THE PHENOLOGY, DISTRIBUTION, AND USES OF AZADIRACHTA INDICA A. JUSS (NEEM TREE) IN TAURA LOCAL GOVERNMENT AREA, JIGAWA STATE, NIGERIA

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DECLARATION

I hereby declare that this Research Thesis titled "The Phenology, Distribution and uses of *Azadirachta indica* A. Juss in Taura Local Government Area, Jigawa State "Nigeria" was undertaken by me, and the ideas and views expressed in this Thesis are mine, and views of other researchers have been duly acknowledged.

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APPROVAL

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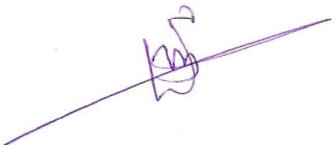
Signature of supervisor: 

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LIST OF ACRONYMS

A. indica	*Azadirachta indica*
A.Juss	*Azadirachta Juss*
AIDs	Acquired Immune Deficiency Syndrome
BBCH	Biologische, Bundesanstalt, Bundesortenamt, Chemical industry.
B.U.K	Bayero University, Kano
BP	British Pharmacopoeia
CBD	Convention on Biological Diversity
GIS	Geographical Information System
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature (Wild Fauna & Flora)
KMO	Kaiser-Meiyer-Olkin
NDVI	Normalized Difference Vegetation Index
NRICT	National Research Institute for Chemical Technology
NGOs	Non-Governmental Organizations
TFAR	Theory of Fluctuation Availability Resources
UN	The United Nations
UNEP	United Nations Environmental Program
WRM	World Rainforest Movement

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ABSTRACT

This study determined the phenology, distribution, and uses of Azadirachta indica *A. Juss* in Taura Local Government Area, Jigawa State, Nigeria. The specific objectives were to: a) determine the phenology of Azadirachta indica in Taura Local Government Area; b) determine the distribution of Azadirachta indica in Taura Local Government Area; and c) determine the level of usage of Azadirachta indica among small scale farmers and administrators in Taura Local Government Area, Jigawa State Nigeria. The study used a descriptive survey and longitudinal (observational) design. Azadirachta indica phenology observation of leaf, flower, and fruits in dry and rainy seasons. The phonological activity in the Neem tree can be inferred that the vegetative and reproductive phenology occurred once a year based on the seasonal pattern of the area. *Azadirachta indica* distribution was established through GPS and GIS software. Normalized difference vegetation index (NDVI) was used to identify and plot the map of the increasing number of Neem trees in the area. The uses of Neem were categorized into three: direct use, ecological uses, and medicinal uses. The study found that Azadirachta indica outnumbered the native trees due to Neem tree characteristics that aid its environmental colonisation. State Government should make a policy to enhance the environmental conditions through tree planting, to improve soils, afforestation, agricultural activities, and climate change mitigation.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

The study focused on the phenology, distribution, and uses of *Azadirachta Indica A. Juss* in Taura Local Government Area Jigawa State, Nigeria. The relevance of Neem trees in the Taura Local Government Area cannot be over-emphasized due to its morphological and physiological strength that aids its colonization in the area. Neem trees help combat desertification, improving afforestation, climate change, and agricultural activities. The phenology, distribution, and uses of the Neem tree help to promote or improve the natural conservation for human sustainable development (Abdulrashid, 2013).

1.1 Background of the study

Plants are an essential component of land resources that must be managed carefully and sustainably to be used by future generations. As a resource, vegetation fulfils certain essential human needs like food, fuel wood, soil fertility, preservation and roofing for homes, and medications (Tukur *et al.,* 2013). One of the fundamental tenets of sustainable development is living within the bounds of the environment. The current surge in human population has a wide range of effects that strain natural resources. Land deterioration, deforestation, and construction activity are a few of these(*Ibid*)

Ecosystem stability and human existence depend on biological diversity and wise resource usage. However, rapid and rising anthropogenic activities producing a chronic reduction in species variety are undermining biodiversity worldwide. As a result, both in the developed and developing worlds, biodiversity protection has emerged as a problem for humanity (UNEP and CBD, 2011).

Through its global strategy for plant conservation, the Convention on Biological Diversity (CBD)has as one of its main goals the preservation of habitats, species, and landscapes. Every country, nation, state, or local government must engage in systematic conservation planning and related conservation activities to meet this biodiversity conservation target (CBD, 2002). The Neem plant is a tropical evergreen tree native to the Indian subcontinent. Neem trees are valuable nitrogen-fixing trees with multipurpose uses (Tukur *et al.,* 2013). It covers entire parts of India extensively and is grown in most tropical and sub-tropical areas of the world (*Ibid*). It works as good windbreakers and shelter belts in arid and semi-arid regions of West Africa. It has a reported value for its herbal medicines, spermicidal. It is treated as a perfect, complete, and imperishable gift of nature (Kumar *et al*., 2013). The Neem tree's importance is in aspects like temperature moderation, regular rainfall, natural fertilizer, and natural bio-pesticides ability, along with economic aspects like producing Neem oil, Neem cake, Neem leaves, and their products (*Ibid*).

Most of the Taura Local Government Area residents are small-scale farmers who do subsistence farming. Most cattle keepers feed their animals by cutting most natural plants during the dry season. The majority of the native trees have been reduced or eliminated, leading to habitat loss (*Ibid*).

Azadirachta indica is a recently discovered species. However, it has remarkable physiological and morphological adaptations that enable it to endure and regenerate even under challenging circumstances and numerous cuttings (Kumar *et al*., 2013). Several factors contribute to its diffusion and dissemination, some of which are listed below: -

i. Birds consume the ripe seed's liquid component and discard and/or disseminate the seeds.

ii. The local farmers transport the seeds contained in local manure to their fields of crops. This helps to propagate and increase land cover under *Azadirachta indica* coverage.

iii. The farmers plant the seeds, and this increases the area under *Azadirachta indica*,

iv. The seed itself can be moved from one location to another by the wind (self-propagation),

v. Some animals excrete seeds that travel from one location to another in their faeces.

vi. Water distribution (Tukur *et al.,* 2013).

The seed can resist challenging circumstances both before and after germination. Not all animals consume the young Neem plant or eat it sparingly. This is attributed to being very beater and unpalatable to some animal species (*Ibid*).

The *Azadirachta indica* is thought to be the most common plant based on frequency and plant distribution over farms, villages, and the few remnant grazing yards in the Taura Local Government Area, Jigawa State, Nigeria. The plant sheds its leaves during the dry season to reduce water loss (Ibid). The *Azadirachta Indica* has enormous branches that provide protection and act as a canopy and windbreak against the wind, and it has a deep tap root system for absorbing water and anchoring the Neem plant firmly on the ground. The deep roots enable it to reach the water table for the essential water and nutrient needs. The Local farmers in Taura operate separate Neem farms in each of the wards for the abovementioned reasons. To improve afforestation, the Jigawa State Ministry for the Environment has installed Neem shelter belts in various wards, including Sabon, Garin, Yaya, Taura, Gujungu, Majia, and Ajaura (Ahmed *et al.,* 2019). The success of the agricultural endeavours has been greatly enhanced by planting Neem trees in Taura Local Government Area (*Ibid*).

Azadirachta indica young seedlings sprouting under local tree species occur in the Local Government Area regularly. In the event of the death or disappearance of the former, these

newly sprouting *seedlings* provide a replacement or substitute and, therefore, sustain the Neem tree prevalence (*Ibid*).

Literature (Ahmed, 2014) has indicated that the invasive species *Azadirachta indica* has remarkable physiological and morphological adaptations that enable it to regenerate and colonize its habitat. Neem seeds are said to have a short shelf life; typically, they lose their viability 3 to 4 months after harvest. Taura Local Government Area's topography, climate, and sites contributed to the region's distinctive pattern of species distribution. It can withstand challenging environmental conditions. The study aims to determine why *Azadirachta indica* outnumbers native trees in the area. Its phenology, distribution, and applications may play a role in this. If managed and used appropriately, the *Azadirachta indica* will prevent land degradation and local participation in the environment's social, economic, political, biophysical, and cultural aspects (Echereme *et al.*, 2015) given its characteristics and phenology,

Because of human overuse, soil has been damaged in many regions of the world, particularly West Africa. Neem trees are the best species for reforestation in such semi-arid areas. Neem tree forestry now goes by the name of "Margo culture". It is ideal for arid areas and large-scale farming (Echereme, 2015) for its ecological, economic, and direct values.

The Federal and State governments have been advocating for Neem tree cultivation for a variety of reasons:

i. Neem has many uses, including leaves for animal feed and sources (Ahmed, 2014), wood for fuel poles for building materials, and seeds for oil. Other uses include serving as manure and pesticide.
ii. The ability of the tree to withstand hot and dry conditions, as well as the high salt content in the soil, makes it highly adaptable and propagated.

iii. The Neem tree is prolific and is widely used as avenue trees, shelterbelts, canal-side plantations, and dune stabilizers, which also serve as windbreakers` Ibid'. These uses underscore the popularity of the Neem tree across the entire West African sub-region.

iv. The Neem tree is a plant that is never evergreen. During the dry season, the plant sheds off its leaves to conserve water. The shaded leaves constitute litter and, eventually, manure, which improves soils by adding organic matter without endangering helpful insects, earthworms, or other below-surface biodiversity (*Ibid*).

Due to the reasons above, most developing nations with drier regions have incorporated Margo culture into their agro-forestry initiatives (Medugu, 2008). It is being grown anywhere feasible in affluent nations as a source of pesticides that can be made from the seeds. It is a fast-growing tree, and scientific research is being done to determine the best circumstances for its growth and development and how it affects the environment, agricultural crops, and eco-balance (*Ibid*).

1.1.1 Historical perspective

Native to the Indian subcontinent, the Neem tree (*Azadirachta* indica) is a tropical evergreen tree that turns deciduous in drier regions (Anonymous, 2006). It was created in the Eighteenth Century (Ahmed, 2014). Due to its therapeutic qualities, it has been utilized in Ayurvedic medicine for more than 4000 years. In Sanskrit, the word "arista" for Neem means "perfect, complete, and imperishable" (Anonymous, 2006). The majority of plant components, indeed all the parts, including fruits, seeds, leaves, bark, and roots, include substances that have been shown to have antiseptic, antiviral, anti-inflammatory anti-ulcer, and anti-fungal properties, anti-ulcer, and anti-fungal properties (Tukur, *et al.,* 2013).

In terms of direct use, ecological importance, and medicinal value, it is also the most significant tree of the Twenty-first Century. It is a member of the Meliaceae family and is frequently referred to as "Indian Lilac" or "Margosa." It has enormous potential in medicine,

pest control, and environmental preservation (Ahmed, 2014), making it attractive to many due to its various uses.

The Neem tree tolerates various climatic, topographical, and edaphic conditions. It thrives on shallow, dry, rocky soils with little to no depth. There are only two species: *Azadirachta excelsa kack*, which is only found in the Philippines and Indonesia, and *Azadirachta indica A.juss*, which is indigenous to the Indian subcontinent (Hansen, 2006). Additionally, it is proven to improve soil fertility and water retention ability. Compared to many other tree species, it is reported that the Neem tree releases more oxygen through photosynthesis (Anonymous, 2006). That means it stabilizes the atmosphere by using/storing more carbon dioxide, thus helping in carbon sequestration into the ground and plant tissues. This study adds that the fact that Northeastern Nigeria is within the Sahel Phytochorion (eco-climatic zone 5) with semi-arid conditions and unpredictable high seasonal variability, both the phenology and the efflorescence have enabled the Neem plant to adapt to the harsh climatic conditions may account for the widespread cultivation of the Neem trees in the Sahel zone.

(Hansen, 2006). Due to the poor nature of the ecosystem and the following overuse of vegetation, Neem plants have continued to dominate the area since that time, replacing and displacing most of the native plants. Indeed, the land cover under the Neem tree coverage is rising. This study adds that the episode of climate change in the Sahel. However, it is negatively impacting human livelihood undertakings and apparently is influencing the Neem tree cultivation and area coverage expansion.

1.1.2 Theoretical perspective

Two theories were used to guide the study: 1) the Theory of Fluctuating Availability of Resources (TFAR) (Thompson *et al.,* 2000) and 2) the Equilibrium theory of Island

biogeography (ETIB) (Mac Authur & Wilson, 1967). The theories were adopted because the study is grounded in them, as explained hereunder:

The theory of "Fluctuating availability" resources is the global issue of non-native plant and animal species encroaching on native ecosystems has the potential to have severe repercussions on social, economic, and ecological systems (New species displacing a native species through colonization and dominance of habitat to invasion by non-native species is identified as the idea of fluctuation in resource availability (Mrowicki *et al.,* 2016). Three factors influencing invisibility are – the number of propagules entering a new habitat (propagule pressure), the traits of the new species, and the weakness of the environment to invasion by the new species (*Ibid*).

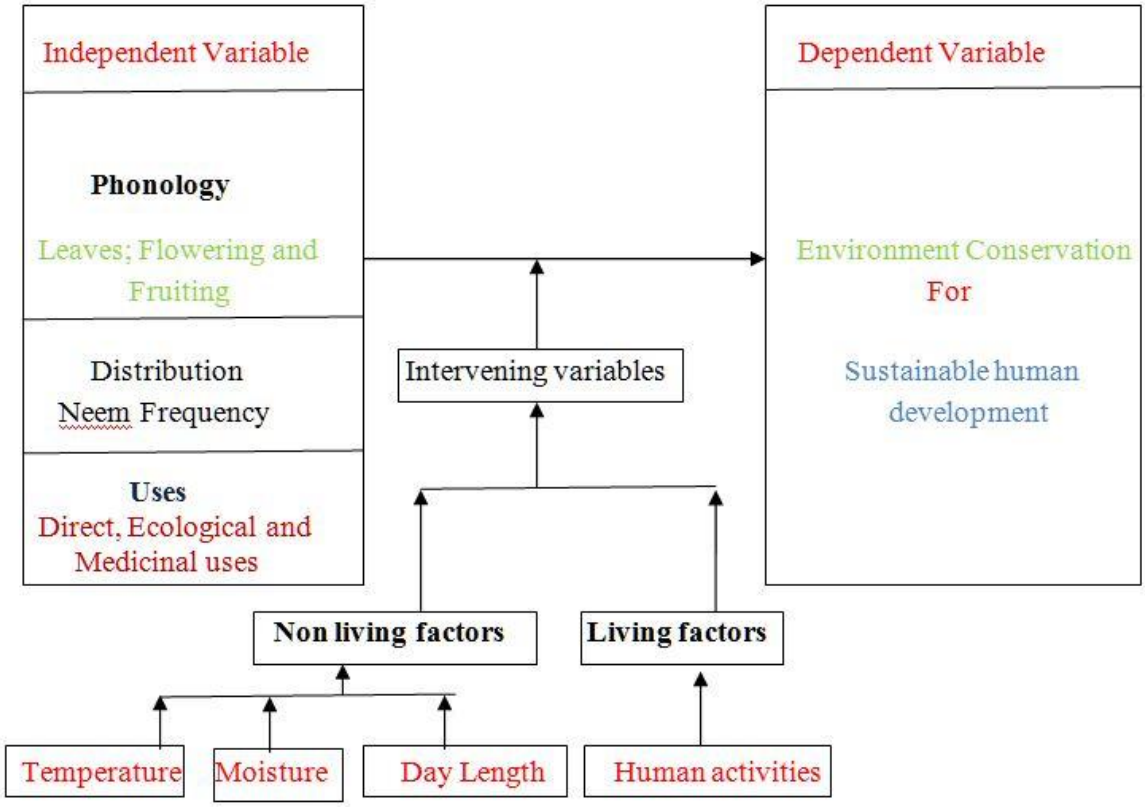
The Equilibrium Theory suggested that the fauna and flora of the Island eventually strike a balance between extinction and immigration. However, the extremely dynamic Island system makes it difficult for the species to reach equilibrium. However, Mac Author and Wilson (1967) noted that the 'Equilibrium Theory of Island Biogeography' (ETIB) allows for broad predictions of future Island biodiversity patterns. The Theory of Island biogeography is then examined in relation to the Island Environment, including topography, regions, characteristics, and climate patterns (*Ibid*). The study adds that the 'Theory of Island biogeography' was seen to be most relevant and has anchored this study because the study has examined aspects such as environment, soils, topography, and climate/weather patterns in the analysis of phenology and distribution of the Neem tree in the study area.

1.1.3 Conceptual Framework

The conceptual framework consists of two major aspects: Independent and Dependent variables. It also consists of intervening variables. The Independent variables consist of Phenology, Distribution, and uses of the Neem tree. The Phenology consists of leaves,

flowers, and fruits. The Distribution consists of Neem Frequency. The uses of the Neem tree were categorized into three: direct use, ecological uses, and medicinal uses. The Dependent variable is the environmental conservation for sustainable human development. The Independent variable is all supported or influenced by the intervening variable, which consists of non-living factors like temperature, moisture, and day length, and the living factor, human activities.

Table 1.1 Conceptual frame words



Source (field data 2023)

1.1.4 Conceptual perspective

As a resource, vegetation meets several essential human needs, including food, fuelwood, and land preservation for soil fertility. Consequently, it is essential to human development (Ahmed *et al.,* 2019). Vegetation resources are thought to be the foundation of life for all

species. As a result, all living things rely solely on vegetation resources, either directly or indirectly (Tukur *et al.*, 2013). However, vegetation complements the life-support system, which consists of Air, Water, and Biodiversity (Krebbs, 1976).

Neem trees are the most prevalent in the partially vegetated Taura Local Government Area. Due to the overuse of plant resources, most native trees are in danger of extinction (*Ibid*). Neem trees are a rare species with the physiological capacity to withstand challenging or unpredictable environmental circumstances or disturbances, such as the high seasonal variability in terms of precipitation and temperatures. Indeed, where other plant species get challenges in terms of water and excessive heat, the Neem tree thrives. Neem phenology, distribution, and uses may significantly affect invasion (Ahmed, 2014). This study was set towards investigating that. The Neem tree Phenology, distribution, and uses may have a significant role in its invasion (Ahmed, 2014). The Neem Phenology makes the species effective in growth and regeneration, capable of withstanding environmental stress (*Ibid*). Phenology, which deals with new growth, leaf fall, flowering, and fruiting-like activities in plants, is the study of the timing of repeating natural phenomena. It studies the connections between climatic variables and recurring events in living things (Echereme *et al*., 2015). Plant life forms have specific relationships with specific climatic conditions. The phonological patterns may have changed due to a change in plant species and the phenological activities brought on by a rise in surface temperature (Zang *et al.*, 2006). Therefore, phenomenological analysis of the Neem tree entailed the analysis of the periodic biological phenomena (the Neem growth) in relation to climate, especially seasonal changes, from a climatological viewpoint. These phenomena served as bases for interpreting local seasons and the climatic zones. They were considered an integral component of bioclimatic factors as far as the Neem tree is concerned in the study area.

The Neem tree is extensively planted in Nigeria's northeast, possibly due to the area's climate and strategic location within the Sahel savanna belt of West Africa (Ahmed, 2014). It is frequently used for fuel, and its leaves are also employed as a traditional medicine for treating illness . Most critically, the Neem tree has successfully managed erosion and desert encroachment . Through dunes, the Neem tree serves various ecological and socio-economic purposes, one of which is halting the desertification and/or stopping the Sahara desert from advancing southwards (Abdulrashid & Yaro, 2014). In dry areas like Adamawa, Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, and Zamfara States, the Neem tree is useful for building shelter belts, acting as windbreaks, providing shade, and creating woodlots (Ahmed, 2014). According to the Science Dictionary (2010), it's also useful for the ecosystem services it provides. These benefits can be classified into several categories. Provisioning services include the products humans derive from ecosystems, such as food, fibres, fuel, drinking water, and medicinal products. Regulating services encompass such processes as control of the climate, purification of air and water, amelioration of erosion, reduction of pests and diseases, and provision of pollination mechanisms. Cultural services comprise the non-material benefits of the landscape, such as recreational pursuits, spiritual renewal, and aesthetic experiences. Underlying all these are the fundamental supporting services of all ecosystems, such as primary production, photosynthesis, nutrient cycling (such as carbon, nitrogen, and sulphur cycles), water cycling, and soil formation. In recent decades, the widespread degradation of many of the world's ecosystems has seen the concept of ecosystem services (Ahmed, 2014).

1.1.5 Contextual perspective

The population in Nigeria is rapidly increasing. This will lead to a rise in the demand for natural resources and the endangering of biodiversity. Natural habitats are being destroyed as a result of rising human population and rising demand for biological resources for plantation

creation, irrigation, the production of food and livestock, and the use of non-timber forest products (Federal Government of Nigeria, 2010). Uses for non-timber forest products (NTFPs) include food, medicine, oil, resin, home furnishings, fuel wood, and tanning. The rural people at the subsistence level have been using these products to make money (*Ibid*). Traditional technology is mainly used in Nigerian agriculture. Large-scale plantations destroy Indigenous plant and animal species' habitats, the establishment of cash crops, excessive bush burning, and overgrazing through increased livestock. The semi-arid regions where the Neem grows are home to 90% of the cattle, where most livestock keepers are. Overgrazing, excessive bush burning, and lack of feed are among the environmental challenges in the area (Nigeria's first National Biodiversity Report, 2001). Along with rising economic growth, desertification, high seasonal variability, prolonged drought, and climate change, habitat destruction is also a result of the earlier factors. Land clearing for diverse purposes results in habitat destruction, which significantly reduces species diversity and causes genetic erosion (Ibid)

1.2 Problem Statement

The physical characteristics of the soil, the type of vegetation, the topography of the region, inherent extreme climate variability, and disruption of the ecological system brought on by poor land management in form of overgrazing, deforestation, over-cultivation, and generally unsustainable environmental management have all been implicated in the problem of desertification in the northern parts of Jigawa state, Nigeria (Nigeria First National Biodiversity Report, 2001). The area has suffered due to the overuse of wood for household and other purposes. More than eighty per cent of the households in the area rely on wood for heating, and about 90% of the area's forest removal is for fuel wood, leading to severe forest cover degradation. A sizable number of 131,757 people populated the Taura Local

Government Area as of the 2006 census (Ahmed *et al.*, 2019). Eighty per cent (80%) of the population is subsistence farmers who depend on trees for firewood, poles, roofing materials, and cattle fodder. Due to overstocking, almost all grazing yards have turned into marginal land with very few plant resources. This has led to the destruction of habitat. Due to human-caused dryness of the environment and consumption of biofuels, most native trees are slowly dying off (*Ibid*).

Conversely, the Neem tree is naturally sprouting everywhere in the environment. It is now the dominant tree species in the region in terms of vigour and density, and limited documented information exists on the Neem tree in the area. To understand why the Neem trees have taken over as the predominant tree species in the region, there was the need to undertake this study to examine the phenology, distribution, and uses of *Azadirachta indica* in Jigawa State, Nigeria's Taura Local Government Area.

1.3 Significance of the Study

The study aimed to investigate why *Azadirachta indica* has outgrown the local natural tree. Species in the Taura Local Government Area, Jigawa State. The qualities that aid in colonising the unfavourable area and its importance to the community were documented through the Neem phenology, distribution, and usage analysis. The study helped demonstrate to the stakeholders (Federal Government of Nigeria, State government, local residents, academics, and non-governmental organizations) the value of Neem trees in preventing desertification and regulating the climate in addition to other benefits accruing from the Neem tree. This study was different because 1) it addressed why the Neem tree was successful in colonizing and dominating the study area; 2) it established its uses; 3) it presented a module for sustainable use and management of the Neem tree in the Taura Local Government area.

1.4 General Objectives

To investigate the Phenology, Distribution, and Uses of *Azadirachta indica* in Taura Local Government Area, Jigawa State, Nigeria.

1.4.1 The specific objectives

The specific objectives were to:

1. Determine the phenology of *Azadirachta indica A. Juss* in Taura Local Government Area, Jigawa state -Nigeria.
2. Determine the distribution of *Azadirachta indica A. Juss* in Taura Local Government Area of Jigawa State, Nigeria.
3. Determine the usage level of *Azadirachta indica A. Juss* among Small Scale Farmers and Administrators in Taura Local Government Area of Jigawa State, Nigeria.
4. Develop a sustainable conservation and management model of the *Azadirachta indica A. Juss* in Taura Local Government Area of Jigawa State, Nigeria.

