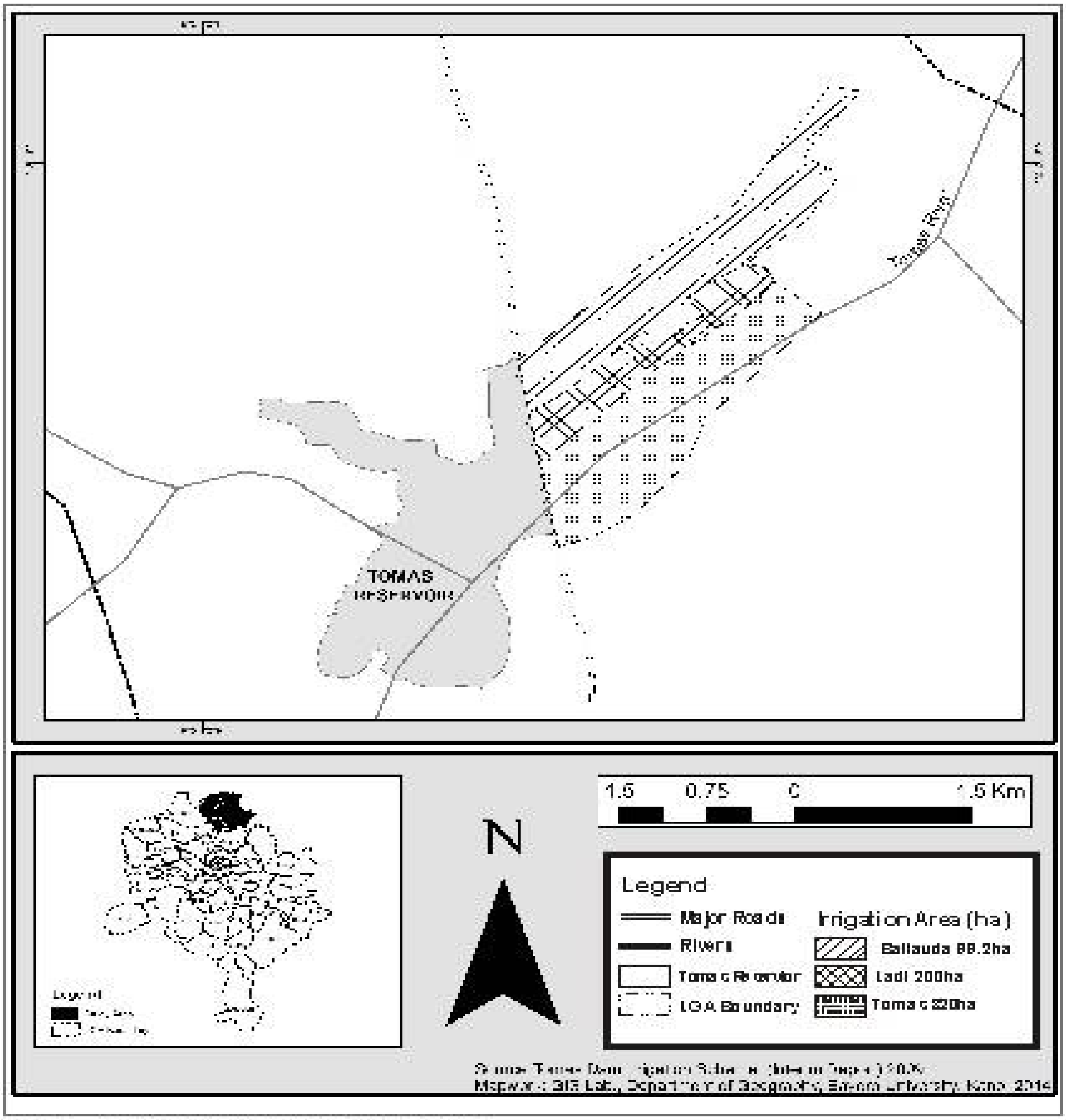

FIG. 2: IRRIGATION AREAS IN TOMAS

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 SOURCES AND TYPES OF DATA

3.1.1 Primary Source

This stage concerns (field work) i.e. the data required for the study and sources from which it will be collected. Soil samples were collected from the identified soil types in the study areas from (0-30cm) depth. Similarly a set of check list was administered to farmers on the field which was formulated in line with the research objectives.

3.1.2 Secondary Sources

The major secondary sources of data include the documented and recorded data from agencies such as Kano State Agricultural and Rural Development Authority (KNARDA) and Kano State Ministry of Water Resources. These sources were used as well as topographical maps (i.e Kano Map).

3.2 RECONNAISSANCE SURVEY AND PREPARATORY WORKS

Reconnaissance survey as a preliminary investigation was conducted by visiting the study sites. In the study sites, a field assistant was engaged so as to help to find out the total hectarage, history and irrigation channel networks (i.e. main canals, distribution canal and field channel). The soil types and their textural class including local names were sought, and the cropping potentials and regime of the identified soil types were ascertained. Similarly, cartographic work was embarked to produce base maps.

3.3 SOIL SAMPLING FRAME AND SAMPLE SIZE

The sampling was carried out based on the identified soil series as in Ballauda, Ladi and Tomas which is taken to be a soil type because of the peculiar cropping regime. However, a density of one sample per 20 hectares was actualized in each plot which measures (20 by 20 hectare). The justification for adopting this method is simply because the plots dealt with increases the precision with which estimates can be made for the area as a whole. Thus, two diagonal transect was laid out in each plot and five individual cores were collected from the edges and centres of the two transects, these gave a total of 5 cores per plot. The respective sizes of these soil types were considered in the collection of the samples (Table 1), where total area was divided by 20 hectares to be a sampling size for that soil type. Thus Ballauda, Ladi and Tomas are having 4, 10 and 16 samples respectively (Table 1).

Table 1: Number of samples per soil type

Soil type	Total area (hectares)	No. of samples
Ballauda	99.2	4
Ladi	200	10
Tomas	320	16
Total	**619.2**	**30**

3.4 SAMPLE COLLECTION

The five soil cores collected from each plot at depth (0-30cm) was bulked, mixed thoroughly from which about 1kg was collected and labelled accordingly. The same procedure was used to collect samples for the three soil types, namely: Ballauda, Ladi and Tomas.

In this study, soil samples were collected and characterized to the top 30cm, because the roots of most arable crops in the area are concentrated within this region of the soil where the bulk of plant nutrients are concentrated (Ekanade, 1994). Also, essential soil nutrients and properties that directly affect the fertility and the productivity of soils were analyzed. These include particle size distribution, exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), Soil pH, available phosphorus, cation exchange capacity, organic carbon content and Total nitrogen. These were the parameters of interest that were analyzed for this research.

3.5 FARMERS INTERVIEWS

Forty-eight copies of check list were administered to farmers in the study sites to investigate the soil type, fertility condition, cropping pattern and management. In each soil type, sixteen copies were administered to farmers. This is with respect to time and information needed to support the work. Here, the purposive sampling techniques was employed were farmers on their farmlands were interviewed. The reason for adopting this is because the study focuses on two levels of experiences. This interview was necessary to support the laboratory investigation and to examine the farmer-irrigation system. Respondents interviewed were those who own and cultivate plots in the area, and who were not below the ages of 20 years. The second set of interview was the focus group discussion which was an extensive discussion with knowledgeable farmers of 30 years and above pertaining soil type in the study site. This was done in order to get a good perspective of the past irrigation activities. This was to enhance appreciation of whatever changes could have occurred since then.

