ECOLOGICAL STUDIES AND REGIONAL DISTRIBUTION OF LATEX-PRODUCING PLANTS IN SOME VEGETATION BELTS OF NORTHERN NIGERIA.

BY

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Declaration

I, Danladi, Yakubu Papi declare that this dissertation entitled'' Ecological studies and regional distribution of latex-producing plants in some vegetation belts of Northern Nigeria,'' was carried out by me, and submitted to the Department of Botany, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Anambra State , Nigeria.

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Approval Page

This dissertation has been approved as meeting the requirements for the award of Degree of Doctor of Philosophy (Ph.D.), in Botany in the Department of Botany, Faculty of Biosciences, Nnamdi Azikiwe University, Awka.

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Dedication

This dissertation is dedicated to Almighty God, for He has been my source of inspiration throughout my stay in this University.

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ABSTRACT

Ecological studies were carried out to ascertain the niche of latex-producing plants considering soil, climate, vegetation and anthropogenic interrelationships. Global Positioning System (GPS) and Stratified random sampling were used to locate towns for data collection. Twenty (20) plots of 15 m x 20 m (300 m^2) in quadrat size were considered, 5 plots from each study area of Southern Guinea Savanna (SGS), Northern Guinea Savanna (NGS), Sudan Savanna (SDS) and Montane Vegetation (MNV). Also a quadrat size of 1 m x 1 m was placed 4 times in each of the 20 plots to enable the counting of forbs and grasses. Soil and vegetation analyses were carried out to determine some parameters. Ordination by Principal Components Analysis (PCA) was used to analyse the data. The results showed that over all, 142 plant species were encountered in all the 20 plots samples. Ten (10) families were noted to exude latex namely, Aloeceae, Sapotaceae, Cohlospermaceae, Euphorbiaceae, Moraceae, Convolvulaceae, Meliaceae, Asclepiaceae, Cactaceae and Apotaceae. Thirty three (33) of the plants collected were latex-producing plants, while 109 were non-latex producing plants. Vegetation attributes such as total number of species and total number of woody individuals have higher mean values for MNV and SGS (36.20 and 27.80; 65.20 and 42.40 per 300 m^2) while lower mean values were recorded for NGS and SDS (24.20 and 11.60; 35.80 and 23.00 per 300 m^2) respectively. Total number of individuals was higher in MNV and SGS with mean values of 85.20 and 73.60 per 300 m^2, while it was lower for NGS and SDS with mean values of 68.60 and 30.00 per 300 m^2 respectively. The abundance of latex-producing plants, girth size of woody plants above 1 metre high and girth size of woody latex-producing plants were higher in SGS and MNV with mean values of (4.60 and 17.60; 473.80 and 471.80; 111.40 and 72.20 per 300 m^2) respectively. Constancy values were calculated as percentages of occurrence of plant species in a plot and mean total number of latex producing plants gave 20.14%, 9.33%, 6.57% and 3.76% for the MNV, SDS, SGS and NGS respectively. Soil samples from the study areas gave a pH range of 5.39–6.83 indicating weak acidic soil. The percentage of soil content was over 96% referred to as sandy texture for all the study areas. The percentage organic matter and percentage nitrogen content showed lower values for SDS and MNV as 0.96% and 1.62%; 0.36% and 0.46% respectively. The ordinations showed clusters representing the four study areas with Lokoja to the north and Jos to the south in a vertical line gradient, while, Katsina study area to the west and Minna to the east in a horizontal gradient. The measured vegetation attributes, namely; total number of species, total number of woody species, species diversities, and basal area of woody species reflected the general south-north decreasing trend in all the parameters. The Montane vegetation of Jos recorded high value for the latex-producing plants, suggesting that the environmental conditions in the area favoured their greater abundance. Since the Montane vegetation was found to be substantially different in the physiographic, climatic and biotic factors, the higher abundance of latex-producing plants in these areas can be attributed to them. The ordination analysis brought out these relations more succinctly, suggesting a good correlation between them. Ten (10) responses on questionnaire administered on natives of the study area, it seems that some people especially in the savanna vegetation do not know these latex-producing plants. This study will elicit greater interest in the study of all aspects of the biology and ecology of latex-producing plants. Specifically, there is need to explore more of their responses and adaptations to their environment, their life histories and phenological characteristics, their diversity and genetic attributes, as well as their ethno-medicinal values.

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CHAPTER ONE

1 .0 Introduction

Latex is a complex emulsion of starch, gum, sugar, oils, alkaloids, etc, which is exuded upon plant tissue damage and coagulates on exposure to air (Hunter, 1994; Hopkins and Harper, 2001). Latex may be natural or synthetic in nature. It can be made synthetically by polymerizing a monomer such as styrene that has been emulsified with surfactants to give a polymer, rubber which could be used in the production of glove, toys, balloons, adhesives etc (Richard *et al.*, 2011). In most plants, latex is whitish but there are some that are yellow, orange or scarlet in colour. According to Mahlberg (1993) latex has been used as a term for describing fluid substance in plants (Mahlberg, 1993). Latex found in nature is a milky fluid found in 10% of all flowering plant species (angiosperms) and this latex has no known function in primary metabolism (Lewinsohn, 1991: Hunter, 1994). Among flowering plants, over 20,000 species (from over 40 families in multiple lineages) contain latex (Metcalfe, 1967). Latex is found in both dicotyledonous and monocotyledonous plants. The finding, that nearly 10% of families of plant species produce latex, implies that latex is a highly convergent trait (Lewinsohn, 1991). In addition, latex has been reported in mushrooms (*Lactarius* species), conifers (*Gnetum* species) and pteridophytes (Metcalfe, 1967).

Tropical plant species are more likely to produce latex than their temperate counterparts. Indeed, some 14% of tropical plant species produced latex compared to 6% of temperate species, and this distribution is not independent of plant phylogeny (Lewinsohn, 1991).

1.1 Background of the study

Latex is used as a defensive strategy against grazing animals, this is because some of the plants latices are very bitter or even poisonous (Agrawal and Konno, 2009). Latex serves mainly as defense against herbivores and insects, thus, it should not be confused with plant sap, they are two separate

substances produce and each has its separate function. Apart from defense function of the latex, other functions involved in the primary metabolism are; storage and movement of nutrients, waste and maintenance of water balance, essentially none of these functions remains credible and none has any empirical support (Mahlberg, 1993; Hunter, 1994).

Traditionally, ecologists have recognized four key variables as being the determinants of savanna structure and function namely; water, nutrients, fire and herbivory (Frost and Robertson, 1987). In competition-based models, water and nutrients are considered the primary determinants, with fire and grazing representing modifiers (Stott, 1991). Trees and grasses coexist in savannas because of their differential ability to acquire and partition limiting resources.

In Nigeria, the forest belt is covering about 20% of the country landmass found in the wetter south, extending inland from the coast. The mean annual rainfall is over 1,300 mm and the rainy season is at least eight months long. The Savanna belt covers the rest 80% of the country (Oguntoyinbo and Oguntala, 1980). Another type of vegetation does exist, called montane vegetation, which has grasses and tree similar to that savanna but found on isolated high Plateau regions in the central and far eastern parts of the country with characterized lower temperatures. For instance, the Jos Plateau, which is one of the highest points in Nigeria, is in a grassland zone, but its vegetation depicts grassland at the top and base of the Plateau, while, the slopes, favoured by moisture-laden and wind, are covered by forests. These are also true of the Mandara Mountain in Adamawa State and the Obudu Plateau in Cross River State (Iloeje, 2001).

The country experiences consistently high temperatures all year round. Since temperature varies only slightly, rainfall distribution, over space and time, becomes the single most important factor in differentiating the seasons and climatic regions. Rainfall occurrence and distribution are however dependent on the two air masses that prevail over the country. Their influences are directly linked to the movement of the inter-tropical continental zone (ITCZ), north and south of the equator

(Zhang *et al*., 2008). The two air masses are the Tropical Maritime (Tm) and the Tropical Continental (Tc). The former is associated with the moisture-laden moving south-west winds (South westerlies) which blow from the Atlantic Ocean, while the latter is associated with the dry and dusty north-east winds (easterlies) which blow from the Sahara Desert. The (ITCZ), is the zone of convergence of the two air masses, and is to the south of the equator, the north-east winds prevail over Nigeria, thus producing the dry-season conditions (harmattan).

Ethno-botany is the scientific study of the relationships that exist between people and plants. Ethno-botanists aim to document, describe and explain complex relationships between cultures and plants, focusing primarily on how plants are used, managed and perceived across human societies. This includes uses in food, clothing, currency, ritual, medicine, dye, construction, cosmetics and a lot more. Intellectual property rights and benefit-sharing arrangements are important issues in ethno-botany. A great deal of information about the traditional uses of plants is still intact with tribal peoples.

Ethno-botanical knowledge encompasses both wild and domesticated species and is rooted in observation, relationship, needs, and traditional ways of knowing plants. Such knowledge evolves over time and is therefore always changing and adding new discoveries, ingenuity and methods. It is estimated that nearly one third of about 15,000 higher plant species in India are used by the tribals and poor people. These plants meet most requirements, both for man and his domesticated animals. The various uses of barks of trees for clothing, fibers and floss for nets, clothing, vegetable fats as an luminant, as a cooking media, bows, bow- strings, fishing nets, floats to carts wheels, wheels spokes, axles, mortars, poles, posts, turnery and combs to musical instruments are all made from these plants (Acharya and Shrivastava, 2008).

Ordination in a literal sense is simply arranging items along a scale (axis) or multiple axes. There are many purposes for doing so but normally the items are arranged as a way of graphically

summarizing complex relationships extracting one or a few dominant patterns from an infinite number of possible patterns. The process of extracting those axes is called ordination because it results in a placement of objects along an axis or dimension. What makes this possible is that the variables are correlated (in the broad sense). Ordination thrives on a complex network of inter-correlation that can make multiple regressions a nightmare (Hill, 1979). Ordination is most often used in ecology to seek and describe pattern. Although, we commonly think erroneously that ordination is a means of generating hypotheses about underlying mechanisms, ordination is used in most sciences.

1.2 History of Latex

Like many plant defenses, latex has been observed, described, and used by humans for thousands of years (Mahlberg, 1993). Historically, latex was classified by its often opaque sticky exudation, and the tendency to coagulate upon exposure to air. As early as the 1600s, the term latex was first used by English-speaking physicians, its function was analogized to lymphatic vessels of animals and it was studied in several plant families. It also carries a disagreeable property that, it becomes a better protection to the plant from enemies than all the thorns, prickles, or hairs put together. The plant produces copious and distasteful sap that serves a most important purpose in its economy.

Kniep (1905) a German published results of the first experiments to demonstrate latex as a resistant trait. He repeatedly damaged leaves of a plant in the Euphorbiaceae until latex no longer flowed from new cuts. Slugs readily ate such leaves, but refused to eat the leaves of intact plants that were not drained of their latex. Nearly a century later, Dussourd and Eisner (1987) showed that such disarming of the latex response, that is, severing or cutting off of the laticifers, was a routine maintenance by mandibulate herbivores of milkweeds before they conveniently eat the meal. Also about 30% of newly hatched monarch butterfly caterpillars (*Danaus plexippus*) died as they were mired in latex of *Asclepias humistrata* (Zalucki and Brower, 1992).

Other explanations for the production of latex in plants have included functions involved in primary metabolism, namely storage and movement of plant nutrients, waste, and maintenance of water balance (Mahlberg, 1993; Hunter, 1994). For example, carbohydrates in *Euphorbia* latex are unavailable to the plant, even when light is prevented from reaching the plant (Nissan and Foley, 1986).

Although, the need for latex production has not been estimated for any plant species, for the fact that latex is often highly concentrated within secondary metabolites, carbohydrates, and enzymes suggests that, it is not a waste product. In *Hevea brasiliensis*, latex can be up to 60% dry mass rubber and 2% nitrogen (Shukla and Krishna, 1971), sugar-mimic alkaloids can make up to 18% of dry mass latex in mulberry, 100 times higher than the average concentration in leaves (Konno *et al*., 2006). Studies of banana indicated that the concentration of latex during exudation is correlated with the turgor pressure of the plant. Milburn and his colleagues (Milburn *et al*., 1990) have suggested that latex may be important in maintaining turgor via osmoregulation. In particular, banana latex contains lutoids, which are transparent vesicles that compartmentalize various inclusions and have osmotic activity (Downton, 1981).

1.3 Storage organ of Latex in plants (Laticifers)

Latex can be distinguished from resins, mucilages, and gums, which also ooze out of plants upon tissue damage. Resins are typically composed of terpenoids and phenolics and delivered from intercellular spaces, sometimes called ducts (not from living cells like laticifers) (Langenheim, 2003). For example, *Bursera schlechtendalii* stores toxic terpenes in pressurized resin duct, following damage or when squeezed may drench an herbivore and coat the leaf surface (Becerra, 1994).

Laticifers take two main morphological forms. Non-articulating laticifers are formed from single cells that often branch, but do not loop or reconnect (Dussourd and Denno, 1991; Pickard, 2008). This form is typified by the laticifers of the milkweeds (*Asclepias* species), which result from

only 16 elongate cells that branch and spread through most above-ground tissues. Such remarkably long and multinucleate branching laticifers are also known from cytological studies of other species, such as *Jatropha dioica* (Euphorbiaceae), where 5 to 7 cells make up the entire laticifer network (Cass, 1985).

Articulating laticifers form loops which are often connected by perforations in the cell walls of neighboring laticifers. Articulating laticifers, such as those produced in the Asteraceae and Caricaceae, are produced by larger chains of cells that form net-like structures, and tend to deliver latex much more comprehensively to local tissues.

All plant parts can contain latex. The commonly examined tissues of latex-bearing plants are stem and leaf tissue. Indeed, there are no latex-producing plants that do not exude the latex in stems and leaves. Exudation of latex in roots appears more variable. *Asclepias* species apparently does not exude latex from roots, although at least a few species have laticifers in root tissues; other species, such as those in the Asteraceae, exude copious latex from roots (Lucansky and Clough, 1986). Latex exudation from reproductive tissues (buds, flowers, and fruits) is commonly observed, but like root latex, is far less studied than stem and leaf latex. Laticifers can transport latex and defensive substances upward of 70 cm to the damaged or exuding points, as was demonstrated for the milkweed rubber vine *Cryptostegia grandiflora* (Buttery and Boatman, 1976).

1.4 Uses of Latex

Latex is used in several ways such as:

- ✓ Rubber is a latex of *Hevea brasiliensis,* used in a wide range of activities e.g gloves, tyres, balloons, finger-cots, isostatic bags, squeeze toys, doll, masks, adhesives etc
- ✓ The latex of *Euphorbia hirta* is used in the treatment of warts (any small rounded protuberance).
- ✓ Styrene based latex is used for immune assays.
- ✓ Opium is the dried latex of *Papaver somniferum*. Morphine, the wonder drug is derived from opium.

- ✓ Latex *of Semecarpus anacardium* is used in the treatment of skin infection, such as topical rubefacient (a medicine for external application that treats redness of the skin).
- ✓ Latex of *Calotropis procera* is used extensively in herbal medicine.
- ✓ Latex of some plants like *Plumeria rubra* is used in biological warfare. When injected, it solidifies in the vein of the individual and kills silently.
- ✓ Mulberry latex is used in the preparation of artificial sweeteners, which are used by diabetic patients (Levine, 1995).

1.5 Adaptation of latex-producing plants to its ecosystem

Latex-producing plants are xerophytic in nature. Xerophytes are plants which are able to survive in an environment with little available water or moisture, usually in environments where potential evapo-transpiration exceeds precipitation for all or part of the growing season. Plants like the cacti and other succulents are typically found in the deserts where low rainfall amounts are the norm, but xerophytes such as the bromeliads can also be found in moist habitats such as tropical forests, exploiting niches where water supplies are limited or too intermittent for mesophytic plants. Plants that live under arctic conditions may also have a need for xerophytic adaptations, as water is unavailable for uptake when the ground is frozen. Their leaves are covered with silvery hairs (creates wind break and light reflective surface).

Adaptations of latex-producing plants include reduced permeability of the epidermal layer, stomata and cuticle to maintain optimal amounts of water in the tissues by reducing transpiration, adaptations of the root system to acquire water from deep underground sources or directly from humid atmospheres (as in epiphytic orchids), and succulence, or storage of water in swollen stems, leaves or root tissues. The typical morphological consequences of these adaptations are collectively called xeromorphism (Carter, 2002).

1.5.1 Water conservation in latex-producing plants.

If the water potential inside the leaf is higher than outside the leaf, the water vapour will diffuse out of the leaf down this gradient. This loss of water vapour from the leaves is called transpiration and the water vapour diffuses through open stomata in the leaf. Although, this is a normal and important process in all plants, it is vital that plants living in dry conditions have adaptations that decrease this water potential gradient and decrease the size of open stomata, in order to reduce water loss from the plant. It is important for a plant living in these conditions to conserve water because without enough water, plant cells lose turgor and the plant tissue wilts. If the plant loses too much water, it will pass its permanent wilting point, where the plant will die (Victor, 2003).

Types of latex-producing plants and water conservation are:

Some plants called xerophytes and latex-producing plants, have adapted their physical structure to suit the rigors such a harsh environment as the desert and rocky terrain. Differences in cellular structure and function, as well as in the basic process of creating carbohydrates from water and carbon dioxide also help plants to survive in arid conditions.

The common process of photosynthesis is called the C_3 cycle because carbon is fixed by the plant into a three carbon compound (phosphoglyceric acid) in order to make carbohydrates. Another process of photosynthesis used by desert plants such as bunchgrass fixes the carbon into a four carbon compound (malate or aspartate acid). This C_4 process, although not used by many plants, is more efficient in maximizing energy gain than normal photosynthesis (Klink and Joly, 1989).

On most days, while in the desert, you receive the sensation that the air is cooler. This is not correct. The temperature of the air is kept higher and the air is drier. Evaporation makes it feel cooler than it is. Plants that live in desert areas must be able to endure tremendous physiological stress. The

problem is not so much heat but drought. Plants almost constantly take up water from the ground and transport it to stems, leaves, and flowers. Most of the water transpires into the air.

The adaptations of desert plants are not limited to structural features. Many of them have distinctive biochemical characteristics, as well. Plants must photosynthesize in order to live. However, CO_2 is needed from the air and whenever the plant opens its stomata, it loses precious water. To get around this, some succulents (including members of the Agavaceae, Aizoaceae, Cactaceae and Crassulaceae), have evolved a system called crassulacean acid metabolism (CAM).

These plants only open their stomata at night when the transpirational stress is lowest. CO_2 is taken in that time and stored as the carboxyl portion of an organic acid. During the day, when light energy is available, the stomata close and the plant releases the CO_2 from the acids to use for photosynthesis. In this way, the plant actually transpires less in the daytime than it does at night. A similar biochemical modification of photosynthesis is C_4-photosnthesis ((Klink and Joly, 1989).

Plants that perform C_4-photosnthesis also have modifications of their leaf anatomy that facilitate uptake of CO_2 by production of an intermediate 4-carbon compound. C_4-plants have higher rates of photosynthesis than other plants in dry, bright environments, but they lose more water in the process than they do in CAM plants. Plants in the desert differ among the families that cause them to be classified as unrelated. At the same time, notice the convergence of characteristics that occurs among the various families.

1.6 Latex-producing plants as Environmental indicators

Latex-producing plants are said to posses the features of xerophytic plants such as sunken stomata, lateral and deep root system, spongy and succulent tissue for conserving water during drought, yet exhibited the ability to colonize disturbed areas where there is water shortage. In such ecosystem, they are three times as many as other individual species when compared to species of

preserved areas (Villela *et al.,* 2006). The proliferation of latex-producing plants in xerophytic environment after interference might be because of two anatomical strategies.

First, this species has unpalatable leaves, which provides resistance to herbivores, because of an abundance of calcium oxalate crystals, phenolic compounds in adaxial surface, and a laticifer system. Second, this species is resistant to desiccation during dry periods because its leaves have extensive amounts of wax on the outer cell walls and it has the ability to retain water because of the multiple epidermis.

According to Franceschi and Nakata (2005), numerous hypotheses about the functions of crystals (for calcium regulation, plant defense and detoxification) are based on the diversity of crystal shapes and sizes, and their prevalence and spatial distribution. The high concentration of Ca in a soil at a study site (Villela *et al.,* 2006) supports the calcium regulation hypothesis, a mechanism for regulating bulk Ca levels in plant tissues and organs that grow in environments where soluble Ca is abundant (Volk *et al.,* 2002; Franceschi and Nakata, 2005).

The physical nature of the crystals and their relative abundance, which makes the leaves of some latex-producing plants like P*achystroma longifolium* unpalatable and it would create a mechanical defense against herbivores (Franceschi and Loewus, 1995; Franceschi, 2001; Hudgins *et al*., 2003; Franceschi and Nakata, 2005). Crystal accumulation occurs along the veins because the site of entry of Ca is the xylem. Consequently, precipitation in the cells surrounding the veins will prevent the Ca from accumulating around the chlorenchyma cells, which could affect cellular function (Macnish *et al.,* 2003).

Phenolic compounds are a huge group of multifunctional carbon-based secondary metabolites that are mainly synthesized from cinnamic acid produced by the shikimate pathway (primary) and the secondary (phenylopropanoid) metabolism (Dixon and Paiva, 1995). A phenolic metabolism in plants

can be induced by certain environmental factors, such as stress, injury or infection, and can protect a plant from insectivores (Rees and Harborne, 1985; Dixon and Paiva 1995; Takahama and Oniki, 2000; Da Cunha *et al.,* 2010). Most of these phenolic compounds have antimicrobial, anti-feedant and antifungal activity that create a defense mechanism against herbivores and microorganisms (Beckman, 2000; Wititsuwannakul *et al.,* 2002; Eichhorn *et al.,* 2007). The phenolic compounds, observed only in the double-layered of the adaxial surface epidermis, are probably part of the chemical defense system that helps *Pachystroma longifolium* resist pathogens and herbivorous. There is no constant relationship between cuticle thickness and water permeability, because thicker cuticles can even have higher permeabilities (Becker *et al.,* 1986). It is known that plant cuticular permeability has contributed to minimizing uncontrolled water loss when the stomata are closed, this has been noted since the earliest terrestrial plants emergence (Becker *et al.,* 1986; Edwards *et al.,* 1996; Kerstiens, 1996).

Cuticular waxes form the main barrier to the diffusion of water and solutes across the cuticle (Schreiber and Riederer, 1996; Buchholz *et al.,* 1998; Buchholz and Schonherr, 2000; Jager *et al.,* 2010). However, Schonherr and Riederer (1996) remarked that the main diffusion barrier is located in a relatively narrow band at or near the outer surface of the cuticular membrane, which they called the limiting skin.

In fact, small, polar but uncharged water molecules diffusing across the cuticle usually move via the lipophilic pathway, dissolved in the amorphous phase of the cuticular wax, while a minor fraction of the water may diffuse through polar pores of molecular dimensions (Riederer and Schreiber, 2001). Although cuticle composition, organization and proportion of wax can vary, the extent of the amorphous phase that is characterized by the lipophilic wax matrix is probably the main barrier to water diffusion (Tenberge, 1992), except in the case of moist environments, where the cuticle swells because of water absorption, which in turn leads to an increase in cuticular transpiration (Schreiber *et al.,* 2001). In the semi-deciduous forest studied, which has a notable dry season, the thick

cuticles of the evergreen *Pachystroma longifolium* have an extensive amount of wax, that could promote resistance to desiccation during dry periods while the underlying adaxial surface of epidermis promotes water storage in the leaf tissues because of the pectic nature of the walls (Takemori *et al.*, 2003).