1.5 General Research Question

What are the phenological, distribution, and uses of *Azadirachta indica A.Juss* in Taura Local Government Area, Jigawa State, Nigeria?

1.6 Specific Research Question

1. What are the phenological patterns of *Azadirachta indica A. Juss* in Taura Local Government Area of Jigawa State, Nigeria?
2. What is the distribution of *Azadirachta indica A. Juss* in Taura Local Government Area of Jigawa State, Nigeria?
3. What is the level of usage of Azadirachta *indica A. Juss* among Small Scale Farmers and Administrators?

4. 4. What model can lead to sustainable conservation and use of the *Azadirachta indica A. Juss* in the Taura Local Government Area of Jigawa State, Nigeria?

1.7 Scope of the study

This section provides information on the extent of the areas the research covers: the geographic, theoretical, and Content scopes.

1.7.1. Geographical scope

The Jigawa state of Nigeria includes the Taura local government district. Taura Town, where its headquarters are located. It is bordered to the west by the Ringim Local Government Area, to the north by the Garki Local Government Area, to the south by the Jahun Local Government Area, and to the east by the Kaugama Local Government Area. The Local Government Area is between latitudes 110^0 N-130^0 N and longitudes 80^0 E-100^0 E, and the landscape is generally flat. The Sudan savannah is the main vegetation making up the main vegetation and is significantly influenced by the Sahara Desert (Ahmed *et al.,* 2019).

1.7.2. Theoretical Scope

This study adopts the 'theory of fluctuating resource availability (TFAR) on invasive species' because this theory attempts to explain how the invasive species can have an international phenomenon with serious repercussions for the ecological, economic, and social systems because it is the Neem Plant invading the local Ecosystems on grandiose scale by non-native plant and animal species. The study selects this theory since it pertains to *Azadirachta indica. Its importance in the Taura Local Government Area community is so immense. T*he Neem tree is the dominant species in the study area. The theory's quantitative aspect results in many testable predictions (Rivera *et al*., 2002).

1.7.3. Content scope

The study focused solely on the Phenology, distribution, and usage of the Neem Tree (*Azadirachta indica*). Since native trees cannot now survive the stress of the environment, the study served to highlight the relevance of Neem trees in the environment as a means of substituting and replacing other tree species, given Neem plants' numerous qualities of adaptation in a hostile environment and the variety of benefits that can accrue from its use.

1.8 Definition of Key Terms

Adaptation Refers to adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their impacts. It refers tochanges in processes, practices, and structures to moderate potential damage or to benefit from opportunities associated with climate change (IPCC, 2014).

Afforestation: The act or process of creating new forests where none had existed before or reforestation of areas long deforested

Climate change The present human-induced climate change caused by the burning of fossil fuels results in significant changes in the mean or variance of climate variables. This is also known as global warming due to emissions of greenhouse gases (GHGs). And carbon-dioxide is the main GHG of concern, but others are methane, nitrous oxide, water vapour, and ozone. These GHGs trap escaping energy emitted by the earth and heat the atmosphere, causing a general warming of the planet (Smit *et al.*, 2000).

Conservation The act of preserving, guarding, or protecting, the keeping of environmental /natural resources or an object in a safe state.

Coordinates A number representing the position of a point along a line, arc, or similar one-dimension figure, sometimes known as 'geo references'.

Deciduous Trees shed leaves in winter or dry season.

Deforestation The process of destroying a forest and replacing it with something else, especially by an agricultural system.

Lance acuminate Blade and pointed in nature.

Land degradation Reduces soil rank, character reputation, or state of destruction.

Margo culture Neem forests are established in arid areas, especially in Southeast Asia.

Morphology: A scientific study of form and structure of organism/plant/animal.

Nomadic Fulani Are cattle keepers that move from place to place with livestock.

Oblique: Having the base of the blade asymmetrical, with one side larger or extending further than the other.

Phenology The study of the time of recurring natural phenomena in plants that deal with new foliage, leaf fall, flowering, and fruiting events.

Photoperiod: The normal duration of natural daylight experienced by an organism, day length (duration of day length).

Physiology Branch of biology deals with the functions and activities of life or living matter such as organs, tissues, or cells.

Serrated Saw-like in nature.

Shelterbelt Tree cover is purposely meant to provide shelter and shade as a windbreaker, common in the Sahel belt of West Africa.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter discussed the following: Taxonomic classification of *Azadirachta indica*, *Azadirachta indica* taxonomy and nomenclature, habitat, environment and the ecology of the Neem tree, reproduction, seed longevity and dispersal, pest and diseases. Also handled included the 'theoretical review, *Azadirachta indica* phenology, and shifting plant phenology in response to global change. The Biological Bundesanstalt, Bundessortenamt and Chemical Industry (BBCH) system of coding the phenological growth stages of plants, organization of the BBCH scale, origin distribution and uses of *Azadirachta indica,* Climatic preference of *Azadirachta indica*, and the *Azadirachta indica* uses for solving problems, and the review enabled some gaps to be identified in the Literature.

2.1. Taxonomic classification of *Azadirachta indica*

This section reviewed the literature on the Neem tree taxonomy, propagation, and plant's resilience to harsh environmental challenges. It sets this beginning with the taxonomic classification of the Neem tree (*Azadirachta indica*). Neem is a member of the Meliaceae family. It has similar properties to its close relative, *Melia azederach.* The word *Azadirachta* is derived from the Persian word 'azadhirakt' (meaning 'noble tree') (Maria *et al.*, 2007).

The taxonomic tree of the Neem is as follows:

Order:	Rutales
Suborder:	Rutinae
Family;	Meliaceae
Subfamily:	Melioideae
Tribe -	Melieae
Genus:	*Azadirachta*
Specie:	*Indica*

Species nomenclatureas"*Azadirachta indica"*

Figure 2.1: *Azadirachta indica* (the Neem tree)

Source: Field data 2017

Figure 2.2: Neem Tree Seeds

Source: Field data 2017

2.2 Azadirachta indica taxonomy and nomenclature

The Neem plant is a member of the Meliaceae family and is scientifically known as *Azadirachta indica*. It is a woody plant with 50 genera and approximately 640 species primarily found in the tropics and subtropics with little distribution in temperate regions (Muellner et al., 2005). The Indian sub-continent is the Neem tree's native land. With a semi-straight trunk measuring 30 to 80 cm in diameter and a height of 15 to 20 meters, it is a sturdy, quick-growing evergreen tree. Its branches can reach up to 20 meters high with up to 30cm long pinnate leaves with 12 to 17 leaflets that are somewhat serrated, lance-shaped, oblique, and 7 cm long. Due to its numerous uses, the Neem tree is known as "Kalpavriksha"(Barstow and Deepu 2018). In terms of agriculture, the Neem tree and its products are utilized in a variety of ways to safeguard the environment and advance sustainable farming. Neem and the products made from it are beneficial in all ways. Neem's essential components, such as leaves, bark, twigs, and branches, are beneficial as quality animal food. When there is no alternative accessible fodder during the dry seasons, farmers most frequently use this plant as animal feed (Kumar *et al.,* 2013).

2.3 Habitat, Environment, and Ecology of Neem

In Taura Local Government Area, Jigawa State, seasonally dry, mixed forests with deciduous trees containing *Dalbergia sissco* and *Acacia species* are the natural habitats of Neem. Although it thrives in a wide range of neutral to alkaline soils, it does best in shallow, rocky, sandy soils and areas where hard calcareous or clay pan is present below the surface. It thrives in soils with a pH between 6.2 and 7.0. It may, however, thrive most effectively in deep, porous, sandy soils. Neem is better suited to stressful situations than other animals (Ahmed, 2014). Additionally, it is proven to improve soil fertility and water retention ability. Neem tree plantations on a wide scale, therefore, aid in the fight against soil erosion,

desertification, deforestation, and excessive global warming. Since Neem produces more oxygen (O2) during photosynthesis than any other tree species, it helps to filter the air. During the sweltering summer months, it has been discovered that the temperature beneath the Neem foliage is 10 °C lower than the ambient temperature in the northern area of India (Anonymous 2006). Neem serves as an effective wind break in locations with little rainfall and strong winds. Neem trees may produce between 10 and 100 tons of dry biomass per hectare when they are fully mature. This biomass is made up of 25% wood, 25% fruits, and 50% leaves (Anonymous, 2006). This study adds that its broad, deep root system is most likely an adaptation to locations that experience seasonal dryness and strong winds in the margins of the Saharan desert. It appears that those characteristics are to enable the plant to survive in harsh environmental conditions.

2.4 Reproduction, seed longevity and dispersal

The male and female flowers of the Neem tree are produced on the same tree, and the blossoms are pollinated by bees and other insects' pollinators during the dry winter/spring season. Given its efflorescence, wind pollination is also possible. Plants begin to bear fruit between the ages of 2 and 5 years and achieve full maturity between the ages of 10-15 years. With an average of 20.5 kg per year per tree, seed production ranges from 11 to 50 kilogrammes tree per year. Since there are roughly 4,000 seeds in a kilogram, the yearly seed production per tree is between 44,000 and 200,000 seeds (Anonymous, 2006). Birds, bats, and possibly feral pigs devour and disseminate fruit, as do these other animals. Under mature Neem trees, a lot of young Neem seedlings are sprouting and frequently renewing the ground through decomposition and mineralization, adding to the soil nutrients (Ahmed, 2014).

2.5 Pest and Diseases

Due to the presence of Azadirachtin and other insecticidal chemicals, Neem trees are typically pest-free. However, a scale insect (*Aonidiella orientalis*) has severely destroyed the Nem plantations in Africa and, to a lesser extent, in India (Ahmed, 2014). Pests of Neem are also referred to as ant, moth, and insect species. Termites and borers can harm live specimens.

2.6. Theoretical Review

2. 6.1. Theory of fluctuating availability resource (TFAR) on invasive species

The global issue of non-native plant and animal species encroaching on native ecosystems has the potential to have repercussions on social, economic, and ecological systems. Unfortunately, research on invasions has largely been anecdotal and non-generalizable up until this point. Three factors explain this situation: a) the number of propagules entering a new habitat (propagule pressure), b) the traits of the new species, and c) the susceptibility (weakness) of the environment to invasion by new species—all have an impact on the actual invasion of an environment by new species (Rivera *et al*., 2002).

According to Rivera *et al*. (2002), invisibility is an environment's emergent characteristic that results from a number of elements, such as the climate of the area, the environment's disturbance regime, and the competitiveness of the local species. Any time there are more unused resources available, a plant community is more vulnerable to invasion. The hypothesis is based on the premise that an invasive species needs to have access to resources like space, light, nutrition/nutrients, and water and that it will have a better chance of successfully invading a population if it does not face fierce competition from native species for these resources.

This presumption is based on the idea that the amount of unused resources should be negatively associated with the degree of competition . Given this presumption, it follows that any element or factors that increase the accessibility of finite resources will also raise a community's susceptibility to invasion. This indicates that invasion-friendly conditions may occasionally become more prevalent in a variety of habitats and vegetation types. Scholars (Rivera *et al*., 2002) indicate that herbivores and diseases may have an impact on how invasive a species is if they are present or absent in an environment. A disturbance may harm or kill some of the local plant species, which would reduce its ability to absorb nutrients, water, and light. Reduced resource uptake would also result from heavy herbivory brought on by grazing, pest outbreaks or a disease that has spread widely throughout the local vegetation. It has long been understood that perturbation plays a significant role in encouraging invasion, and environmental change on a global scale has been said to hasten the entrance of new species . This study adds that most times, the principle of variable resource availability may be applied to these colonization/invasion arguments.

According to Thompson *et al*., (2000), the only way to invade a community is to be fundamentally different from the resident species because they have already filled some niches. Further, the invaders must possess favourable qualities that the pre-existing species do not possess. As a result, variations can be brought on by changes in weather patterns as well as site-specific occurrences and/or large-scale disturbances, pest outbreaks, shifts in the amount of grazing, and anthropogenic factors such as eutrophication .

2. 7 *Azadirachta indica* Phenology

Phenology deals with new growth, leaf fall, flowering, and fruiting-like activities in plants. It is the study of the timing of the repeating of natural phenomenal processes in plant growth. It explains the connections between climatic variables and recurring events in living things.

Characterizing plant communities and ecosystems according to their functional characteristics and explaining the connections between biodiversity and ecosystem functioning (Echereme *et al.,* 2015). Plant life forms have specific relationships with specific climatic conditions. The phenological patterns may have changed as a result of a change in plant species' phenological activities brought on by a rise in surface temperature. During the summer, plant species typically blossom in response to the dry season, phylogenic limitations, or occasionally both. The interaction between numerous abiotic elements and fruiting phenology timing is such an example and is thoroughly investigated in this study. However, the association with temperature and rainfall is of particular interest in this study. Patterns of plant growth and development, as well as the influences of the environment and selective forces on flowering and fruiting behaviour, are all studied by phenologists (Zhang *et al.,* 2006).

The commencement of growth in plants and changes in phenology are influenced by a variety of environmental conditions, and the influence of temperature and moisture has been examined by numerous scholars, as evidenced by Zhang*et al*. (2006). This study posits that understanding the elements that influence phenological patterns in various geographic and eco-climatic regions is crucial because it helps conservation biologists forecast the effects of perturbations like climatic and seasonal variability and intense weather events or global warming on the alien and/or invasive species in areas of invasion.

Tropical woods exhibit significant temporal variation in flowering and fruit abundance. Despite several exceptions, the phenology of many moist tropical forests generally follows the same pattern: the flowering peaks during the dry season, and fruiting frequently occurs during the wet season (Maria *et al.,*2007). Maria *et al.* (2007) maintain that variations in temperature or rainfall correspond with leafing and blooming phonologies. Biotic and abiotic factors influence seed dispersal, germination, flowering and fruiting. There have been reports

of a negative correlation between minimum temperatures during the dry season in Gabon and Kibale, western Uganda, and fruit production the following season. This shows that fruit production benefits from the alternate cycle of dry and rainy seasons .

2.7.1. Shifting plant phenology in response to global change.

Scholars (Maria *et al*., 2007; Finn *et al*., 2007) have established that plants are highly adapted to their seasonal environment and changes in the timing of plant activity (also known as phenology). These offer compelling evidence that species and ecosystems are being impacted by environmental change on a global scale. Indeed, the literature review confirms that several Scales of phenology have been noticed by studies, including early spring blossoming in individual plants and an earlier spring green-up of the land surface visible in satellite photos (Finn*et al*., 2007). This study adds that climate and phenology are closely related from the level of individual plants to the level of the entire ecosystem, and phenology is a significant and frequently disregarded part of plant ecology. For both individuals and communities to produce seeds, the transition between the vegetative and reproductive stages, which take place concurrently with flowering, must be timed properly (Thompson *et al.,* 2000). Elsa *et al.* (2007)also pointed out that by reducing competition for pollinators and other resources, phenological variation among species helps maintain species coexistence in diverse plant communities. The length of the growing season is also determined by the timing of growth onset and senescence, which drives annual carbon uptake in terrestrial ecosystems (Finn*et al*.,2007) because temperature regulates the timing of development both directly and indirectly through interactions with other cues like photoperiod, and global climate change which may drastically alter annual plant phenological rhythm (Elsa*et al.,*2007).

Global average surface temperatures during the past 30 years have risen by 0.2^{0}Cevery decade, according to temperature data (Hansen, 2006). Studies (Kunkel, 2004) have

discovered changes that are consistent with a warmer climate when looking at frost dates, growing season length, increasing degree totals, or other complicated indices. These phenol-climatic measurements represent temperature changes that are pertinent to various stages of plant development.

2.7.2. The Biological Bundesanstalt, Bundessortenamt, and Chemical Industry.System of Coding the Phenological Growth Stages of Plants.

Within the last 19 years, scientists have documented the growth stages of development of many cultivated plants using the enlarged Biological Bundesanstalt. Bundessortenamt, and Chemical Industry System of Coding the Phenological Growth Stages of Plants (BBCH) scale. The BBCH scales are widely utilized in research, administration, and practice in agriculture and horticulture, as well as in phenology, an interdisciplinary field of environmental, meteorological, and climatological science (Meier *et al*., 2009). This study adopted the BBCH to document the growth stages of the Neem tree in the Jigawa State in Northeastern Nigeria due to its popularity and global use.

All monocotyledonous and dicotyledonous plant species can have their phonological growth stages uniformly coded using the BBCH Scale (Meier *et al*., 2009). The German Federal Biological Research Centre for Agriculture and Forestry (BBA), the German Federal Office of Plant Varieties (BSA), the German Agrochemical Association (IVA), and the Institute for Vegetables and Ornamentals all collaborated to produce the results, and this has made enigmatic contribution locally and globally in the science of phenology. This has enabled young scientists to make a couple of research breakthroughs. This study sought to use this method, and it unlocked the analysis of the Neem tree phenological attributes responsible for the propagation, growth and development of the Neem tree in the Taura Administrative Area, Jigawa State, in northern Nigeria.

The basic structures described by Zadoks *et al*. (1974) for cereals and rice are used in the decimal coding, which is divided into principal and secondary plant growth stages analysis. The decimal code has also been adapted to other monocotyledonous crops and described for use with dicotyledonous and perennial crops as well as wild plants. The letters BBCH stand for Biological Bundesanstalt, Bundessortenamt, and Chemical Industry.

Adopted from (Sign,2009), the scale's fundamental tenets include:

- The basis for developing the individual scales is the general scale, as it can be applied to plant species for which there is currently no particular scale available. This accommodating space enables more green plant phenology analysis.
- Each plant species with similar phenological stages is assigned the same code.
- Each code is described, and illustrations are included for significant phases in phenology.
- External morphological traits that are distinct and simple to recognize are utilized to describe the phenological development stages.
- Unless otherwise specified, only the growth of the main stem is taken into account.
- The growth stages pertain to representative individual plants within the crop stand.
- Another factor to take into account is crop stand characteristics.
- Sizes are shown using relative values related to species- and/or variety-specific ultimate sizes.
- The respective ordinal numbers or percentage values correspond to the secondary growth stages 0 to 9. Stage 3 might, for instance, be the third genuine leaf, the third tiller, the third node, or 30% of the eventual length or size characteristic of the species, or 30% of the open flowers.
- The code for post-harvest or storage treatment is 99.

- The code for seed treatment before planting is 00.

2.7.3 Organization of the BBCH scale

The ten distinct and easily distinguished long-lasting developmental phases make up the complete plant developmental cycle. Numbers ranging from 0 to 9 are used to describe these major growth phases in ascending sequence (Meier, 1997). The main growth stages are listed (Table 3). However, due to the enormous diversity of plant species, the order in which various phases of growth occur may change or even be skipped altogether, particularly if the growth is fast in a particular year (Ibid). The main growth stages don't always have to happen in the order that the figures are arranged in ascending order; they sometimes happen simultaneously. A diagonal stroke can be used to denote both growth stages when two or more are occurring simultaneously. Depending on the plant species, the major growth stage of particular importance or the more advanced growth stage must be chosen if just one stage is to be specified. Since the major growth stages of a plant usually refer to time periods during its development, they are insufficient to precisely determine application or evaluation (Meier, 1997).

Secondary stages are utilized when precise indications of certain points in time or steps in a plant's development are required (Kipkoech *et al.,* 2019). They are described as quick developmental steps specific to the individual plant species that are passed one after the other during the respective primary growth stage, as opposed to the principal growth stages. The two-digit code is produced by combining the primary growth phases and secondary stages. For the majority of plant species, the two-digit code provides the ability to precisely define all phenological growth stages .

2. 8. Origin, Distribution and Uses of Azadirachta indica

Neem was first introduced in the 1800s in Nigeria. The Southeast Asian immigrants brought it to Fiji, Mauritius, and Guyana during this century, and the British brought it to Egypt. It has since spread across the tropics with a wide distribution (World Agroforestry Centre, 2002). Two species were identified: *Azadirachta excelsa kack, a* native of the Philippines and Indonesia, and *Azadirachta indica A. Juss,* which is native to the Indian subcontinent, are the two species that have been identified (Fathima, 2004). In India, Bangladesh, Burma, Pakistan, Sri Lanka, Malaysia and Thailand, the *Azadirachta indica A. juss* grows as a wild tree. Neem trees are currently observed flourishing in about 72 nations across Asia, Africa, Australia, and North, Central, and South America (Fathima, 2004). This study adds that it's a dominant tree species within the Sahel Sudan eco-climatic zone in West Africa.

According to Fatima (2004), there are an estimated 25 million Neem trees flourishing throughout the country, and some states in India lead in Neem tree coverage. For instance, the State of Karnataka accounts for 5.5 per cent, Tamilnadu (17.8 per cent) and Uttar Pradesh (55.7 per cent) in ascending order positions, respectively . Along with Andaman and Nicobar Islands, a Union territory, the other Indian states where Neem trees may be found growing are Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Orissa, Punjab, Rajasthan, and West Bengal (Fathima, 2004) Although the tree can be found all over the Indian subcontinent, this is only a generalization.

The Neem tree prefers specific types of soil. The soil must not be saline, mica-rich, silty, or flooded for the tree to thrive. Frost, extreme humidity, or standing water are unsuitable circumstances for it to grow and flourish. It requires sunshine and is frequently grown close to habitation because of its many functions as well as an avenue or as a roadside tree.

According to Kipkoech *et al.* (2019), the Neem tree can be found in tropical dry evergreen forests as well as tropical dry deciduous thorn forests. Tropical evergreen forests, tropical thorn forests, tropical dry deciduous forests in the south, and tropical thorn forests are all parts of the Indian subcontinent.

India leads the world in the production of Neem seeds, with an annual production of 442,300 tons of seeds that create 88,400 tons of Neem oil and 353,800 tons of Neem cake. *Azadirachta indica*, an introduced, naturalized, or invasive plant in East Africa, is a problem in some areas of Kenya, Tanzania, and Uganda (Gardens & Kew 2017). It is a significant issue along areas of the Kenyan and Tanzanian coast, and it is invasive, naturalized, or spreading quickly in West Africa. In some areas of Nigeria, Ghana, Niger, Mali, and other countries, *Azadirachta indica* is invasive, spreading fairly rapidly and colonizing areas with great success and dominance, suppressing the indigenous species. The attributes of thriving in areas with high climatic variability account for its high success rate on the African continent (Gardens & Kew, 2017). *Azadirachta indica* has the potential to spread into a variety of habitats, including shrubland, open woods, grasslands, flood plains, riparian zones, coastal locations, and other areas with disrupted natural vegetation, such as arid and semi-arid regions. Other literature state that the Neem is a weed that is displacing local tree communities through colonisation in the Gambia's natural forest as it spreads more in coverage (WRM, 1999). Its capacity for quick proliferation has reportedly caused issues in Senegal as it suppresses the native species (WRM, 1999). In particular, the Southern Casmance region and the nearby Guinea Bissau were previously regarded as having a problem weed once the Neem tree appeared on the scene (Ebeid & Ali, 2015). This study adds that various pollinators (wind, insects, animals and humans) could be responsible for the widespread proliferation of the Neem tree plant from Chad to the far West African countries. Ahmed (2014) noted that the Neem tree was formally introduced to Brazil in 1986, and since

the 1990s, the plant has been commercially grown in Brazil's southeast, middle, north, and northeast (Anon, 1998). The Neem tree and its seeds are widely dispersed throughout Nigeria, especially in the northern part of the country. The same author maintains that it has been widely distributed in the country since it was brought into Nigeria by Cameroonian traders through Borno State. The *Azadirachta indica*, also known as Dogonyaro in the north by the native communities, has been well-known there for decades, where it has been embraced by the local communities due to a variety of benefits accruing from the plant.

According to (Ahmed, 2014), the Neem tree is extensively planted in Nigeria's northeast due to the area's climate and edaphic (favourable soils) factors and the strategic location within the Sahel Savanna belt of West Africa possessing the requisite conditions for its growth. It was introduced in the region in the Nineteenth Century. The Neem tree is now frequently utilized as fuelwood, and the leaves are used as traditional medicine. It's also frequently utilized as home and family blinds (live fences to secure home environments), particularly during the dry season. Most critically, to mitigate soil erosion and Sahara desert southwards encroachment through sand dunes establishment with a great degree of success. It's partly the implementation of the Greening Sahel Belt Project' of the African Union. Also, the selection of the Neem tree in desert slow-down is because of its numerous ecosystem/ecological values and qualities to thrive in marginal areas where many other plant species do not. This study adds that, in the Taura Local Government Area, nearly every household has some natural blind of their homes made of the planted Neem tree.