3.6 THE FOUR QUARTILE RANKING MODEL

Yusuf (2002) Soil Fertility Ranking Model was employed. It meant to ascertain the fertility of individual farmlands or land facets. This was adopted to assess which of the land facet is more fertile so as to gauge their cropping potentials.

The mean values of ten soil properties tested for the three soil types were used for this model. Each positive property is divided into four and assigned a score. This is relative to the mean values of soil properties of each soil type. A range for each property is found calculated and divided into four (Appendix 10). The upper quartile is graded as 4, next quartile 3 third quartile 2 and the last 1. This is with regard to the positive soil properties (PSP). So soil properties of every soil type are ranked within their quartiles. And this is assigned quality positions as best, good, average and poor respectively. However, with regard to the negative soil properties (NSP), the values scores are reversed making the least quartile to be graded as 4, 3, 2 and the highest quartile been 1. This also goes with properties that have optimum levels (such as pH) in this case, the optimum level is scored as 4, 3, 2 and 1 are counted from both sides of the optimum level (i.e from lower than and higher than the optimum level).

3.7 LABORATORY METHODS

The samples collected were taken to the laboratory. It was initially air-dried and passed through 2mm sieve before subjecting them to the following chemical analysis.

3.7.1 Particle Size Distribution

The hygrometer method, using the Bouycous (1962) hydrometer calibrated in g/l was used in this study because of its ease of operation and adequate result in 2 hours. With two hydrometer readings, the percentage of sand, silt and clay in a dispersed soil were determined and the textural class of soil identified.

Procedure

Exact 50g of soil sample was mixed with 100ml of sodium hexametaphosphate solution (Calgon) to facilitate dispersion. The mixture was shaken and transferred into 1000ml measuring cylinder and the cylinder content was then mixed very well by shaking and the density of the mixture was then measured within 40 seconds of mixing, using a hydrometer. The first reading which signifies silt and clay contents was recorded as R_1 g/l and temperature $T_1{}^0C$. The measuring cylinder was then left to stand for 2 hours shaken thoroughly and then the second temperature reading was also taken i.e $T_2{}^0C$. The silt and clay content were estimated by calculation using the hydrometer reading while the sand content was calculated by difference.

Calibration of the Hydrometer

The hydrometer is optimum at 19.4^0C temperature correction. For degrees below 19.4^0C 0.2 units per degree was subtracted from hydrometer reading and for degrees above 19.4^0C 0.2 units per degree was added to hydrometer reading (Jones, 2001).

Calculations for % Sand, Silt and Clay

%silt + % clay: 40 second hydrometer reading

% sand:

$$\frac{\text{Hydrometer reading (Sample - blank) + temperature correction}}{\text{Weight of soil (g)}}$$

% sand: 100 – (% silt + % clay)

% clay: 2hours hydrometer reading

$$\frac{\text{Hydrometer reading (Sample – blank) + temperature correction}}{\text{Weight of soil (g)}}$$

% silt: 100 – % sand - % clay

3.7.2 Soil pH Determination

20g of soil was weighted and 20ml of distilled water measured were put into a 50ml glass beaker i.e (1:1) soil to water ratio was used to determine the soil pH. The suspension was then allowed to stand undisturbed, using standard buffer solution of pH 7.0 and 4.0 the pH meter electrode was then fully immersed into the soil suspension and the pH value was taken within 30 seconds, after immersion.

3.7.3 Soil Electrical Conductivity (EC)

10g of soil was weighed and 50ml of distilled water i.e (1:5) soil to water ratio, were put into a 50ml glass beaker. The suspension was shaken on a shaking machine for a period of 30 minutes. The suspension was then allowed to stand undisturbed during which the electrical conductivity of the soil suspension was taken using electrical conductivity meter.

3.7.4 Organic Carbon Determination (OC)

The organic carbon was determined using the chromic acid oxidation method of walkey and Black (1934), using lg of soil which was oxidized in 250ml flask with 10ml of normal potassium dichromate solution ($NK_2\ Cr_2\ O_7$) and 20ml concentrated sulphric acid (H_2S0_4).The flask was swirled and allowed to stand for 30 minutes, after which 100ml of distilled water was added followed by 5ml of orthorphosphoric acid and few drops of diphenylamine indicator. The flask content was then titrated with 0.5N ferrous ammonium sulphate solution, until the end point sharply reached green colour. A blank determination was also carried out as outlined above except that no soil sample was added.

Calculations

Organic carbon % = (BV – SV) x 0.03 x M x F x P

Where BV = blank value

SV = sample value

0.03 = constant

M = Concentration of ferrous ammonia sulphate

Wt = weight of soil sample (lg)

P = percentage (100)

3.7.5 Total Nitrogen (N) Determination

The regular macro-Kjedahl was used to determine total nitrogen of the soil samples.

1gramme of the soil sample was mixed with 20ml concentrated sulphuric acid and tablets of copper sulphate mixed catalyst were dropped, after which the mixture was heated in a fumed cupboard, for up to 3hours or until the fume becomes whitish. 10ml of the digest was distilled in a hoskin distillation unit with 10ml of 40% sodium hydroxide (NaoH) solution. The distillate were then trapped into a flask containing 10ml of 2% boric acid and mixed indicator.

CALCULATION

$$\text{Total nitrogen\%} = \frac{0.014 \times VD \times NA \times 100\ (TV - BV)}{Wt \times AD}$$

Where BV = blank volume (blank titration value)

VD = volume digest

NA = normality of acid mixed in titration

AD = Alignot of digest distilled

TV = Titre value (Titration value of sample)

Wt = weight of sample taken

3.7.6 Available Phosphorus (P)

The available phosphorus was extracted using Bray No.1 extracted method and determined by the moly bednum blue method. 3g of the soil sample was weighted into a 100ml plastic bottle; 21ml of the extracted solution was added. The mixture was then shaken for 5 minutes on a mechanical shaker and filtered through whatman No. 42 filter paper. 5ml of the titrate was pipette into a 25ml volumetric flask followed by (5ml of molybdate solution reagent B and mixed well). The mixture was then allowed to stand for 20 minutes for colour to develop fully and the absorbance were read at 882 nm using a spectrophotometer (Model cecil 1000). Phosphorus standards of various concentrations ranging from 0.2 ppm to 1.0ppm were prepared and treated as indicated above and their various absorbance values also determined at 882nm. These were used to plot a straight – line graph from which the individual available phosphate values were extrapolated in ppm.

3.7.7 Exchangeable Bases (Ca, Mg, K and Na)

The exchangeable bases were extracted using 1N NH_4 AOC buffered at pH 7.0. About 10g of 2mm sieved soil sample was weighted into shaking bottle, and 40ml of 1N NH4 AOC was added and the sample mixture was allowed to stand over night. Then the sample was filtered using whatman No. 42. Another 40ml of 1N NH4 AOc was added and shake for 30 minutes then filtered, repeated adding another 40ml of NH_4 AOC, finally the volume is made into 150ml with NH_4 AOC. The leachate was stored for the determination of the bases Ca, Mg, K and Na were read using A.A.S at various wavelength (Model VGP 2010) buck scientific.