The description of the articulated and unbranched laticifers of *Pachystroma longifolium* differs from other Euphorbiaceae, such as *Euphorbia* and *Chamaesyce* that are characterized by the presence of non-articulated laticifers. Da Cunha *et al.* (1998) reported, in *Chamaesyce*, a thicker laticifer cell wall that had a higher quantity of pectic substances than the walls of adjacent cells. The two conspicuous laticifer cell wall layers of *Pchystroma longifolium* are indicative of their different composition, which are possibly comprised of an outer electron-dense layer, representing a polysaccharide-rich layer, and an inner electron-lucent layer, representing a primary cell wall. Although laticifers occur in many different plant organs and tissues (Mahlberg 1993), their occurrence among epidermal cells highlights the constitutive defense of *Pachystroma longifolium*, where an injury to a leaf causes latex to promptly exude from the damaged area.

The physical and chemical characteristics of the latex produced by certain plants can act as a defense against insects and other pathogens, and many types of latex are known to have high concentrations of enzymes (Giordani and Lafon, 1993). Latex contains a diversity of biologically active compounds that provide resistance to herbivores via toxicity or anti-nutritive and mechanical effects. The two major defense-related components in latexes are secondary metabolites (terpenoids, alkaloids, etc.) and different protein classes (Agrawal and Konno, 2009). Various latexes are known to contain glycosidases (Giordani and Lafon, 1993), proteases (Arima *et al.*, 2000; Tomar *et al.* 2008), acid phosphatases (Lynn and Clevette-Radford, 1987a), amylases (Lynn and Clevette-Radford, 1987a), chitinases (Jekel *et al.*, 1991), hevein (Van Parijs *et al.*, 1991), proteinase inhibitors (Archer,

1983), b-1,3-glucanase (Chye and Cheung, 1995) and various other enzymatic activities (Lynn and Clevette-Radford, 1987b; Agrawal and Konno, 2009).

Therefore, the desiccation resistance of latex-producing plants is promoted by extensive amounts of wax on the outer cell walls of its leaves, its ability to retain water because it has a biseriate epidermis, and its defense mechanism against pathogens because of unpalatable leaves caused by the abundance of calcium oxalate crystals, the presence of phenolic compounds in epidermis, and the complex mixture of proteins present in its latex (Villela *et al.*, 2006).

According Coley *et al* (1985), shade-tolerant species tend to have an increased number of defense mechanisms, such as unpalatable leaves, because their potential for tissue replacement is constrained by their low assimilation rate. On the other hand, faster-growing species, that demand more light, tend to be more susceptible to herbivores and expend more resources towards the replacement of tissue. In fact, herbivory can directly decrease the growth rate of the tropical understory and quantitative and qualitative changes in the leaf structure of plant species have been studied as an environmental indicator of this phenomenon (Marquis, 1984; Sagers and Coley, 1995).

1.7 Some Latex-Producing Plant Families

About 10% of flowering plants produce latex and are found in over 40 plant families including Euphorbiaceae, Moraceae, Cannabinaceae, Apocynaceae, Astereaceae, Papaveraceae, Sapotaceae and Asclepidiaceae (Agrawal and Konno, 2009). Latex flows inside laticifers of roots, stems, leaves and fruits (Pickard, 2008). The following are some of the latex-producing plants families:

1.7.1 Cactaceae Family

Cactus is a member of the plant family Cactaceae, native to the America. They are often used as ornamental plants and some are also crop plants for fodder, forage, fruits, and other uses. Numerous species have been used since ancient times by indigenous peoples for their psychedelic effects. Cacti are part of the plant order Caryophyllales, which also includes members like beets, gypsophila, spinach, amaranth, tumbleweeds, carnations, rhubarb, buckwheat, plumbago, bougainvillea, chickweed and knotgrass (Britton and Rose, 1920).

Cacti are unusual and distinctive plants, which are adapted to extremely arid or semi-arid hot environments, as well as tropical environments as epiphytes or hemi-epiphytes. They show a wide range of anatomical and physiological features which conserve water. Their stems have adapted to become photosynthetic and succulent, while the leaves have become the spines for which cacti are well known.

The study of when spines grow and how they can be used to tell the cactus' age is called acantho-chronology. The sharp thorns of the cactus deter unauthorized persons from entering private properties and may prevent break-ins if planted under windows and near drainpipes. The aesthetic characteristic of some species in conjunction with their home security qualities makes them a considerable alternative to artificial fences and walls (Nobel, 1994).

1.7.2 Euphorbiaceae Family

Euphorbia is a genus of plants belonging to the family Euphorbiaceae. Consisting of 2008 species, *Euphorbia* is one of the most diverse genera in the plant kingdom. Members of the family and genus are sometimes referred to as spurges (Victor *et al.*, 2007). *Euphorbia antiquorum* is the

type species for the genus *Euphorbia*, it was described by Carl Linnaeus in 1753 in *Species Plantarum* (Carl, 1753). The genus is primarily found in the tropical and subtropical regions of Africa and the Americas, but also in temperate zones worldwide.

The latex (milky sap) of spurges acts as a deterrent for herbivores as well as a wound healer. Usually it is white, drying colourless, but in rare cases (e.g. *Euphorbia abdelkuri*) yellow. (Tom-Eke and Mathew, 2000).

The terpen-ester composition determines how caustic and irritating to the skin, latex will be. In contact with mucous membranes (eyes, nose, mouth) the latex can produce extremely painful inflammation. In experiments with animals it was found that the terpen-ester resiniferatoxin had an irritating effect 10,000 to 100,000 times stronger than capsaicin, the hot substance found in chili peppers. Several terpen-esters are also known to be carcinogenic.

Therefore, spurges should be handled with caution. Latex coming in contact with the skin should be washed off immediately and thoroughly. Partially or completely congealed latex is often no longer soluble in water, but can be removed with an emulsion (milk, hand-cream). A physician should be consulted regarding any inflammation of a mucous membrane, especially the eyes, as severe eye damage including possible permanent blindness may result from acute exposure to the sap (Carter, 2002).

1.7.3. Moraceae Family

Ficus is a genus of about 850 species of woody trees, shrubs, vines, epiphytes, and hemiepiphyte in the family Moraceae. Collectively known as fig trees or figs, they are native throughout the tropics with a few species extending into the semi-warm temperate zone. The fruit of

most other species are also edible though they are usually of only local economic importance or eaten as bush food. However, they are extremely important food resources for wildlife. Figs are also of paramount cultural importance throughout the tropics, both as objects of worship and for their many practical uses.

Ficus is a pan-tropical genus of trees, shrubs and vines occupying a wide variety of ecological niches, most are evergreen, but some deciduous species are endemic to areas outside of the tropics and to higher elevations (Halevy, 1989). Figs are keystone species in many rainforest ecosystems. Their fruit are a key resource for some frugivores including fruit bats, capuchin monkeys. They are even more important for some birds; Asian barbets, pigeons, hornbills, fig-parrots and bulbuls are examples of taxa that may almost entirely subsist on figs when these are in plenty.

1.8 Savanna Vegetation of Northern Nigeria

Grass-dominated **e**cosystems that contain a significant number of widely spaced trees are termed savannas. Trees may make up as little as 5 percent or as much as 30 percent of the cover of all plants in savanna, but grasses and grass-like plants form a continuous ground cover. Originally, savanna was a term used to describe primarily tropical and subtropical grasslands, which usually have more woody plants than temperate grasslands. These tropical and subtropical savannas occupy large land areas (Keay, 1953)

Savanna may be a product of climatic factors, they may result from unique soil types, or they may be narrow to broad transitional zones between forests and grasslands. Fire and periods of water limitation are present in all savannas. Climatically derived savanna are warm all year but have distinct wet and dry seasons with annual rainfall varying widely from 30 to more than 100

centimetre of rainfall. What is critical about these climates is that during the dry season, rainfall amounts are very low. It is during these dry periods that the grasses are dormant and the trees experience water stress. Fires are also common at this time because the fire, dry fuel (dead foliage) that the grasses produce is very flammable. This allows fires, started by lightning or humans, to start easily and spread quickly. This combination of water stress and fire keeps the tree density low and distinguishes savanna from the adjacent forest (Cole, 1986).

Other savannas occur in areas where there are unique soil conditions. Although most tropical and subtropical savanna soils are poor in nutrients, some also have a hard crust or barrier at some depth in the soil. This crust separates the shallow soil layer that the grasses rely on for water, and which dries during periods of low rainfall, from the deeper soil layers that may retain moisture all year round. Trees in these savannas are located where cracks in the crust occur. In these places the roots of trees can access this deep soil water. Such savannas are referred to as edaphic savanna (Aweto, 1981).

Savanna may occur along the edge of forests where the dominant vegetation shifts from trees to grasses. This transition zone (also called an ecotone) between forest and grassland may be relatively narrow or 50 to more than 100 kilometre wide. The savanna in Nigeria is divided into the following based on amount of rainfall, physiognomy (structure) and floristic composition of woody species only;

The derived savanna is a relict forest, this was originally the drier part of the high forest. Due to bush burning and cultivation over a long period in the zone, the high forest trees were destroyed and the forest that used to exist is now replaced with a mixture of grasses and scattered trees. However, along the streams and in wet low-lying areas were surface water accumulates there are still some traces of forests (Jagtap, 1995). The Guinea savanna is characterized by grasses such as

Pennisetum, *Andropogon*, *Panicum*, *Chloris*, *Hyparrhenia*, *Paspalum* and *Melinis*. These tall grasses are characteristic of the Guinea savanna proper.

The Guinea Savanna zone consists of the larger part of the savanna zone and is sometimes divided into the southern Guinea savanna and northern Guinea savanna. It is the broadest vegetation zone in the country and it occupies almost half of its area. It is located in the middle of the country, extends from southern Nigeria and pushes northward beyond Zaria. It covers an area that has 100 – 150 cm of annual rainfall and where the wet season lasts for 6 - 8 months (Iloeje, 2001).

Comparatively, there are fewer trees in the northern Guinea savanna than in the southern Guinea savanna and the trees are not as tall as those found in the southern Guinea savanna. Most of the tall grasses found in the derived savanna, are also found in the Guinea savanna, however, they are less luxuriant. The appearance of this zone differs from season to season. During the rainy season, the whole zone is green and covered with tall grasses that grow and reach maturity rapidly and thus become fibrous and tough. In the dry season they tend to die and disappear and one can see for kilometres. This clearing is due to several periodical bush-burning that occurs during the dry season between November and April, carried out to either assist in farm clearance or hunting (Iloeje, 2001; Scholes, 2003).

The Sudan savanna is chiefly associated with groundnuts, sorghum and millet cultivation. Grasses found in this zone are not generally tall and thick on the ground as those found in the Guinea savanna zone. Here there is continuous grass cover of the short and feathery grasses on a large scale. The grass vegetation is interspersed with farms, tushock and trees such as shea butter tree (*Vitellaria paradoxa* and *Acacia albida*. The genus Acacia and *Combretum*, especially *Combretum micranthum* are well represented and prolific in the Sudan savanna zone. Also found in the zone are locust bean tree (*Parkia biglobosa*), tamarind tree (*Tamarindus indica*) and mango (*Mangifera indica*). A large

portion of this zone falls within the tsetse fly free belt of West Africa and it is excellent for the rearing and breeding of ruminant livestock (cattle, goats, sheep, donkeys, horses and camels). The nomadic Fulani roam about this zone in search of fodder and water for their livestock.

The Sahel savanna, occupies about 18, 130 km^2 of the extreme northeast corner of Nigeria and is the last vegetation zone of the savanna type between the Sahara dasert and the northern frontier of the Sudan savanna. The annual rainfall is low and the rainy season lasts between three to four months. Here the vegetation is not only sparse but the grasses are very short. This zone is characterized by plants such as *Cenchrus biflorus*, and *Acacia raddiana.* The shrubs that are predominantly scattered in the zone are African myrrh (*Commiphora africana*) and *Leptadenia spartum*. As a rule, this zone is not cultivated without irrigation. The people found in this zone are the nomadic herdsmen, and they are careful not to burn the grass found because sparse as it is it provides the only pasture available for their grazing livestock (Dupouey *et al.,* 2002).

1.9 Montane vegetation located on isolated highlands in Nigeria

The high plateau, the three tracks of the Niger-Benue river system cut across the highland to form three blocks, i.e. the central Plateau in the north, the Eastern and North-Eastern highlands in the east, and the western Uplands in the west. It is important to highlight the fact that, these highlands correspond roughly with the areas of volcanic rocks and uplifted areas of basement complex rocks. This goes to show that these areas were initially high and were able to resist erosion (Iloeje, 2001). Based on the above description, the high plateau consists of;

The Northern Central plateau, this plateau as the name suggests lies in the centre of northern Nigeria and covers nearly one-fifth of the area of the country. The surface is generally flat, but it is dotted here and there with some granite hills and ridges. The highest part is the Shere Hills

north-east of Jos where the elevation exceeds 1, 650 m above sea level (Iloeje, 2001).

The Eastern and North-eastern highlands, these highlands consist of the Mandara Mountains (1, 200–1, 500 m) and the Biu Plateau (600 – 900 m). The Mandara Mountains are a mass of basement complex exposure while the Biu Plateau is of basalt.

In eastern Nigeria, the highlands are made up of two big granite spurs that are western prolongations of the Cameroon Mountains into the Cross River Plains (Iloeje, 2001). These spurs are the Obudu Plateau that stands at a height of over 1, 200 metres above the general level of the land and the Oban Hills with an average elevation of 1 200 m above sea level.

1.9.1 Nigerian soils

Soil types in Nigeria are influenced by the following very broad factors, the climatic and geology of the country. This is expected because the degree of available moisture in the soil is an important factor in soil reactions, fertility and productivity. The soils of the humid tropical forests are quite different from those of the drier forests, which in turn are different from the savanna zone (Oyenuga, 1967; Sobulo, 1985). The major soil types in Nigeria, according to Food and Agricultural organization (FAO) soil taxonomy legends are fluvisols, regosols, gleysols, acrisols, ferrasols, alisols, lixisols, cambisols, luvisols, nitosols, arenosols and vertisols. These soil types vary in their potential for agricultural use (Anonymous, 2001).

None of the soils was rated as Class 1 with high productivity by the FAO (Anonymous, 2001). In-short over 48 % of the Nigerian soils fall into classes 4 and 5, which are mainly vertisols, alisols, acrisols, ferrasols and arensol. These soils usually have low productivity due to inadequate moisture retention capacity and low organic matter. Except for the ferrasols, they are the most dominant types

found in the northern dry parts of the country.The most systematic current information on Nigerian soils is based on the reconnaissance soil survey of the Nigeria project whose field-work was completed in 1985. The geology and geomorphological processes that shaped the landforms greatly influenced the soils.

Nigerian soils can be classified into groups made up of four (climatic) zones that are soil associations. These soil types (classifications) are well distributed among the groups as follow, (Aweto, 1981). Northern zone of sandy soils, this area lies in the very northern parts of the country. In some areas like the Sahel savanna belt, the soils are true to type, being formed under aridity and by the deposition of sand by the wind. These soils might have been formed from wind-sorted desert sands that accumulated over long periods of time when the Sahara desert encroached several kilometres south of its present limits.

The soils of this zone produce much of the groundnut crop, some of the sorghum, cowpeas and large quantities of millet. For instance in Kano, Northern Kaduna, Zamfara and Sokoto states have fine sandy loam, friable and relatively easy to cultivate soils. The soil is little leached and therefore ideal for groundnut cultivation. Whereas in southern Kuduna is found a mixture of soils that disintegrated from local granite, and loss soils that were brought down by winds from the north. The soil is in fact not sandy. These soils are the Zaria loam that produces the largest yield of cotton in Nigeria.

Interior zone of laterite soils, this zone is made up of sands and clays. They are grey to black clays poorly drained and seasonally flooded forming the “fadama”. Soil in this zone is deeply corroded, generally sticky and impervious to water and has low fertility. When the virgin forest on them is cleared it reduces the fertility further, thus making available soil of little agricultural value. When the soil is exposed to the surface, it become as hard as brick and for this reason, the soil here is

most suitable for road paving and wall construction than for farming. However, not only laterite soils are found in this zone. The Biu Plateau has rich soil that is productive and offers prospects for the expansion of the areas of cotton production.

Southern belt of forest soils, soils in this zone broadly represent those of the humid, tropical forest climate zones of the south where the wet season is long, the *harmattan* season short and forest cover is dense. Local soil types depend largely on parent rock. Where the underlying rocks are granite or clay, the soils is a rich clayey loam. The forest soils yield cocoa, oil palm, rubber and they are of considerable importance in Nigerian agriculture.

Zone of alluvial soils, these soils are found on the flooded plains of rivers or on deltas, or along the coastal flats. This zone extends from the coastal inland and runs along the valleys of the Niger and the Benue rivers, thus cutting across the vegetational zones. The soils found in this zone do not depend highly on climate and vegetation for their formation. The underlying parent rock is the most important factor in their formation. Soils in this zone are characteristic of fresh-water soil of grey to white sand, grey clay and sandy clay with humic topsoil. Another group consists of brownish to black saline mangrove soils, with a mat of rootlets (Oyenuga, 1967).

1.9.2 Statement of the Problems

- Information on latex-producing plants in Nigeria is scanty, especially with regard to their uses, abundance and distributions in the various vegetation zones, as well as the ecological factors affecting their distribution in the different vegetation belts of the country.

1.9.3 Justification for the Study

- Given the destructive activities of man and his animals in the study areas, there is the need to carry out an inventory of these latex-producing plants before they become extinct.

- These findings will underscore the need to conserve these plants against destruction by man because of their vast potentials.
- The niches of latex-producing plants need to be identified and ecological factors responsible for their distribution need to be understood.
- The chemical compositions of the latex act as a defense agent against predators (herbivory and ethno-botanical uses), hence inhabitants and other researchers will be enlightened.
- The information obtained from this work will open up research possibilities on latex-producing plants in Nigeria.

1.9.4 Objectives of the Study

- To identify latex-producing plants and their potential uses in the study areas.
- To determine the distribution or niche of latex- producing plants in some vegetation belts of Northern Nigeria.
- To determine the ethno-botanical uses of latex-producing plants by the various tribes in the study areas; and
- to identify non-latex-producing plants that co-exist with the latex- producing plants in the study areas.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Latex of varying amounts are found in species of many plant families including Aceraceae, Apocynaceae, Asclepidaceae, Bognoniaceae, Cricaceae, Clusiaceae, Euphorbiaceae, Fabaceae, Leguminaceae, Liliaceae, Mimosaceae, Moraceae, Oxilidaceae, Papaveraceae, Papilionaceae, Piperaceae, Sapotaceae and Solanaceae. The role of latex is not known with certainty (Agrawal and Konno, 2009). It has been suggested that latex is closely associated with isoprene which may be emitted as gas from plants that may or may not contain latex. The role of isoprene expelled into the air is approximately equal to that of total methane emission. Hunter (1994) described the roles of latex and isoprene in defense mechanism against insect pests, carbon sinks, stores of food, water and anti-dote to ozone toxicity.

2.2 Biochemistry and Mode of Action of Latexes

The physical and chemical characteristics of the latex produced by certain plants can act as a defense against insects and other pathogens, and many types of latex are known to have high concentrations of enzymes (Giordani *et al.,* 1991). The two major defense-related components in latexes are in secondary metabolites (terpenoids, alkaloids, etc.) and different protein classes (Agrawal and Konno, 2009).

Plant latex contains resins which house various secondary metabolites and proteins, often in concentrations that are much higher than in leaves. Indeed, the latex of most species contains a diversity of biologically active compounds. Many of these compounds provide resistance to herbivores via toxicity or anti-nutritive effects, whereas others are involved in the stickiness that can mire insect

herbivores. Several of these defense-related components (e.g., rubber, cysteine protease, alkaloids, etc.) appear in latex of distant phylogenetic groups, suggesting common functions and convergent evolution. Below are common constituents of latex, their mode of action, and possible biological effects on herbivores (Langenheim, 2003).

2.2.1 Secondary Metabolites of latex-producing Plants

Rubber

Rubber (*cis*-1, 4-polyisoprene) is a terpenoid found in the latex of many plant species, across some 300 genera and 8 plant families (Bushman *et al*., 2006; Mooibroek and Cornish, 2000). Both the stickiness and typically white colour of latex are often derived from rubber particles dispersed in the fluid. Rubber can make up a high concentration of fresh latex in (*Hevea brasiliensis* 44.3%, *Ficus* species (Moraceae) 15–30%, *Alstonia boonei* (Apocynaceae) 15.5%, *and Parthenium argentatum* (Asteraceae) 8%) (Mooibroek and Cornish, 2000). At present, it is generally accepted that the primary functional role of rubber in latex is to produce stickiness that entraps whole insects (Dussourd, 1995) or mires their mouthparts (Dussourd and Eisner, 1987).

The stickiness of latex may be caused by at least three factors:

(*a*) Elasticity of *cis*-polyisoprene,

(*b*) Coagulation of rubber particles, and

(*c*) Adhesiveness of rubber particles to the surfaces of insects.

The chemical compositions of latex are:

i. Alkaloids.

Alkaloids are basic natural products containing nitrogen, many of which are toxic and typically do not have a primary function in plants. Alkaloids are produced by a variety of animals, microorganisms, and plants and have been reported from the latex of many species, sporadically

distributed among angiosperm families, including Papaveraceae and Moraceae. For example, isoquinoline alkaloids such as chelidonine, sanguinarine, and copticine total nearly 20% fresh mass of the latex in *Chelidonium majus* (Tom`e and Colombo, 1995). It was recently found that synthetic enzymes involved in the early stage of alkaloid synthesis are localized in parenchymal cells surrounding laticifer cells and that those involved in the late stages of synthesis were localized inside the laticifer (Samanani *et al*., 2006 and Weid *et al*., 2004).

ii. Cardenolides.

Latex of many plants in the Apocynaceae contains cardenolides, and these range from trace amounts up to 30% dry mass of latex (Seiber *et al*., 1982; Malcolm, 1991). Additionally, latex of *Antiaris toxicaria* (Moraceae) contains cardenolides (toxicariosides), which have been used as dart poisons (Carter *et al*., 1997). Cardenolides have also convergently evolved in a few other plant families (e.g., Brassicaceae, Celastraceae, Fabaceae), but in these cases they are not associated with latex.

Most cardenolide-containing plant species produce a diversity of compounds, which differs in chemical structures of the glycosides in the molecule. Differences in the polarity of cardenolides, in particular, have been linked to differential absorption in animal body, and thus with potentially differential toxicity. For example, non-polar digitoxin is almost completely absorbed, irrespective of where it is administered to insects; conversely, ouabain, a highly polar cardenolide, is intestinally absorbed quite slowly (Malcolm, 1991). Nonetheless, the adaptive significance of cardenolide diversity is unknown. Virtually nothing is known about where the cardenolides are produced and how they are transported into the latex (Groeneveld, 1999). Cardenolides have no known functions in plants other than defense.

iii. Terpenoids.