Furthermore, the Neem tree serves other ecological and socioeconomic purposes. One of which is the halting of desertification (Southward advance of the Sahara Desert) (Abdulrashid & Yaro, 2014). Indeed, in over ten Federal States in northern Nigeria (Adamawa, Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, and Zamfara), the Neem tree is used for building shelter belts, windbreaks, shade provision, and creating woodlots and

holding the ground/soil together through the root system in soil erosion control (Ahmed, 2014).

Despite the wide uses of the Neem tree, little information is documented on its enormous potential. This posits that the main causes could be ignorance and low skills in its preservation. Research results (source) indicate that there are multiple benefits to be derived from the Neem tree (‘wonder tree’), which possesses over (137 bio-active constituents), with preventive, curative and health-enhancing properties (Krishnan *et al.*, 2022).

In 2004, during a meeting with important government officials and other foreign organizations interested in investing in the Neem tree in Nigeria, Chief Olusegun Obasanjo, the President of the Federal Republic of Nigeria, brought up the issue of the Neem tree after receiving briefings on the noteworthy accomplishments recorded by the National Research Institute for Chemical Technology (NRICT) in Zaria (Federal Government of Nigeria, 2010). Strong directives were issued to the presidential committee, including:

- The cultivation and growth of high-quality Neem species generally in Nigeria but particularly in the states of Borno, Katsina, Kebbi, and Zamfara in Northern Nigeria.
- To establish medium- and small-scale processing facilities for the manufacture of fertilizers, insecticides, soap, and any other Neem by-products that might be created for both the domestic and global markets.

There is no doubt that the Neem tree's economic impact will boost household income and wealth sustainability for the vast majority of people in northern Nigeria. The chance to plant the Neem tree in Nigeria is also enormous. Because of its bi-products, which can be produced at a profit, it ought to be a national endeavour worthy of consideration. Environmentally speaking, the Neem wood is exceptionally strong, termite-resistant, and capable of enhancing ground-water balance by fixing nitrogen into the soil through a well-developed deep and

wide-span root system (Ahmed *et al.*, 2019). This study adds that it is worthwhile to promote the increase of the Neem tree by choosing and using quality seedlings and the suppression of pests that affect the Neem plant for greater benefits that accrue from it. Neem oil is made from seeds, and Neem has been used for many years in pest control, cosmetics, and medicine due to its therapeutic characteristics (Ahmed *et al.*, 2019). When used as a soil amendment or put to soil, Neem seed cake (the remnant of the Neem seeds after oil extraction) not only enriches the soil with organic matter but also reduces nitrogen losses by suppressing nitrification. It also has nematicide properties. It's also reported that chickenpox and warts can be cured by applying the Neem leaf paste directly to the skin or by taking a Neem leaf bath. Neem leaves are also eaten internally in the form of Neem capsules or turned into tea to boost the body's immunity. The tea is usually consumed internally to treat malarial fever. This team has a strong bitter flavour. In order to treat various foot funguses, it is also used to soak feet. Additionally, reports suggest that it repels termites. Neuromuscular pains can be relieved using Neem leaves. They are also employed for grain storage (Bartow and Deepu, 2018).

African and Indian toothbrushes are also made from Neem twigs (Ahmed, 2014). There are now commercially marketed toothpaste that contain Neem extracts. Due to the discovery that Neem (leaf and seed) extracts are spermicidal, research is being done on the potential use of Neem extracts in contraceptives. Neem produces components that can help with the healing of cuts, burns, earaches, sprains, headaches, and fevers. These compounds also have anti-inflammatory and fever-reducing properties. Both the bark and the roots of Neem are therapeutic. Additionally, powdered bark and roots are used to control fleas and ticks in dogs. Neem possesses anti-bacterial qualities that aid in the treatment of skin illnesses such as eczema, psoriasis, scabies, and acne. Neem extracts also aid in the treatment of a number of other illnesses, including hepatitis, diabetes, AIDS, cancer, heart disease, herpes, allergies,

and ulcers (*Ibid*). The active ingredients in the Neem plant are numerous. Products for health and cosmetic care are made from Neem leaves and stem extracts. Some examples of the goods are medicated soap, bath salts, shampoos, lotion and cream, toothpaste, and leaf capsules. These items boost immunity and purify the skin; some have insect-repellent characteristics, and some are used for pet care (*Ibid*). The Neem extract's use and application on food crops as a pesticide has received approval following successful experimentations (Anonymous, 2006). Neem has been shown in numerous tests to protect crops from pests while being non-toxic to humans, beneficial insects, or birds that promote crop and plant pollination.

2. 9. Climatic preference of *Azadirachta indica*

Neem can grow in sub-arid, sub-humid environments with tropical and sub-tropical climates between sea level and 700 meters above sea level. It does well between mean temperatures of 21^0C and 23^0C (Echereme *et al*., 2015). Although Neem trees can withstand summer temperatures of up to 50°C, they cannot withstand frost or temperatures below 4°C. Neem can endure yearly rainfall as low as 150 mm if its roots have access to groundwater within 9 to 12 meters of the ground surface. Neem thrives best in locations with annual rainfall of 450 to 1200 mm (with optimal growth occurring around 1100 mm) (Ibid). It can withstand 7-8 months of the dry season after it has been established and is an exceptionally drought-tolerant vegetation species (Echereme *et al*., 2015).

2.10. *Azadirachtaindica* for solving global problems

Due to its exceptional qualities, the *Azadirachtaindica* has globally are used for solving a variety of problems. For instance, the gum is poisonous, demulcent, stimulant, and treats infections like catarrh (Ahmed *et al.*, 2019). Due to its medicinal and restorative qualities, it has been utilized in Ayurvedic medicine for more than 4,000 years and is known as "The

Village Pharmacy." Ancient texts "Charak- Samhita" and "Susruta- Samhita," which serve as the cornerstone of the Indian system of natural medicine known as Ayurveda, both highlight the benefits of Neem (World Agroforestry Centre, 2000). According to Ahmed (2014), Neem is a natural source of insecticides, pesticides, and agrochemicals. It is also utilized as a bio-control agent to treat a variety of plant diseases like:

1. Anthracnose 2. Apple Scab 3. Cedar Apple Rust

The Neem plant can be raised in areas where the soil is marginal for crops, where the Neem plant will still flourish in such areas without displacing food production. Even some types of soil can benefit from it, and like all trees, it helps prevent erosion. Neem trees can still be harvested after they have been felled, unlike many species. Thus, using Neem products has the advantage of encouraging the environment to become greener (WAC, 2000). This study adds that the Neem tree is progressively growing to become one of the most widely planted trees in the world, possibly even rivalling the African oil palm in value, with the orderly development of plantations and marketplaces and the consistent availability of uniform, high-quality seeds at stable costs (Ahmed, 2014). This study posits that the Federal and State Governments in Nigeria should provide extension and agronomic support and credit facilities to promote quality and increased production of the Neem tree products with value addition for improved income to address health and household poverty for sustainable development.

2.10.1 Meaning of CBD

The United Nation Convention on Biological Diversity is the United Nation-wide body responsible for the conservation and management of the global biological diversity. Formed in 1945, the CBD coordinates global biodiversity conservation programmes and supports states parties in the sustainable global efforts in biological diversity conservation. The CBD has developed guidelines for genetic resources conservation use and management which states parties have adopted and domesticated through local Acts and policies to implement

the CBD in respective countries. The various direct uses of the Neem tree products fall within the CBD genetic resources framework. Biological Diversity means the variability among living organisms from all sources, including inner alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems (CBD, 1992).

2.10.2 Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD) is the international legal instrument for ``the conservation of biological diversity, the sustainable use of its components and the fairs and equitable sharing of the benefits arising out of the utilization of genetic resources" that has been ratified by 196 nations. Its overall objective is to encourage actions which will lead to a sustainable future. The conservation of biodiversity is a common concern of humankind. The convention on Biological diversity covers biodiversity at all levels. Ecosystems, species and genetic resources also cover biotechnology, including through the Cartagena Protocol on Biosafety. In fact, it covers all possible domains that are directly or indirectly related to biodiversity and its role in development, ranging from science, politics and education to agriculture, business, culture, and much more. The CBD's governing body is the Conference of the Parties (COP). This ultimate authority of all governments (or parties) that have ratified the treaty meets every two years to review progress, set priorities and commit to work plans. The secretariat of the Convention on Biodiversity (SCBD) is based in Montreal, Canada. Its main function is to assist the government in the implementation of the CBD, and its programmes work, to organise meetings, draft documents, coordinate with other international organisations and collect and spread information. The executive secretary is the head of the secretariat (CBD, 1992).

2.10.3 The purpose of the convention on Biodiversity

The CBD is an internal–binding treaty with three objectives:

1. The Conservation of the Biodiversity
2. The sustainable use of its components
3. The fair and equitable sharing of the benefits arising from the use of genetic resources.

2.10.4 The United Nations Convention on Biological Biodiversity

The United Nations Convention on Biological Biodiversity, informally known as the Biodiversity Convention, is a multilateral treaty opened for signature at the Earth Summit in Rio De Janeiro in 1992. It is a key document regarding sustainable development. It comes under the United Nations Environment Programme (UNEP,1992).

The aims of the Rio Convention on Biological Diversity are the key objectives of the Convention on Biological Diversity (CBD). They include convention on biological diversity, its sustainable use, and fair and equitable sharing of the benefits arising from commercial and other utilization of genetic resources.

Three Major Types of Biodiversity

Biodiversity is usually explored at three levels.

1. Genetic diversity
2. Species diversity and
3. Ecosystem diversity

These three levels work together to create the complexity of life on Earth.

Four (4) components of Biodiversity

1. Species diversity
2. Ecological diversity
3. Genetic diversity and
4. Functional diversity

Biodiversity is important because it allows organisms to adapt to their environment and to survive dramatic environmental changes.

2.10.5 Benefits of Biodiversity

Biodiversity supports human and societal needs, including food and nutrition security, energy development of medicines and pharmaceuticals and fresh water, which together underpin good health. It also supports economic opportunities and leisure activities that contribute to overall well-being.

Five major factors affecting biodiversity

1. Change in land and sea use largely through development, deforestation and pollution.
2. Climate change: causes acidification of seas and oceans degrading the marine habitats.
3. Pollution in all its forms and types is harmful and affects biodiversity and its habitats.
4. Direct exploitation of natural resources degrades biodiversity species to extinction levels.
5. Invasive alien species suppresses the native indigenous species thereby colonizing the area.

2.10.6 Meaning of genetic resource

The term genetic resource refers to any biological material which contains genes and or metabolic material that may be derived from genes. They fall within the scope of the Nagoya protocol whenever they are used for research or product development.

2.10.7 The Genetic resources covered by the Convention on Biological Diversity

Article 2 of the CBD defines the term "genetic resources" as ``genetic material of actual or potential value''. Further, it defines the term genetic material as meaning "any materials of plant, animal, microbial or other origin containing a functional unit of heredity.

2.10.8 Uses of genetic resources

Genetic resources are a key source of information for taxonomy, the science of describing and naming species. Taxonomic resource provides crucial information for effective environmental conservation. Genetic resources are the building blocks of life on earth (www.biodiversity.fi>genetic2016).

The access and benefit-sharing provisions of the Convention on Biological Diversity (CBD) are designed to ensure that physical access to genetic resources is facilitated and that the benefits obtained from their use are shared equitably with the providers.

2.10.9 Convention on combating desertification:-

The United Nations Convention to Combat Desertification in those countries experiencing serious Drought and/ or desertification, particularly in Africa (UNCCD), is a convention to combat desertification and mitigate the effects of drought through national action programs that incorporate long-term strategies.

2.10.10 Objective of UNCCD

The objective of UNCCD is to combat desertification and mitigate the effects of drought in countries experiencing serious Drought, particularly in Africa. The states parties have been encouraged to domesticate Acts, Policies and Programmes of Action to implement the UNCCD to counter the challenges of desertification. The states parties that face the threat of desertification are encourages to implement the UNCCD strategies through greening and awareness raising programs.

2.10.11 Desertification

It is defined as a process of land degradation in arid, semi-arid, and sub-humid areas due to various factors, including climatic variations and human activities. Overgrazing is the major cause of desertification worldwide. Other factors include urbanization, climate change, overuse of groundwater, deforestation, natural disasters, and tillage practices in agriculture that make soil more vulnerable to wind. In the Sahel region of West Africa, the African Union supports the Sahara Greening programme through the establishment of the green belt development by supporting tree planting and stabilization of sand duning to counter the advance of the southwards shifting of the Sahara desert in the Sahel region. Desertification has to be combated because it is a threat to one-third of the earth's land surface. It affects the livelihood of millions of people who depend on the benefits of ecosystems that dry lands provide. The Neem tree planting and expasion of Neem forest is in the right direction to combat desertification.

2.10.12 United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 with the ultimate aim of preventing dangerous human interference with the climate system. The 1997 Kyoto Protocol and 2015 Paris Agreement build on the convention.

The objectives of UNFCCC 1992 United Nations Framework Convention on Climate Change

The ultimate objective of all three agreements under the UNFCCC is to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system in a timeframe which allows ecosystems to adapt naturally and enables sustainable development (Ahmed *et al.,* 2019). The principles of the United Nations' Framework Convention on Climate Change are to: 1) be responsible in addressing emissions of greenhouse gases; 2) reduction of climate change impacts through adaptation and mitigation interventions; 3) awareness raising on climate actions; 4) promoting sustainable and responsible consumption; and 5) advocating for climate through communication. These recommendations can be met through the promotion of Neem tree plantation programmes coupled with greening programme of tree planting and skilling of the communities to adapt to challenges of climatic changes and variability.

2. 11. Gaps Identified in the Literature

- So far, the researcher has not come across studies on the Neem tree in Taura Local Government Area (study area) in Jigawa State, Nigeria.
- From the literature reviewed, there was no study that combines phenology, distribution and uses of Neem in the Taura Local Government Area (study area) in Jigawa State, Nigeria.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0. Introduction

This study examined the Phenology, distribution and uses of *Azadirachta Indica A. Juss* (the Neem Tree) in the Taura Local Government area, Jigawa State, Nigeria. This chapter provides a descriptive account of the methods that were used in the study to address the research objectives and the research questions. In particular, it provides information on the steps and procedures used to generate data during the research process. It also details data processing and presentation to answer the central research objective, which shaped and guided the study with the general objective: 'To investigate the Phenology, distribution and uses of *Azadirachta indica A. Juss* in the Taura Local Government Area, Jigawa State, Nigeria, with the aim of formulating a model for sustainable conservation and the management of the *Azadirachta indica A. Juss* (the Neem Tree) in the study area. It also investigated the overall research question: 'What are the phonological distribution and uses of *Azadirachta indica A. Juss* in Taura Local Government Area? This chapter, in particular, explains and justifies the methodology and the approach employed during the study, elaborating on the techniques and tools employed in data collection to provide answers to the research objectives and the questions. It is then followed by a section on research design and approach, which presents how the study was conceived and organized, implemented and presented in a logical order. Following this then comes the descriptive account of various steps and the phases the research passed through (proposal formulation, presentation, validation and clearance by the Kampala International University, The Federal Government and Council for Science and Technology, Office of Governor Jigawa State, and the Administrator of Taura Local Government Area for field clearance and fixing of appointments, and field surveys). This chapter then articulates methods and techniques used in data generation, analysis and management. The study areas of Taura Local Government

Area, Jigawa State, Nigeria, are presented and described, giving the biophysical, socioeconomic and demographic characteristics of the area and respondents with justifications on site selection criteria for the study. The study population, survey design, units of analysis, sampling procedure, sample size determination and techniques employed in data capture are presented and explained in the following sections. This is followed by an explanation of study instruments and tools used for data collection. Data collection methods and procedures are then explained. The section on data management: quality assurance, entry, cleaning, analysis and presentation are then explained. Representativeness, validity and reliability of data are presented. This is followed by explanations of study variables and units of analysis. The Kampala International University codes of ethics for research are presented. Study delimitations and critical highlights of the challenges and limitations experienced during the study are presented.

3.1. Study site description

3.1.1 Vegetation

Taura Local Government Territory is located in the Sudan savannah zone in eco-climatic belt five due to its aridity characterized by high seasonal variability and harsh effects of the Sahara desert. According to LGA NIPOST (2012), there is a lot of pressure as a result of both natural and human influences; the area's total forest cover is lower than the national average of 14.8%. As a result, the area is extremely vulnerable to desert encroachment. This is further exacerbated by anthropogenic factors such as the expansion of land under agriculture and mega-development projects. The region contains grazing lands ideal for raising animals. Taura contains fertile ground that is suitable for both wet and dry season cultivation (Taura LGA NIPOST 2012). This study adds that these land use activities have not happened without adverse impacts on the land, thus increasing the land to become more marginal to the detriment of agriculture, but to the colonisation of the areas by the Neem plant.

3.1.2 Location

The Taura Local Government Area is in the Jigawa State, northern Nigeria, within the dominant Hausa/Fulani communities of northern Nigeria. The area is located at 90.1'11'' – 9^0.6'2" N latitude and 12^0.15'2" – 12^0.38'7" E longitude (Taura LGA NIPOST, 2012). Taura Local Government Area is 653km^2. It has a population of 131,757 people as per the population census of 2006. Taura town serves as the headquarters of the Local Government Area and is populated mainly by the Hausa and/or Fulani tribes, who are nomadic, tending large numbers of livestock. The area is bordered to the north by Garki, the east by Gagarawa, the south by Jahun, and the west by Ringim (*Ibid*).

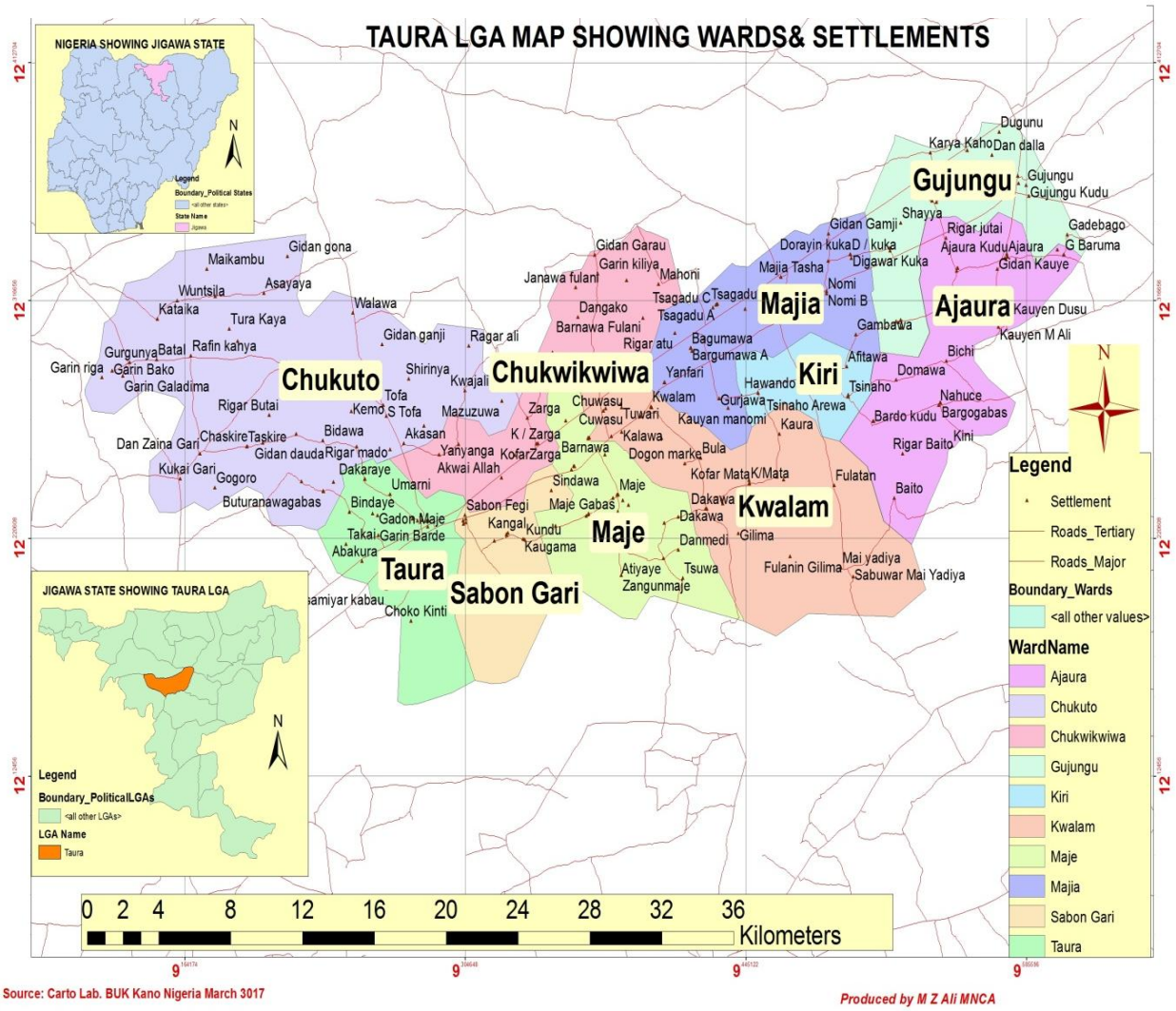


Figure 3.1 Taura Local Government Area Showing Wards and Settlement

Source: Adapted from Bayero University, Kano, Department of Geography Cartography Unit.

3.1.3 Climate and Temperature

The climate of the Taura Local Government Area is characterized by four distinct seasons, each with its own set of weather conditions and with names in Hausa. The four seasons are Kaka (harmattan Period), where it is cold and the temperature is below 21°C. Rani (dry and warm), the Bazara (dry and hot) 310-34^{0}C, and the Damina (wet and warm) season with temperatures of 35° to 40°C ^{0}C. Seasonal temperatures vary significantly, with temperatures ranging from in the region. The annual rainfall total in the Taura Local Government Area is 1000mm, but not well distributed. The climate tends towards semi-arid to dry bush humid, and the rainfall pattern is bimodal, with a short rainy season occupying any time between October and December. The long season occurs between March and June. The annual mean rainfall ranges from 500mm to 1000mm, but this is highly variable both between and within years, and variability has appeared to have increased in the recent past (Taura LGA NIPOST, 2012).

The annual rainfall received is divided over two agricultural seasons, which is an indication that there is hardly enough water to support the common food crops such as maize and beans. The rainfall is of short duration and high intensity with rapid surface run-off; if not harvested, it drains into the river networks and alluvial aquifers before occasionally reaching the main river channels in the landscape (*Ibid*).

3.1.4 The soil

The soils of Taura Administrative Area, in Jigawa State and the surrounding regions, are rich, primarily of lateritic origin, relatively young and fairly sandy and fertile, with calcium, sodium and potassium quantities, which is a necessary ingredient for agricultural production,

but also these soils support varied Sahelian/Sudan woodlands and thickets in riparian areas. The same soils support highly productive agriculture and high population densities in Jigawa State. The soils of the area are sandy to loams up to half a meter deep, ideal for agriculture. However, given the high seasonal rainfall variability, most rainfall effectiveness is small, and drought, which is frequent in the area, causes crops to will (Ahmed *et al.*, 2019). These high seasons are responsible for eco-disasters and require effective adaptation to global changes manifested in the area in terms of adverse impacts of climate change . These characteristics affect natural vegetation growth, particularly the invasive species such as the Neem tree and such effects are not known, as well as adaptation options and strategies used by the communities in Neem tree conservation and are not well documented, which is why this study is undertaken.

3.1.5 Topography

The Taura Local Government Area is mostly flat with no hills or mountains, and it is located between latitudes 11°N and 13°N and longitudes 8°E and 10°E. (Jigawa Research report, 2021).

3.2. Research Philosophy

Research paradigm**:** The study employed positivist thought of reasoning. According to (Creswell, 2011), philosophy positivism adheres to the view that only "factual" knowledge gained through observation (the senses), including measurement, is trustworthy. In positivist studies, the role of the researcher is limited to data collection and interpretation through an objective approach, and the research findings are usually observable and quantifiable. Positivism depends on quantifiable observations that lead to statistical analysis.