3.7.8 Cation Exchange Capacity

5g of oven-dry soil was weighted and placed in a plastic centrifuge tubes. 50ml of sodium acetate was added and stopped tightly and shaken for 10 minutes. The tube was then centrifuged at 2500ppm for 1 minute. The supernatant liquid was poured into a 200ml volumetric flask through a filter paper, it was treated six times in all, with approximately 180ml of extract obtained after the last treatment, the tube was completely drained into the filter paper.

Finally, the volume of the extract was made up of 200ml with ammonia acetate. The sodium was determined on the flame photometer.

3.8 DATA ANALYSES

The results obtained from laboratory were tabulated and subjected to some statistical analysis. The statistical analyses used were aimed at determining any significant difference in the soil nutrient among soil types.

Descriptive statistics like mean, standard deviation, coefficient of variation were used to test the variability of the soil nutrients and organic matter while analysis of variance (ANOVA) was employed to test for significant difference between means. Means that were significantly different were separated using the least significant difference (LSD) as provided by Fisher (1935). Similarly, frequency and percentages were employed in the computation of the result for the check list administered to the respondents in the study area.

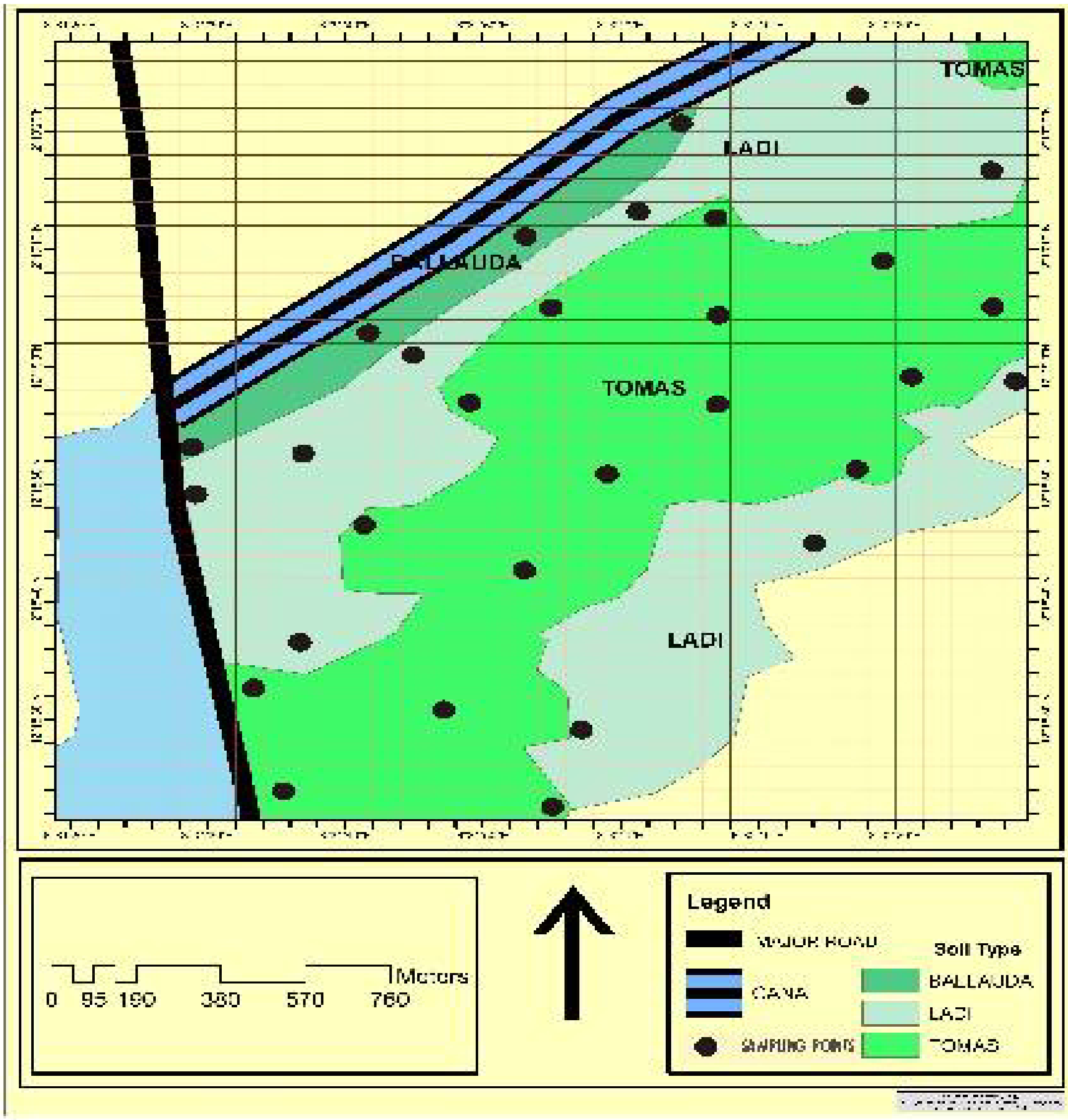

FIG. 3: LAND FACETSAND SAMPLING POINTS IN TOMAS IRRIGATION SITE

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 MORPHOLOGY OF THE LAND FACETS IN TOMAS IRRIGATION PROJECT

The study area comprises two physiographic units; a lower terrace which is the meandering flood plain (Fadama) of Tomas river, and a higher terrace above the flood plain that is Ladi and Ballauda facets (Fig 3).The results of the soil analyses are presented in terms of these facets which are briefly described below.

4.1.1 Lower terrace (Fadama)

This is the meandering flood plain which occurs on both sides of what used to be the Tomas River channel, and had been formed by the river. It stretches in a belt along both sides of the river and has many depressions .These depressions are flooded during the rainy season and wet conditions prevail for a longer part of the year. Most of this flood plain within the study area is now under gravity irrigation.

4.1.2 Transitional belt

This belt is found between the higher terrace and the lower terrace. It is generally very gently to gently sloping, it slopes towards the old river bed with slight irregular micro-relief. It is fairly wide where the area in the lower reaches of the higher terrace is very gentle sloping, while it becomes narrow at the regions of 2-5% land, and almost vanishes in the regions of 5-8% and 8-12% land.

4.1.3 Higher terrace

This is a slightly undulating plain, sloping gently towards the banks of the river bed. It extends upwards on both banks of the river bed (Fig 3). Most of the area is nearly level or very gently sloping with slightly irregular undulating areas of moderate micro-relief and this covers a considerable part of the higher terrace. The general slope of the higher terrace is towards the river. The elevation ranges from 424.3m to 409.7m above mean sea level (Haskoning, 1976).