Terpenoids are an extremely diverse group of carbon-based compounds that are derived from five-carbon isoprene units. Terpenoids are likely to have many functions in plants, including pollinator

attraction, defense, and roles in primary metabolism (e.g., carotenoids that provide additional pigments for harvesting light energy) and can be produced abundantly in latex. The latex of *Lactuca sativa* contains several sesquiterpene lactones (SL), including lactucin and the total SL concentration in the bolting stage of lettuce reached 147.1 mg/ml latex (Sessa *et al*., 2000).

The latex of some Euphorbiaceae, such as *Euphorbia biglandulosa*, contains diterpenes such as phorbol and its derivatives. These compounds have toxicity against insects and mammals, have tumor-promoting activity, and cause skin inflammation. Further, triterpenoids are reported as the major components of the latex of some *Euphorbia* species (Mazoir *et al*., 2008).

iv. Phenolics.

Phenolics are a huge group of multifunctional carbon-based secondary metabolites produced by the shikimate pathway that includes tannins, lignins, and flavonoids. Latex of the sweet potato, *Ipomoea batatas* (Convolvulaceae) contains high concentrations of hexadecyl, octadecyl, and eicosyl esters of *p*-coumaric acids. The overall concentration of *p*-coumarate esters exceeded 3% in fresh vine latex and 10% in root latex of the variety of Jewel (Snook, 1994).

The concentrations of (*Z*)-isomers of C16, C18, C20 coumarates inversely correlated with the acceptability by weevils, indicating that (*Z*)-coumarate esters may participate in the defense of sweet potato against insect herbivores. Additionally, the latex-like resin of *Rhus* species (Anacardiaceae) are well known to contain urushiol, a catechol with a long carbon chain rich in double bonds and a compound known to cause strong skin irritations (Snook, 1994).

v . Proteins

Proteases are enzymes that cleave protein and are found in all living organisms. Various types of proteases are found from latex of plants belonging to diverse phylogenetic clades. For example, cysteine proteases are reported from latex of plant families such as Caricaceae, Moraceae,

Apocynaceae and serine protease from Moraceae, Euphorbiaceae, Apocybnaceae, Convolvulaceae (Arima *et al*., 2000;Tomar *et al*., 2008).

The latex-like resin exudates of mango, *Mangifera indica* (Anacardiaceae), contain both serine and cysteine proteases (Saby *et al*., 2003). In spite of the abundance and frequent occurrence of proteases in plants, an adaptive role of these compounds for plants was not suggested until recently. Direct evidence for the involvement of cysteine proteases in plant resistance against herbivores came from experiments showing that the strong toxicity of papaya leaves against the Eri silkworm (*Samia ricini*) disappeared when latex was washed out of the leaves.

Proteases are digestive and are commonly found in animal guts. Thus, their role as a plant defense appears to be a remarkable turn on the plant-insect interactions, essentially plants eaten by insect. The observation that the dead bodies of caterpillars mired in latex of papaya, fig, and milkweed turn black and soft indicates that all tissues of insects are a potential target of digestion by proteases in latex (Pechan *et al*., 2000).

vi . Protease inhibitors (PIs).

Protease inhibitors are thought to function as anti-nutritive secondary metabolites by binding to proteases and preventing the digestion of protein. Trypsin (serine protease) inhibitors are found in latex of *Carica papaya* (Azarkan *et al*., 2004). Gene expression of trypsin inhibitors is also in the laticifers of *Hevea brasiliensis* (Han *et al*., 2000). Protease inhibitors inhibit proteolysis and utilization of proteins and their defensive roles against herbivores and fungi are well-established in many plants without latex (Zhu-Salzman *et al*., 2008). Trypsin inhibitor, a class-II chitinase and a glutaminyl cyclase, is absent from latex of undamaged leaves, but was strongly induced in latex after damage (Azarkan *et al*., 2004).

vii. Lectins and hevein-like chitin-binding proteins.

Lectins are carbohydrate-binding proteins that have affinity with specific sugar moieties, which often have toxic activities against animals including insects. Several types of lectins have been found in latex from Euphorbiaceae, Moraceae, Apocynaceae, and phloem sap from Cucurbitaceae. Of these, hevein, the major latex protein from *Heava brasiliensis* is important in the agglutination of rubber particles (Gidrol *et al*., 1994), and its m-RNA is induced by wounding (Broekaert *et al*., 1990). Upon exposure to air, hevein binds to receptor proteins and cross-linked rubber particles, thereby causing coagulation of latex.

Coagulation of cucurbit phloem sap not only stops exudation but also glues mouth parts of beetles and can inhibit feeding (McCloud *et al*., 1995). The chitin-binding proteins from *Morus* latex are highly toxic to many caterpillars including the cabbage worm, *Mamestra brassicae* (Ramos *et al*., 2007; Wasano *et al*., 2009). Chitin-binding proteins with hevein-like domains, such as the wheat germ lectin, are toxic and inhibit the synthesis of the insect gut peritrophic membrane (Hopkins and Harper, 2001).

viii. Chitinases

Chitinases, these are enzymes that degrade chitin (important components of insects' gut peritrophic membrane) widely found in plant latex from several plant families including Caricaceae, Moraceae, and Euphorbiaceae. Because chitin is the major constituent of the cell wall of fungi, so the enzyme is destructive to fungi, as a result, it is reasonable to assume that chitinases protect the leaves from infection by pathogenic fungi as well.

Expression of chitinases in the latex of *Caica papaya* increases in response to wounding or treatment with jasmonic acid (Azarkan *et al*., 2004). Chitinases from insect origins show toxic effects on other insects when orally (Kabir *et al*., 2006), suggesting that chitinases in latex may have a defensive role (Lawrence and Novak, 2006).

ix. Oxidases

Polyphenol oxidase (PPO) and peroxidase (POD) are common plant oxidases reported from Euphorbiaceae, Moraceae, and Anacardiaceae (Saby *et al*., 2003). PPOs and some PODs are regarded as plant anti-herbivore defense proteins, because they oxidize mono- or di-hydroxyphenolics that are ultimately converted in *o*-quinones, which then covalently bind to amino acids such as cysteine and lysine, making them inaccessible, and decrease the nutritive value of leaf protein (Walz *et al*., 2004). Lipoxygenases (LOX) are implicated as defense proteins since they are often induced by wounding or jasmonic acid, and since hydroperoxides formed by the oxidation of linolenic acids by lipoxygenases may react with amino acids, in addition to the loss of fatty acids essential for insects (Zhu-Salzman *et al*., 2008).

x. Others

In addition to the above explanation on proteins that were reported from many plant groups, some latex proteins are confined to specific plant taxa and have been suggested to be involved in plant defense. These compounds include phosphatase in Euphorbiaceae. Lipase in Caricaceae, Euphorbiaceae, Apocynaceae, glutaminyl cyclase in Caricaceae (papaya) (Azarkan *et al*., 2004) and gum arabic glycoprotein, a high-molecular-weight, hydroxyproline-rich arabinogalactan-protein found from exudates of *Acacia senegal* (Fabaceae) (Goodrum *et al*., 2000).

Finally, linamarase in cassava leaves and latex is a β-glucosidase that specifically degrades linamarine, also present in the leaves and roots of the same plants and results in the production of hydrogen cyanide that is toxic to most organisms.

2.3 Latex-Producing Plant Defenses against Herbivores

Plants represent a rich source of nutrients for many organisms including bacteria, fungi, protists, insects, and vertebrates. Although lacking an immune system comparable to animals, plants

have developed a stunning array of structural, chemical, and protein-based defenses designed to detect invading organisms and stop them before they are able to cause extensive damage. Humans depend almost exclusively on plants for food, and plants provide many important non-food products including wood, dyes, textiles, medicines, cosmetics, soaps, rubber, plastics, inks, and industrial chemicals. Understanding how plants defend themselves from pathogens and herbivores is essential in order to protect our food supply and develop highly disease-resistant plant species (Grenan, 2006).

Mechanical damage caused by insects is not generally considered true plant disease although plants have developed surveillance systems designed to recognize insect pests and respond with specific defense mechanisms. Plants can distinguish between general wounding and insect feeding by the presence of elicitors contained in the saliva of chewing insects. In response, plants may release volatile organic compounds (VOCs), including monoterpenoids, sesquiterpenoids, and homoterpenoids (Van Loon *et al*., 2006). These chemicals may repel harmful insects or attract beneficial predators that prey on the destructive pests.

For example, wheat seedlings infested with aphids may produce VOCs that repel other aphids. Lima beans and apple trees emit chemicals that attract predatory mites when damaged by spider mites, and cotton plants produce volatiles that attract predatory wasps when damaged by moth larvae. Feeding on one part of the plant can induce systemic production of these chemicals in undamaged plant tissues, and once released, these chemicals can act as signals to neighboring plants to begin producing similar compounds. Production of these chemicals exacts a high metabolic cost on the host plant, so many of these compounds are not produced in large quantities until after insects have begun to feed (Bindscheler *et al*., 2006).

2.3.1 Specialized appendages for plant defenses

The epidermis constitutes the outermost protective tissue system of leaves, floral parts, fruits, seeds, stems, and roots of plants until they undergo considerable secondary growth. It is the first line of defense against invading pathogens and consists of both specialized and unspecialized cells. The epidermal cells of aerial plant parts are often covered in a waxy cuticle that not only prevents water loss from the plant, but also prevents microbial pathogens from coming into direct contact with epidermal cells and thereby limits infection. The cuticle can be relatively thin (aquatic plants) or extremely thick (cacti). The hydrophobic nature of the cuticle also prevents water from collecting on the leaf surface, an important defense against many fungal pathogens that require standing water on the leaf surface for spore germination (Bindscheler *et al*., 2006).

Interspersed among the many unspecialized cells of the epidermis are guard cells which regulate gas exchange through small openings called stomata. These pores allow carbon dioxide to enter the leaf for use in photosynthesis while restricting excessive water loss from the plant. Stomatal pore size is highly regulated by plants, and guard cells can participate in defense by closing in response to the presence of microbe association molecular patterns (MAMPs).

Trichomes (leaf hairs) are specialized epidermal cells found on aerial plant parts that may provide both physical and chemical protection against insect pests. The velvety appearance of dusty miller (*Senecio cineraria*) is caused by thousands of tiny trichomes covering the plant's surface. Trichomes on the surface of soybeans (*Glycine max*) prevent insect eggs from reaching the epidermis and the larvae starve after hatching (Veronese *et al*., 2003). In woody plants, the periderm replaces the epidermis on stems and roots. Outer bark (phellem) is an excellent example of a preformed structural barrier that contains high amount of water-resistant suberin and prevents many pathogens and insects from reaching the living cells underneath.

Thorns are modified branches that protect plants from grazing vertebrates, and include the honey locust tree (*Gleditsia triacanthos*). Many cacti produce thorn-like structures that are actually modified leaves or parts of leaves (e.g., stipules) called spines which serve similar purposes, such as in the barrel cactus (*Ferocactus* species). Botanically speaking, the thorns on the stem of rose plants (*Rosa* species.) are neither true thorns nor spines, they are actually outgrowths of the epidermis called prickles.

2.3.2 Evidence for Latex as a Defensive Mechanism

Various forms of evidences, from the observational to the experimental and comparative, have been accumulated in support of latex as a plant defense against herbivory. Nonetheless, few studies to date have linked variation in plant production of latex to plant fitness (Agrawal, 2005). In the strict sense, a plant defense is any trait that improves the fitness of plants in the presence of herbivores. Thus, it was assumed that latex is defensive, most studies have focused on latex as a trait that reduces herbivory or the preference or performance of herbivores (Karban and Baldwin, 1997).

As a follow-up to several classic experiments show that depressurizing the latex of milkweeds (*Asclepias species)* increased the fitness (survival or growth) of specialized monarch butterfly caterpillars (*Danaus plexippus*). By partially severing a leaf's petiole, the flow of latex to that leaf can be essentially stopped without altering the turgidity of the leaf. This treatment substantially improved fitness of monarchs on four milkweed species with high latex flow, but had relatively minimal effect on larvae when four milkweed species that produce less latex were treated (Zalucki *et al*., 2001). These experiments provide convincing evidence for a role of latex in resistance to a specialist herbivore. Konno *et al*. (2004) further showed that washing papaya and fig leaves free of their latex made them acceptable to herbivores that typically perish on intact leaves (Zalucki and Malcolm, 1999).

Latex of a resistant variety of lettuce (*Lactuca sativa),* almost completely inhibited feeding of *Diabrotica balteata* beetles when painted on leaves of a favored food (Lima bean leaves). Nonetheless,

latex from a different, susceptible variety of lettuce was not deterrent. This study implicated chemical compound in the resistant latex (a moderately polar fraction of the latex) that were not present in the latex of the susceptible lettuce variety (Sethi *et al*., 2008).

Although the weight of evidence suggests that latex is defensive and no strong alternative hypotheses have stood the test of time, the fitness benefits of latex production for plants have not been well quantified (Agrawal, 2005)

2.4 Allergic Nature of Latex

When one comes into contact with latex-producing plants, they can be dangerous. Many of these plants are highly poisonous when ingested, this is a common knowledge. It is remarkable, however, that simply touching these plant species can also be of a serious health hazard. There are much more dangerous poisonous plants in many parts of the world identified today. They can cause severe pain, rashes, blisters and leave scars. Some trees are reported to be so powerful that even raindrops falling from them can irritate the skin. Other plant species can cause blindness through the smoke of burning wood or by rubbing the eyes after touching the leaves.

Allergy to natural rubber (latex) has been recognized as an increasing and clinically important problem in the last few years. It was first recognized in health care workers who are in frequent contact with latex in surgical gloves and other latex-based products in their workplace. Epidemiological studies have indicated that up to 25% of individuals who are in frequent contact with latex may be allergic to latex allergens. More than 40,000 products may now contain natural latex rubber and many articles in everyday use are made from latex. Allergic sensitization and triggering of an allergic reaction may be initiated by inhalation of powder from latex gloves, or by direct skin or mucous membrane contact with the rubber.

Sensitization to the antigens responsible for allergy in latex has led to latex allergy becoming increasingly common in the general population. Vehicle tires, articles of clothing with elastic and other

rubberized materials, children's toys, balloons and other articles in the home and workplace are made from latex. More recently, there have been reports of individuals becoming allergic to the latex in bonding glues used in hair extensions and other cosmetic procedures. Latex allergy is most likely to develop in potentially allergic individuals who already have evidence of other allergies. Synthetic rubber is not a problem for people allergic to natural latex.

An additional concern regarding latex allergy is that some of the allergens that are responsible for triggering the allergic response can be found in a number of, mostly unrelated, food plants. Persons allergic to latex may experience sometimes severe, anaphylactic reactions, both to latex itself, and to the foods containing similar antigens when they consume them.

Information about this interesting subject is usually hard to find, as it is scattered across many different sources like scientific works about dermatology or botany, regional field guides, travel literature, and magazines. The rare scientific tomes on the subject usually describe thousands of plant species in medical and botanical detail, focusing on their effects on workers who are exposed to the same plant species for years.

Natural rubber latex is obtained from the *Hevea brasiliensis* rubber tree. Latex contains more than 35 potentially allergenic molecules. These have been classified according to a naming system based on the designation of the antigen as Hev b. Thus, we have Hev b1, Hev b2, Hev b3, and so on. The molecular size of each antigen has been measured in kilodaltons (kDa), and in some cases the function of the molecule in the plant has been determined.

2.4.1 Active Principles in allergy of Latex

Plants make use of different techniques to scare away unwanted visitors. The plants used the principles as follows marked with symtoms to indicate the techniques:

Mechanical This defense mechanism is mostly obvious, like in prickles, thorns, or barbs. Less visible but also purely mechanical are the sharp edges of certain grasses which can cause unpleasant cuts. Bamboos also belong to the botanical family of grasses, and some bamboo species bear thin bristles on the surface, which can penetrate the skin and cause itching or irritation. There are exceptional lots of mechanically active plants, and although injuries of the skin can cause secondary infections when dirt enters the human body.

Chemical These are poisons that can enter the skin without mechanical action. When the sap of some species gets onto the skin surface, it can lead to painful skin irritation or irreversible damages. Some species can even cause temporary or permanent blindness if a person touches broken parts of the plant and then the eyes. Throwing such plant material into a fire can also be dangerous as the smoke can irritate the skin or also lead to blindness. Typical representatives of this principle belong to the *Euphorbiaceae* family. There are many members of other botanical families, however, that act similar.

Phototoxic This principle occurs in a number of plants of which the best example is the Giant Hogweed. Phototoxic poison acts chemically, but only if the skin is exposed to sunlight at the same time, the poison effect is aggravated or intense.

Mechanical-chemical Some Plants are sophisticated enough to penetrate the skin of the victim mechanically and then introduce a poisonous chemical. The result is an immediate burning sensation of the skin. The best known representatives of this kind are the stinging nettles and their close relatives in all parts of the world. Most mechanically-chemically acting plants belong to the botanical families *Urticaceae* and *Euphorbiaceae*, some of them being much more powerful than the stinging nettle. Under an electron microscope, fragile hollow needles are visible, with nettle cells at the base, filled with liquid poison. When touched, a needle breaks off, leaving an oblique tip, which can enter the human skin like a syringe and release the poison (Lawson, 1966).

Allergizing. Another powerful principle, mainly found in members of the botanical family called *Anacardiaceae*. Infamous examples are the *Toxicodendron* species native. The first encounter with one

of them often goes unnoticed. This contact allergizes the victim and subsequent contacts can cause gradually more severe skin irritations. Many individuals who are allergic to latex are also allergic to the proteins that are bound to the isoprene molecules responsible for the elasticity of rubber (Evans and Schmidt, 1980).

2.4.2 Latex Allergies in Plant Foods

Some of the antigens in natural latex are structurally identical to antigens in some fruits and nuts, and occasionally latex-allergic people develop symptoms after consuming these foods. The fresh fruits that commonly cause such allergic reactions are banana, avocado and chestnut. Other foods less commonly associated with latex allergy are, mango, potato, shea butter fruit, pawpaw, and cassava

Some foods are known to contain antigens sufficiently similar to the allergens in latex as to trigger an allergic reaction in latex-sensitive individuals. As in all cases of potential allergenic cross-reactivity, not all persons with latex allergy will develop symptoms when exposed to these foods, clinical expression of an allergy is an individual idiosyncrasy. However, many practitioners advocate that a patient with established latex allergy should be instructed to avoid all foods that have been demonstrated to exhibit the allergens associated with latex allergy because of the risk that as a result of repeated exposure to the allergen, the reaction might escalate to an anaphylactic reaction.

2.4.3 Symptoms of Latex Allergy

Typical symptoms of latex allergy include hives (urticaria), tissue swelling (angioedema), itching (pruritis), runny nose, itchy, watery eyes, sneezing, wheezing and asthma in asthmatics, throat tightening (laryngoedema), coughing, drop in blood pressure (hypotension) and in extreme cases, anaphylaxis. In addition to systemic reactions, latex causes contact allergy with hives, angioedema, itching and conjunctivitis where the latex comes into contact with skin and mucous membranes.

2.4.4 Effects and Treatment of Latex Allergy

After skin contact with one of the plants that has latex allergy, typical symptoms are burning, redness, itching, swelling, or development of blisters. Chemical contact poisons are often oily substances which do not evaporate and thus can contaminate equipment for years. The poisons can be spread across the skin by scratching or they can get into the eyes when the eyes were rubbed with hands. People do react differently to the poisons and the effect of contact poisons is often increased when a person is exhausted or sweating. Washing with water and soap is generally a good idea. If stinging hairs or bristles are on the skin, they should first be removed with adhesive tape or tweezers. In severe cases a doctor must be consulted.

2.5 Sampling of Vegetation Characteristics

Vegetation structure and floristic composition are usually measured or estimated on a plant community basis. Barkrnan (1979) distinguished between textures, the composition of morphological elements, structure, the spatial arrangement of these elements, the temporal arrangement, including phenology. Four overall measurements, some of them are more widely used than others;

- **Stratification**, the arrangement of phytomass in layers. Usually a tall tree, low tree, tall shrub, low shrub, dwarf-shrub, tall herb, low herb and moss layer are distinguished if separated from each other.
- **Cover.** Percentage cover is the relative area occupied by the vertical projection of all aerial parts of plants, as a percentage of the surface area of the sample plot. This can be determined for the vegetation as a whole or for separate layers. Cover is usually estimated by eye, but can also be determined more accurately through the line-intercept method in sparse vegetation, where contacts between the line and plant parts are counted, or the point-intercept method in dense short vegetation where contacts with a cross-wire grid are counted, or the cover pin frame in dense taller vegetation, where pins are moved vertically downwards and contacts

with plant parts are counted (because pins can hit plants at several heights total cover can exceed 100%).

- **Phytomass.** Total phytomass (plant biomass) in the plant community, is expressed as dry-weight ha^{-1}. Phytomass is usually determined by removing the standing crop, the above-ground phytomass during the period of maximal development. Phytomass can be determined per layer so that a vertical phytomass profile can be obtained and interpreted in terms of species interactions and light climate (Fliervoet, 1985). Barkman (1989) developed a method and apparatus to determine pine phytomass denseness and its horizontal and vertical distribution. This method is also destructive, but only small sections of plant mass are cut. Such profiles can be fruitfully linked to measurements of microclimate.

2.6 Sampling of Species Characteristics

The species composition of a plant community, the key element in its definition, is described in its simplest form by a list of species occurring in the sample plot. The list is mostly restricted to vascular plants and almost to their above-ground parts, often easily recognizable mosses, liverworts and lichens are included. The quantity a species attains can be called its performance, but often the term abundance is used, even if this is only one of the following quantitative measures:

- **Abundance** refers to the number of individuals on the sample plot. Because individuality in many (clonal) plant species is difficult to determine, the concept of plant unit, a plant or part of a plant behaving like an individual, is needed, if only for a quantitative approach of species diversity based on the distribution of plant units over species (Williams, 1964). Density is a derivate variable, being the abundance per unit area.
- **Frequency** is the number of times a species occurs in subplots within the sample plot or within an under limited phytocoenosis (formally plottless sampling).

- **Cover** can be measured species-wise, it is usually estimated along a cover scale. Many scales have been proposed (Van der Maarel, 1979), some of which more or less linear (e.g. with 10% intervals), some geometrical, e.g. still used five-point geometrically (Trass and Malmer, 1978).
- **Cover-abundance** is a combined parameter of cover - in case the cover exceeds a certain level, e.g. 5% and abundance. This total estimate (Braun-Blanquet, 1964) has been both criticized as a wrong combination of two independently varying parameters and praised as a brilliant integrative approach. It reminds us of the product of density, frequency and cover, which has been popular for some decades.
- **Basal area**, the area outline of a plant near the surface, is of particular interest for trees and can be used for tree volume estimations. A related measure is tree diameter at breast height (DBH; at 1.30 m), which is more often used in standard forest descriptions.
- **Phytomass** can be measured per species, even if this is a very tedious work. These data can be used to accurately relate species performances to each other and to follow species performances in time series of observations and experiments.
- **Sociability,** the gregariousness of plant units of a species, has been a standard parameter included in phytosociological relevance (Braun-Blanquet, 1964). Dierschke (1994) presented examples of root-shoot ratio differentiation within a plant community. Titlyanova *et al*., (1999) showed how in steppes the below-ground phytomass is more homogeneously distributed, both over the area and over the species.