Positivism

The study adopted positivism for a number of reasons: 1) it is the rejection of metaphysics (abstract truth, nature of existence); 2) it is a position that holds that the goal of knowledge is simply to describe phenomena that we experience; 3) positivism is the philosophy of the science that information is derived from logical and mathematical treatments and reports of sensory experience; 4) positivism holds that society, like the physical world, operates according to general laws. Introspective and intuitive knowledge is rejected. Positivism is a philosophical system deeply rooted in science and mathematics. It's based on the view that whatever exists can be verified through experiments, observation and mathematical/logical proof (*Ibid*).

Research approach:

The study adopted a mixed approach; both quantitative and qualitative in effort to abstract data from the field.

Quantitative approach

The quantitative approach applies statistics, optimization models, information models, computer simulations and other quantitative techniques to the management process. Data collected from the field is analysed and presented in form of frequencies to make meaning. Some of it are analysed using statistical inferences to establish the level of significance through inferential statistics.

Quantitative Approaches to Research

There are four main types of quantitative research;

Descriptive, correlation, causal-comparative/quasi-experimental and experimental research (Creswell, 2011). For this study and given the set objectives, descriptive and experimental

research undertaking was implemented in the analysis of the Neem tree phenology in the Taura Administrative Area, Jigawa State.

3.3. Research Design

Any research is valid when its conclusions are true. It is reliable when the findings are repeatable. Reliability and validity of research require the planning of inquiry and a detailed strategy of how the research will be conducted (Creswell, 2011). Two aspects of the design are critical: first, specifying what one wants to find out (properly posing the problem or phrasing the issues to be studied; second, determining how to do it; in short, making controlled scientific inquiry. States that "Research design" is planning a strategy for conducting research. It plans what is to be observed, how it is to be observed, when/where it is to be observed, why it is to be observed, how to record the observations, how to analyse and interpret observations and generalize. Research design is thus a detailed plan of how the goals of research will be achieved. Ultimately, in this study, the research design was set to attain the realisation of the research goal through a controlled scientific inquiry process as detailed as follows:

The study took into account the phenology, distribution, and applications and/or the use of *Azadirachta indica A. juss* in the Taura Local Government Area through a descriptive survey and a longitudinal (observational) design. According to Creswell (2011), observation is the deliberate, methodical, and selective act of seeing and listening to an event as it is happening, while watching is observations accompanied by note-taking. In this study, the researcher chose to employ the observation method over other research techniques because it allows for the collection of information about the phenomena under research more elaborately and in detail, particularly when backed with a camera and voice recorder captured data. Data about *Azadirachta indica A. juss* phonological observations were gathered using the Biologische

Bundesanstalt, Bundessortenamt and Chemsche Industry (BBCH) scale for purpose observational approach. The descriptive study design is a scientific approach to data collection and interpretation that entails data abstraction, analysis and presentation into meaningful charts, tables and descriptions for scholarly comprehension for stakeholders without alterations (Martyn, 2008). For purposes of this study, Six (6) principal growth stages were used for phenological analysis: a) leaf development (LD) to determine changes in leaf blade and size; b) leaf end (LE) to establish and/or analyse range of development c)the flower development (FD) to analyse its duration d) the flower end (FE) to evaluate its duration e) the fruit development (FrD) to determine its periods and f) the fruit end (FrE) to analyse its duration. The secondary growth stages are numbered from 0-9; 0 is the start, and 9 is the end (Echereme, 2015). (1-8) They are the functional numbers, which are in percentages: 1 = 10% and 8 = 80%, respectively. Geographical Information System (GIS) satellite data and global positioning System (GPS) were used to geo-reference the Neem trees along transects in the study area, and Normalized Difference Vegetation Index (NDVI) was calculated/determined and used for the Neem tree distribution. For the Neem tree uses, a social survey questionnaire was used to capture/generate data from the respondents. The social survey questionnaire was administered face to face with the respondents, and this provided an opportunity to obtain firsthand information on the uses of the Neem tree among the respondents in the Taura Administrative area.

3.4. Sample Size Estimation

The entire population of Jigawa State's Taura Local Government Area (LGA) served as the study's target population. There are 131,757 people living in Taura in LGA, as per the 2006 national census. Table 3.1 presents wards with estimated populations in the Tauwa Local Government Area. Estimates are used based on records from the Wards' leadership and the Jigawa State Government.

Table 3.1: Population of sampled small-scale farmers in Taura Local Government Area

Administrative area	Wards/parishes	Estimated population
Taura Local Government Area	Taura	40
	Sabon garin `ya `ya	40
	Maje	38
	Chakwaikwaiwa	40
	Majia	40
	Kwalam	40
	Kiri	40
	Ajaura	40
	Chukuto	40
	Gujungu	40
Total population of 10 wards		**398**

Source: Field data

Suffice to point out that , farmers make up 80% of the population

Using Slovan's formula, the sample size determined is 398 respondents (N=398) as detailed here below:

$$n = \frac{N}{1 + N(e)^2}$$

The target population was 105,405.6. The sample size used was obtained using the formula of Slovene's as follows:

n = sample size
N = population size
I = constant
e = the level of precision
N = 105405

e = 0.05

$$n = \frac{105405}{1 + 105405(0.05)^2}$$

$$n = \frac{105405}{1 + 105405 \times (0.0025)}$$

$$n = \frac{105405}{264.5125}$$

n= 398.488

The Taure Local Government Area was selected for the study because it's the area where the Neem Tree is widely spread, and it's thought to be due to anthropogenic (human) influence.

3.5. Sampling technique

The study employed purposive and simple random sampling to arrive at the household head or any other member of the household as a respondent during the data collection. The researcher approached the Ward Administrative Leader, who presented a list of households in the administrative area that had lived in the community for over ten (10) years, was involved in the Neem Tree propagation and management and were in a better capacity to provide the requisite research information on the rainfall, temperature, soils and Neem Plant propagation and uses. The researcher was led to the respondents' homes by the Administrative chairperson of the Wards. To attain the required number of respondents, the researcher computed the sample size and the sampling units required in specific administrative units in specific wards, and the researcher visited forty (40) respondents for each ward till the required number of respondents was attained for data collection for the study.

3.6. Data Collection Method

This study was gender-focused and multi-stakeholder research where men and women who were heads of households were interviewed. Data in this study was largely from primary sources (self-generated) but also the analysis of written records such as the district development plans. The data collection methodology and analysis were based on the study objectives as illustrated below:

The study was guided by three objectives, namely to: 1) determine the phenology of the *Azadirachta indica* in Taura Local Government Area; 2) determine the distribution of the *Azadirachta indica* in Taura Local Government Area; 3) determine the level and the uses of the *Azadirachta indica* in Taura Local Government Area, Jigawa State, Nigeria. Stated below

are the various techniques employed in data collection for the aforementioned research objective.

For ObjectiveI: To determine the phenology of the *Azadirachta indica* in the Taura Local Government Area, the Biologische Bundesanstalt, Bundessortenamt and Chemsche Industry (BBCH) systems of coding of the phenological growth stages of the plant were used as explained in 3.6.1.

3.6.1 Methodology of phenology analysis

The Biologische Bundesanstalt, Bundessortenamt and Chemsche Industry (BBCH) systems of coding the phenological growth stages of plants were used. The BBCH was developed by (Meier 1997) in the analysis of green plant phenology. Techniques such as observations on optimum conditions are recorded of leaf growth by setting some constant (greenish-brown tint) in establishing leaf growth and distinguishing new leaves from matured leaves. Measurements and recordings were taken for analysis, and findings were recorded in concert with the BBCH assessment guide for phenology.

3.6.2 Criteria for optimum conditions

Throughout the observations, the researcher ensured that the conditions were constant and that the phenology assessment guiding principles were followed. For instance, an indicator of leaf growth was the new leaves' greenish-brown tint, which distinguished mature leaves from those that were still growing. Inflorescence development and emergence served as a sign of flowering. Green fruits turning into yellow fruits indicated the development of the fruit (Maria *et al*., 2007).

3.6.3 Scale:

Meier's (1997) and Zadoks *et al.*,(1974) expanded the Biologische Bundesanstalt, Bundessortenamt and Chemsche Industry) (BBCH) scale was utilized, with six (6) of the ten (10) key growth phases being chosen and placed chronologically according to their course of natural development(Zadoks *et al*., 1974). The primary growth stages that were used in this study are leaf development (LD), leaf end (LE), flower development (FD), flower end (FE), fruit development (Fr D) and fruit end (Fr E), which are coded with the letters H, I, J, K, L, and M, respectively, based on Zadoks *et al.*,(1974) placement of each stage. The Secondary growth phases were established to fill in the gaps left by the principal growth stages' inability to adequately portray the brief developmental changes that occurred over time in the principal growth stages. The primary growth stages were coded from 0 to 9, with 0 designating the beginning and 9^{th} the conclusion. The secondary growth stages were divided into 10 per cent, 20 per cent, 30 per cent, 40 per cent, 50 per cent, 60 per cent, 70 per cent, and 80 per cent based on the meso stages between 0 and 9 (that is,1,2,3,4,5,6,7 and 8). The 2-digit scale BBCHxy utilized in the phenological records was ultimately inspired by the major and secondary growth stages (Meier, 1997). The primary growth stage was denoted by the letter "y," whereas the secondary growth stage was denoted by the letter "x." For instance, (BBCH (H1)) represents 10% of leaf growth, (BBCH (H8) represents 80%, and (BBCH (H9)) represents the final 10% of leaf development.

3.6.5 Objective II *Azadirachta indica A. juss* distribution:

The second objective of the study was to determine the distribution of the *Azadirachta indica* in the Taura Local Government Area in Jigawa State, Nigeria. The distribution of *Azadirachta indica* in various Taura Local Government Area locations, such as in the settlements, farms, grazing yards, shelter belts, and roadsides, was mapped using the global positioning system (GPS), where the *Azadirachta indica* observations (locations of the Neem

plants on the ground were recorded and geo-referenced) geographic information system (GIS), and normalized difference vegetation index (NDVI).

3.6.6 The Description of Normalized Difference Vegetation Index (NDVI)

The descriptive Vegetation Index was used to measure spatio-temporal changes in green vegetation. Indeed, the Normalized Difference Vegetation Index (NDVI) is a straightforward numerical indicator and an effective tool for measuring spatio-temporal changes in green vegetation. The NDVI is a dimensionless index that measures the difference in plant cover between visible and near-infrared reflectance and can be used to calculate how much greenery is present in an area of land (Weier and Herring, 2000). Using this reflected light in the visible and near-infrared bands, the NDVI index detects and measures the presence of live, green vegetation. NDVI is a measure of the vegetation's greenness, or the density and health, of each pixel in a satellite image (Weier & Herring, 2000).

3.6.7 The formula for NDVI

The values of absorption and reflection of red and NIR light will be compared to understand how healthy a plant is. The simple mathematical formula (below) calculates the NDVI and, in turn, transforms raw satellite data into vegetation indices, where:

$$NDVI = \frac{NIR-RED}{NIR+RED}$$

Red and NIR band data are combined into a single, representative value using the NDVI algorithm. By deducting the reflectance in the red spectral region from the reflectance in the NIR, it achieves this. This is then divided by the total of red and near-infrared reflectance. The NDVI will always have a value between -1 and +1. Inorganic items like stones, roads, and buildings are represented by values between -1 and 0, along with dead vegetation. Live

plants' NDVI values range from 0 to 1, with 1 denoting the healthiest conditions and 0 the least healthy (Weier & Herring, 2000).

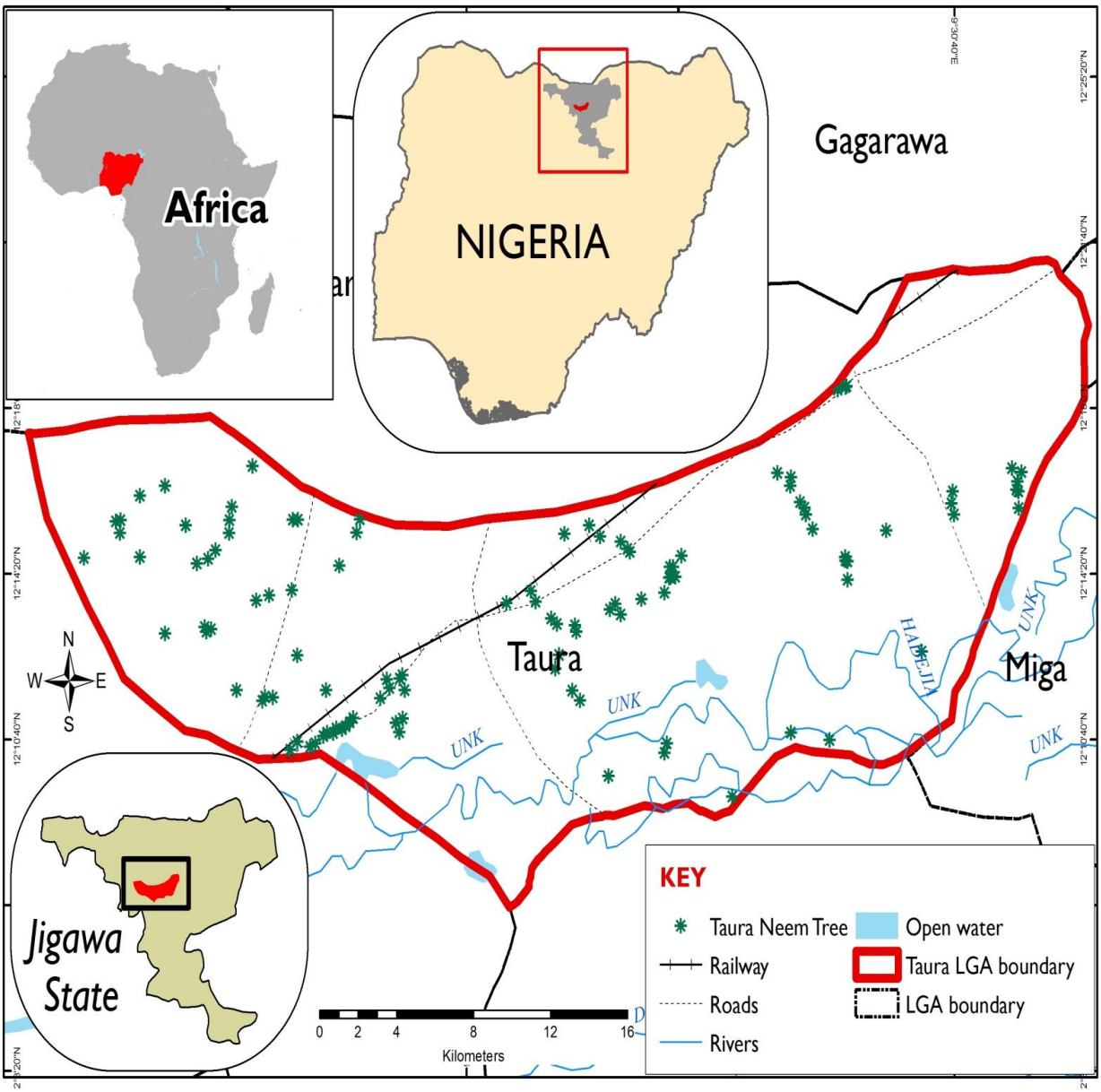


Figure 3.1: Neem Tree Distribution Map in Taura Local Administration Area

Source: Adapted from Makerere University Uganda Cartography Department (2018).

3.6.8 Objective (III) *Azadirachta indica A. juss* (the Neem tree) uses:

Objective three (3) was to document the various uses of Azadirachta indica in Taura Local Government Areas of Jigawa State, Nigeria. Data was gathered using semi-structured interview questions. Two different types of questionnaires were used, one for local farmers

and the other for Taura Local Government Area and the administrators from Jigawa State, Nigeria's Ministry for the Environment. The questionnaire was divided into two sections: part A was for personal (bio data) information, and section B was for the actual questions and themes under examination.

3.7. Validity of the Instrument

Face validity was determined using professional judgment. The supervisors validated the questionnaires to make sure they were relevant and applicable. Field's suggestion of Kaiser-Meyer-Olkin (KMO) was used to establish the construct validity of the instrument (Field, 2009). Values of 0.90 and above are considered to be exceptional, 0.80 to be terrific, 0.70 to be good, 0.60 to be acceptable, and 0.50 to be unsatisfactory.

Table 3.2 shows the KMO values for the construct and were acceptable.

It shows that the sample for the study was adequate because the local farmers' average for KMO was 0.822, interpreted as very good, while for the administrators, the KMO average was 0.916, interpreted as very good.

Table 3.2.: KMO validity co-efficient for the construct

Construct/variables	*KMO /Value*	*Interpretation*
Local farmers		
Direct use	0.836	Great
Ecological	0.749	Good
Medicinal	0.881	Great
Local farmers average	0.822	Great
Administrators		
Direct use	0.867	Great
Ecological use	0.908	Excellent
Medicinal use	0.922	Excellent
For administrators only	0.978	Excellent
Administrators average	0.916	Excellent

Source: Field data, 2017

3.8 Reliability Test

The consistency of a measure is what determines its reliability. When a test consistently produces the same result under the same circumstances, it is considered dependable (Martyn & Lyndsay, 2009). The reliability, or internal consistency, of a group of scale or test items, is evaluated using Cronbach alpha reliability. In other words, the degree to which a measurement is a consistent representation of a notion of what is meant by its reliability and one way to assess the strength of that consistency is by the use of Cronbach alpha reliability (Chelsea, 2015). When the Cronbach alpha reliability value is larger than 0.9, it's very good. Greater than 0.8 good. Greater than 0.7 is acceptable. Greater than 0.6 is questionable. Greater than 0.5 is unacceptable, less than 0.5. (Chelsea, 2015). However, the usual range for Cronbach alpha reliability. The coefficient is 0 to. Below are the reliability statistics of Cronbach alpha reliability.

Table 3.3 Cronbach's alpha coefficient measures the internal consistency, or reliability, of a set of survey items. Use this statistic to help determine whether a collection of items consistently measures the same characteristic. Cronbach's alpha quantifies the level of agreement on a standardized 0 to 1 scale. Higher values indicate higher agreement between items. High Cronbach's alpha values indicate that response values for each participant across a set of questions are consistent. For example, when participants give a high response for one of the items, they are also likely to provide high responses for the other items. Field, 2009 said that this consistency indicates the measurements are reliable and the items might measure the same characteristic. Conversely, low values indicate the set of items does not reliably measure the same construct. High responses for one question do not suggest that participants rated the other items highly. Consequently, according to Chelsea, 2015 the questions are unlikely to measure the same property because the measurements are unreliable. For this statistic, data usually originate from survey responses, assessment instruments, and test scores. Data can be continuous but will often be Likert and binary values. The calculations assume that all items measure the same trait using the same scale. Statisticians call this a tau equivalent model (Ibid).

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same construct. High responses for one question do not suggest that participants rated the other items highly. Consequently, the questions are unlikely to measure the same property because the measurements are unreliable. For this statistic, data usually originate from survey responses, assessment instruments, and test scores. Data can be continuous but will often be Likert and binary values. The calculations assume that all items measure the same trait using the same scale. Statisticians call this a tau-equivalent model. Taura Local farmers show an average of 0.773 interpreted as acceptable, while 0.775 indicated that of the administrators. Based on the interpretation made by Creswell, 2011), it indicated that the sample was adequate.

Table 3.3: Cronbach alpha reliability test

Construct	Number of Items	Cronbach alpha coefficient	Interpretation
For local farmers			
Direct use	5	0.752	Acceptable
Ecological use	6	0.825	Good
Medicinal use	4	0.741	Acceptable
Local farmers average		**0.773**	**Acceptable**
For Administrators			
Direct use	5	0.721	Acceptable
Ecological use	6	0.801	Good
Medicinal use	4	0.799	Acceptable
Administrators only	5	0.781	Acceptable
Administrators average		**0.775**	**Acceptable**

Source: Field data

3.9 Questionnaire pretesting

The term "pilot study" describes scaled-down prototypes of a larger study. It is also used to describe the specific pretesting of a certain research instrument, such as a questionnaire (Teijligen & Hundley, 2016). A pilot study increases the likelihood of success in the main

study. The pilot study was carried out with a sample of 50 respondents similar to the study's population in the hopes of improving the questionnaire, gathering data on the language's clarity, identifying any gaps, developing and testing adequate research instruments, determining the viability of a (full-scale) study, determining whether the sampling framework and technique are effective, and identifying logistical issues that may arise.

3.10 Statistical Analysis

Both Descriptive statistics and statistical analysis were employed, which included frequencies, percentages and analysis of variance (ANOVA) for Small Scale Farmers and Administrators.

Descriptive statistics refers to a branch of statistics that involves summarizing, organizing, and presenting data meaningfully and concisely. It focuses on describing and analyzing a dataset's main features and characteristics without making any generalizations or inferences about a larger population. The primary goal of descriptive statistics is to provide a clear and concise summary of the data, enabling researchers or analysts to gain insights and understand patterns, trends, and distributions within the dataset. According to (Chelsea, 2015), this summary typically includes measures such as central tendency (such as the mean, median, mode), dispersion (range, variance, standard deviation), and shape of the distribution (skewdness, kurtosis). Descriptive statistics also involves a graphical representation of data through charts, graphs, and tables, which can further aid in visualizing and interpreting the information. Common graphical techniques include histograms, bar charts, pie charts, scatter plots, and box plots. By employing descriptive statistics, researchers can effectively summarize and communicate the key characteristics of a dataset, facilitating a better understanding of the data and providing a foundation for further statistical analysis or decision-making processes (Chelsea, 2015). Analysis of variance (ANOVA) is an analysis tool used in statistics that splits an observed aggregate variability found inside a data set into

two parts: systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use the ANOVA test to determine the influence that independent variables have on the dependent variable in a regression study (*Ibid*).

3.11. Ethical consideration

The researcher took the following steps to guarantee ethical standards regulating the conduct of the research and followed in order to assure adequate confidentiality of the respondents' information. The respondents were asked to sign a consent form by the researcher to confirm that all of their information had been obtained. The researcher and his assistant undertook field observations and recordings of plant phenology related to the six main growth stages, including leaf development, leaf end, flower development, flower end, fruit development, and fruit end. The researcher adequately recognized and acknowledged all authors' ideas and the sources used in the research work.

3.12 Research Assumptions

This research undertaking was premised on the following important assumptions: 1) The Neem tree conservation policy and management protocol and other instruments were in place to guide the Neem tree conservation management to address management challenges of the Neem tree use in Taura Local Government Area, Jigawa State; 2) the Local Government in Taura Local Government Area is at the vanguard of environmental conservation to address the challenges posed by global warming and climate change, and the promotion of the Neem tree in climate change mitigation and combating the advance of the Sahara desert progressing southwards using the Neem tree through sand dunes stabilization; 3) there was deliberate awareness raising to the communities by the Local government in Taura Administrative area on the Neem plant and environmental conservation and the effective conservation management of all the environmental resources; 4) and enhance the communities' adaptive

and resilience capacities cross-sector wide, and sensitize and create awareness among the stakeholders, in addressing the issues of climate change; 5) The evaluation study was premised on the understanding that the policy instrument was anticipatorily made involving all stakeholders including the vulnerable ruralpoor and local government institutions and therefore, the policy performance was reflected among the rural communities in the study sites; 6) The communities, local government in Taura Local Government Area incorporated climate change issues in the environmental and conservation management; and 7) Time was available to handle all the investigation on the Neem tree in the study area in a timely fashion.

3.12 Limitation of the study

The result of phenology was subject to change due to shifts in temperature, day length and moisture. This was due to human activities and other non-living factors that can affect the environment. The phenological activities are generally dynamic and subject to changes in environmental conditions.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Historical and philosophical underpinning of the study

4.1.1 History of Neem tree in Africa

Neem was introduced into Ghana between 1919 and 1927. It quickly gained popularity and, from there, was spread throughout West Africa. Today, towns and villages throughout the Sahel, even in the most remote areas, contain Neem. In many cases, they comprise 100 per cent of the Shade trees in villages (Ahmed, 2014).

4.1.2 History of Neem tree in Nigeria

First introduced into Africa in the Mid-1920s, the adaptability of Neem to arid climates quickly made it the most widely used species for multipurpose tree planting in the Sahel. Presumably, due to its insecticidal properties, Neem tends to be relatively free of damaging insects (*Ibid*).