Table 2: Particle size distributions of soils of the three land facets

Land facets	Soil property	Mean	S.D	C.V	Soil Textural Class
Ballauda	Sand%	80.62	3.28	4.07	Loamy Sand
	Clay%	9.88	3.08	31.2	
	Silt%	9.5	5.17	*54.4	
Ladi	Sand%	80.12	5.82	7.26	Loamy Sand
	Clay%	5.68	2.99	*52.6	
	Silt%	14.2	4.85	*34.2	
Tomas	Sand%	90	0.08	0.09	Sandy
	Clay%	3	1.32	*45.7	
	Silt%	7	3.2	*44	

Source: Laboratory work (2015)

C.V = Coefficient of variation * Highly Variable C.V>33% (Spiegel, 1973)

4.2 PHYSICAL PROPERTIES OF THE SOIL TYPES IN TOMAS IRRIGATION PROJECT

4.2.1 Particle Size Distribution

The particle size distribution of the three soil types is presented here. The particle size distribution provides an insight into the soil fertility condition and possibly the moisture retention ability. However two of the soil types fall within the sandy loam textural class (Table 2).

shows that sand fraction is the dominant particle size in all the soil types having mean values ranging from (80.12%) in Ladi which is the lowest to (90%) in Tomas the highest. As shown, there is little variability in the sand distribution of the study area. This may be attributed to the nature of parent material which influences soil characteristics (Beets, 1990). Similar observations were also reported by Esu (1983) who stated that Nigerian Savanna soils tend to be generally coarse textured in nature. These findings agreed with Daniel (1985) who worked on the soils of Tomas River Project Kano, where he observed an increase in coarse sand by 34.5%

The result of the clay content distribution as depicted in Table 2, shows that Ballauda, Ladi and Tomas have mean values of 9.88%, 5.68% and 3% respectively but there is high variability of clay mineral distribution in Ladi and Tomas while low variability for Ballauda soil types. This probably might be due to illuviation process (Singh, 1997) which indicates the intensity of weathering of the clay size particles. This is in agreement with reports of Wild (1996) that indicates that tropical soils have undergone intense weathering. Singh (1997) reported that clay was found to be higher in the subsoil. Similarly Essiet (1985), working on soils in irrigated field in Kano River Project, noticed decrease in clay content from 16% to 10% and silt from 13% to 10%. The decrease in clay fractions might be due to erosion caused by continuous irrigation and rainfall. In these processes, finer particles are preferentially carried away leaving behind the coarse sand particles.

The result of the silt content (Table 2), shows a mean range of 14.2% in Ladi, 9.5% in Ballauda and 7% in Tomas but there is high variability of distribution in the three soil types. These can mostly be attributed to cultivation and management or probably due to intensity of weathering of silt in the area (Essiet, 1989).

Table 3: Variability in soil properties among the three land facets

		Ballauda				Ladi				Tomas	
Soil property	**Mean**	**S.D**	**C.V**		**Mean**	**S.D**	**C.V**		**Mean**	**S.D**	**C.V**
Total Nitrogen %	**0.3**	**0**	**0**		**0.3**	**0.06**	**20**		**0.4**	**0.3**	***75**
Phosphorous PPM	**454**	**215**	***47.4**		**470**	**239**	***50.9**		**377.4**	**21.2**	**5.6**
Exchangeable K Cmol/kg	**0.3**	**0.05**	**16.7**		**0.5**	**0.2**	***40**		**0.4**	**0.2**	***50**
Exchangeable Ca Cmol/kg	**6.2**	**1.1**	**17.74**		**7.5**	**5.7**	***76**		**4.8**	**1.7**	***34.2**
Exchangeable Mg Cmol/kg	**0.1**	**0.03**	**30**		**0.06**	**0.04**	***66.7**		**0.06**	**0.03**	***50**
Exchangeable Na Cmol/kg	**2**	**0.07**	**3.5**		**2.8**	**1.2**	***42.9**		**1**	**0.3**	**29**
Electrical conductivity Ums/cm	**21**	**2.37**	**11.3**		**37.4**	**36.5**	***97.6**		**31.5**	**20.4**	***65**
Cation Exchange Capacity Cmol/kg	**4.1**	**1.38**	***34**		**3.7**	**3.2**	***86.5**		**3**	**1.31**	***44**
pH	**7**	**0.32**	**4.57**		**7.3**	**0.8**	**10.1**		**7**	**0.4**	**5.6**
Organic Carbon%	**0.2**	**0.07**	***35**		**0.5**	**0.3**	***60**		**0.3**	**0.3**	***100**

Source: Laboratory work (2015)

CV= Coefficient of Variation **Highly variable C.V > 33.0% (Speigel, 1973)*

4.3 CHEMICAL PROPERTIES OF THE SOIL TYPES IN TOMAS IRRIGATION PROJECT

4.3.1 Soil pH (Soil Reaction)

Table 4 shows the mean value of the soil pH in the study area. It ranges from 7.0 to 7.3 that is slightly alkaline (Appendix I). These soils are statistically the same at 5% least significant difference. Similarly, table 3 indicates less variability of pH among the three soil types.

This findings, agrees with Daniel (1985) who also noticed an increase in pH value from 6.37 to 7.5 in Tomas River Project Kano. According to Daniel (1985), the high values of pH results from organic matter contents and relatively high basic cations supplied through fertilizer application (Table 11). Similarly, Rudolph (1999) observed an increase in soil pH in the Kano River Project (KRP) from 5.3 in (1974) to 7.0 in (1987). This finding indicates that alkaline condition which is slightly neutral in reaction occurs under irrigation in the savanna. So there is need for proper soil management practice to minimize nutrient translocation or loss due to erosion, leaching and/or accumulation of salts.

Table 4: pH and EC Values of soil types

	Ballauda		**Ladi**		**Tomas**		
Soil property	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**LSD**
pH	7	0.32	7.3	0.8	7	0.4	6.49
EC Ums/cm	21	2.37	37.4	36.5	31.5	20.4	5.6
		P = 0.05					

4.3.2 Electrical Conductivity (EC)

The result presented in Table 4 indicates that Ballauda, Ladi and Tomas have mean values of electrical conductivity ranging from 21.0 ums/cm, 37.4 ums/cm and 31.5 ums/cm respectively. And this is statistically different at (5% LSD).

This finding is far from Daniel (1985) who observed changes in salinity from 0.04 to 0.11 in Tomas irrigation Project Kano. Similarly, Tanko (1994) working in Kano River Project (KRP) area, observed changes in soil salinity from 0.04 in (1974) to 1.56 (1987).

The implications of the increase noticed in the mean Ec values at the Irrigated site suggest a tendency towards salinity in the area. And presently, these soils can be classified as high (Appendix II)

4.3.3 Soil Organic carbon

The mean values for organic carbon in the study area range from 0.2% in Ballauda to 0.5% in Ladi (Table 5). This is rated low in terms of soil fertility index (Appendix II) and the three soil types are statistically the same at (5% LSD). Similarly, (Table 3) indicates high variability of organic carbon among the three soil types.

Jones (1975) quoted values of 1.05% for most African savanna soils. This implies that the value obtained in the study area is normal for its environment. Essiet (1997) reported that West African Savanna soils have organic matter range from about 0.5% in the brown and reddish brown soil to about 2% in vertisol.