For this purpose, permanent sample plots can be established which are regularly, preferably annually, investigated. In order to interpret changes in species characteristics the data should be more accurate than in a spatial context. However, to reduce the effects of subjectivity more exact data, notably on phytomass, are preferred.

2.7 Some Characteristics of the soil

2.7.1 Soil pH

The soil pH is a measure of the acidity or alkalinity in soils. pH is defined as the negative logarithm (base 10) of the activity of hydronium ions (H+ or, more precisely, H_3O+ aq) in a solution. In water, it normally ranges from -1 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is alkaline. Soil pH is considered a master variable in soils as it controls many chemical processes that take place (Feng *et al*., 2007). It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient. The optimum pH range for most plants is between 5.5 and 7.0, however many plants have adapted to thrive at pH values outside this range.

Acidity in soils comes from H^+ and Al^{3+} ions in the soil solution and adsorbed to soil surfaces. While pH is the measure of H^+ in solution, Al^{3+} is important in acid soils because between pH 4 and 6, Al^{3+} reacts with water (H_2O) forming $AlOH^{2+}$, and $Al(OH)_2^+$, releasing extra H^+ ions. Every Al^{3+} ion can create 3 H^+ ions. Many other processes contribute to the formation of acid soils including rainfall, fertilizer use, plant root activity and the weathering of primary and secondary soil minerals. Acid soils can also be caused by pollutants such as acid rain and mine spoiling (Salako *et al*., 2001).

Alkaline soils have a high saturation of base cations (K^+, Ca^{2+}, Mg^{2+} and Na^+). This is due to an accumulation of soluble salts which are classified either as, saline soil, sodic soil, saline-sodic soil or alkaline soil. All saline and sodic soils have high salt concentrations, with saline soils being dominated by calcium and magnesium salts and sodic soils being dominated by sodium. Alkaline soils are characterized by the presence of carbonates. Soils in areas with limestone near the surface are alkaline from the calcium carbonate in limestone constantly mixing with the soil. Groundwater sources in these areas contain dissolved limestone (Feng *et al*., 2007).

Plants grown in acid soils can experience a variety of symptoms including aluminium (Al), hydrogen (H), and/or manganese (Mn) toxicity, as well as potential nutrient deficiencies of calcium (Ca) and magnesium (Mg).

Aluminium toxicity is the most widespread problem in acid soils. Aluminium is present in all soils, but dissolved Al^{3+} is toxic to plants; Al^{3+} is most soluble at low pH, above pH 5.2 little aluminum is in soluble form in most soils. Aluminium is not a plant nutrient, and as such, is not actively taken up by the plants, but enters plant roots passively through osmosis (Buol *et al*., 2002)

Nutrients needed in large amounts by plants are referred to as macronutrients and include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S). Elements that plants need in trace amounts are called trace nutrients or micronutrients. Trace nutrients are not major components of plant tissue but are essential for growth. They include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), cobalt (Co), molybdenum (Mo), and boron (B). Both macronutrient and micronutrient availability are affected by soil pH.

2.7.2 Percentage Total Nitrogen Content

Nitrogen exists in the soil system in many forms and changes (transforms) very easily from one form to another. The route that nitrogen follows in and out of the soil system is collectively called the nitrogen cycle and is biologically influenced. Biological processes, in turn, are influenced by prevailing climatic conditions along with the physical and chemical properties of a particular soil. Both climate and soils vary greatly across the world and affect the nitrogen transformations for the different areas. Nitrogen, present or added to the soil, is subject to several changes (transformations) that dictate the availability of nitrogen to plants and influence the potential movement of NO_3^- to water supplies.

Organic nitrogen that is present in soil organic matter, crop residues, and manure is converted to inorganic nitrogen through the process of mineralization**.** In this process, bacteria digest organic

material and release ammonium (NH_4^+) nitrogen. Formation of NH_4^+ increases as microbial activity increases. Bacterial growth is directly related to soil temperature and water content. The ammonium supplied from fertilizers is the same as the ammonium supplied from organic matter.

Ammonium-nitrogen has properties that are of practical importance for nitrogen management. Plants can absorb NH_4^+ N^-. Ammonium also has a positive charge and, therefore, is attracted or held by negatively charged soil and soil organic matter. This means that NH_4^+ does not move downward in soils. Nitrogen in the ammonium form that is not taken up by plants is subject to other changes in the soil system (Hernandez and Mitsch, 2007).

Nitrification is the conversion of NH_4^+ -N to NO_3^- -N. Nitrification is a biological process and proceeds rapidly in warm, moist, well-aerated soils. Nitrification slows at soil temperatures below 15^{o}C, thus, the general recommendation is that ammonical (NH_4^+ forming) fertilizers should not be applied in fall until soils are below 15^{o}C. Nitrate is a negatively charged ion and is not attracted to soil particles or soil organic matter like NH_4^+. Nitrate-N is water soluble and can move below the crop rooting zone under certain conditions.

Denitrification is a process by which bacteria convert NO_3^- to N gases that are lost to the atmosphere. Denitrifying bacteria use NO_3^- instead of oxygen in the metabolic processes. Denitrification takes place where there is waterlogged soil and where there is ample organic matter to provide energy for bacteria. For these reasons, denitrification is generally limited to topsoil. Denitrification can proceed rapidly when soils are warm and become saturated for 2 or 3 days (Groffman and Crawford, 2003; Wacker *et al*., 2009).

A temporary reduction in the amount of plant-available nitrogen can occur from; immobilization (tie up) of soil nitrogen. Bacteria that decompose high carbon-low nitrogen residues, such as corn stalks or small grain straw, need more nitrogen to digest the material than is present in the

residue. Immobilization occurs when nitrate and/or ammonium present in the soil is used by the growing microbes to build proteins. The actively growing bacteria that immobilize some soil nitrogen also break down soil organic matter to release available nitrogen during the growing season. There is often a net gain of nitrogen during the growing season because the additional nitrogen in the residue will be the net gain after immobilization-mineralization processes (Clement *et al*., 2002).

2.7.3 Percentage Soil Organic Matter

Soil organic matter (SOM) is the organic matter component of soil, consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. Soil organic matter exerts numerous positive effects on soil physical and chemical properties, as well as the soil's capacity to provide regulatory ecosystem services. Particularly, the presence of soil organic matter is regarded as being critical to soil function and soil quality.

The positive impacts of soil organic matter result from a number of complex, interactive edaphic factors; a non-exhaustive list of soil organic matter's effects on soil functioning includes improvements related to soil structure, aggregation, water retention, soil biodiversity, absorption and retention of pollutants, buffering capacity and the cycling and storage of plant nutrients. Soil organic matter increases soil fertility by providing cation exchange sites and acting as reserve of essential nutrients, especially nitrogen (N), phosphorus (P), and sulfur (S), along with micronutrients, which are slowly released upon soil organic matter mineralization. As such, there is a significant correlation between soil organic matter content and soil fertility (Schipper *et al*., 1994).

The mass of soil organic matter in soils as a percent generally ranges from 1 to 6% of the total topsoil mass for most upland soils. Soils whose upper horizons consist of less than 1% organic matter

are mostly limited to desert areas, while the soil organic matter content of soils in low-lying, wet areas can be as high as 90%. Soils containing 12-18% soil organic content are generally classified as organic soils (Voroney and Winter, 1993).

2.8 Ordination as a Tool for Ecological Analysis

Ordination in a literal sense is simply arranging items along a scale (axis) or multiple axes. There are many purposes for doing so but normally the items are arranged as a way of graphically summarizing complex relationships extracting one or a few dominant patterns from an infinite number of possible patterns.

The process of extracting those axes is called ordination because it results in a placement of objects along an axis or dimension. What make this possible is that the variables are correlated (in the broad sense). Ordination thrives on the complex network of inter correlation that can make multiple regression a nightmare (Hill, 1979).

Ordination is most often used in ecology to seek and describe pattern. Although we commonly think that ordination is a means of generating hypotheses about underlying mechanisms, ordination is used in one form or another in most sciences. For example multi- dimensional scaling was used to elucidate complex chemical kinetics.

In community ecology, the most common use of ordination is to describe the strongest patterns in species composition. When the underlying factors are thought to vary continuously, this activity is often termed “gradient analysis”. The underlying concept is that species abundance varies along environmental or historical gradients. Species composition changes as you go up mountain and species composition changes with time.

One occasionally hears the criticism that users of ordination tend to manipulate the results to fit their precautions. A related criticism is that ordination reveals only the obvious patterns that we already knew. Both of this criticism surely applies to ordination at times, more often ordination helps people to see the data more clearly (Hill and Gauch, 1980). Ordination often helps to:

- Select the most important factors from multiple factors imagined or hypothesized.
- Separate strong important patterns from weakness and
- Reveal unforeseen pattern and suggest unforeseen processes.

2.8.1 Ordination as Data Reduction

Data reduction means to summarize a data set containing many variables into a smaller number of composite (synthetic) variables. Ordination is a method of data reduction that results in continuous synthetic variable (axes). In contrast, classification reduces a multivariate data set into discrete classes.

The goals of data reduction are summarized as follows;

- The issue in reduction of dimensionality in analyzing multi response situations between attainment of simplicity for understanding visualization and interpretation, on one hand and retention of sufficient detail for adequate representation on the other hand.
- Reduction of dimensionality can lead to parsimony of description of measurement or of both. It may also encourage consideration of meaningful physical relationships between the variables as for example, summarizing (mass, volume) data in terms of density mass/volume.

After extracting the synthetic variables or axes, one usually attempts to relate them to other variables. In community ecology the most common procedure is to first summarize a matrix of sample units by species into a few axes representing the primary gradient in species composition. Those axes are related to measured environmental variables.

Ordination methods can also be used to provide an operational definition for a process, concept or phenomenon that is difficult or impossible to measure directly. For example, an ordination of species compositions or symptomology along an air pollution gradient may be used to define biological impacts of air pollution (Knight and Loucks, 1969).

Type of ordination methods are as follows;

Ordination method	**Suggested method of variance**
- Bray Curtis	- Built in with residual distance over original distance
- Canonical correspondence analysis	- After the fact with relative Euclidean or chi-square distance
- Correspondence analysis	- After the fact with chi-square distance
- Detrended correspondence analysis	- After the fact with relative Euclidean distance
- Non-metric multidimensional scaling	- After the fact with same distance measure as used in analysis
- Principal correspondence Analysis	- Built in with ratio of eigenvalues to total variance
-Weighted averaging	- After the fact with relative Euclidean

2.8.2 Principal component Analysis

Principal component analysis (PCA) was one of the earliest ordination techniques applied to ecological data. PCA uses a rigid rotation to derive orthogonal axes, which maximize the variance in the data set. Both species and sample ordinations result from a single analysis. Computationally, PCA is basically an eigenanalysis. The sum of the eigenvalues will equal the sum of the variance of all variables in the data set. PCA is relatively objective and provides a reasonable but crude indication of relationships. The sum of the eigenvalues will equal the sum of the variance of all variables in the data (Jolliffe, 2002).

PCA was invented in 1901 by Karl Pearson (Pearson, 1901) Now it is mostly used as a tool in exploratory data analysis and for making predictive models.

PCA is a method that reduces data dimensionality by performing a covariance analysis between factors.

This method is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. The number of principal component is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has as high a variance as possible (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (uncorrelated with) the preceding components (TerBraak and Prentice, 1988).

PCA method was used to determine the association between plant communities and environmental variables, i.e. in an indirect non-canonical way (TerBraak and Prentice, 1988). PCA operation can be thought of as revealing the internal structure of the data in a way which best explains the variance in the data. It is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data

The one advantage of PCA is that once you have found patterns in the data, and you compress the data, ie by reducing the number of dimensions, without much loss of information and when PCA finds the mathematically optimal method (as in minimizing the squared error), it is sensitive to outliers in the data that produce large errors PCA tries to avoid. It therefore is common practice to remove outliers before computing PCA.

Although it has severe faults with many community data sets, it is probably the best technique to use when a data set approximates multivariate normality. PCA is usually a poor method for community data, but it is the best method for many other kinds of multivariate (Schervish, 1987).

To be precise, if you originally have dimensions in your data, and so you calculate eigenvectors and eigenvalues, and then you choose only the first eigenvectors, then the final data set has only dimensions. What needs to be done now is you need to form a feature vector, which is just a fancy name for a matrix of vectors. This is constructed by taking the eigenvectors that you want to keep from the list of eigenvectors, and forming a matrix with these eigenvectors in the columns.

Deriving the new data set is the final step in PCA, and is also the easiest. Once we have chosen the components (eigenvectors) that we wish to keep in our data and formed a feature vector, we simply take the transpose of the vector and multiply it on the left of the original data set, transposed. In the case of keeping both eigenvectors for the transformation, we get the data and the plot. This plot is basically the original data, rotated so that the eigenvectors are the axes. This is understandable since we have lost no information in this decomposition.

In contrast to Correspondence Analysis and related methods, species are represented by arrows. This implies that the abundance of the species is continuously increasing and decreasing in the opposite direction.

CHAPTER THREE

3.0 Materials and Methods

3.1.1 Description of Study Areas

Lokoja the capital of Kogi state is located between $7^{o}\ 46^{1}N - 6^{o}\ 48^{1}E$ (Anonymous, 2012). The area enjoys both wet and dry seasons with the total annual rainfall of between 1,100 mm and 1,300 mm. The rainy season lasts from April to October, while, dry season, lasts from November to March. Lokoja is very dusty and cold as a result of the north-easterly winds, which bring in the harmattan from November to February. The mean annual temperature is about $27.7^{o}C$ and average relative humidity of 48% (Anonymous, 2008).

In Lokoja study area, 5 plots were sampled, one plot in each area as follows; Army Barracks' land at Zango Dagi and Ganaji, Natakum, Lokogoma and Otokiti Village.

All the plots sampled in Lokoja study area represent Southern Guinea savanna, and have about the same successional status with little anthropogenic activity, thus having dense vegetation cover with few herbs and shrubs.

Minna the capital of Niger State lies between $8^{o}\ 20^{1}N$ - $7^{o}\ 20^{1}E$ (Anonymous, 2012). Niger State experiences distinct dry and wet seasons with annual rainfall varying from 1,000 mm to 1,200 mm. It has a temperature of $25^{o}C$ - $37\ ^{o}C$ and average relative humidity of 42%.

Generally, the fertile soil and hydrology of the State permits the cultivation of most of Nigeria's staple crops and still allows sufficient opportunities for grazing, fresh water fishing and forestry development.

In Minna study area five plots were sampled, two from Shiakwata on the way to Kaduna from Minna town, while three plots samples were collected at Kogu near Nigerian National Petroleum Corperation (NNPC) depot, Minna. The Plots selected in Minna represent Northern Guinea Savann

and have about the same successional status, conspicuously devastated by human activities in aspect of cutting firewood for fuel and cultivating land for farming.

Katsina is the state capital of Katsina state. Today, it has been an important seat of learning and a commercial centre of the trans-saharan trade. A sizeable number of migrants from southern Nigeria, especially the Yorubas and lgbos, are found and they dwell mostly in towns. The state can be classified into two zones climatically tropical continental and semi arid continental, with total annual rainfall figures ranging from 600 mm around to over 700 mm. The average relative humidity ranges from 13% to 22%. The semi arid area has an average temperature of 26^{o}C to 40^{o}C.

In Katsina study area 5 plots were selected randomly, two plots were sampled near Army Barracks 8km from Katsina town, while three plots samples were collected from Dutsin-ma about 40 km from Katsina town. Both plots were 5 km apart and having the similar successional status. The Katsina study area had serious human influences, apart from cultivation of crops and cutting of firewood for fuel and income, the inhabitants also engaged in rearing of heavy weighted animals like camels, donkeys, cows and others. The hooves of the animals can be destructive when they step on plants. All the plots in Katsina study area represent Sudan savanna vegetation and regarded as young vegetation in age because the vegetation had been interfered with and left to regenerate.

Jos, the Plateau State capital is located in Nigeria's middle belt. It is located between 9° 53^{1}N and 9° 51^{1}E. Bare rocks are scattered across the grasslands, which cover the plateau. The altitude ranges from around 1,200 metre to a peak of 1,829 metre above sea level in the Shere Hills range near Jos. Years of tin mining had also left the area strewn or scattered with deep gorges and lakes.

Though situated in the tropical zone, a higher altitude means that Plateau State has a near temperate climate with an average temperature of between 18°C and 22°C. Harmattan winds cause the coldest weather between December and February. The mean annual rainfall varies from 1,100 mm to

1, 600 mm on the Plateau. The average relative humidity ranges from 26% to 51% (Anonymous, 2008).

In the Jos study area, five plots were selected, two plots were sampled from New Fabro, Jos East with a distance of about 25 km from Jos town. While other plots samples were located in Wokkos and Pankshin, both sites were about 110 km from Jos town having rocky terrain and have lower temperature than Jos because of sparse human settlements and open environment which allows wind penetrating into Pankshin town. The last plot sampled was in Zawan of Jos South Local Government Area, about 18 km form Jos town. All the plots sampled in Jos study area represent Montane vegetation and had similar successional status.

3.2 Site Selection for Sampling Using Global Positioning System (GPS)

Four vegetation belts located in Northern Nigeria were visited for data collection namely, Southern Guinea savanna (SGS), Northern Guinea savanna (NGS), Sudan Savanna (SDS), and Montane Vegetation (MNV). The following acronyms were assigned to the various vegetation belts to ease referencing in due course.

Global Positioning System (GPS) from National Remote sensing, Jos was used in the selection of study areas to avoid bias.

Plate 1 showed grids of different X and Y coordinates using Arc-GPS 9.3 Version from National Centre for Remote Sensing, Jos, to select towns (Anonymous, 2010). Plate 1 showed grids of X and Y coordinates using Arc-GPS 9.3 Version. The longitudes used were 4.50, 7.00, 9.50 and 12.00 at interval of 2.5 for uniformity (Anonymous, 2010).

All the towns that represented the savanna study areas were selected on longitude 7.00 while the town that represented montane vegetation study area was picked on longitude 9.50.

Plate 2 shows the different states in Nigeria visited for this study

Plate 3 shows the lower and upper limits of the different vegetation belts in Nigeria to serve as a guide.

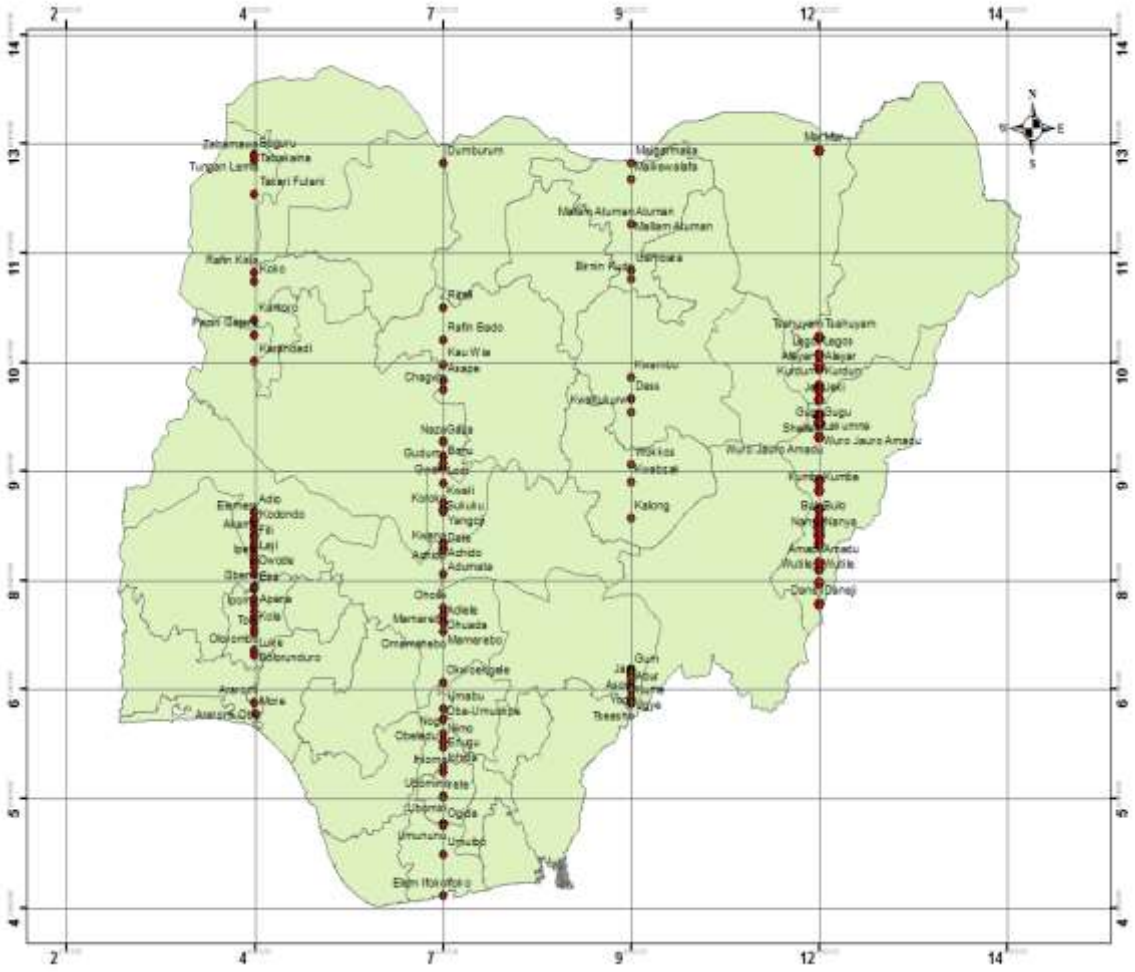
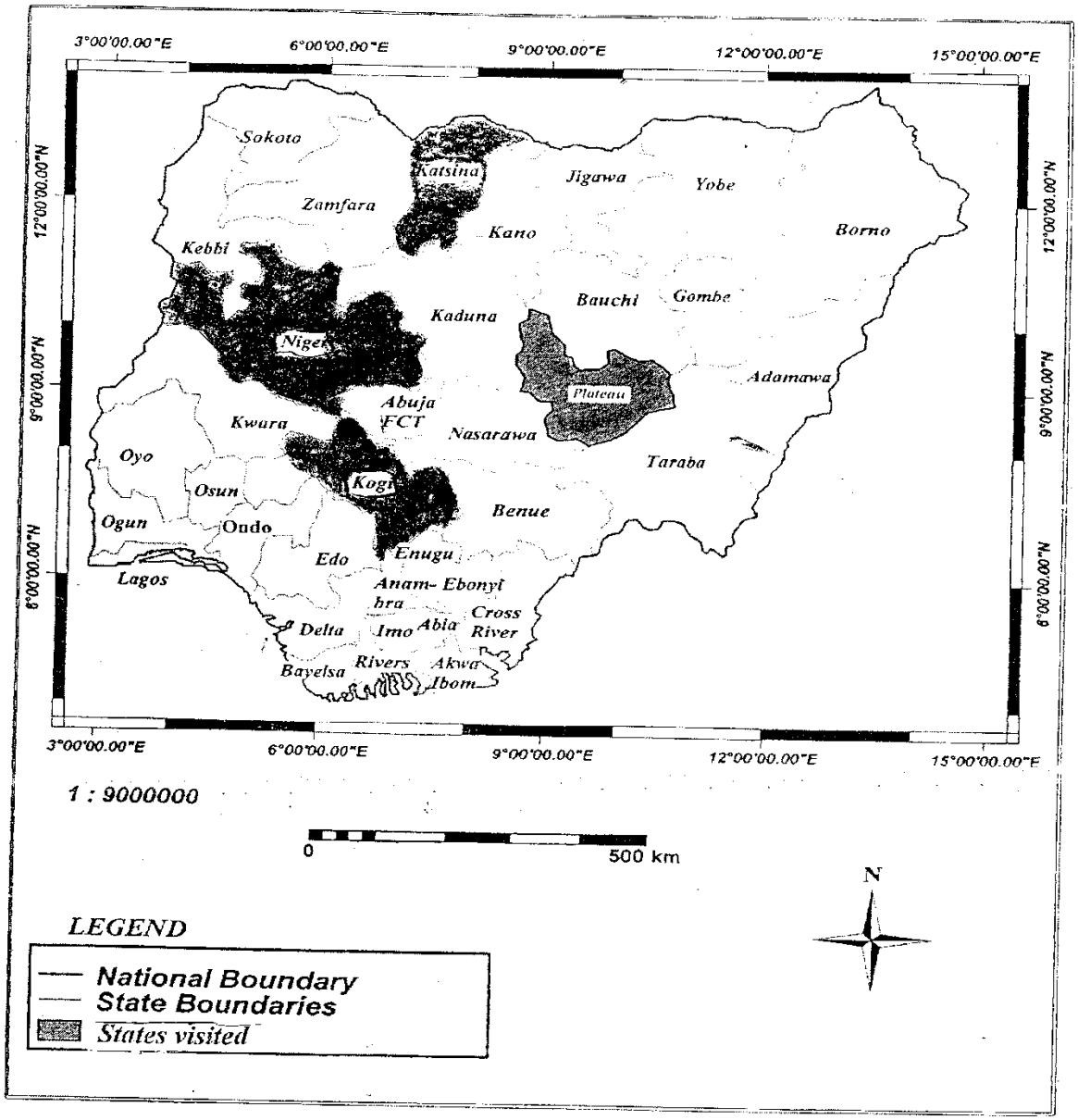


Plate 1: Map of Nigeria showing the use of GPS in the selection of the study areas.