4.1.3 The coming of the Neem tree to Nigeria

It is one of the legacies of the late Sardauna of Sokoto, Sir Ahmad Bello. He is believed to have brought some seedlings as trials from India during one of his visits, and experts have attributed its success to the similarity in climate between Nigeria and India (Ahmed, 2014).

4.1.4 Regions where Neem is grown in Nigeria

It is widely found in Northern Nigeria, with millions of trees planted across Borno, Katsina, Yobe, Adama, Zamfara, Kebbi, Sokoto, Niger, Nasarawa, Kano and Jigawa states to control desertification. The leaves and seeds are used to make medicine and oil for treating a wide range of sicknesses, pests and other maladies *'Ibid'.*

4.1.5 Neem-northern Nigeria economic tree

The 2009 global hunger index released by the International Food Policy Research Institute (IFPRI) ranked Nigeria 46th with 18-4 per cent. The economic hardship is undoubtedly excruciating; the Neem tree, which is medicinal with economic value, has been left unexplored, as this report shows. Neem is ubiquitous in northern Nigeria. The Neem tree, popularly referred to in the Hausa language as Dogon Yaro, is a tree in the mahogany family with broad dark brown stems and widely spread branches. It grows above 15-20m and produces evergreen leaves with white fragrant flowers and fruits. It is also drought-resistant (Ahmed 2014).

4.2 Philosophical underpinning of the study

4.2.1 Positivism Reasoning

Positivism is a philosophical school that holds that all genuine knowledge is either true by definition or positive, meaning a posterior fact derived by reason and logic from sensory experience. Other ways of knowing, such as intuition, introspection, or religious faith, are rejected or considered meaningless.

4.2.2 Positivism stance

Positivism uses brief, clear, concise discussion and does not use a descriptive story from human feelings or subjective interpretation. This study solely uses the number as a variable and emphasizes the use of statistical methods for processing such empirical data. Thus, the positivism paradigm is only using quantitative methods. Positivism can be defined as the self-governing, independent and objective existence of truth'' Since it is a research paradigm that is established "on the Ontological principle and doctrine that truth and reality is free and independent of the viewer and observer (Aliyu *et al.,* 2014).

4.2.3 Four Main Assumptions of Positivism

Positivism leads to the following four sets of assumptions: Ontological assumptions (nature of reality); there is one defined reality, fixed, measurable and observable. Epistemological assumptions (Knowledge): genuine knowledge is objective and quantitative. The goal of science is to test and expand theory.

4.3 Results and discussions on phenology

In this chapter, results obtained from the field observation on leaf development (LD), Leaf end (LE), Flower Development (FD), Flower end (FE), Fruit Development (Fr D) and Fruit End (Fr D) of *Azadirachta indica* are presented and discussed.

These Phenology observations considered the seasonal pattern of the study area, which influenced the phenol phases of the *Azadirachta indica*. The savannah area, specifically the Taura Local Government area, is characterized by four major seasons in a year. Their names are (in the Hausa language) as follows: 1) Kaka (harvesting period marking the end of rain season); 2) Rani (end of harvesting and the harmattan period); 3) Bazara (the period between harmattan and rain season); and 4) Damina (rainy season) (Ahmed *et al.*, 2019).

Table 4.1: Seasonal pattern of the study area

No	*Season in Hausa*	*Condition*	*Period*	*Temperature range*
1.	Kaka	Dry and cold	October to March	21°C
2.	Rani	Dry and warm	March to May	30°-39°C
3.	Bazara	Dry and hot	May to June	31°-34°C
4.	Damina	Warm and wet	June to September	35°-40°C

Source: Filed data

On observation, there are fluctuations and overlappings of the periods stated due to the anthropogenic effects on the natural resources and temperature variability. The phenology of mature *Azadirachta indica* was observed over a one-year period from March 2016 to February 2017. Six principal growth stages, Leaf development (LD), leaf end (LE), flower development (FD), flower end (FE), fruit development (Fr D) and fruit end (Fr E), were observed.

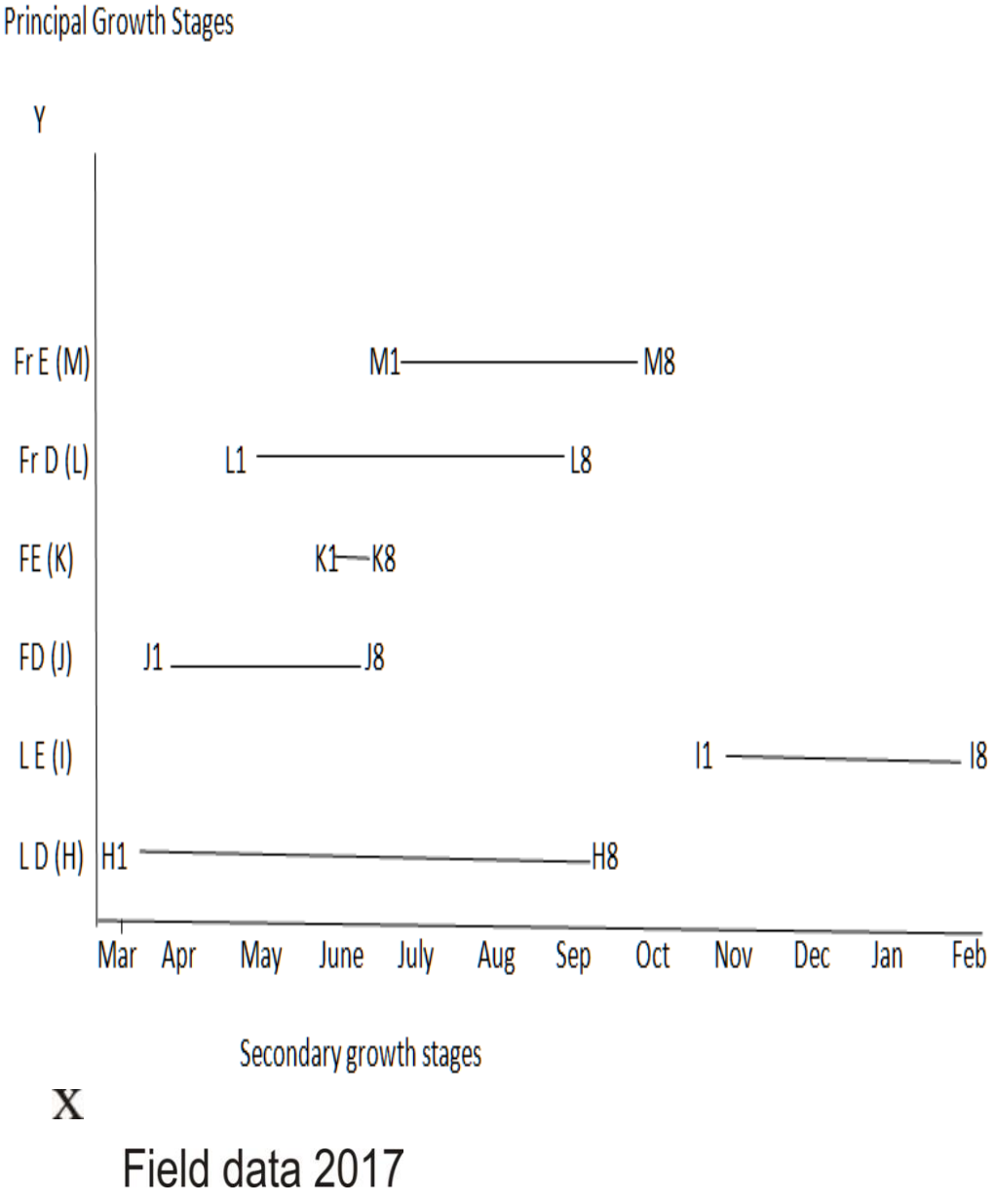


Figure 4.1 Six principal Neem growth stages (the phenology)

4.4. Explanation of the Figure

The table above shows the phenological activities of *Azadirachta indica* growth comprised of the x and y axes. The Y axis indicates the principal growth stages (primary growth stages), and the x axis indicates the secondary growth stages (the meso stages).

Keywords for the explanation above

The six principal growth stages were named H, I, J, K, L, and M, representing leaf development (LD), leaf end (LE), flower development (FD), flower end (FE), fruit development (Fr D), and fruit end (Fr E) respectively. The secondary growth stages were numbered 0, 1,2,3,4,5,6,7,8, and 9 (0 at the start and 9 at the end). The meso stages are the functional numbers from 1 to 8 denoted with percentages as 1=10%, 2=20%, 3=30%, 4=40%, 5=50%, 6=60%, 7=70% and 8=80%.

The phenological activities of *Azadirachta indica* from March 2016 to February 2017 are shown in the table above. Leaf Development (LD) started in the first week of March 2016 BBCH(H1) at 10%, and it came to a peak in August and September 2016 BBCH(H8) at 80% and ended in October 2016 BBCH(9) 00%.

The Leaf end (LE) started in November 2016 at BBCH (I1) at 10%, and it came to a peak in February 2017 at BBCH (I8) at 80%. The Flower development (FD) started in the first week of April 2016 at BBCH (J1) at 10% and came to a peak in mid-June 2016 at BBCH (J8) at 80%. The Flower end (F E) started in the first week of June 2016 at BBCH(KI) at 10% and came to a peak in late June 2016 at BBCH (K8) at 80%. It was considered to be the shortest period of the year. The Fruit development (Fr D) started in mid-May 2016 at BBCH (L1) at 10% and peaked in September 2016 at BBCH (L8) at 80%. The Fruit end (Fr E) started in mid-July 2016 at BBCH (M1) at 10% and peaked in October 2016 at BBCH (M8) at 80%.

4.5 Discussion on *Azadirachta indica* phenology

In the analysis of the *Azadirachta indica* phenology, the observations showed that the species displayed differences between life stages in leaf development, leaf end, flower development, flower end, fruit development and fruit end. Leaf development was considered to be the emergence of green leaves of the whole plant. This was observed in nearly all Neem trees under surveillance. Changes were observed in all the phenological aspects evaluated. Flowering was considered to be the occurrence of open flowers, and the occurrence of fruit development was considered to be between flower disappearance and fruit appearance. The fruit was considered to be mature when fully developed when it changes colour from green to red or yellow. Green fruits displayed a change of colour and or texture between successive observations, thus green to red or yellow. Leaf development started in March 2016 when the temperatures were warm, and it reached its peak in October 2016.

The leaf development of the Neem is regulated by the length of the photoperiod (daylight activity). The leaf and flower development appear to be related to moisture, temperature and the day length, which is in conformity with the observation made by the other workers (Singh and Kushwaha 2006). The leaf end was concentrated in the cool and dry winter months of the year. The leaf shedding is caused by a combination of increasing leaf age and declining photoperiod due to changes in temperature and daylight. Fruit development and fruit ripening occurred between June 2016 and September 2016 (before and during the rainfall period), and it continued up to October 2016.

Following the observed trend in the phenological activity in *A. Indica*, it can be inferred that vegetative and reproductive phenology in *A. Indica* occurred once a year based on the seasonal pattern, which is not in concordance with Echereme *et al.*, (2015). I compared the work on the phenology of Echereme (2015) and my own, which was done in Taura Local

Government Area, Jigawa State, Nigeria. The work of Echereme 2015 on phenology was done in Nigeria in Anambra State. The vegetation zone of Anambra State is a tropical rainforest zone where rainfall duration is 7 to 8 months of the year, while in Taura Local Government Area Jigawa State, the rainfall duration is 2 to 4 months of the year. Therefore, the phenological activities of the Neem tree in Onitsha, Anambra State, were twice as much compared to the Neem phenology in Taura Local Government Area Jigawa State, Nigeria. This is because the Taura Local Government Area has a long dry season and short rainy season since the area falls in a Sudan savanna zone. This relates to the nature of the seasonal pattern of precipitation within Nigeria. Plants are finely tuned to the seasonality of their environment and shifts in the timing of plant activity. This study of phenology in the *Azadirachta indica* provides compelling evidence that species and ecosystems are being influenced by global environmental change.

Studies (Echereme, 2015) have observed shifting phenology at multiple scales, including earlier spring flowering in individual plants and an earlier spring green-up of the land surface revealed in satellite images. Experimental and modelling approaches have sought to identify the mechanisms causing these shifts, as well as to make predictions regarding the consequences due to both living and non-living factors (such as human activities, temperature, moisture, and the length of the day.

Phenology is a dominant and often overlooked aspect of plant ecology, from the scale of individuals to whole ecosystems. The timing of the switch between vegetative and reproductive phases that occurs in concerts with flowering is crucial to optimal seed development for individuals and populations. The findings here are consistent with Maria *et al.,* (2007), who indicated that the variation among species in their phenology is an important mechanism for maintaining species co-existence in diverse plant communities by reducing competition for pollinators and other resources. Through this study, it can be asserted that the

Neem tree, due to its physiological and morphological qualities, helps in its ability to produce more leaves, flowers, and millions of fruit, which are capable of disposal for further regeneration and invasion of new areas leading to its dominance and coverage. The timing of growth on set and senescence also determine growing season length, thus driving annual carbon uptake in terrestrial ecosystems (Hansen *et al.*, 2006). This study adds that global climate change significantly alters plant phenology because temperature influences the timing of development along and through interactions with other cues, such as photoperiod.

Thermometer records showed that over the past 30 years, global average surface temperatures increased by 0.2^{o}C per decade (Hansen *et al*., 2006). In addition, numerous studies examining frost dates, growing season length, growing degree totals, or more complex indices have found changes in temperature that are consistent with climate warming (Kunkel *et al.*, 2004). These phenol climatic measures represent changes in temperature that are relevant for different phases of plant development when the average rainfall is 600 to 1000 millimetres. These changes are less with reduced amounts of precipitation.

4.6 Conclusion

Change that occurred both living (human activities) and nonliving (like changes in temperature, moisture (rainfall) and day length. The most striking problem related to phenology is human activities in the form of deforestation for timber, fuel wood, roofing of houses and construction activities like roads, housing, and construction of industries. The increasing human population puts more pressure on the grazing yards and forest land and eventually makes the vegetation very difficult to undergo normal phonological activities for subsequent regeneration.

4.7 Distribution of *Azadirachta indica*

4.7.1 The GPS and GIS software 10.5 Version and Normalized Difference Vegetation Index (NDVI) were used

The normalized vegetation index graphs were made based on the Neem tree distribution as follows;

The Normalized Difference Vegetation Index (NDVI) values were used in terms of distributions of Neem trees. They are as follows: 0-1= Severe, -0.9-0= very high. 0.1-0= high, 0.1-0.1= medium, 0.2-0.1 =low, 0.2-0.3 very low, 0.4-1 =poor

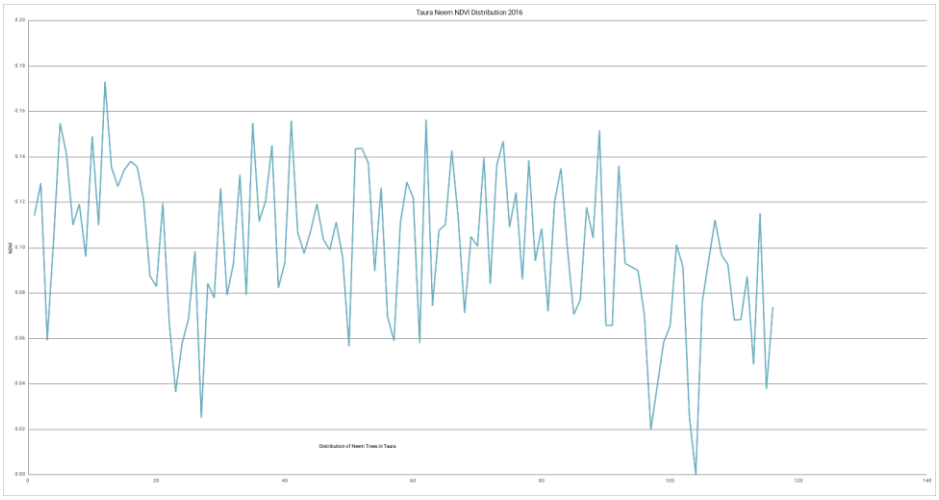


Figure 4.2 Taura Neem NDVI Distribution 2016

Source: Field data

2.7.2: Normalized Difference Vegetation Index

Objective 2 was to determine the distribution of the *Azadirachta indica* in the Taura Local Government Area. The Normalized Difference Vegetation Index (NDVI) 2016 in Taura Local Government Area, from the NDVI values, showed that there was an increasing value in

the Neem tree distribution starting from -1 to 0.17. These had shown an increasing level of Neem trees in Taura Local Government Area. Data is presented in the figure 4.3.

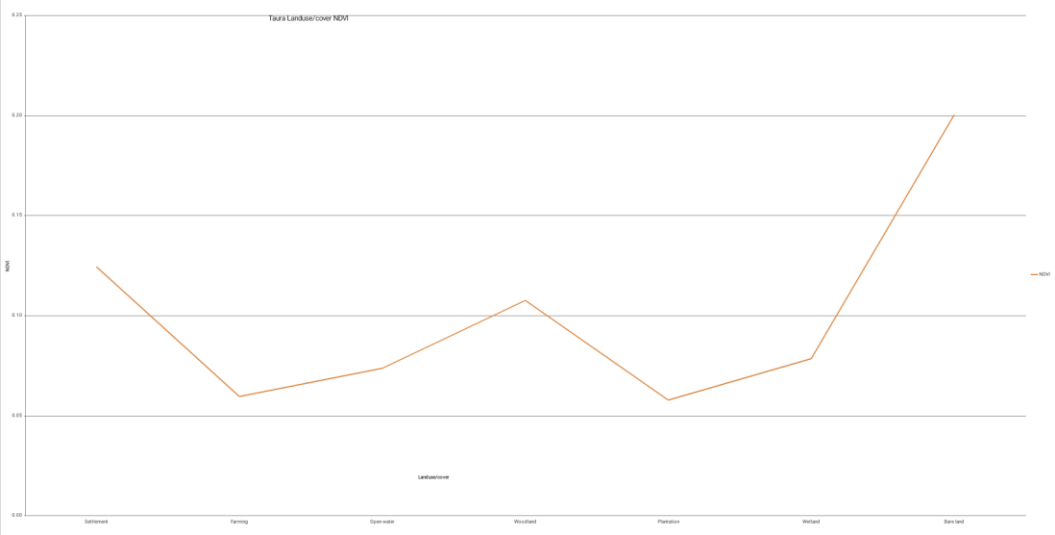


Figure 4.3: Figure 4.3: Taura Local Government Area Land Use/ Cover NDVI 2016

Source: Field data 2017

4.7.3 Discussion on Azadirachta indica distribution

The global positioning system (GPS) and geographical information system (GIS) software (GIS 10.5 version and VGT Extract, Satellite imagery: Google Earth Image 2016—2020, Spots final 2016 5m Rs) were used. These indicated that the *Azadirachta indica* is the most dominant tree species. It is seen sprouting everywhere in the environment. This was because so many factors had contributed to the disappearance of the native tree in the environment. The actual invasion of an environment by new species is influenced by three factors: a) the number of propagules entering the new environment (propagule pressure), b) the characteristics of new species and c) the susceptibility (weak nature) of the environment to invasion by new species (invisibility), (Maria*et al*., 2007). Invisibility is an emergent property of an environment which is the outcome of several factors, including the region's climate, the environment disturbance regime and the competitive abilities of the resident species (Maria *et*

al.,2007). The invisibility may also be affected by the presence (or absence) of herbivores and pathogens. Disturbances could damage or destroy some of the resident vegetation, reducing light, water and nutrient uptake. This study adds that the successful expansion of the Neem tree is due to its strong physiological and morphological adaptation that suits it to survive and is capable of regeneration even in harsh conditions.

4.8. Discussion on respondents' perceptions of the Neem tree use

Out of the 398 questionnaires distributed to the respondents (local farmers) and the 10 that were given to Administrators, only 360 were retrieved from the local people, and all questionnaires that were distributed to the administrators were returned. This represents a 91% response rate.

4.8.1. Background characteristics of the local farmers

The data collected from the respondent's bio-data included Ward, Village, Age, and Gender, Highest qualification, occupation and marital status (Table 4.1) .as.

From table 4.3, it was noticed that the ages between 28 – 37, 38 – 47 and 48 – 57 are the most active ages for farming activities. Most of the local farmers have no Western education, and some attend primary education. The majority of the local farmers are married, 72%. The demographic characteristics affect the distribution of the Neem trees in the Taura Local Government Area because the male respondents are the most active farmers as compared to their female counterparts. Only a few females participated actively in farming practices. Indicate whether gender influence is positive or negative on the Neem tree cultivation.

Table 4.2: Demographic attributes for local farmers

Age of the respondent	**Frequency**	**Percent**
Respondents		
18-27	31	8.6
28-37	100	27.7
38-47	85	23.6
48-57	102	28.3
58-67	37	10.3
68 and above	5	1.5
Total	**360**	**100.0**
Gender of the Respondent		
Male	283	78.6
Female	77	21.4
Total	**360**	**100.0**
Occupation of the respondents		
Farmer	235	65.3
Civil servant	93	25.8
Business	32	8.9
Total	**360**	**100.00**
Highest Educational qualification		
Non-formal	148	41.1
Primary	130	36.1
Secondary	38	10.6
NCE/Diploma	31	8.6
Degree/HND/equivalent	13	3.6
Total	**360**	**100**
Marital Status of the Respondents		
Single	63	17.5
Married	260	72.2
Divorced/separated	32	8.9
Widowed	5	1.4
Total	**360**	**100**

Source: Field data 2017

4.8.1.1 Results: Direct use of the Neem tree

An analysis of the uses of the Neem tree was undertaken (Table 6). The results indicate that the majority (61%) of the local farmers use Neem trees as a source of firewood. The local farmers have been using dead Neem tree leaves as local manure in the fields of crops for a long period of time, ranging from five to ten years already. The local farmers use Neem trees as timber and as poles for the roofing of houses. A large proportion (74% and 73%) of the respondents reported that the Neem tree is not affected or destroyed by termites and other wood pests, respectively.

In terms of the frequency of use, the results showed that 61.4% of the respondents reported using it every day, 21.7% indicated using it once a week, and 16.9% stated that they used the Neem tree twice a week. These results show that the Neem tree is central to local community households' needs and use. Results further reveal that 43.1% used the Neem tree as local manure; a large proportion (74.4%) of farmers used Neem for Timber and roofing due to its quality of resisting pests, and 54.4% used it as livestock feed. These varieties of uses make the Neem tree a critical ingredient central for making sustainable households' livelihoods among the smallholder farmers in Taura Local Government Area. Also, the Neem tree's qualities of resisting pests, serving as manure, and wood and poles for households' use enable its adoption by many smallholder farmers. The Neem tree propagates vegetative, maintained by the residents for the numerous benefits that have come with it. This finding is consistent with that of Echereme 2015 on phenology in Onitsha, Anambra State, Nigeria. This study adds that with the variety of uses emanating from the tree, sound management and conservation management plans should be designed and implemented, given that there will be a great need to churn Neem products through processing and value addition. This has sustainable supply implications.

Table 4.3: Direct use of Neem trees

Use Neem as a source of firewood?	**Frequency**	**Per cent**
Respondents		
Everyday	221	61.4
Twice a week	61	16.9
Once a week	78	21.7
Total	**360**	**100.0**
Dead Neem leaves are used as local manure.		
2 years ago	63	17.5
5 years ago	155	43.1
10 years ago	140	38.9
None	2	.6
Total	**360**	**100.0**
Neem tree is used for timber because		
It is easy to obtain	92	25.6
It is not affected or destroyed by termites and other pests	268	74.4
Total	**360**	**100.00**
Neem tree is used for roofing houses because		
It is easy to obtain	94	26.1
It is not affected or destroyed by termites and other pests	276	73.9
Total	**360**	**100**
Neem tree is used as animal fodder because		
Unavailability of other indigenous plant species	174	45.6
Neem tree is more abundant in the area	196	54.4
Total	**360**	**100**

Source: Field data

4.8.1.2 Ecological use of Neem tree

An analysis of the ecological uses of the Neem tree was done. The parameters under review included the Neem tree use for shelter and shade, methods of dispersal, soil erosion control, reduction of water evaporation from the ground, sensitivity to changes in temperature, halting the spread of desert by improving afforestation and seasonality. The results (Table 4.4) show that a large proportion (61%) reported that the Neem tree is the most common species in the area, capable of withstanding stress and can easily regenerate, and is a growing tree species. A big proportion (71%) reported that the Neem tree had many dispersal methods. The dispersal mechanism was mainly through bats and birds. The same proportion (71%) reported that the Neem tree was used to control erosion as manifested by its growth along degraded areas such as in the gullies.