However, the low levels of organic carbon noticed could be attributed to the removal of crop residues after harvest by local farmers. Also, a large number of wild and domesticated animals grazes the field. These low values of organic carbon as reported by Jones and Wild (1996) might partly be attributed to the rapid organic matter mineralization thereby affecting any appreciable level of humification.

Table 5: Organic carbon and nitrogen values of soil types

	Ballauda		**Ladi**		**Tomas**		
Soil property	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**LSD**
Nitrogen%	0.3	0	0.3	0.1	0.4	0.3	1.38
Organic Carbon%	0.2	0.07	0.5	0.3	0.3	0.3	1.27
		P = 0.05					

4.3.4 Total Nitrogen (N)

The mean values for total nitrogen in Ballauda, Ladi and Tomas are 0.3%, 0.3% and 0.4% respectively. And these are statistically the same (Table 5) at 5% least significant difference.

Both Ballauda and Ladi exhibit low level of variability while Tomas shows high variability (Table 3). The soil is ranked medium in total nitrogen content (Appendix II).

It was observed during the field survey of respondents that green beans and soya-beans were inter-cropped similarly most farmers applied urea to their farm plots. Jones (1975) explained that there is a linear relationship between organic matter, organic carbon and total nitrogen. Essiet (1998) recorded a higher value of total nitrogen at the post irrigation period at Kadawa irrigated area as compared to pre- irrigation period. He observed a significant difference between the levels of the two areas. Application of Nitrogen fertilizers, planting of leguminous crops and green manuring will help in incorporating nitrogen into the soil.

4.3.5 Available Phosphorus (P)

Based on the result illustrated in (Table 6), the mean values for available phosphorus range between 377ppm in Tomas to 470ppm in Ladi. However Ballauda and Ladi showed high variability of phosphorous. This is evident in their extremely high standard deviation values while Tomas exhibit low variability as indicated by the low standard deviation value of 21.2. The available phosphorous distribution among the three soil types is statistically the same at 5% least significant difference

According to Kowal and Kassam (1978), average content of available phosphorus in the surface of savannah soils range from 80-150ppm. This therefore shows that the values obtained in the study area rise above the stated given average. Similarly, this finding supported Essiet (1990) who worked in irrigated field and noticed total and available phosphorus mean values within the range of 59.7ppm to 273.5ppm.

From the above, it is obvious that the available phosphorous in the study area is very high and this could be attributed to fertilization (Table 11) where farmers apply 3-5 times within a cropping cycle before harvest.

Table 6: Nitrogen, phosphorus and potassium values of soil types

	Ballauda		Ladi		Tomas		
Soil property	Mean	S.D	Mean	S.D	Mean	S.D	LSD
Nitrogen%	0.0	0	0.3	0.06	0.4	0.3	1.38
Phosphorus ppm	454	215	470	239	377.4	21.2	491.3
Potassium Cmol/kg	0.3	0.05	0.5	0.2	0.4	0.2	0.92
			P = 0.05				

4.3.6 Exchangeable Bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+)

a. Calcium (Ca^{2+})

The mean values for calcium in Ballauda, Ladi and Tomas are 6.2 cmol/kg, 7.5cmol/kg and 4.8 cmol/kg respectively. And this is statistically the same at 5% least significant difference (Table 7). The data in Table 3 indicates high variability of calcium between Tomas and Ladi while Ballauda shows low variability. This soils are rated high in terms of calcium availability (Appendix II).

This finding agrees with Tanko (1994) who recorded a mean value of 5.1 in the Kadawa Irrigation Project Kano. Essiet (1990) observed an increase in the exchangeable ca+mg from 5.1 to 7.2 which does tally with this finding and he attributed this to the application of chemical fertilizer. Moreso, the concentration of calcium and other cation especially magnesium normally reduces the effect of sodium. Such conditions are approximately neutral in reaction.

Table 7: Calcium and Magnesium values of soil types

	Ballauda		Ladi		Tomas		
Soil property	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**LSD**
Calcium Cmol/kg	6.2	1.1	7.5	5.7	4.8	1.7	6.19
Magnesium Cmol/kg	0.1	0.03	0.06	0	0.06	0.03	0.03
			P = 0.05				

b. Magnesium

As indicated in (Table 7), Ladi and Tomas have mean values for magnesium which is 0.06 cmol/kg and this is statistically the same and different from Ballauda which has a mean value of 0.10 cmol/kg at (5% LSD). Similarly, Table 3 shows high variability of magnesium between Ladi and Tomas while Ballauda exhibited low variability. And this is rated low (Appendix II).

This finding agree with (Roudolf 1999) who equally observed decrease from 0.5 to 0.32 indicating a 3.2% decrease while Kodiya (1988) observed a decrease from 0.80 to 0.63 for South Chad Irrigated Scheme. Daniel (1985) equally observed a decrease in the level of magnesium in the Tomas Irrigation Project. Essiet (1990) observed an increase in the exchangeable ca + mg form 5.1 to 7.22 which does not tally with this finding. However the decrease in magnesium in the study area could be attributed to irrigation and largely to the high decomposition of grasses and lack of these elements in soils could signify acidity.

c. Potassium (k+)

The result in Table 6, indicates that Ballauda, Ladi and Tomas have mean values of potassium as 0.3cmol/kg, 0.5cmol/kg and 0.4cmol/kg respectively are statistically the same at 5% least significant difference. Similarly, Table 3 indicates high variability between Ladi and Tomas in

Potassium while Ballauda exhibited low variability. And the potassium level is rated very high (Appendix II).

Daniel (1985) recorded an increase in potassium at the Tomas irrigation Scheme. And this could be attributed to the application of mineral fertilizer (NPK) at least 3-5 times within a cropping cycle (Table 11).

d. Sodium (Na^+).

The mean values for sodium showed that Ladi has the highest with a mean value of 2.8 cmol/kg while Tomas is 1.0cmol/kg. And these values are statistically the same at 5% least significant difference (Table 8). However, Table 3 shows that Ballauda and Tomas exhibit low variability in sodium while Ladi shows high variability and this is evident in their standard deviation values. And this is rated high (Appendix II).

Table 8: EC and Sodium values of soil types

	Ballauda		**Ladi**		**Tomas**		
Soil property	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**LSD**
EC ums/cm	21	2.37	37.4	36.5	31.5	20.4	5.6
Na Cmol/kg	2	0.07	2.8	1.2	1	0.3	1.87
			P = 0.05				

The increase in sodium level in the irrigated sites could be attributed to the introduction of the cation through irrigation water. This finding agrees with that of Rudolf (1999) who observed a slight increase in exchangeable sodium from 0.32 to 0.33. Essiet (1990) reported an increase from 0.63 to 0.83. They all attributed the increase to the application of irrigation water.

The implication of this to the soil is that the increase in sodium can have negative effects on both crops and soil fertility. Large concentration of sodium in soil can be toxic to plant. Therefore, the need to monitor the sodium level and improve management practices that will minimize the development of salinity

4.3.7 Cation Exchange Capacity (CEC)

The result obtained indicates that Ballauda, Ladi and Tomas have 4.1 cmol/kg, 3.7 cmol/kg and 3.0 cmol/kg mean values for CEC. And this is observed to be statistically the same at 5% least significant difference (Table 9). Similarly table 3 indicates that the three soil types exhibits high variability. And this is rated low in terms of soil fertility (Appendix II).