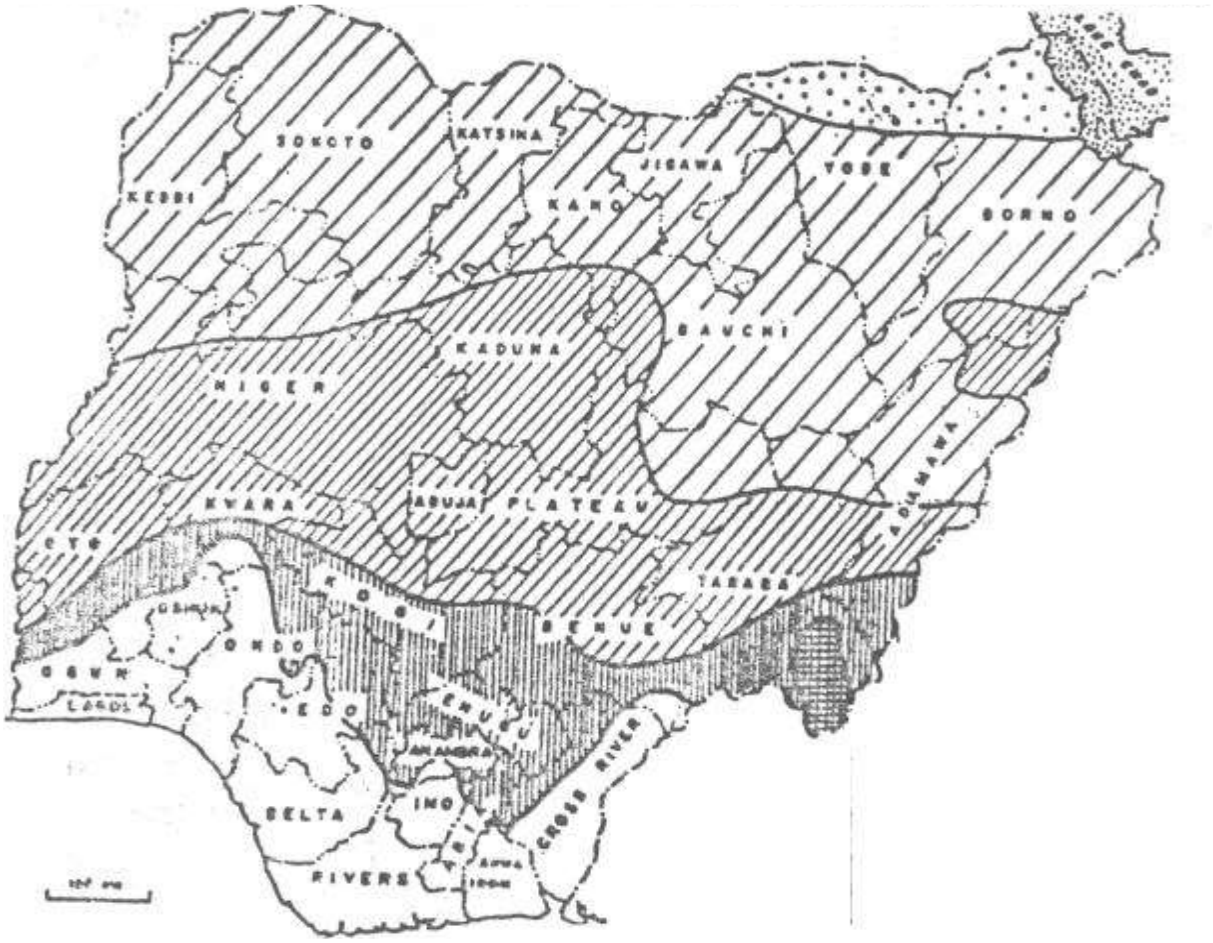
Source – National Centre for Remote Sensing, Jos



SOURCE: National Centre For Remote Sensing Jos, Nigeria

Plate 2: Map of Nigeria showing the different states visited

Source-National centre for remote sensing



KEY	
	Sahel savanna
	Sudan savanna
	Montane vegetation
	Guinea savanna
	Derived savanna
	Tropical rainforest

Plate 3: Map of Nigeria, showing vegetation belts
Source: Keay's Sheme

3.3 Plot Size used for the Study

In each study area, a plot size of 15m x 20m (300 m^2) was randomly established for data collection through stratified random sampling (Braun-Blanquet, 1964 and Van der Maarel, 1988).

Each plot was divided into four equal sub-plots and 1 m x 1 m woody quadrat was randomly placed, one in each quarter to enable the counting of grasses and forbs.

3.4 Vegetation Sampling

The study areas cut across four vegetation zones in Northern Nigeria namel; Southern Guninea Savanna (Lokoja), Northern Guinea Savanna (Minna), Sudan Savanna (Katsina) and Montane Vegetation (Jos). On each plot of 300 m^2 the following activities took place

- ✓ The trees and shrubs in each plot were counted, while for those above 1m high, their girth sizes, diameter at breast height (dbh) (130 cm) were measured , using a tape measure.
- ✓ Plant parts were cut, those that exuded latex were identified and those not identified in the field were taken for identification.
- ✓ Plant materials collected were placed in a plant press for preservation. Unidentified plants in the field were coded and herbarium specimens were prepared to ease identification later.
- ✓ Photographs were also taken to serve as reference in case of difficulty during identification.
- ✓ Plots for data collection within each study area were about the same successional status, as far as the eyes could see.

Some precautional measures were taken in the data collection. Plant samples were collected in areas where the vegetation had not been recently tampered with by man. Edge effects such as mountain base, road construction sites, foot paths, mining sites and valley were taken into

consideration so that, the overall results of the data collected become credible, and also, plots for data collection on a vegetation type were of the same successional status for meaningful comparison.

Sahel savanna is situated in the north east flank of Nigeria and this research was not able to cover such vegetatation belt as a study area because of the ethno-religious crisis that engulfs the zone.

3.5 Vegetation Analysis

Species occurrences in each study area were recorded on a plot by plot basis in a matrix form (Plot code and species) and this formed the basis for computing plots totals. The plot totals were used for a number of other computations which included the density per square meter, species diversity and evenness, constancy value, percentage distribution and basal area.

Species density (± 95% confidence limit) was computed, calculating variance in a systematic sampling.

The species densities were determined by the following formula.

Density = $\frac{No.of\ each\ species}{Total\ area\ sampled}$

Confidence limit refers to as the uncertainty of sub-sampling, is expressed by

$$\mu = \bar{x} \pm t\frac{s}{\sqrt{n}}$$

Where:
m = "true" value (mean of large set of replicates)
$\bar{x}$ = mean of subsamples
t = a statistical value which depends on the number of data and the required confidence (usually 95%).
s = standard deviation of mean of subsamples
n = number of subsamples
(The term $s/\sqrt{n}$ is also known as the standard error of the mean.*)*
The number of degrees of freedom has to be established by: *df* = *n* -1.

The species diversity was calculated using the Shannon-Weiner index of diversity, while, evenness was calculated from Shannon-Weiner's value. The diversity of species in a particular area counts not only the number of species found but also in their numbers. The number of species in an area, is called richness or diversity index and the relative abundance of species, is called evenness (Shannon, 1948; Hill, 1973; Hurlbert, 1971).

Ecologists have developed many indices of species diversity, the values of which depend upon levels of species richness and evenness. A commonly applied measure of species diversity is the Shannon-Wiener index. The following were steps used in the calculation of species diversity and evenness of this study. Species evenness ranges from zero to one, with zero signifying no evenness and one, a complete evenness (see appendix 11).

The species diversity of the sample plots would be determined by using the Shannon-Wiener's index of diversity.

$H^1 = -\sum_{i-1}(Pi)x(In\ Pn)$

$H^1{}_{Max} = Ins$

H^1 = Shannon- Wiener Index of diversity

$-\sum$ = Negative summation sign

Pi= Proportion of I species in the community

In = Natural log

S= number of species

Constancy values for all the species were calculated as the percentage the total plots in which a species occurred (Braun- Blanquet, 1964). The percentage distribution of each species in each study area was also computed by using 20 % when a plant species occurred in each of the 5 plots that make up a study area. So plant species present in the 5 plot of a study area gives 100 % distribution. Similarly, the constancy value for each species in a plot was calculated by using 25 % a plant species occurred in the four study areas and that gave the constancy value for that species.

Basal area is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at their base. The measurement was taken at the diameter at breast height (DBH) (1.3 m or 130 cm) of a tree above the ground and included the complete diameter of every tree including the bark. The basal areas of plants based on plot by plots were computed in m^2/hectare.

In each plot, plant specimens (flowers, leaves and fruit) were collected. Unfortunately, at the time of this survey about 80% of the plants were neither at their flowering or fruiting stages which were vital parts during plant identification. Plant specimens were collected at the commencement of rainy season, when shrubs and trees were recovering from the scourge of dry season sunshine, while grasses and forbs were trying to grow again on soil surface.

The plant samples encountered were arranged in a plant press on the field before leaving the plots to maintain the three dimensional structures (length, breath and width) of the plant parts collected. These preserved plant materials in plant press and the photographs taken on the field during the study will aid during identification of plant specimens subsequently.

To estimate a tree's basal area BA, use the tree's diameter at breast height DBH in centimeters with the following formula:

For the DBH in cm use: $BA = 0.00007854 \times DBH^2$

The result will be in m^2/ hectare.

Books by (Cope, 2001: Zhang *et al*., 2008) and Authorities were contacted in various higher institutions. Some of the plant species encountered were identified on the field, but the bulk of unidentified ones were placed in the plant press and later taken to individuals for identification. People contacted were; Mr. J.J. Azila of the Federal School of Forestry, Jos and Mr. E.O. Agyeno of the Department of Plant Science and Technology, University of Jos.

3.6 Soil Sampling

Using soil auger, 12 sites within each plot were sampled to a depth of 15 cm (top soil). To ensure that all parts of a plot were sampled, each plot was divided in four sections and three sampling points were randomly selected in each quarter for soil collection. Twenty (20) soil samples were collcted for soil analysis.

All the soil samples collected from one plot were further broken into small pieces, stones and gravels were discarded and the soil was mixed thoroughly. Only about 2 kg of the original composite sample was taken at random, placed in a polythene bag and carefully labeled with the location and number of the plot before being transported to the laboratory for analysis (Haase, 1992; Ukpong, 1994).

In the laboratory, large lumps were further broken up and the soil was finally spread out on a large sheet of paper on benches and allowed to air dry. When air dry, the soil sample was ground in a mortar with a woody pestle which allowed the aggregate particles to be crushed but no actual broken down occurred. The sufficiently ground soil was sieved through a 2 mm sieve, while stone and large root residues were discarded. The fine soil which passed through a 2 mm sieve was stored in labeled small polythene bag ready for analysis.

3.7 Soil Analysis

3.7.1 Textural Class Determination

This was carried out by means of hydrometer method (Bouyoucos, 1962; Ibitoye, 2008).

Air-dry soil of the quantity 51g which had passed through the 2 mm sieve was weighed and transferred to suitably labeled containers. A quantity of air-dry 51 g soil sample represents approximately 50 g oven-dry soil.

The percentage of sand, silt and clay in the inorganic fraction of soil was measured in this procedure. The method was based on Stoke's law governing the rate of sedimentation of particles suspended in water. The samples were treated with 25 ml of 5% sodium hexametaphosphate (calgon) along with 100 ml of distilled water to complex Ca++, Al3+, Fe3+, and other cations that bind clay and silt particles into aggregates.

They were all stirred with a stirring rod before transferring to a mechanical shaker where they were shaken for 24 hours. At the end of the shaking, the suspension was carefully transferred into labeled 1 litre glass cylinders.

With the hydrometer in suspension, distilled water was added to the lower blue line. After filling up to the line, the hydrometer was removed.

Each soil sample in the glass cylinder was then stirred with a rubber attached to the end of a glass rod. The stirring was done several times to ensure effective dispersion of particles.

About 20 to 30 seconds after stirring was done, the hydrometer was gently lowered into the suspension until it was floating. The first reading of the hydrometer was taken at 40 seconds. The hydrometer was removed and the temperature of the suspension was taken with a thermometer.

In this way, the hydrometer and temperature readings were taken for all the 20 cylinders containing the soil samples from the 20 plots. After 3 hours, the hydrometer was again allowed gently into the suspension and lowered to float. The hydrometer readings were taken for each soil suspension in each glass cylinder.

The first reading measured the percentage of silt and clay in the suspension, while the second reading measured the percentage of sand.

Calculations;

Temperature and density corrections:

- ✓ Add 0.2 units to the readings of the samples for every (20^oC), and subtract 0.2 units for every below (20^oC).
- ✓ Subtract the density of the blank at each reading, from the corresponding density readings for the samples.

% clay = corrected hydrometer reading at 3hr x 100/ weight of sample

% silt = corrected hydrometer reading at 30 seconds x 100/ weight of sample - % clay

% sand = 100% - % silt - % clay

Textural classes of the plots were read off from a soil textural triangular.

3.7.2 Determination of Soil pH

This was done on the 2 mm sieved soil sample. 10 g of soil were suspended in 20 ml of 0.01 ml Calcium Chloride solution. The suspension was allowed to stay for 30 minutes, stirring occasionally.

The pH meter used was MSE'S spectro-plus instrument in the Federal College of Land Resources, Kuru, Jos.

The pH meter was calibrated with pH 7.0 and 4.0 buffer before used. The electrodes were inserted gently into the partly settled soil suspension and the pH read off on the pH meter when the reading became steady. No stirring was done during the measurement.

After each measurement, the electrodes were rinsed with de-ionised water and wiped dry with a clean filter paper.

From time to time, the electrodes were standardized again with the buffer solution to ensure that there was no fluctuation. Readings of all the 20 samples were repeated two times to ensure reproducibility and that the instrument was in good working condition (Ibitoye, 2008 and Carter, 1992).

3.7.3 Determination of Percentage of Soil Organic Matter

This was carried out on 0.5 mm sieved soil samples. The Walkley-Black titrimetric method was used (Walkley and Black, 1934; Ibitoye, 2008).

1.0 g of sieved soil was weighed out in triplicate and transferred to 500 ml conical flask. By means of pipette, 10 ml of 1N potassium dichromate solution (49.04 g of $K_2Cr_2O_7$ made up to 1 litre with distilled water) was added. The flask was swirled gently to mix.

20 ml of concentrated sulphuric acid was added rapidly using a graduated cylinder. The soil was swirled gently until soil and reagents were mixed, after which it was swirled more vigorously for 1 minute. The flask was rotated again and allowed to stand for about 30 minutes.

After standing for 30 minutes, 100ml of distilled water was added to dilute the mixture. 10 ml of 85% ortho-phosphoric acid, about 0.2 g sodium fluoride and 3-4 drops of diphenylamine indicator were added.

The excess dichromate was titrated using 0.5 N ferrous ammonium sulphate (prepared by dissolving 196.1 g Fe $(NH_4)_2.6H_2O$ in 800 ml water containing 20 ml concentrated sulphuric acid and diluted to 1 litre), until a green colour was reached. The colour changes were dark green to blue to light green.

Two reagent blanks were run, using the same procedure except that no soil was used.

Soil samples calculation using plots. Formulae used.

(a) Milliequivalent of oxidisable material per gram (Meq. Ox/g) =

$$\frac{\text{ml of } Fe^{2+} \text{ for blank-ml } Fe^{2+} \text{ for sample x normality of } Fe^{2+}}{\text{Wt of soil in gram}}$$

(b) % Carbon = Meq. ox/g x 0.003x100 x f

Where f=correction factor

Therefore % carbon=Meq. ox /g x 0.399

(c) % organic matter = % C x 1.729

For all calculation, ml of Fe^{2+} for blank (average of 2 readings) = 22.15 and stand normality of Fe^{2+}= 0.5 (Carter, 1992 ; Ibitoye, 2002).

3.7.4 Determination of Total Percentage Soil Nitrogen.

Reagents

1. Sulfuric acid, concentration H_2SO_4 reagent grade

2. Digestion catalyst- Mix together 1000 g of ground sodium sulfate (reagent anhydrous Na_2SO_4) or potassium sulfate, and 25 g cupric sulfate (reagent anhydrous $CUSO_4$) 10 g of Sodium selenium (Se) powder.

Procedure

1. Weighed 3.0 g of soil, was added inserted into a 75 ml volumetric digestion tube.
2. 3 g scoop of digestion catalyst was added and mixed thoroughly with the dry soil.
3. 10 ml of concentrated H_2SO_4 was added to the soil catalyst mixture. Note that, it is essential that all dry material be completely moistened and thoroughly mixed with the acid to ensure complete digestion.
4. Blank solutions were prepared for each set of sample analyzed by following step 2-3 above using no soil. Allow the samples and blank to stand overnight.
5. Tubes were placed on a digestion block at 15^0C. Samples were checked every 20 minutes for foaming. After one hour (or more, if foaming persist), temperature raised to 25^0C and continue

digestion for one hour. After one hour at 25^0 C temperature was to 35^0C and heat until samples were completely digested, usually about two additional hours. At completion, mineral soil was grayish-white while organic soil was blue-green in colour.

6. Samples were removed from block and left under a fume hood to cool. Then 10-20 ml distilled water was added to each tube to keep the samples from hardening.
7. The ammonium nitrogen content of the digest solution was determined with a rapid flow analyzer, which relies on ammonium to complex with salicylate to form indophenols blue. This colour was intensified with sodium nitroprusside and measured at 660 nm. This determination was made using the Kjeldahl distillation method. The samples were analyzed on an auto-analyzer by continuing with steps 8-9 below to determine total Nitrogen using calculation in this method.
8. Samples were brought to volume with deionized water in 75 ml digestion tubes and mixed.
9. Clear digested solutions were analysised either by allowing samples to settle overnight and pipetting an aliquot or by filtering through and acid washed filtering apparatus fitted with what-man filter paper. Digest solutions were refrigerated prior to analysis.

Calculation

Percentage total Nitrogen= (ppm NH_4 +-N in digest solution) x $\frac{75ml}{sample\ size\ (g)}$ x $\frac{1}{10.000}$

The Kjeldahl method outlined by Carter, (1993) was modified by eliminating the water from the digestion step. One further modification was the determination of NH_4-N spectrophotometrically rather than by Kjeldahl distillation and titration (Ibitoye, 2008 and Koptsik *et al*., 2003).

3.7.5 Ordination (Principal component Analysis)

Ordination serves to summarize community data (such as species abundance data) by producing a low-dimensional ordination space in which similar species and samples are plotted close together,

and dissimilar species and samples are placed far apart (Knapp, 1984; Haase, 1995). Ordination techniques are used to describe relationships between species composition patterns and the underlying environmental gradients which influence these patterns. Data interpreted using ordination were collected in a species by sample data matrix, similar to the matrix. Sample data may include measures of density, biomass, frequency, importance values, presence/absence, or any number of abundance measures (Hill, 1973; Abdi and William, 2010).

The following procedures were followed in ordinating the dta using principal component analysis.

- The dta input of data matrix, where the variable to be analyzed are arranged in rows and columns.
- The data matrix was transformed into standard scores, this is the transformation of the above data matrix above into standard sores.
- The correlation matrix, using, a zero-order correlation analysis of each variable with all other variable in the data set was carried out, yielding a matrix of correlation coefficients.
- Extracting of the loading and eigenvalues of the correlation matrix was obtained by multiplying each component extracted by square root of the corresponding eigenvalue.
- The adequacy of the solution was arrived at by obtaining the sum of the squares of the loadings of the results in variable on each component and expressing the result in percentage.
- The matrix of component scores, the last step in the principal component analysis was the calculation of the components scores. To obtain this, the matrix of standard scores was multiplied by matrix of component loadings (Udofia, 2011).

The data colleted on the field were subjected to Principal components analysis (PCA) to explain the distribution of two or more variables. SPPS programme was used for the ordinations.

The data collected were entered and extracted via principal component analysis, rotation was through quartimax with Kaiser Normalization using IBM-SSPS statistic-22 (2013) model of software. Different ordinations were carried out to explain the interactions in this study. They were as follows;

Ordinate diagrams based on three axes were plotted. In all the ordinations, standardization of data was carried out using the Z-score transformation.

$$Z = \text{score transformation} = \frac{X_1 - \bar{X}}{SD}$$

Where;

X_1 = is the original value of the ith variables being transformed

$\bar{X}$= is the mean of the variable

SD = is the standard deviation

Four ordinations were carried out as follow;

Table 1.0 shows code of attributes drawn from biotic and abiotic factors could probably affect the distribution of latex-producing plants in some vegetation belts of Northern Nigeria.

The factors are as follows: vegetation attributes rainfall, soil attributes, mean temperature values and percentage relative humidity. The codes from I to VII are vegetation attributes, codes from VIII to XI are soil attributes and codes from XII to XIV are climatic attributes. These factors were ordinated to ascertain their individual or collective effects on latex-producing plants in these study areas.