An analysis of the Neem tree sensitivity to temperature viability was undertaken. Respondents (66.1%) reported that the Neem tree is highly sensitive to temperature variability in the dry season, where the plant sheds off its leaves to minimize the loss of water, thus maintaining water in the plant. When the season is warm and dry, the plant produces more leaves to enable it to continue with its phenological process, photosynthetic processes in carbohydrate production and other plant processes. This research adds that the Neem plant can be seen in an area where resources such as nutrients are very few for other plants to thrive. This is an added quality of survivorship in difficult areas.

Table 4.4: Ecological Uses of Neem Trees

Neem tree is used for shelter and shade.		
Respondents	**Frequency**	**Per cent**
It is the most frequent species in the area	222	61.7
It is the plant that withstands environmental stress and is capable of regeneration	130	36.1
Neem shade is very conducive for shelter and shade	8	2.2
Total	**360**	**100.0**
The Neem tree has various methods of dispersal and is the most fast-growing species in the area.		
It is dispersed by bats as they suck the liquid portion and throw the seed away	257	71.4
It is dispersed through animal faces	95	26.4
It is dispersed by human beings	8	2.2
Total	**360**	**100.0**
Neem tree is used to control soil erosion.		
Neem tree is seen along a degraded area	180	50.0
Neem tree is seen sprouting along gully areas	180	50.0
Total	**360**	**100.00**
Neem tree helps in the reduction of evaporation from the soil surfaces.		
It can easily withstand environmental stress	122	33.9
It can easily survive on marginal land (plant resources are very few).	238	66.1
Total	**360**	**100**
Neem tree is sensitive to changes in temperature (seasonal variations).		
When the season is windy, dry and cold, the Neem shades its leaves.	136	37.8
When the season is warm and dry, the Neem produces more leaves.	224	62.2
Total	**360**	**100**

Neem helps in converting drought and halting the spread of desert by improving afforestation.

It can be seen underneath other trees.	238	66.1
It can be seen sprouting all over the environment.	100	27.8
Neem acts as a substitute for other old or dead trees.	22	6.1
Total	**360**	**100**

Source Field Data 2017

4.8.1.3 Medicinal uses of Neem tree

Analysis of the medicinal uses of the Neem tree was undertaken (Table 8). A very large proportion (93.1%) of the respondents reported that all parts of the Neem tree are medicinally useful, but the leaves, roots and branches are of much more importance. In terms of parts uses, 40% reported leaves used for various treatments; 25.3% stated that the branches are very useful, and 24.7% said that the roots were used for medicinal purposes as well, while a very small proportion (6.9%) reported that they did not use the Neem tree parts for medicinal purposes. However, a large proportion (67%) revealed that the Neem tree was prepared for use mostly through boiling, and it is used in small quantities because of its strong chemical concentrations that are bound to be harmful to the human body in large quantities. Nonetheless, the Neem tree parts are used to treat ailments such as malaria, yellow fever and stomach ache. It has been in use locally since its introduction into the area over twenty years ago. It's like the great gift from Mother Nature, where a single plant provides a variety of uses to address a myriad of sicknesses. This has saved households' from the would-be immense medical costs through financial savings that can be put to other uses. This has made the communities have incentives towards the conservation and management of the Neem tree in their land tenure. Both the medicinal and ecological values are cherished by the communities, and this sets the Neem tree apart in Taura Local Government Area, Jigawa State.

Table 4.5: Medicinal use of Neem tree

the Neem tree part used		
Category	**Frequency**	**Per cent**
Bark	9	2.5
Leaves	146	40.6
Root	89	24.7
Branches	91	25.3
None	25	6.9
Total	**360**	**100.0**
How do you prepare it for use?		
Cutting	92	25.6
Boiling	243	67.5
None	25	6.9
Total	**360**	**100.0**
In what quantity do you use them?		
Large quantity	71	19.7
Small quantity	264	73.3
None	25	6.9
Total	**360**	**100.00**
Is neem plant used to cure?		
Malaria	100	27.8
Yellow fever	168	46.7
Toothpaste	5	1.4
Stomach ache	62	17.2
None	25	6.9
Total	**360**	**100**

Source: Field data 2017

Table 4.6: Small-scale farmers - ANOVA

Variables		Sum of squares	Df	Mean square	F	Sig.
Direct uses	between groups within groups total	60.884 31.489 92.373	2 357 359	30.442 .088	345.124	.000
Ecological uses	between groups within groups total	65.712 12.791 78.503	2 357 359	32.856 .036	917.024	.000
Medicinal uses	between groups within groups total	149.959 57.363 207.322	2 357 359	74.979 .161	466.633	.000

Source: Field data 2017

Explanation for the Table 4.6

Analysis of variance (ANOVA) results for Neem use indicate F=30.442, P=.000for direct uses; F=917.024, P=.000 for ecological uses; and F=466.633, P=.000 for medicinal uses. The results indicate that most respondents recognize the three most important uses of the Neem tree and appreciate it in peoples' lives. Indeed, this can incentivize the Neem tree conservation among the population.

4.8.2 Background characteristics of administrators

Analysis of the bio-data of the administrators (Table 4.6) shows that by gender, a big proportion (90%) were male and only 10% female. All the respondents (100%) are in the 48-57 years age bracket civil servants. In terms of literacy levels, 50% attained a National Certificate in Education/Diploma, and 40% obtained a Degree or Higher National Diploma. The targeting of the administrators as respondents in this study was deliberate. These results show that the respondents had a long horizon in knowledge of environmental resources and Neem tree use and conservation management.

Table 4.7: Bio-data characteristics of administrators

Age of the respondent	**Frequency**	**Per cent**
48 – 57 years	10	100.0
Gender of the Respondent		
Male	9	90.0
Female	1	10.0
Total	**10**	**100.0**
Occupation of the respondents		
Civil servant	10	100.0
Highest Educational qualification		
Secondary	1	10.0
NCE/Diploma	5	50.0
Degree/HND/ or its equivalent	4	40.0
Total	**10**	**100**
Marital Status of the Respondents		
Married	10	100

Source: Field data 2017

4.8.2.1 Direct use of the Neem trees (for administrators)

Analysis of the perception of the administrators on the direct use of the Neem Tree was undertaken. The results (Table 10) show a large proportion (60%) use the Neem tree as firewood twice a week, and the same proportion have used dead Neem leaves as local manure

for 2 to 10 years. In the same proportion (60%), the Neem tree is timber and used for the roofing of houses. The justification provided is that Neem is not affected or destroyed by termites and other pests at all. There were no differences under direct use and between the local farmers and the Administrators. This was because both respondents were farmers and used the Neem tree in a similar fashion in the same culture and the study area. This study adds that more uses of the Neem, such as livestock pasture/feed, pest control, and manure for gardens, roofing, and fuelwood needs, have added community liking for the Neem plant. Besides, it is propagated mainly through wildlife (especially the bats), and it's widespread in the area. Given its ability to grow in gully areas, the sustainability and availability of the Neem tree for use among the local communities is largely guaranteed.

Table 4.8: Direct uses of Neem trees (administrators)

How often do you use Neem as a source of firewood? **Category**	**Frequency**	**Per cent**
Everyday	2	20.0
Twice a week	6	60.0
Once a week	1	10.0
Once in a month	1	10.0
Total	**10**	**100.0**
Dead Neem leaves are used as local manure.		
2 years ago	2	20.0
5 years ago	4	40.0
10 years ago	3	30.0
None	1	10.0
Total	**10**	**100.0**
Neem tree is used for timber because		
It is easy to obtain	4	40.0
It is not destroyed by pests	6	60.0
Total	**10**	**100.00**
Neem tree is used for roofing houses because		
It is easy to obtain	3	30.0
It is not affected or destroyed by termites and other pests	7	70.0
Total	**10**	**100**
Neem tree is used as animal fodder because		
Unavailability of other indigenous plant species	6	60.0
Neem tree is more abundant in the area	4	40.0
Total	**10**	**100**

Source: Field data 2017

4.8.2.2 Ecological uses of the Neem tree by the administrators and communities

The ecological uses were assessed using the following parameters (use of the Neem tree for shelter, Neem tree dispersal, soil erosion control, reduction of evapotranspiration, and the Neem resilience to seasonal variability and changes) (Table 11). A large proportion (60%) reported that the Neem tree withstands environmental hardship and is capable of regeneration. This study adds that, where other tree species succumb to prolonged drought, the Neem tree manages that by shedding off leaves to minimize loss of water through evapotranspiration. On methods of the Neem seed dispersal, a big proportion (70%) stated that the Neem seed dispersal was by bat; 30% pointed out that the dispersal was by animal faeces. On control of soil erosion, 70% stated that propagation was through the root. This study adds that the root systems and the crown (leaves and branches) support control of soil erosion. Indeed,30% of the respondents had reported that the Neem trees grow along gulleys where other tree species do not easily grow. Evaluation of the water conservation in the Neem tree (80%) indicated that the Neem can survive in marginal areas by shedding its leaves to withstand the environmental stress of drought (dryness and coldness) through shedding off of leaves and producing leaves in hot and rainy times, thereby withstanding the high seasonal variability and climatic stress plants experience in hard times. This study adds that the neem tree can be seen along the degraded areas and appears to be doing well in terms of phenology. Due to its special adaptation and dispersal qualities, Neem can be seen underneath other tree species and act as a substitute for other tree species in the case of successfully invading and colonizing areas. These qualities have made it possible for the Neem plant to help in converting drought and halting the spread of desertification. Neem is sensitive to changes in temperature. When the conditions are windy and dry, the Neem tree sheds its leaves to avoid excess water loss (evapotranspiration). However, in wet and warm conditions, the Neem regenerates more leaves for photosynthesis and other plant metabolism.

These phenological qualities and attributes have made the Neem tree adapt to its harsh environmental conditions and the challenges of the Sahara desert advance southwards. A neem conservation management plan should be developed for livelihood and environmental sustainability.

Table 4.9: Ecological use of Neem (for administrators)

Neem tree is used for shelter and shade		
Category	**Frequency**	**Per cent**
It is the most frequent species in the area	4	40.0
It is the plant that withstands hardship and is capable of regeneration	6	60.0
Total	**10**	**100.0**
The Neem tree has various methods of dispersal and is the most fast-growing species in the area.		
It is dispersed by bats as they suck the liquid portion and throw the seed away	7	70.0
It is dispersed through animal faces	3	30.0
Total	**10**	**100.0**
Neem tree is used to control erosion.		
Neem tree is seen along a degraded area	7	70.0
Neem tree is seen sprouting along gully areas	3	30.0
Total	**10**	**100.00**
Neem tree helps in the reduction of evaporation from surfaces.		
It can easily withstand environmental stress.	2	20.0
It can easily survive on marginal land (plant resources are very few).	8	80.0
Total	**10**	**100**
Neem tree is sensitive to changes in temperature (seasonal changes).		
When the season is windy, dry and cold, the Neem tree sheds its leaves	5	50.0
When the season is warm and dry, the Neem tree produces more leaves.	5	50.0
Total	**10**	**100**
Neem trees help in converting drought and halting the spread of desert by improving afforestation.		
It can be seen underneath other trees	3	30.0
It can be seen sprouting all over the environment	4	40.0
Neem acts as a substitute for other old or dead trees	3	30.0
Total	**10**	**100**

Source: Field Data 2017

4.8.2.3 Medicinal uses of the Neem tree

Analysis of uses of the medicinal values of the Neem tree included: a) parts of the Neem tree, b) material preparation, c) quantities used, and d) the cure details using substances from the Neem tree (Table 12). On the Neem parts, 30% reported that both the roots and the leaves were used; 20% stated having used the branch; and a similar proportion (20%) did not use any part of the Neem plant. A huge proportion (80%) reported having used the Neem tree. This demonstrates the significant medicinal value the Neem tree possesses. This study adds that the entire Neem plant (leaves, roots, bark and branches) has medicinal value and warrants this tree to be conserved and managed for posterity, given its great ecological and medicinal values. This study is consistent with the findings of Echereme (2015), who underscored the wide benefits accruing from the Neem.

Medicinal values of the Neem tree and their preparations were analysed. A large proportion (60%) reported boiling the Neem plant parts before administering it; 20% reported cutting it and placing it within the vicinity for it to saturate through the atmosphere; and a small proportion (20%) reported not using the Neem Plant for medicinal purposes. Nonetheless, this study adds that a very big proportion (80%) have acknowledged using Neem tree materials for medicinal purposes. This finding is consistent with Echereme (2015), who emphasized the medical benefits of the Neem tree. This study adds that the medicinal value of the Neem plant is great, and the Neem plant is popular among the local residents in the Taura Local Government Area, Jigawa State, Nigeria. In a poor community, these medicinal attributes set the Neem tree apart in addressing households' health challenges. Indeed, its vast propagation and variety of services/uses underscores its popularity beyond the Taura Local Government study Area since it can be accessed with ease.

Analysis of the Neem tree's curative role was undertaken. The study revealed that 30% of the respondents used it to cure yellow fever and stomach, while 20% used it for treating malaria

diseases. Indeed, this study adds that having cheap treatment for common diseases among the vulnerable in rural settings is a great plus that supplements government efforts in the provision of healthcare services in the Taura Local Government area. Further analysis revealed a variety of curative roles Neem plays in the study area. Its conservation and management should encompass genetic resources strategy, use and conservation headed by the Federal Government of Nigeria. This study adds that with more research on the Neem plant, more benefits, including medicinal values, will be discovered. This is a direction and path worthwhile undertaking.

Table 4.10: Medicinal uses of Neem trees (for administrators)

Which part of the Neem tree do you use?		
Category	**Frequency**	**Per cent**
Leaves	3	30.0
Root	3	30.0
Branches	2	20.0
None	2	20.0
Total	**10**	**100.0**
How do you prepare it?		
Cutting	2	20.0
Boiling	6	60.0
None	2	20.0
Total	**10**	**100.0**
In what quantity do you use them?		
Large quantity	2	20.0
Small quantity	6	60.0
None	2	20.0
Total	**10**	**100.00**
Is neem plant used to cure?		
Malaria	2	20.0
Yellow fever	3	30.0
Stomach ache	3	30.0
None	2	20.0
Total	**10**	**100**

Source: Field data 2017

4.8.2.4 Policy performance evaluation- the Federal Government of the Jigawa State Nigeria

The Federal Government of Nigeria ratified International environmental conventions such as 1) the Convention of Biological Diversity (UNCBD), 2) the United Nations Convention on Combating Desertification (UNCCD), and 3) the United Nations Framework Convention on Climate Change (UNFCCC). Analysis of policy performance (the role of the Federal Government of Nigeria was analyzed) as per the Neem tree conservation and management. The parameters analyzed included a) the Neem tree's role in addressing desertification, b) the Neem tree seeds production and propagation, c) the establishment of sandbanks, d) the establishment of tree shelter belts, e) the development of wind belts and f) afforestation programs.

The analysis was intended to evaluate through the state Ministry of Environment what has been achieved so far. All (100%) respondents reported that the Neem tree is a desirable plant for environmental conservation; 60% indicated that there is support for the nursing of Neem tree seedlings, and all respondents (100%) revealed that there is a distribution of seedlings to stakeholders for free; while a very large proportion (90%) pointed out that a Neem tree belt for controlling wind (as windbreaks) has been established. Further analysis has shown that 50% of the state ministry is promoting the planting of Neem trees all year along the roadside. These results underpin the central ecological role the Neem tree plays in addressing challenges posed by climatic changes and seasonal variability. This study adds that the Nem tree mitigates desertification to a great extent through sand dunning through natural propagations and afforestation programmes in the Taura Local Government Area. Indeed, in an effort to push it to a larger scale, the Jigawa state Ministry for Environment has established the Neem tree shelter belt for the purpose of wind control and to improve afforestation in Taura Local Government Area for ecological/environmental benefits. The

seedlings are freely distributed to farmers' will. Promote Neem afforestation in the areas for the variety of ecosystem services from the Neem tree. This is in the right direction for the benefit of the communities and the local environment. This finding is in agreement with the Jigawa State Ministry of Environment Nigeria, which maintained that, even when it is an alien species, the Neem tree is like ‘a salvation plant’ that has been introduced in the Jigawa state at a time when both desertification and climate change challenges are at their peaks in the study area. Given the special phenological qualities, the Neem tree will help to diffuse the adverse impacts of global change on the area.

Table 4.11: Administrators perception of the Medicinal Use of the Neem tree

Neem trees promote afforestation and reduce the level of desertification.		
It is desirable to some extent	10	100.00
The state government, through the Ministry of Environment, nurse Neem seedlings every year		
It is true they nurse it every year	6	60.0
It is not true for every year	4	40.0
Total	**10**	**100**
The state government, through the Ministry of Environment, distribute the Neem seedlings free of charge during the rainy season.		
Yes, it is true	10	100
The state Ministry for Environment has established a Neem tree shelter belt for the purpose of wind control in the Taura Local Government Area.		
Yes, it is true	9	90.0
No, it is not true because I have not seen any shelter belt	1	10.0
Total	**10**	**100**
The state Ministry of Environment has been planting Neem trees along the roadsides and some grazing yards as part of the afforestation program.		
Yes, they do every year	5	50.0
Yes, they do it, but not every year	5	50.0
Total	**10**	**100**

Source: Field data 2017

Table 4.12: Administrators descriptive statistics

Variables	N	Minimum	Maximum	mean	Std. Deviation
Occupation of the	10	1.00	2.00	1.4000	.51640
respondents	10	1.00	2.60	1.8200	.40497
Direct use	10	1.00	1.75	1.4500	.25820
Ecological Uses	10	1.00	3.00	2.2000	.56273
Medicinal Uses					

Source: Field Data 2017

4.8.2.5 Explanation of the Administrator's Descriptive Statistic

The Administrator's descriptive statistics (Table 4.12) show direct use mean (1.8200), Ecological uses (1.4500), and Medicinal (2.2000). Based on the given means, the Neem tree had a tremendous relevance perceived by the Administrators.

4.8.3 Discussion on Azadirachta indica uses.

Results show that the Neem trees were very important in the lives of the communities. They provide shelter and shade. Neem is one of the main shade plants in most homesteads, and it can be seen lining most of the roadways in the study area. It is one of the most prevalent and useful trees that can regenerate and resist hard environments (Ahmed, 2014). This is good because this will cut down on afforestation costs. Use such as controlling soil erosion and desert encroachment is of utmost importance to the Taura local people. In terms of firewood, lumber, and large animal feed, it has made a significant contribution to community households' livelihoods and will prevent future environmental deterioration, especially

during the dry season. This study adds that the Neem tree plays significant ecological roles through the services it provides: groundwater recharging and water infiltration, soil erosion prevention through root and crown systems, trapping and slowing rainwater, energy conservation, carbon sequestration, heat island reduction and improvement of air and water qualities.

This study further adds that, like most green plants, the Neem tree generates wood for a variety of uses; it is a good recreational and aesthetic feature fostering empathy and, therefore, improving relationships among the communities in the Taura Local Government Area in the Jigawa State in Nigeria. Indeed, given the Neem tree phenology, the leaves filter the harmattan wind/air pollutants from the Sahara desert, the flowers are food for the pollinators who aid flora reproduction (fertilization and seeds production), while pollinators such as bees produce honey and variety of apiary bi-products for human use. Furthermore, the Neem tree supports grass, herbaceous plants and shrubs and supports nutrient cycling. These ecosystem services abound and keep the Sudan savannah belt ecosystem alive.

Further, the study found out that the Neem tree is the main medicinal plant in the region and has been reported to treat a number of illnesses among the local population in the Taura Local Government Area. According to the findings, *Azadirachta indica* has a good influence on a variety of human applications, including direct uses, ecological uses, and medical uses. It is reportedly effective in treating malaria, yellow fever, and stomach ailments. People also use it as insecticides to chase away insect pests from their homesteads. It has definitely other benefits not recorded in this study, and this variety of benefits has not only made people appreciate the Neem tree but is a popular plant nearly every person seeks to protect and conserve, as re-echoed in the Taura Local Government efforts in its conservation management.

Because of its agility and ability to withstand harsh environments, largely through adaptation strategies such as the shedding of leaves in harsh times, the Neem tree grows in marginal lands with poor soils. Marginal land is land that has little or no agricultural or industrial value. Marginal land has little potential for profit and often has poor soil or other undesirable characteristics. This type of land is often located at the edge of arid and/or semi-arid areas or other desolate sites. The environment stands to gain ecologically.

In addition, Ari-are plants are adapted to their arid environment in several ways: the small leaves on the Neem plants help reduce moisture loss during photosynthesis. Small leaves mean less evaporative surface per leaf. In addition, a small leaf in the sun doesn't reach as high a temperature as a large leaf. This enables the Neem plant to conserve the badly required water for its osmotic processes, thereby making the Neem plant perfectly adaptable to the harsh environment in the Taura Local Government Area on the fringes of the Sahara desert. This finding is consistent with Abdul Rashid *et al.* (2014), stating that the Neem plant can grow anywhere, and the rest of the land is preserved for food and other agricultural production. Its presence provides ecological benefits to the soils through ground recharging with water and nutrients.

Other worthwhile noting benefits of the Neem tree include its resistance to termite attack, wood borers' ability to penetrate, and the fact that the fungi cannot penetrate it. These are attributes that set the Née tree apart and superior to the many other trees in the area. These qualities have made it popular among the local communities in the Taura Local Government Area, Jigawa State, Nigeria. This finding is consistent with the Abdul-Rashid & Yaro (2014) findings that underscored the exceptional traits and values of the Neem tree. Government intervention to promote Neem conservation will generate a lot more benefits locally and beyond. This study adds that Neem promotion should focus on multiple Neem product development with value addition.

Neem in the Taura Local Government Area is an arid plant and is adapted to its arid environment in many ways. For instance, the small leaves help reduce moisture loss during photosynthesis. Further, the small leaves mean less evaporative surface per leaf. In addition, a small leaf in the sun doesn't reach as high a temperature as a large leaf. The leaves and stems of the Neem tree have a thick, waxy covering, keeping the plants cooler and reducing evaporative loss in the dry season. The Neem carry most, or all of their photosynthesis in their green stems, and the Neem plants grow leaves during the rainy season and then shed them when they become dry again. So, the Neem plants photosynthesize in their leaves during wet periods and in their stems during drought. The roots are also adapted to help them survive better in marginal lands by having shallow, widespread roots to absorb a maximum of rainfall moisture with some tap roots to get water that is deep underground.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

In Taura Local Government Area, *Azadirachta indica* was discovered to be the most prevalent (abundant) plant species because of its phenological attributes. The Neem tree has apical dominance whereby the main central stem of the plant is dominant, with main branches and sub-branches constituting the crown, usually large and dense on full maturity. These attributes allow the Neem tree to effectively perform its ecological functions.

According to the Neem tree applications and the phenology, it has been demonstrated to be of tremendous relevance to the local people for various uses, as already explained in this report. In addition to acting as a windbreaker (due to the creation of several Neem tree shelter belts), it has significantly aided in the prevention of the southward Sahara desert encroachment through the planted green shelterbelts and the stabilized sand dunes.

Its abundance has significantly improved agricultural productivity and has helped to manage the climate change challenges through the ecosystem services the plant has continued to provide. The environmental settings are related to its phenological rhythm. It can regenerate and provide quality seed crops despite being highly sensitive to changes in temperature and photoperiod.

The seasonal pattern of the study area (Taura Local Government Area Jigawa State, Nigeria) was taken into account and the four different periods, resulting in Kaka, Rani, Bazara, and Damina, each with their own conditions and temperature. The study found that the Neem plant was significantly influenced by the different seasonal characteristics and resulted in various phenological manifestations: leaf development (LD), lead end (LE), flower development (FD), flower end (FE), fruit development (FrD), and fruit end (FrD), of Neem

tree. The seasonality of their environment affects plants in subtle ways, including changes in the timing of plant activity (phenology). This study concludes that phenology is sensitive to all environmental factors (vegetative and reproductive occurrence in Neem plants). The Normalized Difference Vegetation Index (NDVI) graph was drawn on the Neem tree distribution to demonstrate the area's growing Neem tree population. Neem trees are classified into three applications for both local farmers and administrators: direct usage, ecological uses, and medicinal uses. These can be maintained through a comprehensive Neem conservation and management strategy with a focus on propagation, product development marketing and environmental conservation.