These findings agree with Daniel (1985) who worked on Tomas River Project Kano where he observes a decrease in CEC from 12.9 to 6.56. Essiet (1999) reported a slight increase from 7.0 to 8.85 on the soils of Kano state irrigated fields similarly Kodiya (1988) also reported an increase from 39.7 to 50.88 on the soils of the South Chad Irrigation Scheme. They attributed the increase to the high clay content. FAO (1979) observed that, CEC values of 8-10 meq/100g are satisfactory for irrigated agriculture provided other factors are favourable.

According to Essiet (2001), increase in the quality of clay, organic matter and pH also increase the CEC which results in high fertility. This implies that, for sustainable irrigation practices the soils in the study area need improvement.

Table 9: CEC and Organic carbon values of soil type

	Ballauda		Ladi		Tomas		
Soil property	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**LSD**
CEC Cmol/kg	4.1	1.38	3.7	3.2	3	1.31	3.78
Organic carbon %	0.2	0.07	0.5	0.3	0.3	0.3	1.27
			P = 0.05				

4.4 SOIL FERTILITY AND AGRICULTURAL POTENTIALS OF THE THREE SOIL TYPES

The physical and chemical soil properties generate data on inherent nutrient capital for each soil type. However it did not aggregate this into a single figure for each soil type thereby indicating its rank or fertility status relative to other soil types (see Appendix X). Therefore, applying [Yusuf's, 2002] soil fertility ranking model to some selected soil fertility indicators like organic carbon, pH, CEC, clay, nitrogen, phosphorus and potassium etc. The fertility status of the three soil types were determined as shown in Table 10. The table shows the cumulative sum for the land qualities as well as the fertility rank of each soil type as described below.

Table 10: Four Quartile soil fertility ranking

Soil type	Clay	O.C	N	P	K	CEC	pH	EC	Na	Sand	Total value	Rank/ Order
Ballauda	2	3	1	3	2	2	1	3	3	2	22	1
Ladi	2	1	2	3	1	1	3	2	4	2	21	2
Tomas	1	2	1	2	3	2	2	3	2	1	19	3

4.4.1 Ballauda

This is the portion which is severely cropped. It attracts varieties of both vegetables, cereals and legumes. This is owing to the friable nature of the soil and management which has taken place over the years. As shown in Table 10, it ranked highest in the overall ranking order and varieties of crop combination abound here like tomatoes and soya beans, maize and tomatoes, onions and pepper, tomatoe, salad and maize, onions, tomatoes and maize, green beans, tomatoes and maize, onions and maize, maize, tomatoes and pepper etc. It was learnt that maize is mostly been inter-cropped with other low-lying crops to provide shade against dessication from the scotching sun. However, unlike other soil types, water is being supplied frequently to disallow soil dessication. This is because of the skeletal nature of the soil and its terrain.

4.4.2 Ladi

This is the mid-slope of the three physiographic units. It ranked second in clay content which was highly distributed. It ranked second overall in the ranking order. But the dry season rice is the most cultivated crop here this is owing to the fact that, this soil type for the most part of the year is been wet. And this conditions aggravates especially during the rainy season were only sugarcane substitute it. These two crops mentioned above tolerate to a certain degree the effect of salinity which it ranked highest among the three soil types (Tables 4 and 8) in addition to the nature of the terrain.

4.4.3 Tomas

This is the foot slope of the study site. It ranked highest in sand fraction and both the silt and clay distribution was highly variable. However, it ranked third in the overall ranking order (Table 10). Variety of crop combination found here include sugarcane, okro and pumpkin, onions and sugarcane, sugarcane and okro, sugarcane, tomatoes and pumpkin. In all these, vegetables were inter-cropped with sugarcane due to the sand fractions which predominates. But this is only possible during the dry season as residual moisture is been utilized however during the rainy season, only sugarcane is being cultivated.

Table 11: Soil management practices in Tomas Irrigation project

	Ballauda	**Ladi**	**Tomas**
Cropping System			
Single	37.5	100	43.75
Double	43.75	0	12.5
Mixed	18.75	0	43.75
Major crops grown in the last 5-years			
One	25	100	31.25
Two	37.5	0	31.25
Three	25	0	31.25
Above	12.5	0	6.25
Fertilizer Type			
One	56.25	100	75
Two	43.75	0	25
Frequency of Use			
Three	18.75	43.75	12.5
Four	56.25	56.25	12.5
Five	25	0	75
Manure Use/ Frequency			
Once	56.25	0	25
Not Used	43.75	0	75

Source: field work (2015)

4.5 SOIL MANAGEMENT PRACTICES IN THE THREE LAND FACETS

The Tomas irrigation farmland is tapped for both its rainy and dry season cropping potentials. Therefore the need to manage nutrient to ensure sustainable farming system. In the three land facets, different cropping system, cropping combinations, fertilizer type/frequency and manure use were adopted as explained below.

4.5.1 Ballauda

The result of the checklist administered yielded the information in Table 11 which shows that the farmers on these plots adopt the double cropping system with the cultivation of crops notably among which are maize/tomatoes, pepper/tomatoes, maize/onion, tomatoes/soya beans. This has a score of 43.75% (Table 11). And the most dominant kinds of fertilizers being applied are the NPK and Urea which is applied at least three times before harvest. However, unlike the mineral fertilizer, the manure use/frequency is very low and in most cases it is only applied once.

4.5.2 Ladi

In this land facet, its terrain is always wet during the dry season as a result of the residual moisture. Therefore dry season rice predominates in the whole farm plots. As show in Table 11, only NPK is being applied all through the growing season to the harvest period. Meanwhile the use of manure is totally neglected.

4.5.3 Tomas

In this land facet, sugarcane is inter-cropped with okro, rice, onion, tomatoes and pumpkin. This is well indicated in Table 11. And the application of NPK and Urea as mineral fertilizer predominates with a frequency of 4-5 times before harvest. But the application of organic manure is very low as indicated by 75% (Table 11).

4.6 OVERALL POTENTIALS OF THE SOIL TYPES

Generally, the cropping potentials for the three soil types can be said to be appreciable from the interview granted to the land cultivators. They affirm that returns from farm produce per plot are economically viable to keep one in business. One thing of note here is that, the variability in soil type has provided economic diversity not only in crop types grown but equally in period of harvest of the cultivable crops. For instance, vegetables mostly grown in Ballauda are harvested within the first quarter of the year. While upland rice grown in Ladi is harvested in March/April but sugarcane grown in Tomas extends into the rainy season except for intercropped okro and tomatoes that could be harvested before such period. However, the reason for mostly cultivating vegetable crops cannot only be attributed to the favorable climatic setting for such crops but could also be adduced to the fact that as the soil types is approaching salinity, there is the need to optimize and make judicious use of scarce resources. As these crops cultivated are mostly tolerable to a certain degree of salinity (Appendix XI).

CHAPTER FIVE

Summary, Conclusion and Recommendations

5.1 SUMMARY OF FINDINGS

The summary of the findings of this study is given below.

The soil textural class as of the three soil types is loamy sand for Ballauda and Ladi while Tomas is sandy loam thus Tomas is more sandy.