Table 1: The list of 14 site attributes (and their codes) used in the ordination by principal component analysis

Code	Site attributes
I	Total number of species
II	Total number of all individuals
III	Relative % contributions of 5 most abundant species
IV	Relative % contributions of most abundant species
V	Species diversity
VI	Density of latex-producing plants
VII	Mean girth size of woody species above 1 metre high
VIII	Soil pH
IX	Sand/clay ratio
X	Percentage soil organic matter
XI	Percentage soil nitrogen content
XII	Mean annual rainfall
XIII	Mean temperature value
XIV	Percentage relative humidity

Table 2.0 shows codes of attributes drawn from abiotic factors namely, soil factors, rainfall, temperature, percentage relative humidity and the density of latex-producing plants to investigate the effects of these abiotic factors on the distribution of latex-producing plants. The code ‘Z1’ represents the density of latex-producing plants, codes ‘Z2 to Z5’ represent soil attributes and ‘Z6 to Z8’ represent climatic attributes.

Table 2: Latex-producing plants and list of 8 attributes and their codes used in principal ordination by component analysis

Code	Latex-producing plants and some site attributes
Z1	Density of Latex-Producing plants
Z2	Soil pH
Z3	Sand/clay ratio
Z4	Percentage soil organic matter
Z5	Percentage soil nitrogen content
Z6	Mean annual rainfall
Z7	Mean temperature value
Z8	Percentage relative humidity

Table 3.0 indicates plots and their codes in plot ordination by Principal Component Analysis. Thes plots were ordinated to find out whether or not clusters were formed (pattern) to explain a relationship. The codes from ‘A to ’ E represent the plots sampled in Sothern Guinea savanna (Lokoja study area), codes ‘F to J’ represent plots sampled in Northern Guinea savanna (Minna study area), codes ‘K to O’ represent plots sampled in Sudan savanna (Katsina study area) and codes ‘P to T’ represent plots sampled on Montane vegetation (Jos study area).

Table 3: The 20 plots and their codes in the plot ordination by principal component analysis

Plot Codes	Location
A	Lokoja
B	
C	"
D	"
E	"
F	"
G	Minna
H	"
I	"
J	"
K	"
L	Katsina
M	"
N	"
O	"
P	"
Q	Jos
S	"
T	"
U	"
V	"

Table 4.0 shows the codes of 24 most abundant common species of plants used in species ordination by principal components analysis. These plant codes were ordinated to show relationships which were translated to patterns. The codes range from ‘a to x’. Each is representing a particular species. These plants occurred in different densities in different study areas.

Table 4: The list of 24 most abundant commom species and their codes used in in the ordination of species by principal component analysis

Code	Species
a	*Asparagus africana* Lam.
b	*Albizia lebbeck* (L.) Benth
c	*Annona senegalensis* Pers
d	*Adansonia digitata* L.
e	*Anogeissus leiocarpus* (DC.) Guill & Perrs
f	*Balanites aegyptica* (L.) Del.
g	*Carissa edulis* Vahl.
h	*Combretum molle* R. Br. Ex. G. Don.
i	*Combretum tomentosum* G. Don.
j	*Diospyros mespiliformis* Hotcht ex. A. DC.
k	*Daniellia oliveri* (Rolfe) Hutch & Dalz
l	*Detarium microcarpum* Guill & Perr
m	*Gardenia aqualla* Stapf & Hutch
n	*Ipomoea asarifolia* (Desr) Roem & Schult
o	*Khaya senegalensis* (Desr) A. Juss.
p	*Parkia biglobosa (*Jac q.) R. Br. Ex. G. Don.
q	*Piliostigma thonningii* (DC) Hoschst
r	*Sarcocephalus latifolius (*Smith) Bruce
s	*Tamarindus indica* L.
t	*Terminalia avicennioides* Guill & Perr
u	*Terminalia albida* Scott Alliot
v	*Vitellaria paradoxa* Gaertn. F.
w	*Vitex doniana* Sweet
x	*Ziziphus mauritania* Lam.

3.8 Ethno-botanical survey

In each study area, 20 respondents were administered questionnaire. Each copy of questionnaire comprises 10 questions, to ascertain their knowledge of how latex-producing plants are used by the natives of such study areas. Data collected as responses were sorted out and subjected to percentages. The responses to questions 3, 4, 7, 8, and 9 were optional ('yes' 'no' and 'undecided') while responses to questions 1, 2, 5, 6, and 10 engaged the respondent to recount on the questions. The questions are showed on Table 5.

Table 5: Questionnaire on Ethno-Botanical Uses of Latex Producing Plants in Vegetation Belts of Nigeria.

I wish to assure my respondents that that information given to me shall be used for the purpose of academic study and nothing more, so respondents should feel free to give out answers to my questions. The questions are as follows and tick (√) where appropriate:

1. What ethnic group or groups dwell in this area?
2. What are the main land –use practices in your locality?
3. Do you know of latex that oozes out from plants? Yes( ), No ( ) and Undecided ( )
4. Do you have latex-producing plants in your locality? Yes ( ), No ( ) and Undecided ( )
5. List some latex-producing plants you have in your compound and in the wild.
6. List the uses of latex-producing plants by your people.
7. Do you know of any latex-producing plants that are poisonous to man? Yes ( ), No ( ) and Undecided ( )
8. Do you know of latex-producing plants that are eaten by herbivores? Yes ( ), No ( ) and Undecided ( )
9. Do you know of some latex-producing plants that have thorns and spines? Yes ( ), No ( ) and Undecided ( )
10. What happens when you come across latex-producing plants during bush clearing to commence farming activity?

3.9. Collection of Climatological Data

Data on climatic and weather conditions were obtained from the internet for the various study areas. They are namely; mean annual rainfall, average relative humidity and minimum and maximum temperatures values (see appendix 6).

CHAPTER FOUR

4.0 RESULTS
4.1 Plant Species Composition

Table 6 shows the list of latex-producing plant families encountered in the field. In all, 33 of the plants collected were latex-producing plants, while 109 other plant species collected were non-latex producing plants (Appendix 1).

The total number of plant species encountered in each study area was as follows: SGS (58), NGS (39), SDS (23), and MNV (89) which gave a total number of 209 species, but in all, a total of 142 plant species were encountered in all the study areas (Appendix 1). The different plant species collected in the different vegetation belt are shown in (Appendices 2-5). The differences that existed in the vegetation attributes of the study areas were not unconnected with the different climatic, soil factors and anthropogenic activities of man in the environment.

A total of ten (10) families were latex-producing. They are as follows: Aloeceae, Sapotaceae, Cohlospermaceae, Euphorbiaceae, Moraceae, Convolvulaceae, Meliaceae, Asclepiaceae, Cactaceae and Apotaceae.

The forbs and grasses were found to include: *Hyptis sauveolens, Kyllinga ereata, Laportea aestuans, Mariscus alternifolius, Mimosa pudica, Sida rhombifolia, Senna tora, Urena lobata, Fimbristylis laxifolius, Colocasia esculenta and Cyperus eragrotis, etc.*

Table 6: The list of Latex-producing plantsand their families collected in the study areas.

S/NO	Botanical name	Family	Common name
1	*Aloe schweinfurthii* Engl.	Aloaceae	'-
2	*Carissa edulis* Vahl.	Aloaceae	Simple Spine num-num
3	*Chrysophyllum albidum* G.Don	Aloaceae	white star apple
4	*Cochlospermum Planchonii* Hook F. ex. Planch	Cochlospermaceae	Dye plant
5	*Euphorbia heterophylla* L.	Euphorbiaceae	Painted euphorbia
6	*Euphorbia hirta* L.	Euphorbiaceae	Pill-pod sand mat
7	*Euphorbia Kamerunica* Pax.	Euphorbiaceae	Cactus
8	*Euphorbia lactea* L	Euphorbiaceae	Mottled spurge
9	*Euphorbia mauritanica* L	Euphorbiaceae	Spurge
10	*Euphorbia milli* L	Euphorbiaceae	Christ thorn
11	*Euphorbia neriifolia* L.	Euphorbiaceae	India spurge tree
12	*Euphorbia tirucalli* L.	Euphorbiaceae	Pencil plant
13	*Euphorbia trigona* L	Euphorbiaceae	African milk Weed
14	*Euphorbia unispina* N.E.Br.	Euphorbiaceae	Candle plant
15	*Ficus abutilifolia (*Miq) Miq	Moraceae	Fig discifera
16	*Ficus aurea*	Moraceae	Florida strangler fig
17	*Ficus capreifolia* Delile	Moraceae	River sand paper
18	*Ficus exaperata* Vahl.	Moraceae	Paper fig
19	*Ficus glumosa* Del.	Moraceae	Mountain rock fig
20	*Ficus platyphylla* Delile	Moraceae	Flake rubber
21	*Ficus sur* Forssik	Moraceae	Broom cluster fig
22	*Ficus sycomorus* (Miq.)E.C.Berg	Moraceae	Sycamor fig
23	*Ficus thonningii* Blume	Moraceae	Common fig
24	*Ipomea carnea (*Mart. Ex Choisy) D. Austin	Moraceae	Gloria Da La Manana
25	*Ipomoea asarifolia* (Desr.) Roem &Schult	Convolvulaceae	Ginger leaf morning glory
26	*Ipomoea involcrata* P.Beauv.	Convolvulaceae	Morning glory
27	*Ipomoea triloba*	Convolvulaceae	Little bell
28	*Khaya sensgalensis* (Desr)A.Juss	Meliaceae	African mahogany
29	*Leptadenia hestata* (Pers.) Decne	Asclepiaceae	Laptaden
30	*Opuntia dillenii* Haw	Cactaceae	Prickly pear
31	*Opuntia lindheimeri* Engelm	Cactaceae	Taxas prickly Pear
32	*Opuntia littoralis (*Engelm.) J.M. Coult.	Cactaceae	Coastal Prickly Pear
33	*Vitellaria paradoxa* Gaertn F.	Sapotaceae	Shea butter tree

4.2 Vegetation Attributes

- ✓ Table 7a: shows that Jos (Montane vegetation) had more plant species than the savanna vegetation types. The trend of occurrence showed a decreased in number of species from South (Lokoja study area) to North (Katsina study area), that is from southern guinea savanna to Sudan savanna.
- ✓ Total number of woody individuals, total number of all individuals followed a similar trend. However, the Shannon-Weiner diversity index did not follow a consistent trend being highest in Sudan savanna (Katsina) and lowest in Northern Guinea savanna (Minna).
- ✓ Evenness was highest in the north Sudan savanna (Katsina) and followed the same trend as the diversity index.
- ✓ Relative percentage contribution of five most abundant species and relative percentage contribution of most abundant species were north and decreased southwards, with Jos area having the least values (Table 7a).

Table 7a: Vegetation attributes used for the study of latex-producing plants (LPP) in the vegetation belts (SGS, NGS, SDS and MNV) of Northern Nigeria

Location	Total no. of species	Total no. of woody individuals	Total no. of individuals	Relative % contribution of 5 most abundance species	Relative % contribution of most abundance species	Shannon's Diversity index	Evenness
Lokoja (SGS)	27.80 ± 2.69	42.40 ± 6.20	68.60 ± 10.79	35.63± 2.20	48.47 ± 4.88	0.18 ± 0.03	0.82 ± 0.02
Minna (NGS)	24.2 ± 2.00	35.80 ± 6.97	73.60 ± 13.81	48.41 ± 2.62	65.03 ± 6.05	0.15 ± 0.01	0.81 ± 0.03
Katsina (SDS)	11.60 ± 1.80	23.00 ± 2.84	30.00 ± 2.43	63.26 ± 4.76	65.12 ± 3.99	0.58± 0.007	1.11 ± 0.44
Jos (MNV)	36.20 ± 1.07	65.20 ± 9.90	65.200 ± 6.40	31.03 ± 3,34	37.56 ± 7.32	0.26 ± 0.01	0.64 ± 0.11

KEY	
SGS	Sourthern Guinea savanna
NGS	Northern Guinea savanna
SDS	Sudan savanna
MNV	Montane vegetattion

Table 7b: shows additional vegetation attributes as follows;

- ✓ The density of latex-producing plants was highest in MNV but did not show any consistent trend from SGS to SDS (Table 7b)
- ✓ The density of all species, abundance of latex-producing plant and mean girth sizes of woody plants above 1m high and latex-producing plants and basal area of woody plants decreased from southern Guinea to Sudan savanna with Montane vegetation having high value (Table 7b).

- ✓ However, the abundance of latex-producing plants species did not follow a consistent trend. Montane vegetation in Jos had the highest abundance of latex-producing plants (Table 7b).

Table 7b: Additional vegetation attributes used for the study of latex-producing plants (LPP) in the vegetation belts (SGS, NGS, SDS and MNV) of Northern Nigeria

Location	Density of latex producing plants (m^2)/ha	Density of all species (m^2)/ha	Abundance of latex producing plants	Mean girth size of woody plants above 1m high (cm)	Mean girth size of woody Latex producing plants above 1 m high (cm)	Basal area of woody plants
Lokoja (SGS)	0.015 ± 0.2	0.23 ± 0.2	4.60 ± 1.29	473.80 ± 85.71	72.20 ± 29.84	19.94 ± 6.67
Minna (NGS)	0.007 ± 0.1	0.19 ± 0.2	2.00 ± 0.45	289.20 ± 35.82	25.00 ± 7.46	6.97 ± 1.69
Katsina (SDS)	0.009 ± 0.1	0.1 ± 0.2	2.80 ± 0.37	156.00 ± 15.79	11.60 ± 4.76	1.99 ± 0.38
Jos (MNV)	0.10 ± 0.09	0.24 ± 0.2	17.20 ± 5.11	471.80 ± 45.71	111.4 ± 38.08	18.14 ± 3.26

KEY	
SGS	Sourthern Guinea savanna
NGS	Northern Guinea savanna
SDS	Sudan savanna
MNV	Montane vegetattion

Table 8: shows the 24 most abundant species along with their constancy values and percentage distribution of plant species in the four study areas. The four areas studied had some common species as shown in Table 8. For example, the following species are found in most of the plots at varying densities. The plants were as follows: *Annona senegalensis, Adansonia digitata, Anogeissus leiocarpus, Combretum molle, Combretum tomentosum, Ipomoea asarifolia, Piliostigma thonningii, and Vitellaria paradoxa.*

TABLE 8: The 24 most dominant species, their constancy value and percentage distribution in the four study areas SGS, NGS, SDS and MNV used in the study of latex producing plants in the vegetation belts of Northern Nigeria.

S/no	Species	Constancy	Percentage Distribution			
			SGS	NGS	SDS	MNV
1	*Asparagus africana* Lam	25	40	0.0	20	40
2	*Albizia lebbeck* (L) Benth	20	0	40	00	40
3	*Annona senegalensis* Pers	60	60	80	40	60
4	*Adansonia digitata* L.	45	40	10	60	60
5	*Anogeissus leiocarpus* (DC.) Guill & Perrs	70	80	60	80	60
6	*Balanites aegyptica* (L.) Del.	50	80	'00	60	60
7	*Carissa edulis* Vahl.	25	60	'00	'00	40
8	*Combretum molle* R.Br. Ex. G. Don.	45	60	60	60	60
9	*Combretum tomentosum* G. Don	50	80	40	60	20
10	*Diospyrous mespiliformis* Hotcht ex. A, DC.	30	40	'00	40	40
11	*Daniella oliveri* (Rolfe) Hutch & Dalz	40	60	60	'00	40
12	*Detarium microcarpum Guill & Perr*	30	'00	40	60	20
13	*Gardenia aqualla* Stapf & Hutch	45	60	60	'00	60
14	*Ipomoea asarifolia* (Desr) Roem & Schult	55	60	60	60	60
15	*Khaya senegalensis* (Desr) A. Juss.	45	60	60	'00	60
16	*Parkia biglobosa* (Jac.q.) R.Br. Ex. G. Don.	40	40	60	'00	60
17	*Piliostigma thonningii (*DC.) Hoschst	55	60	60	40	60
18	*Sarcocephalus latifolius (*Smith) Bruce	60	60	100	'00	80
19	*Tamarindus indica* L.	50	60	80	'00	60
20	*Terminalia avicennioides* Guill & Perr	25	'00	60	'00	40
21	*Terminalia albida* Scott Alliot	30	60	60	'00	'00
22	*Vitellaria paradoxa* Gaertn F.	55	60	40	60	60
23	*Vitex doniana* Sweet	35	40	40	'00	60
24	*Ziziphus mauritania* Lam.	35	40	40	'00	60

* Constancy is the percentage of all the plots sampled in which a species occurred.

There were, however, some variations in species composition and density from one study area to another. For instance, latex-producing plants like *Euphorbia kamerunica*, *Euphorbia tirucalli*, *and Canarium schweinfurthii* were noticeably absent in most plots in Lokoja, Minna and Katsina study areas, while these latex-producing plants were in abundance in Jos study area.

Table 9: compared the number of individuals of latex- producing plants with the total number of individuals of all the species. From this Table 9, it was obvious that the study areas of Lokoja, Minna and Katsina had less number of species of latex-producing plants than Jos study area.

The trend of abundance of latex-producing plants seemed to be in the decreasing order from Montane vegetation→ Southern Guinea Savanna → Sudan Savanna→ Northern Guinea Savanna and showed percentage values of 20.14%, 9.33%, 6.57% and 3.76% respectively when compared with all other species.

Table 9: Mean total number of latex-producing plants (± 95 % confidence limit) in 5 plots compared with mean total number of all individuals encountered in each study area of (SGS, NGS, SDS and MNV used in study of Latex - producing in some vegetation belts of Northern Nigeria.

S/no	Study Area	Latex-producing plants	All Individuals
1	Southern Guinea Savanna (5 plots)	4.6 ± 3.57	70.0 ± 28.58
	% of total	6.57%	
2	Northern Guinea Savanna (5 plots)	2.0 ± 1.24	53.2 ± 40.71
	% of total	3.76%	
3	Sudan Savanna (5 plots)	2.8 ± 1.04	30.0 ± 6.74
	% of total	9.33%	
4	Montane Vegetation (5 plots)	17.2 ±14.19	85.40 ± 17.78
	% of total	20.14%	

Table 10: shows comparison of the ratios of the total density of all individual plants to density of latex–producing plants. It was noticed that among the plots in Lokoja, Minna and Katsina study areas had higher ratios, while Jos study area had lower ratio which implied that, Jos had greater abundance of latex-producing plants. The ratio on plot 15 was higher similar to those in the study areas of savanna vegetations, this is because it had features of Northern Guinea savanna.

Table 10: Ratio of total number of individual and the total number. of Latex-producing Plants (LPP)

Plot no.		Number of non-latex and latex- producing plants	Ratio
1	Lokoja	102/8	13:1
2	"	57/4	14:1
3	"	86/7	12:1
4	"	47/3	16:1
5	"	58/1	58:1
6	Minna	97/2	49:1
7	"	55/3	18:1
8	"	112/1	112:1
9	"	36/3	12:1
10	"	68/1	68:1
11	Katsina	30/4	7:1
12	"	35/3	11:1
13	"	22/2	11:1
14	"	28/3	9:1
15	"	35/2	18:1
16	Jos "	97/2	49:1
17	"	86/12	7:1
18	"	100/21	5:1
19	"	65/33	2:1
20	"	78/18	4:1

4.2.2 Basal area and girth size

A comparison of the basal area of latex-producing plants with those of all species on plot by plot basis (Table 11) showed that the basal areas of latex-producing plants were closely related to those of the plots confirming the dominant status of the mature plots because they had higher values for basal area as seen in Tables 7a and 7b.

The basal areas of the plants in Lokoja and Jos study areas were higher, indicating that they had larger and more mature trees. The plant species in the plots in the study areas of Minna and Katsina had smaller girth sizes and possessed younger plant species, so the basal area for the plants gave lower values.

Table 11: Basal area of Latex -producing plants compared to the basal area of all woody species above 1m high in the sampled plots in vegetation belts (SGS, NGS, SDS and MNV) of Northern Nigeria

Location	All species (m^2/ha)	Latex producing plants (m^2/ha)	% total difference
Lokoja (SGS)	19.94	5.0×10^{-3}	3.3×10^{-3}
Minna (NGS)	6.97	6.6×10^{-4}	3.6×10^{-3}
Katsina (SDS)	1.99	2.9×10^{-4}	6.0×10^{-3}
Jos (MNV)	18.14	4.4×10^{-2}	1.9×10^{-2}

4.3 Soil Attributes

Table 12: shows that the soils in the study areas were slightly acidic in reaction with soil pH range of 5.39- 6.83.

The percentage of sand was between 96.84-97.03%, the percentage of silt ranged from 2.91-2.97% and percentage of clay was within a range of 0.06-0.20%. Sand particles formed the largest constituents of over 96% in all the plots sampled in the four study areas of Lokoja, Minna, Katsina and Jos. All the soil samples from the various study areas belong to sandy textural class.

All the soil samples collected from various plots showed no observable trend for ratio of clay and silt. The sand/clay ratio had the range of 33.32-33.07 for all the study areas.

The range of values for the percentage organic matter was 0.96-3.66% pointing to a lower soil nutrient for SDS and MNV and percentage nitrogen content was also lower with a range of 0.36-0.45% for SDS and MNV as would be expected, since both organic matter content and nitrogen content in the soil influences each other.

Table 12: Soil attributes of the plots used for the study of latex-producing plants (LPP) in the vegetation belts (SGS, NGS, SDS and MMV) of Northern Nigeria

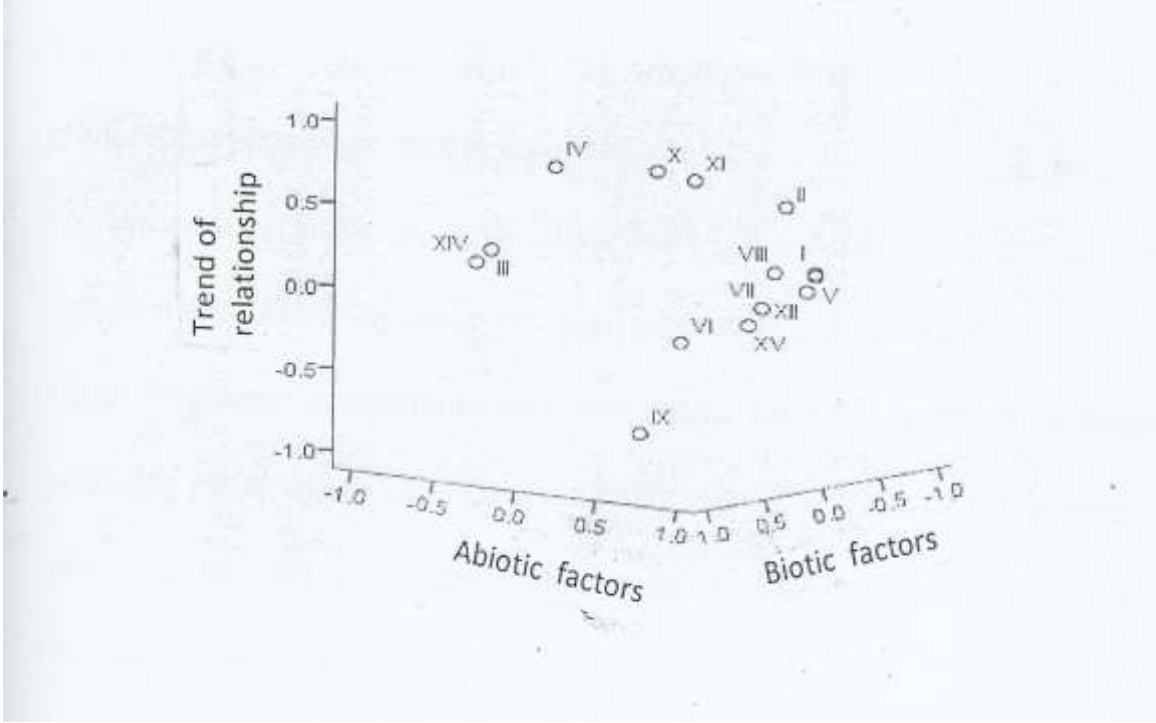
Study Area	Soil pH	% Sand	% Silt	% Clay	Sand /Clay Ratio	Textural Class	% Organic Matter	% Total Nitrogen
SGS	6.83	97.03	2.91	0.06	33.32	Sandy	2.49	0.46
NGS	6.64	96.84	2.97	0.20	32.68	Sandy	3.66	0.48
SDS	5.39	96.96	2.93	0.10	33.07	Sandy	0.96	0.36
MNV	6.33	96.94	2.93	0.10	33.1	Sandy	1.62	0.45

4.4 Ordination Diagrams By Principal Component Analysis

Based on the ordination diagram is shown in (Figure 1), using the codes and site attributes shown in Table 1, four groups of associations emerged;

- ✓ In the first group of associations existed as I and V/XII, shows that total number of species and diversity were influenced by mean annual rainfall.