5.2 Recommendations

These recommendations are proposed and teased to address specific challenges that came out during the subject under study. They are set and teased to the attention of specific stakeholders (the local communities, the administrators in the Taura Local Government Administrators in the Administrative Area, The Jigawa State, and the Federal Government of Nigeria.

1.2.1 Taura Local Government

- The Taura Local Government should make a policy to enhance the environmental conditions through tree planting, mega afforestation and reforestation programmes,climate-smart agriculture, and nature-based adaptation and mitigation to impacts of climate change in the area to address threats from high seasonal and climatic variability in the study area.
- Build the capacity of the local systems with resources to address environmental challenges through integrated climate-smart agriculture and agroforestry and agro-

pastoralism programs aimed at enhancing grassroots households' resilience to poverty, seasonal variations and climate change in the Administration Area in Taura, Jigawa State.

5.2.1 Recommendations for Jigawa State

- Neem tree product development should be promoted, and product value added through industrialization for improved product quality and profits, targeting local and foreign markets. This will create employment opportunities and improve social services.
- The Jigawa State should support the development of comprehensive land use plans with integrated programs that address environment, household poverty, food security and environmental conservation supported with research and capacity development for small-scale farmers in agroforestry, climate-smart agriculture, Neem development through afforestation and industrialization to promote Neem products for the State, the country and external markets.
- Improve policies and relevant laws and support programmes that will address challenges of poverty through forestry programs, including the promotion of the Neem to commercial levels in all the administrative areas within the Jigawa State. Associated programs of suppressing the Sahara desert through greening belts, sand dunning, expansion of programs that provide woodlots and attendant low-carbon energy-efficient technologies and adoption and use of renewable energies should be promoted, and communities should be encouraged to adopt.
- Related social services should be identified, mapped, and provided for integrated service delivery (water, electricity, paved all-weather roads, health care, schools and

specialised centres for skilling the population in development and environmental programs.

- A Neem development centre should be developed for Neem promotion in agronomy, product development and quality control, and marketing. Programs for its propagation through seeds and seedlings distribution at cost-free be promoted to further the area under Neem plantations. This will be integrated with tree species that could provide timber, fuelwood, fruits and ecological benefits.

5.2.2 Recommendations for the Federal Government of Nigeria

The study found out that the Neem tree is used variously due to its varied uses but is still constrained by a couple of challenges.

- The Federal Government of Nigeria should create an enabling legal and policy environment for Neem production and promotion.
- Develop agronomists 'capacity to expand land under Neem production with tools and devices to manufacture a variety of quality Neem products targeting local and global markets. This will come through capacity development and skilling, provision of technology and linkage to markets.

CHAPTER SIX: FRAMEWORK (MODEL) FOR SUSTAINABLE NEEM PLANT CONSERVATION MANAGEMENT

6.1 Introduction

This chapter presents a framework model for sustainable Neem tree conservation management and improved utilization. The model has been constructed/developed after analysis of the research findings on the Neem phenology, distribution, and the uses and challenges affecting sustainable use of the Neem plant in the Taura Local government Area, Jigawa State, Nigeria. Nature conservation is an amoral philosophy, and conservation movements focus on species protection from extinction, maintaining and restoring species and the attendant habitats for species' future, and the accrued ecosystem services that follow. This study attempted to address gaps and challenges in the conservation management of the Neem tree given the plethora of variety of uses the plant offers. Based on the findings, a framework (model) is developed, and recommendations are made for sustainable Neem plant conservation and management for sustainable community households' use. Future research directions are presented.

6.2 A framework for sustainable Neem plant conservation for Taura Local Government Area

After a careful analysis, a three-dimensional model (Figure 6.1) is developed and presented to guide the improvement of the Neem plant conservation for environmental and household benefits in the Taura Local Government Area, Jigawa State, Nigeria. The model underscores the urgency to address the challenges and gaps identified and address them. Three broad strategies are proposed: a) Environmental/natural resources conservation, b) community participation in natural resources conservation, and c) policy and regulatory and regulatory enforcement in natural resources conservation.

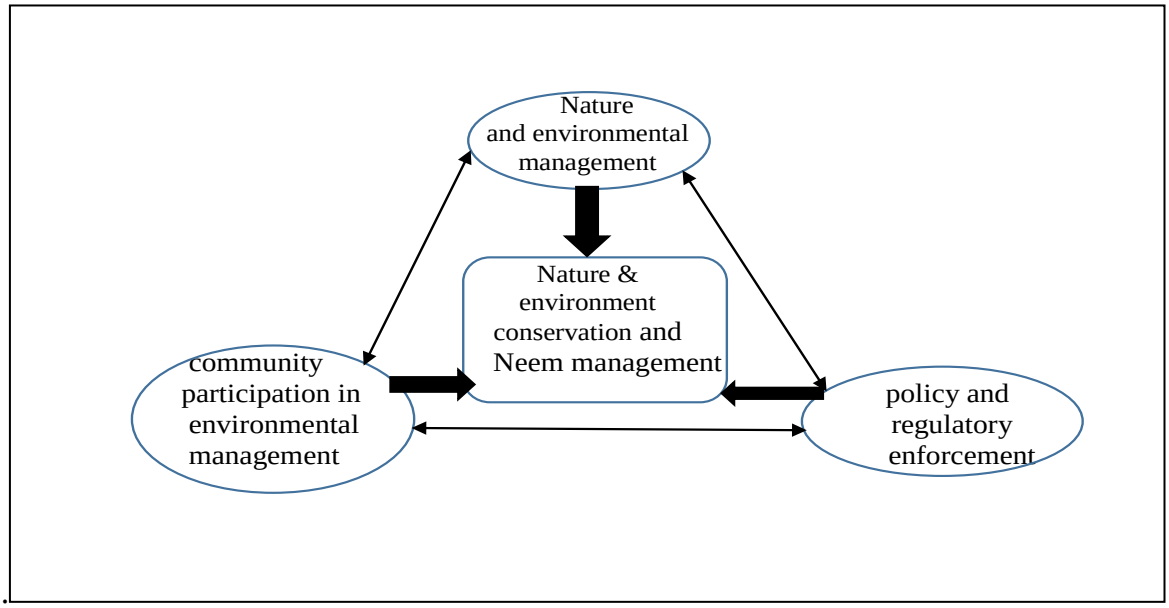
The environmental/natural resources conservation is picked from the study in that the Neem plant plays a crucial role in deterring the southward advance of the Sahara desert. Indeed, given its phenology, the Neem plant is perfectly adapted towards establishing along arid areas with marginal lands on the fringes of the desert. Because the Neem tree is able to disseminate and propagate along the gullies, a sustainable environmental/natural resources plan developed with broad ecological and social outputs with benefits will help to address identified issues. This will entail land use planning for agriculture, commerce, and forestry, including the Neem farming attained through soil and land management programmes.

An integrated approach through climate-smart agriculture in marginal areas on the fringes of the desert will focus on the adoption of adaptation technology aimed at water and soil conservation, thus promoting the land's ability to grow more crops, including the Neem plant. Indeed, improving agricultural assets and value chain will foster further extraction of benefits from the Neem plant through value addition to a variety of products accruing from the Neem. These will make the communities endeavour to conserve and manage the Neem Plant for posterity. This will result in better land management, such as land use planning for agriculture, improving agricultural assets, improved food production through climate-smart agriculture, rehabilitation of degraded and marginal lands, and undertaking land water conservation. All that will come with the skilling of the land owners for sustainability.

The study identified gaps such as a lack of community organization in addressing challenges emanating from the desert and the southwards movement of sand dunes. The model underscores community participation in environmental and natural resource conservation, which is critical. The participatory planning process will be guided to generate land use planning, field farm schools for field demonstrations and skilling of the farmers in climate-smart agriculture focusing on soil and water conservation and weed and pests suppression and farming the Neem for commercial benefits through techniques that improve its

phenology and output as well as linking the smallholder farmers to the markets for Neem products. The study found that there were gaps in the policy and regulatory enforcement, which were generally lacking. The policy framework provides guidelines on how agriculture and natural resources will be managed. Smallholders will be guided with regulations to create fields of the Neem tree for various quality products and use, such as drugs for various ailments, insecticide, oil, poles, and thatch, among others. Local regulations will be enforced to have the Neem plant on particular fields while the rest of the land can be allocated for other land use. Detailed land use planning will be implemented in concert with guidance from the Jigawa State and the Ministry for Federal Affairs. Both the Ministries of Forestry and Environment and the Ministry of Agriculture will be involved in such policy framework development with the local communities at the centre of it, and the process will be anticipatorily done. The regulations will be developed, debated and enforced by community governance structures, with local communities at the centrepiece, taking the lead. This model has been tested for its validity and accuracy.

Figure 6.1 the Framework (model) for sustainable Neem conservation management



Source: Field data 2017

REFERENCES

Abdulrashid, L., & Yaro, A. (2014). The role of shelterbelt in Desertification Control: local perspectives, observations and Analysis from Semi-Arid Areas of Katsina State, Northern Nigeria. *International Journal of humanities & Social studies*, **2**(7): 7.

Ahmed, A. M. (2014). Harnessing Neem tree potential for wealth creation, environmental protection. *Department of mass communication, university of Maiduguri, Borno state Ms. Chari*.

Anonymous. (2006). Neem-Growing Neem, Organic Farming, health, animal health, environmental use, home use, economic potential, patents, New Bazaars, Research Papers, world Neem Conference. Neem Foundation. Mumbai, India.

Centre, W. A. (2002). *Agroforestry Database. Nairobi, Kenya: ICRAF* . Retrieved from World Agroforestry Centre: http://www.worldagroforestrycentre.org/Sites/TreeDBS/AFT/AFT.htm

Chelsea, G. (2015). *Research Data Services + Sciences Using and nterpreting Cronbach ' s Alpha, (Statistical Consulting Associate University of Virginia Library)*. Retrieved from http://data.library.virginia.edu/using-and-interpreting-cronbachs-alpha/

Creswell, J. W. (2011). *Educational Research: Planning Conducting and Evaluating Quantitative and Qualitative Research. 4th End* . Boston : Pearson Education.

Ebeid, A. F., & Ali, E. F. (2015). Phonological study of some trees species at different Ages in Aswan, Egypt. *International journal of science and Research* , **4**(7), 506-513.

Echereme, C. B., & Mbaekwe, E. I. (2015). The use of extended BBCH scale in evaluation of vegetative and reproductive phenology in Umbrella Tree (Terminalia catappa Linn.) Occurring in Onitsha, south eastern Nigeria. . *International Journal of Environmental Biology*, **5**(4): 88-92.

Echereme, C. B., & Mbaekwe, E. I. (2015). Tropical Phenology: Individual Level Phenological study of Neem (Azadirachta Indica A. Juss) occurring in Onitsha, Nigeria, . *International Journal of Science Research Publication*, **3**(11): 1032 – 1037.

Echereme, C. B., Mbaekwe, E. I., & Ekwealor, K. U. (2015). Phenological study of Flamboyant Tree (Delonix regia (Boj.) Raf.) Growing in Don Bosco Youth Centre, Onitsha, Anambra State, Nigeria. *International Journal of Science Research Publications* , **5**(9): 1-4.

Elsa, E. C., Isabelle, C., Annette, M., M, H. A., & Mark, D. S. (2007). Shipfting plant phenology in response to global change. *TRENDS in Ecology and Evolution*, **22** (7): 357-365.

Fathima, S. K. (2004). Investigation on the biology and management of phomopsis Azadirachta indica on neem. *PhD. Thesis, University of Mysore, Mysore, India*.

Field, A. (2009). *Discovering statistics using SPSS, Sage publications.* Los-Angeles, U.S.A.

Finn, G. A., Straszewski, A. E., & Peterson, U. (2007). A general growth stage key for describing trees and woody plants. *Annals of Applied Biology* , **151**: 127-131.

Gliem, J. A., & Gliem, R. R. (2003). *Calculating , Interpreting , and Reporting Cronbach ' s Alpha Reliability Coefficient for Likert-Type Scales, (1992), 82–88.* .

Hansen, J. (2006). Global temperature change. *Proceedings National Academy Science* , 14288-1429 .

Kunkel, K. E. (2004). Temporal variations in frost- free season in the United States: 1896-200.Geophys. *Res. Lett*, 31, L03201 DOI: 10.10292003GL 018624 .

Mac Authur, R. H., & Wilson, E. O. (1967). The Theory of Island biogeography. *Monographs in population Biology,Princeton, N. J. Princeton University press*.

Maria, M., Mucunguzi, P., & Kare, A. L. (2007). Phenology of Asteraceae in selected districts of Central Uganda. *African Journal of ecology, ,* **45**(3): 67-72.

Martyn, S. (2008). *Descriptive research design*. Retrieved from explorable: https://explorable.com/descriptive- research –design

Martyn, S., & Lyndsay, T. W. (2009). *Definition of Reliability*. Retrieved from Explorable: https://explorable.com/definition-of-reliability.

Medugu, N. I. (2008). Assessment of an afforestation Projects in Kano and Jigawa state, Nigeria . *PhD Preliminary research findings on saving Nigeria from drought 1: Leadership, No 920, Nigeria press Abuja*.

Meier, U. B., Leirholder, H. B., Feller, C., Hack, H., Heb, M., Lancashire, D. P., . . . Zwerger, P. (2009). Meier, U. B. Leirholder, H. Buhr, L. , Feller, C., Hack, H., Heb, M. Lancashire, D. P. Schnock, U., Staub, R. Boom T. V. Weber, E & Zwerger, P. (2009). The BBCH system of coding the phonological growth stages of plants- History and publications. *Journal for Kulturpflazen,* **61**(2), 41-52.

Muellner et al. (2005). Aglaia (Meliaceae): an evaluation of taxonomic concepts based on DNA data and secondary metabolites. *American Journal of Botany*, **92**(3):534-543.

Muellner, A. N., Samuel, R. C., Pannell, C. M., & Greger, H. (2005). Aglaia (Meliaceae): an evaluation of taxonomic concepts based on DNA data and secondary metabolites. *American Journal of Botany,* **92**(3):534-543.

Report, N. F. (2001).

Rivera, G., Elliott, H., Caldas, L. S., Nicolossi, G., Coradin, V. T., & Borchert, R. (2002). Increasing day-length induces spring flushing of tropical dry forest trees in the absence of rain. *Trees* , **16**: 445 – 456.

Sekaran, U. (2003). *Research methods for business: A skill building approach.* New York, NY: John Wiley and Sons.

Singh, K., & Kushwaha, C. P. (2006). Diversity of Flowering and Fruiting Phenology of Trees in a Tropical Deciduous Forest in India. *Annals of Botany* , **97**, 265-276 .

Teijligen, E. R., & Hundley, V. (2016). *The importance of pilot studies* . Retrieved from http://sru.survey.ac. Uk/SRU35.html

Thompson, e. a. (2000). Fluctuation Resources in plant communities: a general Theory of invisibility. British Ecological Society. *Journal of Ecology **88,*** 528-534.

Tukur, et al. (2013). Indegenous tree inventory and their multipurpose uses in Dutsinma Area, Katsina State, Nigeria. *European Scientific Journal*, 288-300.

Tukur, R., Adamu, G. K., & Abdurashid, I. (2013). Indegenous tree inventory and their multipurpose uses in Dutsinma Area, Katsina State, Nigeria. *European Scientific Journal*, 288-300.

Weier, J., & Herring, P. (2000). Measuring vegetation (NDVI and EVI). *NASA Earth observatory,*.

WRM. (1999). *WRM Campaign Material. Tree plantations: impacts and struggles. Africa. Gambia. Montevideo, Uruguay: World Rainforest Movement*. Retrieved from http://www.wrm.org.uy/plantations/material/impacts5.html

Zadoks, J. C., Chang, T. T., & Konzak, C. F. (1974). A decimal code for the growth stages of cereals. *Weed Research*, **14**: 415 – 421.

Zhang, G., Song, Q., & Yang, D. (2006). Phenology of Ficus racemosa in Xishuangbanna, Southwest China. *Biotropica*, **38**: 334-341.

APPENDICES

APPENDIX I: FIELD RECORD ON PHENOLOGY

The phenological activities of *Azadirachta indica* (Neem tree) for the period of one annual cycle from March 2016 to February 2017.

Based on the six principal growth stages, leaf development (LD), leaf end (LE), flower development (FD), flower end (FE), fruit development (Fr D) and Fruit end (Fr E).

Observations were made in the year from March 2016 to Feb 2017, and the breakdown is as follows;

Leaf development (LD) — started in the first week of March 2016 (10%), peaked in August/September 2016 (80%), September 80% and ended in October 2016.

The first week of March started (10%), peaked in August 2016 (80%), and lowered in.

October 2016.

Lead end (LE) started in November 2016 at 10% and peaked in February 2017 (80%)

Flower development (FD) started in the first week of April 2016(10%) and was the peak in June 2016 (80%).

Flower end (FE) started in the first week of June 2016 (10%) and peaked in late June 2016 (80%).

Fruit development (Fr D) started in mid-May 2016 (10%), became peak in September 2016 (80%)

Fruit end (Fr E) started in mid-July 2016 (10%) and became peak in October 2016(80%).

APPENDIX II: AZADIRACHTA INDICA PHENOLOGY

Methodology of phenology

The BBCH systems of coding the phenological growth stages of plants were used.

Criteria for optimum conditions

I ensured uniform conditions during the observations. The greenish-brown colour of the new leaves was a criterion for leaf development, and this clearly distinguished old leaves from the young developing ones. Flowering was marked by inflorescence emergence and development. Fruit development was marked with a colour change from green to yellow fruits.

Scale: The extended BBCH (Biologische Bundesanstalt, Bundessortenamt and Chemsche Industry) scale of Meier (1997) based on Zadoks *et al*. (1974) was used by selecting six (6) principal growth stages out of the ten (10) principal growth stages chronologically arranged according to their course of natural development, were used for data collection.

The principal growth stages used in the present study include leaf development (LD), leaf end (LE), flower development (FD), flower end (FE), fruit development (Fr D), and fruit end (Fr E), coded with alphabet H, I, J, K, L and M respectively, following their placements according to Zadoks *et, al.* (1974).

Since the principal growth stages were insufficient to reveal the short developmental changes in the course of time in the principal growth stages, secondary growth stages were introduced to fill these gaps. They were coded 0 to 9, where 0 denoted the start, whereas 9 denoted the end in the primary growth stage.

The meso stages between 0 and 9 (i.e. 1,2,3,4,5,6,7 and 8) were taken as percentage values of activity, 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80% in the secondary growth stages. On

the whole, the principal and secondary growth stages gave rise to the 2-digit scale BBCHxy used in the phenological records. The letter ‘y’ denoted the principal growth stage, while ‘x’ denoted the secondary growth stage. Thus (BBCH (H1)) for example, represents 10% of the leaf development, (BBCH (H8) represents 80%, and (BBCH (H9)) represents the end of leaf development.

APPENDIX III: QUESTIONNAIRE FOR LOCAL FARMERS (SMALL SCALE FARMERS)

My name is Ahmed Aliyu Maje. I am a Ph.D. student at Kampala International University (KIU) Uganda. I am conducting research on the topic, "The Phenology, Distribution and Uses of *Azadirachta indica* (Neem Tree) in Taura, Local Government Area, Jigawa state, Nigeria". This is an Interview scheduled that aims to analyze the uses of *Azadirachta indica* (Neem Tree). I would like you to assist by answering the questions that will be asked below. Thank you.

Respondent Number ……Date…….

PART 1: DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

1. Ward ……..
2. Village ……
3. Age

   a) 18-27 years ☐ b)28-37 years ☐ c) 38-47 years ☐

   d) 48-57 years ☐ e)58-67 years ☐ f) above 68 years ☐

4. Gender

   a) Male ☐ b)female ☐

5. Occupation

   a) Farmer ☐ b) civil servant ☐ c) Business ☐ d) others /specify ……..…

6. Education level

   a) Non formal ☐ b) primary ☐ c) secondary ☐ d) NCE/ Diploma ☐

   e) Degree /HND or its equivalent ☐ f) Postgraduate Degree ☐

7. Marital status

   a) Single ☐ b)married ☐ c) Divorced / Separated ☐ d) Widowed ☐

Part II

Questionnaire on the uses of Azadirachta indica (Neem Tree)

Direct use questions

1. How often do you use Neem tree as a source of firewood?

   a) every day b) twice a week c) once a week d) Once in a month

2. Dead Neem leaves are used as local manure?

   a) two years ago b) 5 years ago c) 10 years ago d) not using it at all

3. Neem tree is used for timber because,

   a) It is easy to obtain. b) It is not affected or destroyed by termites and other pests

4. Neem tree is used for roofing of houses because

   a) It is easy to obtain. b) It is not affected or destroyed by termites and other pest

5. Neem tree is used as animal fodder because?

   a) The unavailability of other indigenous plant species b) Neem is more abundant in the area

Ecological uses

6. Neem tree is useful for shelter and shade

   a) It is the most frequent species in the area

   b) It is the plant that withstands environmental stress and is capable of regeneration

   c) Neem shade is very conducive for shelter and shade

7. The Neem tree has various methods of dispersal and is the most fast-growing species in the area.

   a) It is dispersed by bats as it sucks the liquid portion and throws the seed away.

   b) It is dispersed through animal faeces. c) it is dispersed by human beings

8. Neem trees are used to control soil erosion

   a) Neem tree is seen along the degraded area. b) Neem tree is seen sprouting along gully areas

9. Neem trees help in the reduction of evaporation from the soil surfaces.

a) It can easily withstand environmental stress. b) It can easily survive on marginal land (plant resources are very few)

10. Neem tree is sensitive to changes in temperature (seasonal variation).

a) When the season is windy, dry and cold, the Neem shades its leaves. b) When the season is warm and dry, the Neem produces more leaves.

11) Neem helps in converting drought and halting the spread of deserts.

a) It can be seen underneath other trees. b) Neem can be seen sprouting all over the environment. c) Neem act as a substitute for other old or dead trees

Medicinal uses

12. Which part of the Neem tree do you use?

a) The Bark b) Leaves c) roots d) branches e) others/ specify ……

13. How do you prepare it for use?

a) By cutting b) by boiling c) others/ specify ……

14. In what quantity do you use them?

a) Large quantity b) small quantity c) I don't use it d) others /specify ……

15. Neem plant is used to cure

a) Malaria b) yellow fever c) toothpaste (e) stomach ache

Questionnaire for Administrators (Part I)

My name is Ahmed Aliyu Maje. I am a Ph.D. student with Kampala International University (KIU) Uganda. I am conducting research on the topic, "The Phenology, Distribution and Uses of *Azadirachta indica* (Neem Tree) in Taura, Local Government Area, Jigawa state, Nigeria". This is an Interview scheduled that aims to analyze the uses of *Azadirachta indica* (Neem Tree). I would like you to assist by answering the questions that will be asked below. Thank you.

Respondent Number ……Date…….