In the three soil units investigated that is, Ballauda, Ladi and Tomas; it was observed that mean values for Nitrogen (N), Phosphorus (P), Organic Carbon (O.C), Cation Exchange Capacity (CEC). Calcium (Ca), and Magnesium (Mg) are statistically the same for the three units. This shows that no much variation among the three soil units.

Moreover, in the three soil units, the findings revealed high mean values of electrical conductivity with the lowest been 21.0 Ums while the highest is 37.4 Ums and this was observed to be statistically different. Similarly, the range of sodium mean values in the study area is 1 cmol/kg to 2.8 cmol/kg. This indicates a typical irrigation area where these parameters (Ece and Na) are induced by irrigation.

In the soil fertility ranking of the three soil units, Ballauda was found to be highly suitable and it has the highest cropping potentials with crops like vegetables, maize and green beans been cultivated followed by Ladi then Tomas. And best suited for rice and sugarcane respectively. In all soil units, there are limiting factors which affects potentialities and this thus creates room for crop diversification.

5.2 Conclusion

The provision of irrigation water particularly in the study area is one of the most important factors in the expansion of agricultural production and increasing productivity of cultivated (irrigated) lands. However, the gradual rise in the Ec and Na values implies salinity problems in the near future with continuous irrigation and this could affect productivity.

5.3 Recommendations

The increasing level of salinity and sodium indicates that there is the need for a routine check to detect and correct any signs of soil degradation. Similarly, the increase in some of these macro elements may lead to poor harvest on the long run. As was noticed in the Ece and Na values and the possibility of these approaching toxic levels. Monitoring of the nutrients is of top priority. Therefore, for adequate and sustainable crop production in this irrigation area, it would be necessary to check, monitor and maintain a nutrient balance in this environment.

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Appendix I: Soil Reaction

Soil Reaction	pH
Extremely acid	4.0
Acid	4.0-5.0
Moderately acid	5.1-6.0
Slightly acid	6.1-6.9
Neutral	7.0
Slightly alkaline	7.1-7.5
Moderately alkaline	7.6-8.0
Alkaline	8.1-9.0
Extremely alkaline	9.0

Source: Wood, Hutchean and Rackman 1974

Appendix II: Critical limits for Interpreting levels for analytical parameters

Parameters	Low	Medium	High
Ca cmol/kg	<2	2.0-5.0	>5.0
Mg cmol/kg	<0.3	0.3-1.0	>1.0
K cmol/kg	<0.15	0.15-0.30	>0.3
Na cmol/kg	<0.1	0.1-0.30	>0.3
EC cmol/kg	>5	5.0-10	>10.0
CEC cmol/kg	>6	6.0-12.0	>12.0
Organic Carbon g/kg	<10	10.0-15.0	>15.0
Total Nitrogen g/kg	<0.1	0.0-0.2	>0.2
Available P (ppm)	<10	10.0-20.0	>20

Source: Esu (1991)

Appendix III: Physical Properties of Ballauda Soil type

Samples	Sand%	Clay%	Silt%	Textural Class
1	83.12	8.88	8	Loamy Sand
2	83.12	12.88	4	Loamy Sand
3	81.12	10.88	8	Loamy Sand
4	75.12	6.88	18	Loamy Sand

Appendix IV: Physical properties of Ladi soil type

Samples	Sand%	Clay%	Silt%	Textural Class
1	79.12	10.88	10	Loamy Sand
2	79.12	2.88	18	Loamy Sand
3	79.12	2.88	18	Loamy Sand
4	79.12	2.88	18	Loamy Sand
5	79.12	6.88	14	Sand
6	85.12	4.88	10	Loamy Sand
7	83.12	4.88	12	Loamy Sand
8	87.12	2.88	10	Loamy Sand
9	85.12	6.88	8	Loamy Sand
10	65.12	10.88	24	Sand Loam

Appendix V: Physical properties of Tomas soil type

Samples	Sand%	Clay%	Silt%	Textural Class
1	87.12	4.88	8	Sand
2	85.12	2.88	12	Loamy Sand
3	85.12	2.88	12	Loamy Sand
4	87.12	2.88	10	Sand
5	87.12	2.88	10	Sand
6	83.12	4.88	12	Loamy Sand
7	79.12	2.88	18	Loamy Sand
8	91.12	4.88	4	Sand
9	91.12	4.88	4	Sand
10	87.12	2.88	10	Sand
11	87.12	4.88	8	Sand
12	85.12	4.88	10	Loamy Sand
13	83.12	6.88	10	Loamy Sand
14	83.12	6.88	10	Loamy Sand
15	83.12	4.88	12	Loamy Sand
16	83.12	4.88	12	Loamy Sand

Appendix VI: Chemical properties of Ballauda soil type

Samples	Na	Ca	Mg	AVP	CEC	EC	N	K	pH	O.C
1	2	6.3	0.1	600	2.8	17.83	0.3	0.28	6.4	0.1
2	2	4.5	0.13	83	5.7	24.2	0.3	0.3	7.2	0.1
3	1.9	7.6	0.06	587	2.7	22.1	0.3	0.24	7	0.2
4	2.1	6.3	0.09	544	5.3	20	0.3	0.36	7	0.2

Appendix VII: Chemical properties of Ladi soil type

Samples	Na	Ca	Mg	AVP	CEC	EC	N	K	pH	O.C
1	1.9	6.1	0.07	114.5	2.3	19.87	0.4	0.92	7	0.1
2	1.8	5.3	0.1	687	2.4	13.7	0.2	0.18	7	0
3	1.8	5.4	0.1	673	1.4	32.4	0.3	0.13	6.8	0.2
4	2.2	5.6	0.01	658	1.7	48.7	0.3	0.14	6.6	0.2
5	1.9	6	0.06	630	2.4	25.7	0.3	0.14	6.8	0.3
6	2	6.3	0.06	601	3.2	35	0.4	0.16	7	0.2
7	2	6.4	0.07	544	1.8	22.3	0.3	0.1	7.2	0.1
8	2	4.2	0.01	573	2	19.08	0.3	0.1	7.4	4.1
9	2	5.5	0.1	129	8.4	14.98	0.3	0.1	7.4	0
10	10.2	24.4	0.03	86	11.3	142.6	0.4	3.02	9.6	0.1

Appendix VIII: Chemical properties of Tomas soil type

Samples	Na	Ca	Mg	AVP	CEC	EC	N	K	pH	O.C
1	0.6	3.8	0.06	358	6.5	20.8	0.3	0.28	6.2	0.3
2	0.4	5.3	0.04	372	3.7	20.7	0.2	0.27	6.8	0.6
3	0.6	8	0.09	386	4.1	61.6	0.4	0.63	6.6	1.1
4	1.3	5	0.06	429	4.4	38.7	0.2	0.3	7	0
5	1.4	7.3	0.01	372	4.1	84.8	0.3	0.59	6.8	0.9
6	1.3	7	0.09	372	2.7	21.5	0.3	0.86	7.2	0.4
7	1.2	6.1	0.06	386	3.5	61.3	0.5	0.73	6.8	0.3
8	1.2	4.4	0.06	400	1.9.	27.5	0.3	0.36	7	0
9	1.2	6	0.04	370	1.9	36.9	0.3	0.48	6.8	0
10	1.2	4.2	0.09	358	1.4	15.89	0.6	0.38	6.8	0.2
11	0.7	2.9	0.06	415	2	10.3	0.3	0.22	7.4	0.1
12	0.8	2.2	0.06	365	2.2	10.1	0.3	0.27	6.8	0.2
13	0.9	3.2	0.09	372	2.1	18.65	0.2	0.31	7	0.1
14	0.9	5.2	0.04	372	1.9	17.63	0.3	0.34	7.4	0.1
15	0.8	2.8	0.06	343.5	1.8	21.4	0.4	0.33	7	0.3
16	0.9	3.7	0.09	365	3.3	35.6	1.5	0.19	8	0.2