- ✓ The second association was between VII/XV, meaning that mean girth size of woody plants was associated with relative humidity.
- ✓ The third group of association comprises of III/XIV, implying that relative percentage contribution of 5 most abundance correlated with mean temperature values.
- ✓ The fourth group of association was between XI/X showed association between percentage nitrogen content and percentage soil organic matter.
- ✓ There other non-associated variables.



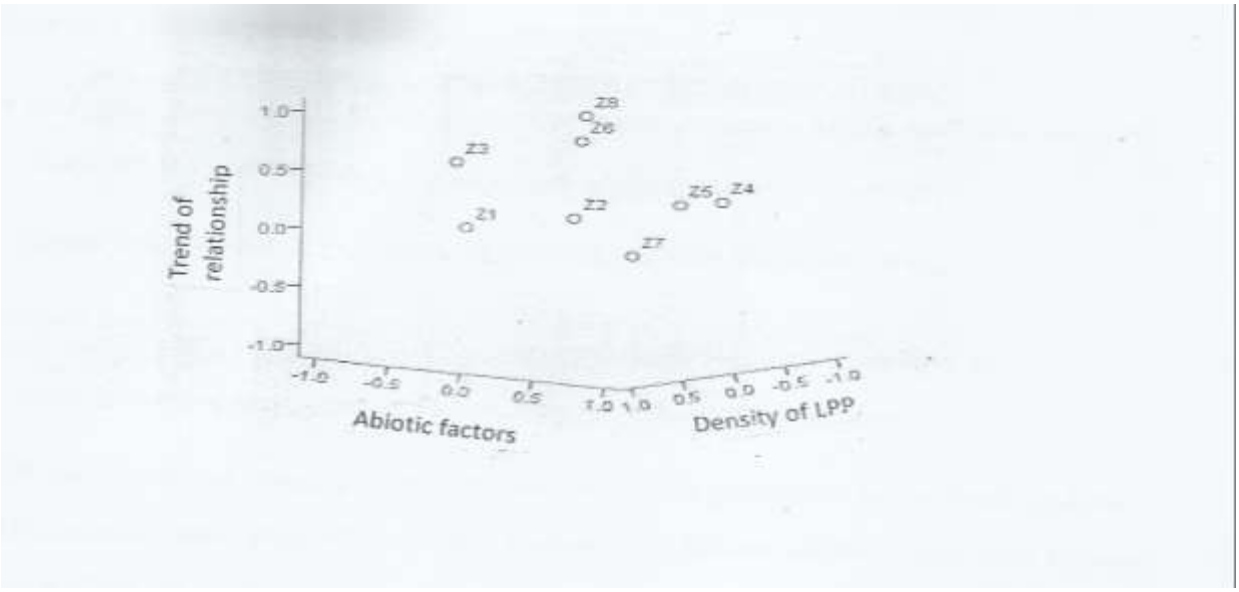
KEY

Code	Attributes	Code	Attributes
I	Total number of species	VIII	Soil pH
II	Total number of individuals	IX	Sand/clay ratio
III	Relative % contributions of 5 most abundant species	X	Percentage soil organic matter
IV	Relative % contributions of most abundant species	XI	Total percentage soil Nitrogen
V	Species diversity	XII	Mean annual Rainfall
VI	Density of Latex-Producing plants	XIII	Mean Temperature value
VII	Mean girth size of woody species above 1 meter high	XIV	Percentage Relative Humidity

Figure 1:.Ordination by principal component analysis of 14 site attributes.

From the ordination diagram (Figure 2), the codes and the attributes showed in Table 2. Two groups of associations were observed:

- ✓ The first group comprises of Z8 and Z6 representing that mean annual rainfall had influence on percentage relative humidity.
- ✓ The second association was between attributes Z5 and Z4 which implies that percentage organic matter was dependent on the total percentage soil nitrogen.
- ✓ There were other conspicuous non- associations like Z1 representing density of latex-producing plants which stood far apart. Others were Z3, Z2 and Z7 representing sand/clay ratio, soil pH and mean temperature value respectively, impling that there was no abservable ssociation between them.



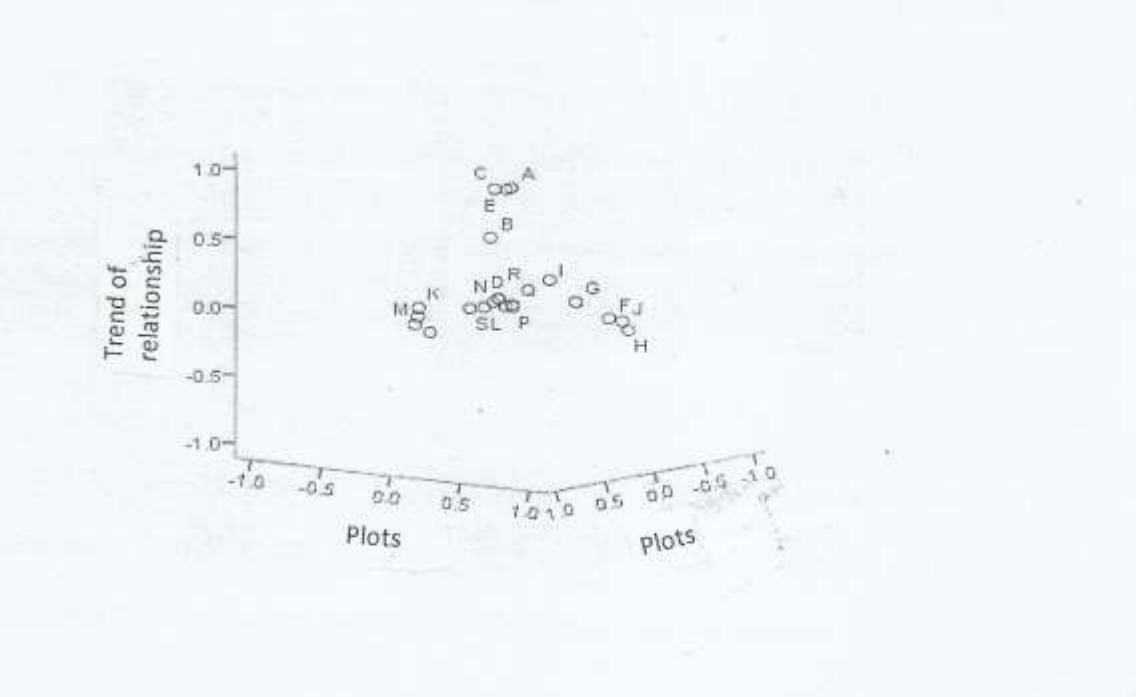
KEY	Attributes
Z1	Density of Latex-Producing plants
Z2	Soil pH
Z3	Sand/clay ratio
Z4	Percentage soil organic matter
Z5	Total percentage soil Nitrogen
Z6	Mean annual Rainfall
Z7	Mean Temperature value
Z8	Percentage Relative Humidity

Figure 2: Ordination of latex-producing plants and 8 other attributes by principal component analysis.

The plots ordination diagram is shown in (Figure 3), the list of plots and their codes in ordination diagram were shown in Table 3 Four groups of association were noticeable. The groupings gave a unique pattern, depicting the four study areas.

- ✓ First group shown A, B, C and E, these plots were located in Lokoja study area and were clustered to show relationship.
- ✓ Second group depicted F, H, I and J, the plot were within the Minna study area.
- ✓ Third group shown K, M and O, these plots fell in the Katsina study area.
- ✓ Fourth groud shown P, Q, R and S, these plots fell within the Jos study area.

In the conspicuous groupings, plots were re-arranged in a north–south and west-east gradients, where Lokoja and Jos study areas fell into vertical gradient, while Katsina and Minna study areas fell into horizontal gradient. This pattern is contrary to their original positions of the study areas on the map of Nigeria.



KEY

Code	Location	Code	location
A	Lokoja	K	Katsina
B	"	L	"
C	"	M	"
D	"	N	"
E	"	O	"
F	Minna	P	Jos "
G	"	Q	"
H	"	R	"
I	"	S	"
J	"	T	"

Figure 3: Ordination of all the 20 plots in all the study areas by principal component analysis.

The ordination diagram of the species is shown on Figure 4, the list of 24 most common species and their codes were shown in Table 4. Four possible clusters or groups were formed.

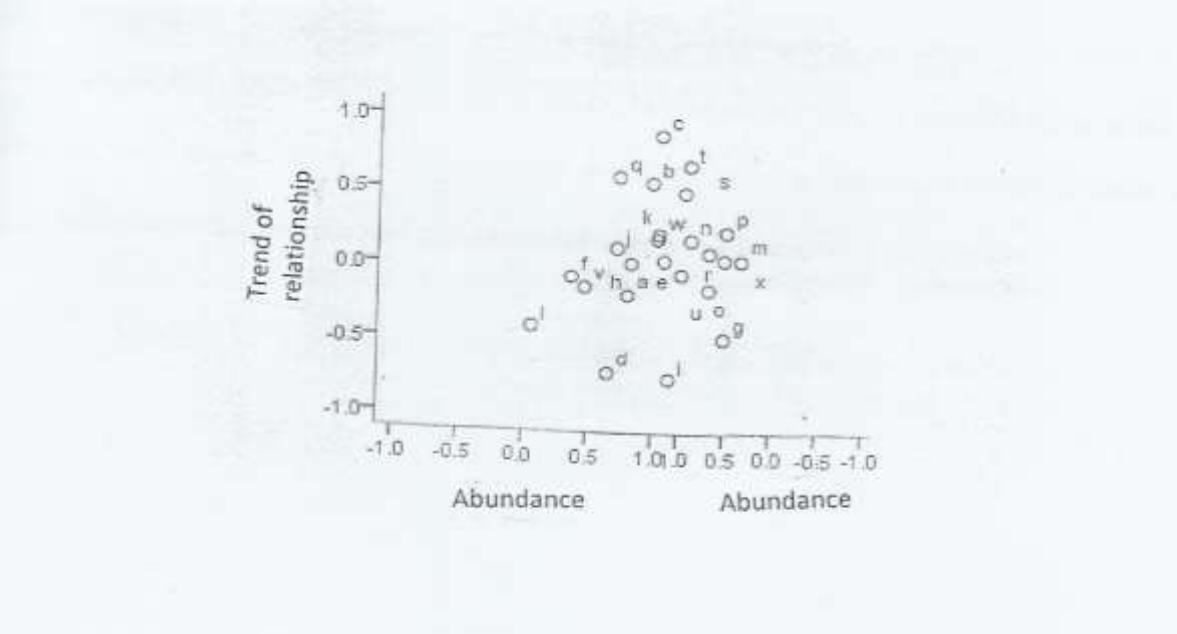
- ✓ The first group included plants that were more abundant in Lokoja study area, namely; *Piliostigma thonningii (q), Adansonia digitata (b), and Terminalia albida (t).*

- ✓ The second group comprises plants that were more abundant in Minna study area, namely; *Gardenia agualla (m), Sarcocephalus latifolius (r),* and *Ziziphus mauritiania (x) and Parkia biglobosa (p.)*

- ✓ The third group consists of plants species which were found to be more abundant in the Katsina study area: they are*; Balanites aegyptica (f), Diospyros mespiliformis (j) Annona senegalensis (a), Combretum molle (h)* and *Terminalia avicennoides (u).*

- ✓ The fourth group consisted of species found in Jos study area, namely; *Daniellia oliveri (k), Anogeissus leiocarpus (e), Vitex doniana (w)* and *Ipomoea asarifolia (n).*

The associations showed the arrangement of the plant species which portrayed a pattern of occurrence of species in the four study areas, this could be gleaned from the constancy table (Table 8) and density of plants on plot by plot basis.



KEY

Code	Plant Species	Code	Plant Species
a	*Asparagus africana* Lam.	m	*Gardenia aqualla* Stapf & Hutch
b	*Albizia lebbeck* (L.) Benth	n	*Ipomoea asarifolia* (Desr) Roem & Schult
c	*Annona senegalensis* Pers	o	*Khaya senegalensis* (Desr) A. Juss.
d	*Adansonia digitata* L.	p	*Parkia biglobosa* (Jac q.) R. Br. Ex. G. Don.
e	*Anogeissus leiocarpus* (DC.) Guill & Perrs	q	*Piliostigma thonningii* (DC) Hoschst
f	*Balanites aegyptica* (L.) Del.	r	*Sarcocephalus latifolius* (Smith) Bruce
g	*Carissa edulis* Vahl.	s	*Tamarindus indica* L.
h	*Combretum molle* R. Br. Ex. G. Don.	t	*Terminalia avicennioides* Guill & Perr
i	*Combretum tomentosum* G. Don.	u	*Terminalia albida* Scott Alliot
j	*Diospyros mespiliformis* Hotcht ex. A. DC.	v	*Vitellaria paradoxa* Gaertn. F.
k	*Daniellia oliveri* (Rolfe) Hutch & Dalz	w	*Vitex doniana* Sweet
l	*Detarium microcarpum* Guill & Perr	x	*Ziziphus mauritania* Lam.

Figure 4: Ordination of 24 most abundant species by principal component analysis.

It is important to note that all the interactions that occurred between latex-producing plants, other plant species and non-living factors (abiotic factors) during the study were portrayed during the four ordinations carried out. The correlation coefficient for figures 1-4 are seen in appendices 7-10, which is obtained from the data matrix entered and extracted using principal component analysis.

4.5. Responses to Ethno-botanical questionnaire

Table 13, shows the responses to questions on the questionnaire. The percentages of those that answered 'No' as response showed higher percentages in the three study areas of the savanna vegetation, while the percentage of those that answered 'No' by inhabitants on montane vegetation were lower. Those inhabitants who answered 'Yes' as responses depicted lower and higher percentages for savanna and montane vegetations respectively**.** Yes stands for positive answer while no stands for negetive answer by respondents.

Table 13, Responses of inhabitants to Ethno-botanical Questionnaire

		Responses by individuals in each study area (%)		
	Question no.	Yes	No	Undecided
SGS	3	30	50	20
	4	40	40	20
	7	10	80	10
	8	10	90	00
	9	20	70	10
NGS	3	20	60	20
	4	40	30	30
	7	20	70	10
	8	20	60	00
	9	30	60	10
SDS	3	10	80	10
	4	40	50	10
	7	10	90	00
	8	20	80	00
	9	10	70	20
MNV	3	80	10	10
	4	90	10	00
	7	80	10	10
	8	90	10	00
	9	100	00	00

- Responses to question 1. The ethnic groups in study areas were given as follows:

SGS –Nupe, Gwari, Bassa and Fulani

NGS-Nupe, Gwari and Fulani

SDS- Hausa and Fulani

MMV- Berom, Ngas, Anaguta and Jarawa

- Responses to question 2. The land –use practices of the people were as follows;

SGS- Fishing and minimal rearing of animals by the Fulani herdsmen

NGS-Farming, cutting of plants for fire wood and rearing of cattle

SDS- Massive cutting of plants for firewood and intensive rearing of cattle

MNV- Farming, rearing of cattle and mining of tin and columbite.

- Responses to question 5. The inhabitants who accepted that they had latex-producing plants in their compound and in the wild, only named agricultural and ornamental plants like *Carica papaya, Mannihot esculentum, Ficus and Plumera rubra.* While the inhabitants on montane vegetation gave a good number of latex-producing plants in the wild like: *Canarium species, Euphorbia, Cactus species, Ficus species etc.*

Responses to question 6. The uses of latex-producing plants as mentioned by some inhabitants were as follows;

Responses from inhabitants of Southern Guinea savanna (SGS)

- Used in production of cheese from cow milk via coagulation- *Calotropis procera*
- Used as horticultural and ornamental plants–*Carica papaya, Ficus glumosa and Caesalpinia pulcherrima*
- Used in producing biological weapon-*Plumera rubra, Plumera obtusa*
- Used for rope and dye -making - *Cochlospermum planchonii*

Responses from inhabitants of Northern Guinea Savanna (NGS)

- Used as food-*Ipomoea batata*
- *Used as* Ornamental plant-*Ficus sur*
- Used for the production of rope and dye - *Colchlospermum planchonii*
- Used to coagulate protein in milk by Fulani - *Calotropis procera*
- Responses from inhabitants of Sudan Savanna (SDS)
- Used as horticural plant- *Carica papaya*
- Used as food – *Manihot esculentum, Ipomoea batata*

Responses from inhabitants of Montane Vegetation (MNV)

- ✓ Used as food – *Canarium schweinfurthii*
- ✓ Used as ornamental plant (fencing of compound) –*Euphorbia kamerunica*
- ✓ Burning of the latex to chase snake out of the house – *Canarium schweinfurthii*
- ✓ Chasing of snakes from the immediate surrounding by planting- *Opuntia littoralis*
- ✓ Used for the demarcation of farmlands- *Euphorbia kamerunica*
- ✓ Used for treating of pile - *Euphorbia kamerunica*
- ✓ Used for poisoning arrow during war- *Caesalpinia pulcherrima*
- ✓ Used for curing chicken against air-borne disease- *Ricinus communis*
- ✓ Used for the production of body and hair creams- *Vitellaria paradoxa*

Responses to question 10. The people said that when they come across the plants, they cut it immediately before they continue with the clearing because they are aware of the plant poisonous effects, in case it touches an individual's body.

CHAPTER FIVE

5.0 Discussion

The total number of woody individuals and the total number of all individuals were higher in Jos and Lokoja study areas probably because of the higher amount of rainfall experienced less anthropogenic activities by man and reduced feeding on latex-producing plants by animals probably due to the disagreeable property of latex-producing plants on montane vegetation.

Minna and Katsina study areas showed less value for these parameters possibly because of the differences in land-use practices and climatic factors experienced in these areas (Frost and Robertson, 1987). That is to say, Lokoja and Jos study areas had more number of species but differences in species number and type encountered still existed. Latex-producing plants formed heterogeneous stands with about 14% in Lokoja, Minna and Katsina study areas, while Jos study area recorded 86% in the plots sampled.

The attributes considered in this study that seemed useful in assessing the successional status of the various study areas were species diversity index, girth size and basal area. These attributes were more useful because all the occasionally left tall tress like *Canarium schweinfurthii, Vitelliaria paradoxum, Adansonia digitata and Borassus aethiopium* were considered in the computation of the data.

The plant species in the Jos and Lokoja study areas that contributed to the high basal area were *Canarium schweinfurthi, Borassus aethiopium, Vitex doniana, Sarcocephalus latifolius, Vitellaria paradoxa, Vitex doniana, Ficus exasperata, Ficus sur etc*. Some of these plants are economic trees, which were preserved during land clearing for the comencemnet of farming activities, while others are latex-producing plants that were not palatable and safe for eaten by grazing animals because of the latex they exude, so they were able to grow to maturity (Japtap, 1995).

In general, most of the savanna species in the Minna and Katsina study areas encountered had their girth sizes concentrated between 11 cm-16 cm girth classes and are regarded as younger plots, While Lokoja and Jos study areas had their girth size condensed between 15cm-75 cm. In terms of girth classes alone, according to Sanford *et al.* (1982) classification, plots 1, 2, 3, 4, 5, 16, 17, 18, 19, and 20 were regarded as matured, while plots 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15 were regarded as younger. The girth class distributions of latex-producing plants can not be ranked favorably with those of other species in terms of size because normally girth sizes of latex-producing plants are small adapted to retention of water in them as in xerophytic environment.

Sanford *et al.* (1982) had found girth size class distribution very useful in assessing the maturity of the plots in the Guinea savanna. There was a good relationship between successional status and survival of latex-producing plants. Thus, latex-producing plants were more in matured plots than in younger plots reasons being that, they are less disturbed.

According to Heinrich and Siegmar (2002) latex-producting plants of Cactaceae and Euphorbiaceae families grow very slowly and are not available at the pioneer stage of sucession. For example, Saguaro plant (*Cactus* species) grows slowly but may live up to 200 years. When at 9 years old, they are about 15 cm high and after about 75 years, the cacti develop their first branches. So, these plants can not grow to a reasonable height before they are destroyed in places that experience intermitted anthropogenic activities.

The plots ordinations showed that there were a lot more relationships among the plots within a particular study area than between study areas, but these relationships were not sharply defined, indicating that the differences were rather elusive. This was shown in the relationships among the plots from some of the study areas, notably Lokoja and Jos study areas were related in terms of the species diversity, girth size and basal areas.

Ordination diagrams for figures 1 and 2 showed that percentage relative humidity and mean annual rainfall were responsible for the different mean girth sizes of plants, species density and diversity of woody species of above 1 metre high. Temperature was responsible for relative percentage contribution of 5 most abundant species. Soil pH was responsible for total number of individual species. Rainfall plays a vital function in the distribution of plants and their girth sizes.

This rearrangement of the four study areas which contradicted their positions of the study areas on the Nigeria Map might not be unconnected with decreasing trend of species density, diversity and latex-producing plants from the south to the north keeping important relationship between Lokoja and Jos study areas on vertical line, while sustaining relationship between Katsina and Minna study areas within the same horizontal line (Abdi and Williams, 2010).

It seems the positioning of these plots ordination diagram were based on the ratio of the total number of individuals to the number of latex- producing plants. Those study areas with low ratios implied high number of latex-producing plants aligned in north-south middle vertical gradient, while those plots with high ratios implied low species density and diversity aligned at east-west horizontal gradient. Another conspicuous reason for this arrangement is that a study area with similar characteristics in terms of type of plants, girth size, climate factors constituted plants in the study area to cluster together forming a group.

The ordination diagrams emphasized further the importance of climatic and vegetation attributes as factors responsible for the differences in plant species that existed in the plots. Latex-producing plants slightly associated with mean annual rainfall, which had influence on percentage relative humidity and mean temperature values. It is not surprising to note that the plots were re-arranged in relation to decreasing density and diversity patterns of plant species including latex-producing plants and the mean annual rainfall from the south to north and from west to east. This

decreasing trend was not unconnected also with decreasing pattern of tropical maritime air-mass to the north and east.