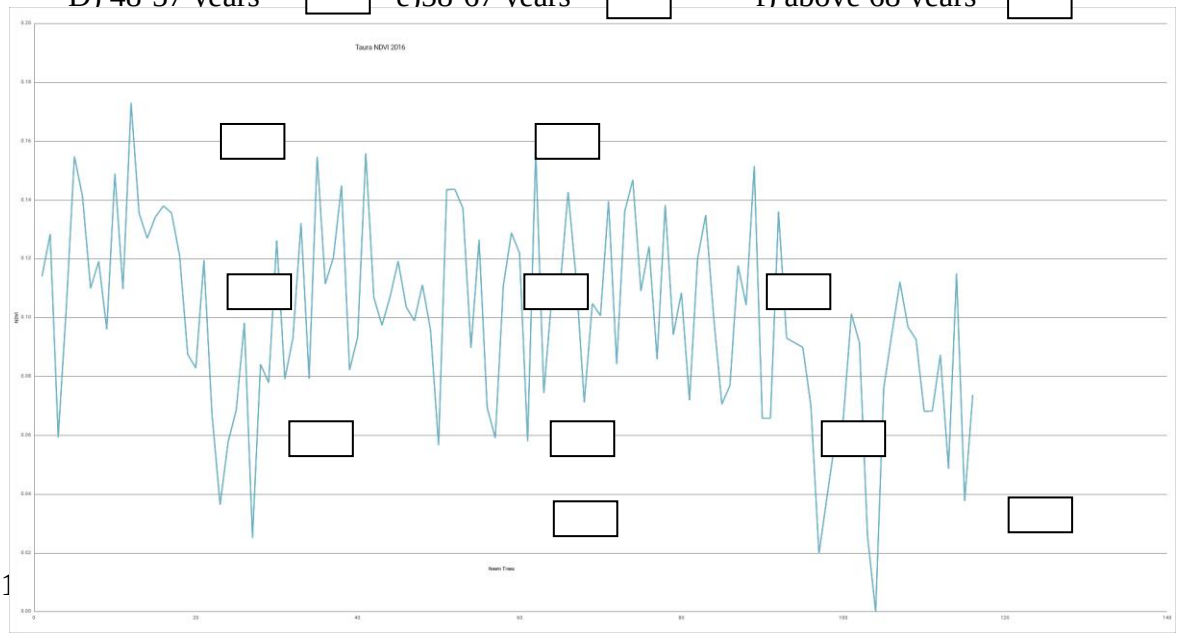
JIGAWA STATE MINISTRY FOR ENVIRONMENT

PART 1: Demographic Characteristics of the Respondents

8. Age

b) 18-27 years ☐ b)28-37 years ☐ c) 38-47 years ☐

D) 48-57 years ☐ e)58-67 years ☐ f) above 68 years ☐



1

b) Single b)married ☐ c) Divorced / Separated ☐ d) Widowed ☐

Part II

Questionnaire on the uses of Azadirachta indicia (Neem Tree)

Direct use questions

1. How often do you use the Neem tree as a source of firewood?

a) every day b) twice a week c) once a week d) Once in a month e) others/ specify

……

2. Dead Neem leaves are used as local manure.

a) two years ago b) 5 years ago c) 10 years ago d) not using it at all

3. Neem tree is used for timber because,

a) It is easy to obtain. b) It is not affected or destroyed by termites and other pests

4. Neem tree is used for roofing of houses because

a) It is easy to obtain. b) it is not affected or destroyed by termites and other pest

5. Neem tree is used as animal fodder because,

a) The unavailability of other indigenous plant species b) Neem is more abundant in the area

Ecological uses

6. Neem tree is useful for shelter and shade

a) It is the most frequent species in the area

b) It is the plant that withstands hardship and is capable of regeneration

c) Neem shade is very conducive for shelter and shade d) others/ specify……

7. The Neem tree has various methods of dispersal and is the fastest-growing species in the area.

a) It is dispersed by bats as it sucks the liquid portion and throws the seed away.

b) It is dispersed through animal faeces. c) it is dispersed by human beings

d) Others/ specify……

8. Neem tree is used to control soil erosion

a) Neem tree is seen along the degraded area. b) Neem tree is seen sprouting along gully areas

c) Others/ specify……

9. Neem trees help in the reduction of evaporation from the soil surface.

a) It can easily withstand environmental stress. b) It can easily survive on marginal land (plant resources are very few).

10. Neem is sensitive to changes in temperature (seasonal variation).

a) When the season is windy, dry and cold, the Neem shades its leaves. b) When the season is warm and dry, the Neem produces more leaves

11) Neem helps in converting drought and halting the spread of deserts.

a) It can be seen underneath other trees. b) Neem can be seen sprouting all over the environment. c) Neem acts as a substitute for other old or dead trees.

Medicinal uses

12. Which part of the Neem tree do you use?

a) The Bark b) Leaves c) roots d) branches e) others/ specify ……

13. How do you prepare it?

a) By cutting b) by boiling c) others/ specify ……

14. In what quantity do you use them?

a) Large quantity b) small quantity c) I don't use it d) others /specify ……

15. Neem plant is used to cure.

a) Malaria b) yellow fever c) toothpaste (d) stomach ache

f) Others/specify.

For Administrators Only

16. Neem trees promote forestation and reduce the level of desertification

a) Not at all b) it is desirable to some extent c) others/specify……

17. The state government, through the Ministry for Environment, nurse Neem seedlings every year

a) It is true they nurse it every year. b) It is not true for every year. c) Others/specify

18. The state government, through the Ministry for Environment, distributes the Neem seedlings free of charge during the rainy season

a) Yes, it is true. b) no, it is not true. c) I don't have any idea about the distribution

d) Others/specify……

19. The state Ministry for the Environment has established a Neem tree shelter belt for the purpose of wind control in Taura Local Government Area.

a) Yes, it is true. b) No, it is not true because I have not seen any Neem shelter belt

9c) others/specify……

20) The state Ministry of Environment has been planting Neem trees along the roadsides and some grazing yards as part of a forestation program

a) Yes, they do every year. b) Yes, they do it, but not every year. c) It is not true they don't do it. d) Others/ specify ……

APPENDIX IV: NORMALIZED DIFFERENCE VEGETATION INDEX OF NEEM

NDVI	X values	Y values	Tree type	Percentage
0.114054000009	4794821920012	25488596400	Neem	0.00000000000
0.128283000009	5104682350012	26934391500	Neem	0.00000000000
0.059275100009	5098434390012	26480555000	Neem	0.00000000000
0.103460000009	5111505560012	26077903200	Neem	0.00000000000
0.154675000009	5412349250012	26934820100	Neem	0.00000000000
0.141103000009	5402155870012	26999225300	Neem	0.00000000000
0.109921000009	5426563670012	27648019000	Neem	0.00000000000
0.119037000009	5407825900012	27298431600	Neem	0.00000000000
0.095998500009	5382455290012	27790861600	Neem	0.00000000000
0.148798000009	5412772680012	26306334100	Neem	0.00000000000
0.109704000009	4285322290012	27616699800	Neem	0.00000000000
0.172905000009	4349478810012	27449298300	Neem	0.00000000000
0.135297000009	4345841480012	27137373500	Neem	0.00000000000
0.126878000009	4391073580012	26530773700	Neem	0.00000000000
0.134160000009	4412281100012	26332392300	Neem	0.00000000000
0.137886000009	4418583740012	26080896300	Neem	0.00000000000
0.135531000009	4450490510012	25535993800	Neem	0.00000000000
0.120849000009	4612846990012	24354111400	Neem	0.00000000000
0.087426500009	4603036590012	24512527800	Neem	0.00000000000
0.082807900009	4603382430012	24385920600	Neem	0.00000000000
0.119351000009	4613738280012	23662309900	Neem	0.00000000000
0.067076600009	4960137020012	21030209400	Neem	0.00000000000
0.036405300009	4348949670012	18024691900	Neem	0.00000000000
0.057779600009	4529528620012	17755923200	Neem	0.00000000000
0.068577400009	4074205880012	15666834600	Neem	0.00000000000
0.098128900009	3769238770012	17632607700	Neem	0.00000000000
0.025068500009	3758893870012	17278259400	Neem	0.00000000000
0.084095300009	3497180920012	16428930800	Neem	0.00000000000
0.077764400009	3364436180012	19210436200	Neem	0.00000000000
0.126130000009	3327712060012	19581649800	Neem	0.00000000000
0.079043300009	3248569800012	20395570500	Neem	0.00000000000
0.092972600009	3265086310012	20893651100	Neem	0.00000000000
0.132022000009	3345909600012	21746350300	Neem	0.00000000000
0.079189100009	3340423810012	21987867800	Neem	0.00000000000
0.154629000009	3229028750012	22243308900	Neem	0.00000000000
0.111427000009	3255480460012	22030484100	Neem	0.00000000000
0.120368000009	3554043540012	22388513400	Neem	0.00000000000
0.144817000009	3529180150012	22776781700	Neem	0.00000000000
0.082164600009	3503593990012	22569117900	Neem	0.00000000000
0.093356200009	3650286890012	22953349500	Neem	0.00000000000
0.155696000009	3758439870012	23187916400	Neem	0.00000000000

0.106762000009.3809366440012.23775013800Neem 0.00000000000
0.097354900009.3783215060012.24139810000Neem 0.00000000000
0.106968000009.3837705200012.24555938500Neem 0.00000000000
0.119088000009.3596186680012.24694853000Neem 0.00000000000
0.103536000009.3585444910012.24811649000Neem 0.00000000000
0.098898800009.3554219180012.25077921000Neem 0.00000000000
0.111072000009.3457516110012.25264538900Neem 0.00000000000
0.095779500009.3407090740012.25681150800Neem 0.00000000000
0.056587000009.3291196470012.25364248700Neem 0.00000000000
0.143430000009.1046065250012.24475857400Neem 0.00000000000
0.143596000009.1214919090012.25392143500Neem 0.00000000000
0.137163000009.1218067540012.25875940800Neem 0.00000000000
0.089702300009.1194802000012.25829018500Neem 0.00000000000
0.126299000009.1306843580012.26768999900Neem 0.00000000000
0.069386100009.1308295260012.24506384800Neem 0.00000000000
0.059024500009.1424655290012.27131044800Neem 0.00000000000
0.110868000009.1833628290012.27871962300Neem 0.00000000000
0.128742000009.1736239010012.26364195800Neem 0.00000000000
0.121808000009.1725540440012.25869601400Neem 0.00000000000
0.057901700009.1724222240012.25393938300Neem 0.00000000000

0.156337000009.1660738520012.24765828100Neem 0.00000000000
0.074270000009.1626515060012.24448616900Neem 0.00000000000
0.107464000009.1573176570012.24275298200Neem 0.00000000000
0.110044000009.1520848600012.25680905300Neem 0.00000000000
0.142589000009.1424179330012.21682517900Neem 0.00000000000
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0.071170900009.1617432020012.21745657000Neem 0.00000000000
0.104745000009.1610088470012.21932894500Neem 0.00000000000
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0.119943000009.2461422930012.19985931900Neem 0.00000000000
0.134779000009.2473069280012.19676550900Neem 0.00000000000
0.099741500009.2042476490012.20876493000Neem 0.00000000000
0.070507500009.2239123680012.24193810500Neem 0.00000000000
0.076858200009.2336091630012.25909393800Neem 0.00000000000

0.117569000009.2320324410012.25408537000Neem 0.00000000000
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0.065672600009.2017377210012.23281262700Neem 0.00000000000
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0.058334700009.2182072930012.18025910000Neem 0.00000000000
0.065392700009.2251760790012.18149242200Neem 0.00000000000
0.101152000009.2287816410012.18403059700Neem 0.00000000000
0.091394300009.2521363900012.20017945500Neem 0.00000000000
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0.075904300009.2545041470012.19596315900Neem 0.00000000000
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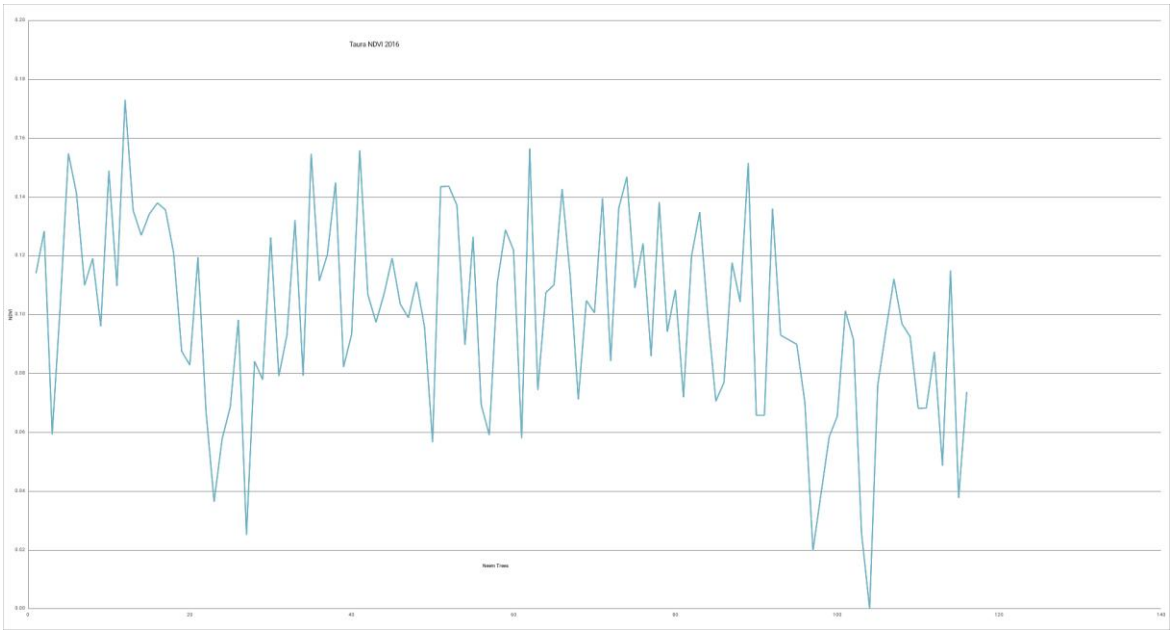
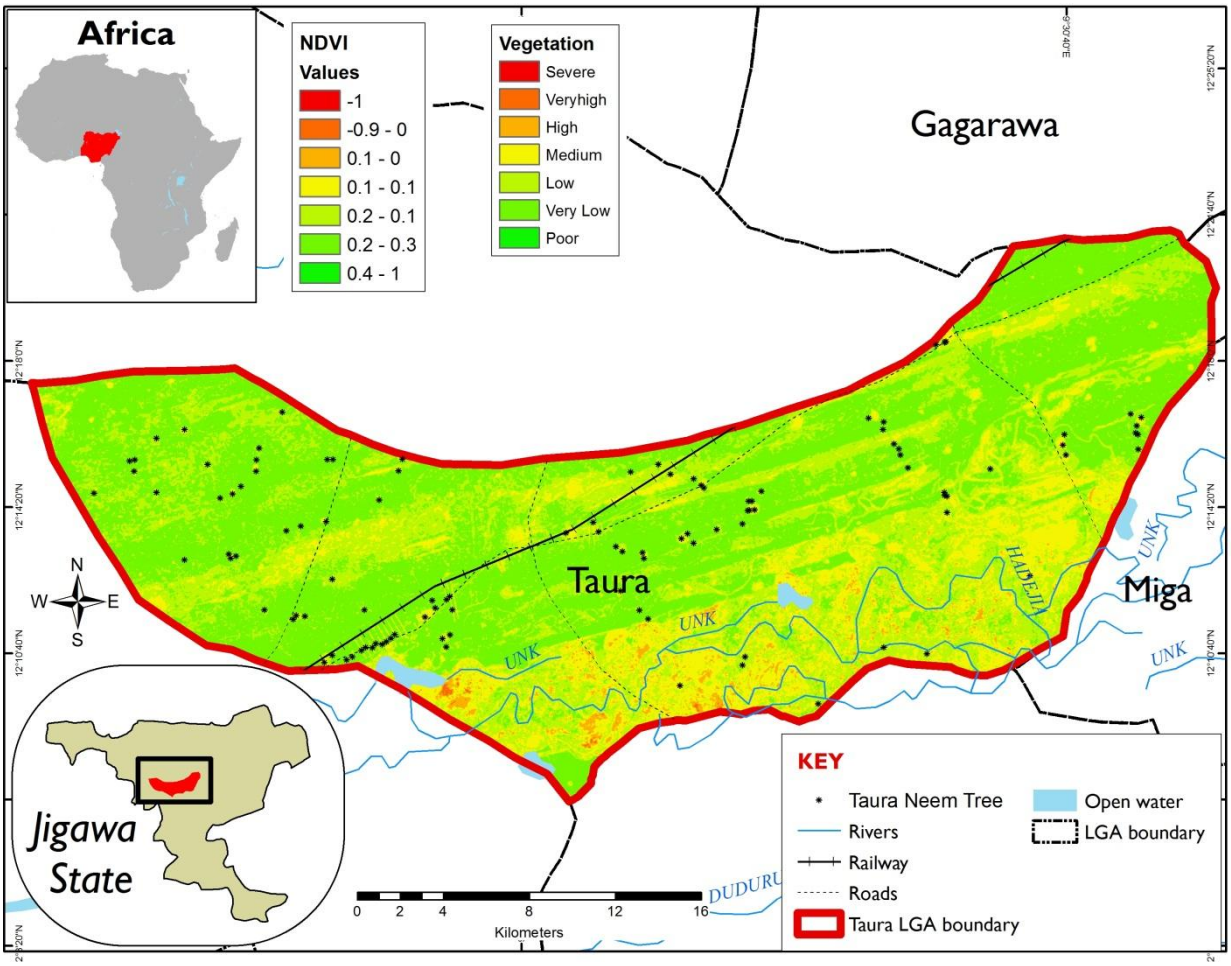
0.073652600009.3785827940012.23764487400Neem 0.00000000000

Normalized Difference Vegetation Index (NDVI) 2016 in Taura Local Government Area

Taura Local Government Area Land use/ Cover NDVI 2016

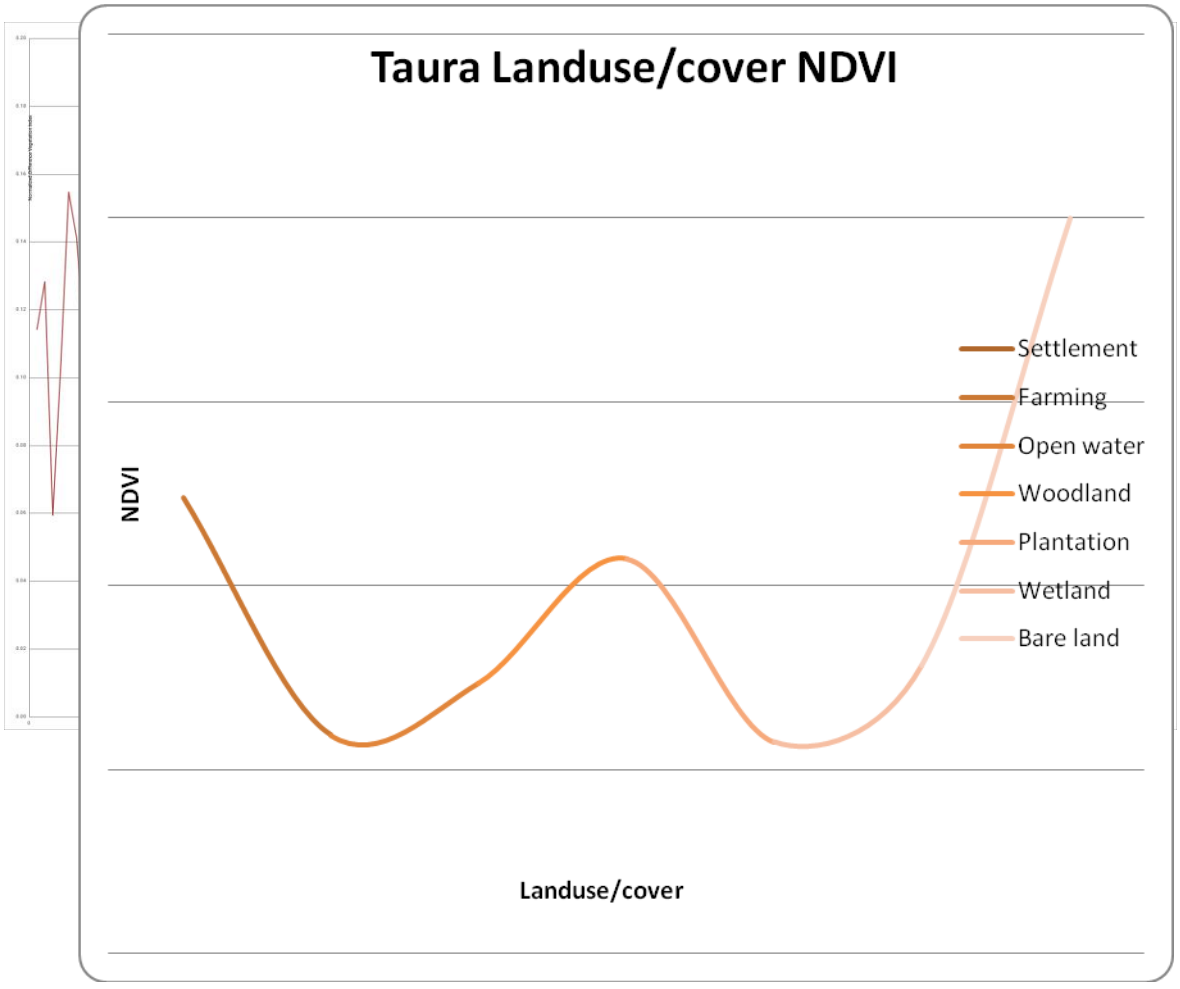


APPENDIX V : TAURA LGA NEEM TREE DISTRIBUTION MAP



Source: Field data, 2017

OID_	Landuse	NDVI
	1Settlement	0.12420400000
	2Farming	0.05935740000
	3Open water	0.07342700000
	4Woodland	0.10727700000
	5Plantation	0.05756990000
	6Wetland	0.07817340000
	7Bare land	0.19992100000


Taura Landuse/cover NDVI
NDVI
Landuse/cover
Settlement
Farming
Open water
Woodland
Plantation
Wetland
Bare land

APPENDIX VI: INTRODUCTORY LETTER

FROM JIGAWA STATE COLLEGE OF EDUCATION GUMEL TO THE MINISTRY OF ENVIRONMENT

PROVOST
Dr. Dahiru Abdulkadir
N.C.E., B.A. Ed (BUK), M.A (ABU), Ph.D (BUK)
Tel: 064 - 650227

unammad Tanimu Hadejia MNIM, M.Inst. A.M
B.A (Hons) A.B.U Zaria

JIGAWA STATE COLLEGE OF EDUCATION
P.M.B 1002, GUMEL, JIGAWA STATE

JSCOE/G/SP/M/66

18TH JANUARY, 2017

THE DIRECTOR

JIGAWA STATE MINISTER OF ENVIRONMENT

Sir

RE: INTRODUCTION LETTER IN RESPECT OF AHMED ALIYU MAJE

M. Ahmed Aliyu Maje is a PhD research candidate in Kampala international university, Uganda . He is sponsored in Jigawa State College of Education, Gumel to pursue a Higher Degree at the a fore mentioned university.

The candidate is now referred to your ministry for an assistant in relation to his research

His thesis is on Phenology, distribution and uses of *Azadrachta indica A. Juss* in Taura Local Government Area, Jigawa State, Nigeria. Please accord him any necessary assistance he may require to fully conduct his research.

Best regards,

Usmand 18/01/2017.

MUHAMMAD USMAN FAGWALAWA

CHIEF EXECUTIVE OFFICER

FOR. AG. REGISTRAR

APPENDIX VII: TRANSMITTAL LETTER FOR DATA COLLECTION

KAMPALA INTERNATIONAL UNIVERSITY
EXPLORING THE HEIGHTS

Ggaba Road, Kansanga PO BOX 20000 Kampala, Uganda
Tel: +256(0) 41-266813 * Fax: +256 (0) 41-501 974
E-mail: admin@kiu.ac.ug *website: http: // www.kiu.ac.ug

SCHOOL OF ENGINEERING & APPLIED SCIENCES (SEAS)
DEPARTMENT OF BIOLOGICAL & ENVIRONMENTAL SCIENCES

10th June, 2016.

RE: Transmittal Letter For Data Collection

This is to introduce to you **Ahmed Aliyu Maje (PHD ENV/43158/142/DF)** who is a student in the department. He is expected to produce his student card, which carries a photograph, as proof of identity.

Ahmed is undertaking a study leading to a thesis titled "The Phenology ,Distribution, and uses of Azadirachta indica A. juss (Neem tree) in Taura local government area, Jigawa State, Nigeria" as a partial fulfillment for the requirement of Doctor of Philosophy in Science in Environmental Management of Kampala International University.

By this letter we request you to grant him permission to undertake his study in your industry/organization. All information provided to him shall be treated with utmost confidentiality.

Any assistance rendered is highly appreciated.

Yours sincerely,

KAMPALA INTERNATIONAL UNIVERSITY * SCHOOL OF ENGINEERING & APPLIED SCIENCE *
KIU
10 JUN 2016

Mrs. Anne Tumushabe .K
Head of Department