Appendix IX: Descriptive statistics of the various soil chemical properties under investigations

		Ballauda				Ladi				Tomas			
Soil property	**Mean**	**S.D**	**N**		**Mean**	**S.D**	**N**		**Mean**	**S.D**	**N**	**F**	**LSD**
Total Nitrogen %	**0.3**	**0**	**4**		**0.3**	**0.06**	**10**		**0.4**	**0.3**	**16**	****8.36**	**1.38**
Phosphorous PPM	**454**	**215**	**4**		**470**	**239**	**10**		**377.4**	**21.2**	**16**	****18.09**	**491.3**
Exchangeable K Cmol/kg	**0.3**	**0.05**	**4**		**0.5**	**0.2**	**10**		**0.4**	**0.2**	**16**	****13.71**	**0.92**
Exchangeable Ca Cmol/kg	**6.2**	**1.1**	**4**		**7.5**	**5.7**	**10**		**4.8**	**1.7**	**16**	****15.1**	**6.19**
Exchangeable Mg Cmol/kg	**0.1**	**0.03**	**4**		**0.06**	**0.04**	**10**		**0.06**	**0.03**	**16**	****18**	**0.03**
Exchangeable Na Cmol/kg	**2**	**0.07**	**4**		**2.8**	**1.2**	**10**		**1**	**0.3**	**16**	****20.9**	**1.87**
Electrical conductivity Ums/cm	**21**	**2.37**	**4**		**37.4**	**36.5**	**10**		**31.5**	**20.4**	**16**	****49.8**	**5.6**
Cation Exchange Capaci Cmol/kg	**4.1**	**1.38**	**4**		**3.7**	**3.2**	**10**		**3**	**1.31**	**16**	****14.15**	**3.78**
pH	**7**	**0.32**	**4**		**7.3**	**0.8**	**10**		**7**	**0.4**	**16**	****13.53**	**6.49**
Organic Carbon%	**0.2**	**0.07**	**4**		**0.5**	**0.3**	**10**		**0.3**	**0.3**	**16**	****14.04**	**1.27**
Source Laboratory work (2015)													

**Significant at P>0.05
LSD (P=0.05)
N=Number of samples

Appendix X: Four Quartile Ranking Model (Yusuf, 2002)

a. **Positive soil properties (PSP)**

Examples for clay (Physical properties of Ballauda soil type (see Appendix III)

$\frac{A - B}{4}$ = C (Quartile Value)

Where A = 12.88

B = 6.88

Both A and B are range of values for clay in Ballauda soil type

$\frac{12.88 - 6.88}{4} = \frac{6}{4} = 1.5$

C = 1.5; therefore, it gives the value for dividing the value of each property into quartiles. Thus adding to the least value B demarcates the limit of each quartile

Example; 1.5 + 6.88 = 8.38

Value score

Poor	1	6.88 – 8.38
Average	2	8.38 – 9.88
Good	3	9.88 – 11.38
Best	4	11.38 – 12.88

N.B: For positive soil properties (PSP), the value scores increases with increase in demarcated range values (direct relation).

b. **Negative soil properties (NSP)**

Example for Na (Sodium) Chemical properties of Ladi soil type (see appendix VII)

$\frac{A - B}{4}$ = C (Quartile Value)

Where A = 10.2 $= \frac{10.2 - 1.8}{4} = \frac{8.4}{4}$

B = 1.8

C = 2.1

C = 2.1: Thus adding C to the least value B demarcates the limit of each quartile.

Example; 2.1 + 1.8 = 3.9

Values score

Best	4	1.8 – 3.9
Good	3	3.9 – 6.0
Average	2	6.0 – 8.1
Poor	1	8.1 – 10.2

NB: For negative soil properties (NSP), the value score increases with decrease in demarcated range values (Inverse relation)

c. **<u>Optimum level property (OLP)</u>**

Example for pH (chemical properties of Tomas soil type (see Appendix VIII)

$\frac{A-B}{6}$ = C (Quartile Value)

Where A = 8.0 $\frac{8-6.2}{6} = \frac{1.8}{6} = 0.3$

B = 6.2

C = 0.3; Thus adding C to the least value B demarcates the limit of each quartile

Example: 0.3 + 6.2 = 6.5

Value score

Best	4	6.2 – 6.5
Good	3	6.5 – 6.8
Average	2	6.8 – 7.1
Poor	1	7.1 – 7. 4

NB: In this case, the optimum level (OL) is scored as 4, 3, 2 and 1 from both sides of the optimum level (i.e from lower to higher optimum level)

Appendix XI: Crop tolerance and yield potential as influenced by soil salinity

Crops	**100%**	**90%**	**75%**	**50%**	**0%**
Tomatoes	2.5	3.5	5.0	7.6	13.0
Pepper	1.5	2.2	3.5	5.1	8.6
Cabbage	1.8	2.8	4.4	7.0	12.0
Onions	1.2	1.8	2.8	4.3	7.4
Sugarcane	1.7	3.4	5.9	10.0	19.0
Beans	1.0	1.5	2.3	3.6	6.3
Lettuce	1.3	2.1	3.2	5.1	9.0
Maize	1.7	2.5	3.8	5.9	10.0

Source: (Biswas and Arar 1988 in Olujide 1995)

Check list for the investigation of soil type, fertility conditions, cropping pattern and management in Tomas Irrigation site, Kano

SECTION A

1. Name_________________________________
2. Marital status (a) Single (b) Married
3. Education qualification of the respondents

a. Primary and Adult Education ( )

b. O' Level (WAEC, GCE and NECO) ( )

c. N.C.E, ND ( )

d. Degree/HND ( )

e. Quranic Education ( )

4. Soil Type_________________

   Farm size (plot)_________________

   Location ___________ (a) hill slope, (b) mid slope (c) foot slope

5. Cropping system

   Single ______________

   Double _____________

   Mixed ______________

6. Major Crops grown in the last five years
7. Fertility level compared to other farm plots within the soil type
8. Soil properties

   Colour___________________

   Texture____________________

   Water holding capacity________________

9. Fertilizer

   Type _______________________________

   Frequency of use ______________________

   Manure use/frequency ___________________

10. Crops frequency grown and fertility level of soil type

Soil type	Crops grown	Fertility
________________	__________________	Good, fair, poor
________________	__________________	Good, fair, poor
________________	__________________	Good, fair, poor