A careful examination of the ordination diagrams for plots and species showed they resemble each other and it was possible to superimpose plot ordination diagram on the species ordination diagram and still a similar trend will be obtained, reflecting the gradient for north-south and east-west trend as seen in plot and species ordinations. The niche of latex-producing plants and high species density were shown by the denser cluster of codes in the Jos location and species ordination diagrams.

There were strong association between latex-producing plants and other plants like Acacia species that have thorns, spines and trichomes, It was thought that, latex-producing plants will easily be injured because of their succulent stem, spongy tissues and waxy cuticles, and that when injured, they would not get healed at a faster rate because of the conserved and abundance water that constitute the make up of the plants. Therefore, it was not out of place, to say latex-producing plants can occur in any of the vegetation belt in Nigeria in association with other plants in both savanna and montane vegetations. The environmental conditions had no noticeable impact on the limitation of the survival and abundance of latex-producing plants in any ecological zones of Northern Nigeria.

Latex-producing plants had xerophytic features like sunken stomata, thick waxy cuticle, succulent stem, thorns, spines or trichomes, spongy tissues for water conservation, extensive root system for water absorption. So, if anthropogenic activities were to be controlled, climatic and edaphic factors had neglegeable effects on the survival of latex-producing plants. This was shown in the ordinations diagrams, latex-producing plants did not associate with any of the biotic and abiotic factors, thus, these plants can flourish in all the study areas.

Based on the aforementioned reasons for the survival of latex-producing plants, these plants could be nursed and sold by youth to the public for their adaptive features and aesthetic value. Examples of

such plants are as follows; *Aloe schweinfurthii, Euphorbia tirucalli, Euphorbia trigona, Euphorbia milli, Euphorbia kamerunica, Euphorbia unispina, Opuntia littoralis, Opuntia lindheimeri, Ficus exasperata, Ficus glomusa and Ficus thonningii*. Some of these plants had been domesticated and being used at home as ornamentals long before now in Nigeria and the world at large because it is of economical value and it is less stressful to keep them as ornamentals, since one does not need to water them in the dry season.

The results obtained from analysis of soil attributes especially soil texture had showed no clear cut difference on the possible relationship between soils attributes, species composition and density of latex-producing plants.

When the values for soil pH and percentage organic matter were compared with those of Nnadi and Balasubramanian (1982), they appeared to be higher, but this can be accounted for by the different methods of soil preparation and analyses. The major difference may be due to pore size of the sieve used in sieving soil samples which were used for the percentage total nitrogen content and percentage organic matter determinations. Some soil scientists prefer using 2.00 mm sieve, while other including (Haase, 1992; Ukpong, 1994) prefer further sieving with 0.5 mm sieve. For this work, 2.0 mm was used.

The percentage nitrogen content for Katsina study area was less and it was different from the percentage nitrogen content values for the other three study areas. The reason might be due to inadequate rainfall, which might have affected nutrient break down in the soil. It was obvious that when rainfall is inadequate, nutrients are tied to partially decaying leaves, hence the nutrient would not be available in the soil, and this is because, before soil analysis was carried out, sieving was done which removed plant remnants and stones.

The low clay and silt content indicates that the soil will be generally be very well drained and very well aerated, pointing to a lower moisture status during the dry periods. This could give rise to xerophytic condition which favoured latex-producing plants.

The soil analysis showed low results for organic matter in Katsina study area. The probable reason might be the high anthropogenic activities such as rearing of animals and inadequate rainfall in the Katsina study area which will not favour recycling of nutrients and fast removal of organic matter via cutting of trees for firewood to survive (Aweto, 1981, Rawson, 1995).

The soils in the four study areas were similar in soil textural class sandy, as a result, this may not account for survival and availability of latex-producing plants in Jos study area only, while they were conspicuously scanty in other study areas.

The result for percentage nitrogen content for Katsina and Jos study areas were low, probable because of inadequate amount of rainfall for microbial activities to hastened recycling of nutrient in Katsina and low temperature values recorded in Jos, this temperature conditions make the microbes passive or inactive in causing decay and the nutrients will be tied to partially decaying plant materials, hence making it not available for plant use (Rawson, 1995).

Sanford *et al* (1982) observed that, although, moisture regime out-weighs edaphic features in influencing overall vegetation type and soil properties, so closely significant are soil moisture and soil nutrients status which extremely affects vegetation and soil at a local level. Therefore, similarly soil textural class and sand/clay ratio as in the four study areas do not give dependable indication that the few measured soil attributes completely explained the disparity in the distribution and abundance of latex-producing plants in the study areas. It was probably, because of this lack of clarity of the effects of soil attributes on the vegetation that Siderius (1974) concluded that, although, certain relationships

may exist between soil and vegetation, a wide range of other factors must be taken into consideration before arriving at a conclusion on soil and vegetation interactions.

Since, the difference in the properties of soil in the study areas was discernable, soil might not be responsible for the greater occurrence of latex-producing plant in the Jos study area and less latex-producing plants in other study areas. The high plateau and the rocky terrain of Jos study area, exposes the vegetation to strong and cold winds, which could be responsible for the low mean temperature value and low relative humidity and this could have resulted in higher species diversity and higher density of latex-producing plants (xerophytes) observed in the area (Smith and Young, 1987). It makes high rocky areas unreachable by man activities and his animals. This might be possible because, any injury inflicted on succulent and spongy tissues of latex-producing plants can easily dry up and besides microbes will not be active to cause more damage to the plant tissues because of low temperature.

In the Jos and Katsina study areas recorded low mean temperature value and low rainfall respectvely, these factors have serious impact on microbial activities, as a result, the performance of microbes will be impeded, Therefore, soil analysis results indicated low percentage organic matter for Katsina and Jos study areas, Minna and Lokoja study areas showed higher percentage because of favourable rainfall and high temperature value which invariably enable microbes to cause decay and subsequent release of nutrients into the soil for plants to use. In a nut shell, when temperatures are low microbial activities were hampered, which also affects most biological functions including crop growth, development in plants. When temperature is at 44^{o}C, microbes are at their best and also plant growth are boostered through cell division, but below 15 ^{o}C microbes are passive (Senioniti *et al*., 1986). Also low temperature plays a vital role in the survival of latex-producing plants on montane vegetation in the sense that when these plants are injured, because of the low temperature on montane vegetation, microbes would be passive not capable of causing decay of the plant part through the

injured spot or kill the plant via the injured spot. If it were to be in the savanna vegeatation were temperatures are high, microbial activities will be enhanced and subsequently the plants will be killed.

From the results obtained and observations made on the field, the possible cause of the distribution of latex-producing plants could be anthropogenic activities. Although, environmental factors were not studied in any detail, the climatic data for these study areas were collected from internet. Nevertheless, some inferences could be made from the few data available. From the ordination, a gradient was observed in a pattern of climate (particularly rainfall) decreasing towards the north from the south. For example, in the ordination of plots, Lokoja study area was to the north, while Jos was to the south. This was not unconnected to the amount of rainfall experienced in the study areas. This pattern was seen contrary to the positions or the locations of these study areas on the Map of Nigeria.

Apart from climate and edaphic factors, there was the possible influence of man in modifying the prevailing environmental factors and ultimately species composition and density. These factors will be discussed even though, they were not directly investigated. The extent of species composition and density observed in the plots studied may therefore be related to the level of humans and other disturbances in the various study areas. According to Walker (1980) human disturbance was the third major factor after rainfall and soil types which give rise to quite different vegetation types under otherwise similar environmental conditions. Human influence was very much marked in Katsina study area where a large area of the vegetation were cut down for firewood and even exported to Chad and Niger Republics, also rearing heavy weighted animals that were capable of damaging plants especially latex-producing plants that were fragile. Followed by Minna study area where the vegetation was devastated by cutting of trees and shrubs for firewood, while Lokoja and Jos study areas had reduced human interference on the vegetation because of the nature of the dense vegetation which harbor tse-tse fly that causes Nagana disease to cattle and the rocky nature of the vegetation respectively.

Close look at the list of species dominance in all the plots that had latex-producing plants confirmed that the existing species were those that were not the favorites of grazers. Some of these plants were preserved on land because of their economic importance to man as food, shade and medicine, for example, *Canarium schweinfurthii, Ficus sur and Ficus exasperata* etc. According to Frost and Robertson (1987) grazing animals may determine the relative abundance of different species in a habitat due to selection between the plants on offer in a pasture, both between species and within species. In the selection process by the grazers, latex-producing plants were normally not eaten because of the latex that oozes out of the plants.

Apart from the afore-mentioned factors that could have affected the distribution of latex-producing plants, mining was a factor in the influences by man, especially in Jos study area. Mining activity in Jos had devastated the land, making it inhabitable for citizens also rendered the place unfit for cultivation of crops for human consumption. Although, no investigation was carried out to ascertain the effect of mining on the composition and density of latex-producing plants but one can opine that, the effect of mining might not have impacted negatively on the species diversity and density on latex-producing plants, this is because, plots that had traces of mining activity still had latex-producing plants but of different girth size and basal area.

Fire is another factor which plays a major role in the vegetation development of any habitat especially the savanna vegetation. The various fire outbreaks in savanna are responsible for the differences in density of plants with un-adaptable parts that are susceptible to yearly fire (Jeltsch *et al.,* 2000; Higgins *et al.,* 2000). The fire outbreak does not reach higher areas that have rocky terrain and have no grasses to serve as fuel for igniting, proper burning and significant impact of the fire.

Walker (1980) observed that fire had become a feature of savanna vegetation through-out evolution and that species had evolved mechanisms to cope with it. Some latex-producing plants do not have the mechanism to withstand the yearly fire, more so, that it takes about a decade before latex-

producing plants get established in the soil. This is the reason why they were most often, seen growing on rocky terrain where fire intensity is highly reduced because grasses or vegetation cover around the rocky environment is also reduced.

Frost and Robertson (1987) said fire is one major catastrophe reliable for repeated hazard which hastens succession and constitutes a stabilizing factor through it limitation of the number of species. As a result, latex-producing plants are unspecialized in terms of environmental requirements. Elements of climate, soil, and human interferences interact, though to varying levels, in creating a niche for it. This conforms to the conclusions of the De-kock (1980) who observed that drought–resistant crops must relatively not fastidious with regard to soil and climate requirement. Therefore, they should be able to adapt to a wide range of soil and climatic conditions.

The poor representation of latex-producing plants in Minna and Katsina Study areas could probably be due to human interference and the time frame for such plants to regenerate from any type of disturbance or injury, determines the dominance of latex-producing plants. Latex-producing plants take up to 9 years to start appearing on a plot during succession, thus, they are not pioneers in a successional setting and at a tender age they are fragile, when injured at that age, they get decayed as a result of microbial activity favoured by high temperature value and low percentage relative humidity (Heinrich and Siegmar, 2002).

Of greatest importance to the continued survival and spread of latex-producing plants is the increasing influence of man on the ecosystem. The activities of man will further lead to large scale destruction of the vegetation with it attendant consequences of erosion hazard in the drier part of Nigeria and it can also lead to accelerated desertification. Thus, with the increase activities of man, latex-producing plants will continue to reduce abundance species composition. When plants are trampled upon by man or his animals, high temperature availability plays a significant role and adequate relative humidity aggreviate the situation by easying decay and death of the plants in the

environment (Rawson, 1995). Conservation programs for these latex-producing plant species must be taken into account to protect latex-producing plants against extinction.

The responses of the inhabitants provided some useful information on the uses of the latex-producing plants. They, however, refused to disclose information, saying that the information they have should be reserved for their future generation and is therefore, not meant for outsiders

From the responses of the inhabitants to the questionnaire administered, it seems that people in the savanna study areas do not know most of the latex-producing plant unlike those on the montane vegetation who responded adequately and positively because they know many of the plants, including the harmful ones.

They added that, these latex–producing plants exhibit xerophytic characteristics, thus, survive in dry habitat and evergreen, as a result, these plants are always in the wild for the inhabitants to use in various ways to better their living.

5.1 Conclusion

- ✓ The measured vegetation attributes include; total number of species, total number of woody species, species diversities, basal area of woody species reflected the general south-north decreasing trend in all the parameters.
- ✓ The above trend follow again the general south – north decreasing trend in some climatic variables such as rainfall, tropical maritime air-mass, relative humidity and also the general south to north increasing trend in solar radiation and temperature intensities.
- ✓ The montane vegetation differed substantially from the savanna study areas in all the vegetation parameters and showed significant increases in these variables.

- ✓ The trend in soil attributes did not differ markedly from south-north in nearly all the study areas considered, implying that soil factors might not have played any prominent role in the distribution of latex-producing plants.

- ✓ The montane vegetation of Jos recorded high value for the latex-producing plants, suggesting that the environmental conditions in the area favoured their greater abundance.

- ✓ Since the montane vegetation was found to be substantially different in the physiographic (tarrain and slope), climatic and biotic factors, the higher abundance of latex-producing plants in these areas can be attributed to them. The ordination analysis brought out these relations more succinctly, suggesting a good correlation between them.

- ✓ From the responses to the questions from the residents of the study areas, it is clear that anthropogenic activities on montane areas are much less than in the savanna areas and this may also explain the observed higher values of latex-producing plants in the montane areas. Also there was a general lack of information on latex-producing plants in the savanna unlike those in the montane areas of Jos, possibly because of their lesser abundance in those areas.

- ✓ Many uses of latex-producing plants were obtained from the study areas, and such uses include: food, medicine, ornamental, fibre, etc.

- ✓ In all, the factors that define the niche of latex-producing plants can be found in the climatic, physiographic and biotic conditions of the areas. The higher elevations and their colder environment as well as their rocky nature make them inaccessible to man, his livestock and even bush fire.

- ✓ Latex-producing plants were found in all the study areas, although their abundances varied significantly, pointing once more to the possible climatic, physiographic and biotic influences.

5.3 Recommendations

- ✓ Taking into cognisance immense uses of latex-producing plants, there is the need to conserve and mange them substantially.
- ✓ This study should elicit greater interest in the study of all aspects of the biology and ecology of latex-producing plants. Specifically, there is need to explore more of their responses and adaptations to their environment, their life histories and phenological characteristics, their diversity and genetic attributes, as well as their ethno-medicinal values.

5.4 Limitations of the Study

The following issues were responsible for limiting the scope of this study:

- ✓ The issue of kidnapping in the southern part and ethno-religious crisis in the north-eastern part of Nigeria.
- ✓ Accessibility to some plots was difficult due to lack of good roads or rocky nature of some of the study areas.
- ✓ Similarity in the successional status of the four study locations could not be guaranteed due to the different intensities of anthropogenic activities and diversities in soil, climate and physiographic factors.
- ✓ Lack of distinct growth rings in the tropical trees makes it impossible to ensure that all the studied plots are in the same successional age.

Defination of Operational Terms (Glossary)

Basal area: Basal area is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at their base.

Biochemistry: The chemical characteristics and reactions of a particular living organism or biological substance (as chlorophyll).

Coagulate: To cause to become viscous or thickened into a coherent mass.

C_3 cycle: this is a common photosynthetic pathway where carbon is fixed by a plant into a three carbon (phosphoglyceric acid) in order to make carbohydrate.

C_4 cycle: is a photosynthetic pathway where desert plant fixed carbon into four carbon compound (Malate or aspartate acid) to maximize energy gain than in normal or common photosynthesis.

Crassulacean acid metabolism (CAM)- Refers to a photosynthetic pathway where desert plants that open their stomata in the night when the transpiration stress is lowest and close in the day to conserve energy.

Cacticeae: A family (Cactaceae, the cactus family) of plants that have succulent stems and branches with scales or spines instead of leaves and are found esp. in dry areas (as deserts).

Carcinogenic: Causing or tending to cause cancer.

Exudation: A substance that oozes out from plant pores.

Euphorbiaceae: A family of plants of the order Geraniales.

Evapo-transpiration: Process where moisture is returned to the air by evaporation from the soil and transpiration by plants.

Emulsion: a colloid in which both phases are liquids.

Flavonoids: Any of a large class of plant pigments having a chemical structure based on or similar to flavones.

Forbs: a boat- leaved herbaceous flowering plant that is not a grass.

Herbivores: Animals that feeds chiefly on grass and other plants.

Harmattan: A dusty wind from the Sahara that blows toward the western coast of Africa during the winter.

Homoterpenoids: Example of volatile organic compound release in response of insect bite on plant.

Hydrophobic nature: lacking affinity for water; tending to repel and not absorb water; tending not to dissolve in or mix with or be wetted by water.

Inflammation: A response of body tissues to injury or irritation; characterized by pain and swelling and redness and heat.

Latex: A milky exudate from certain plants that coagulates on exposure to air.

Laticifers: A plant duct containing latex.

Lipopolyssaccharides: Example of micro-associated molecular pattern that triggered plant cell against defense.

Metabolite: Any substance involved in metabolism (either as a product of metabolism or as necessary for metabolism).

Monocotyledonous: (of a flowering plant) having a single cotyledon in the seed as in grasses and lilies.

Mucilage: A gelatinous sticky substance secreted by plants, use for adhesive.

Morphine: An alkaloid narcotic drug extracted from opium; a powerful, habit-forming narcotic used to relieve pain.

Osmo-regulation: (biology) the homeostatic regulation of osmotic pressure in the body in order to maintain constant water content.

Ordination: Logical or comprehensible arrangement of separate elements.

Ooze: Pass gradually or leak through or as if through small openings.

Photosynthesis: synthesis of chemical compounds with the aid of radiant energy and light, especially formation of carbohydrates from carbon dioxide and a source of hydrogen (as water) in the chlorophyll-containing tissues of plants exposed to light.

Phosphoglyceric acid: either of two isomeric acid phosphates $C_3H_5O_3(OPO_3H_2)$ of glyceric acid that are formed as intermediates in photosynthesis and in carbohydrate metabolism.

Psychedelic effects: Relating to, or being drugs, capable of producing abnormal psychic effects (as hallucinations) and sometimes psychotic states.

Prickles: a fine sharp process or projection, especially a sharp pointed emergence arising from the epidermis or bark of a plant.

Phenolic: Thermosetting resin or plastic made by condensation of a phenol with an aldehyde and used especially for molding and insulating and in coatings and adhesives.

Polyphyletic origin: Relating to, or derived from different ancestral stocks, specifically relating to or being a taxonomic group that includes members (as genera or species) from different ancestral lineages.

Resin: any of various solid or semisolid amorphous fusible flammable natural organic substances that is usually transparent or translucent and yellowish to brown found in plants

Savanna: Term used for grassy vegetation with sparse distribution of trees in tropical or subtropical regions.

Sticky: Able or tending to stick; having the properties of an adhesive.

Succulent: plant adapted to arid conditions and characterized by fleshy water-storing tissues that act as water reservoirs.

Spurges: Any of numerous plants of the genus *Euphorbia*, usually having milky often poisonous juice.

Stipules: Leafy outgrowth at the base of a leaf or its stalk; usually occurring in pairs and soon shed

Sahara: The world's largest desert (3,500,000 square miles) in northern Africa.

Stomata: Minute epidermal pore in a leaf or stem through which gases and water vapour can pass.

Sesquiterpenoids: Example of volatile organic compound released in response to insect bite on a plant.

Tropics: Part of the Earth's surface between the Tropic of Cancer and the Tropic of Capricorn; characterized by a hot climate.

Trichomes: These are leaf hairs or specialized epidermal cells found on the aerial plant that may provide both physical and chemical protection against insect pest.

Terpene: An unsaturated hydrocarbon obtained from plants.

Temperate: (of weather or climate) free from extremes, mild or characteristic of such weather or climate.

Xerophytes: Plant adapted to life with a limited supply of water; compare hydrophyte and mesophyte.

Xeromophism: Having the features of xerophytic plant.

Zonation: Any of the regions of the surface of the earth loosely divided according to latitude or longitude.

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Appendix 1

Plant species and their families encountered during the plant sampling of some vegetation belts in Northern Nigeria

	Plant Species	**Family**	**Common Name**
1	*Acacia ataxacantha D.C.*	Fabaceae	Flame thorn
2	*Acacia ehrenbergiana* Hayne	Fabaceae	Desert acacia
3	*Acacia erythrocalyx* Brenan	Fabaceae	-
4	*Acacia hockii* D. Wild	Fabaceae	-
5	*Acacia kirkii* Oliv.	Fabaceae	Flood plain acacia
6	*Acacia occidentalis* Rose	Fabaceae	Sonoran tree cat claw
7	*Adansonia digitata* L.	Bombacaceae	Baobab
8	*Afzelia africana* Smith ex. Pers	Bombacaceae	African oak
9	*Albizia lebbeck (*L)Benth	Bombacaceae	Woman's tongue
10	*Albizia malacophylla* (A. Rich) Walp	Bombacaceae	Flood plain acacia
11	*Alchornea cordifolia* Schmach &Thonn	Bombacaceae	-
12	*Allophulus africanus* Lam	Sapindaceae	-
13	*Aloe schweinfurthii*	Aloeceae	-
14	*Anacardium occidentale* L	Anacardiaceae	Cashew
15	*Annona senegalensis* Pers.	Annonaceae	African custard apple
16	*Anogeissus leiocarpus* (DC) Guill &Perrs	Combretaceae	African Birch
17	*Asparagus africanus* Lam.	Asparagaceae	Bush asparagus
18	*Azadirachta indica* A. Juss	Myrtaceae	Neem tree
19	*Balanite aegyptica* (L)Del.	Balanitaceae	Soap berry tree
20	*Bombax costatum* Pellg & Vilill	Bombacaceae	Red kapok tree
21	*Borassus aethiopum* Mart	Arecaceae	African fan palm
22	*Boscia angustifolia* A. Rich	Capparaceae	Rough leave shepherd tree
23	*Bridelia ferruginea* Benth.	Euphorbiaceae	-
24	*Bridelia micrantha* (Hochst)Bail	Euphorbiaceae	Mitzeerie
25	*Brillantaisia nites* Lindau	Acanthaceae	Spatula Plant
26	*Canarium schweinfurthii* Engl.	Apocynaceae	Bush candle tree
27	*Capparis fascicularis*	Capparaceae	Zizag capar bush
28	*Carissa edulis* Vahl.	Apocynaceae	Simple Spine num-num
29	*Chromolaena adorata* L. King & Robinson	Compositae	Christmas bush
30	*Chrysophyllum albidum* G.Don	Sapotaceae	white star apple
31	*Cissus araliodes* P. Janch	Ampelidaceae	-
32	*Cissus populna* Guill & pers	Vitaceae	Edible stemmed vine
33	*Cissus quadrangularis* Linn.	Vitaceae	Veld grape
34	*Cleome ciliata* Schum & Thom.	Capparidaceae	Wild mustard
35	*Cletis integrifolia*	Ulmaceae	African nettle tree
36	*Cochlospermum planchonii* Hook F. ex. Planch	Cochlospermaceae	Dye plant
37	*Cola laurifolia* Mast	Sterculiaceae	-
38	*Colocasia esculenta* (Linn.) SColt	Araceae	Elephant ear
39	*Combretum collinum*	Combretaceae	Variable Combretum
40	*Combretum fragrans* F. Hoffm.	Combretaceae	-

41	*Combretum molle* R.Br.ex G. Don.	Combretaceae	Velvet bush willow
42	*Combretum tomentosum* G. Don	Combretaceae	-
43	*Commiphora africana* (A.Rich) Engl	Burseraceae	African myrrh
44	*Cordia sinensis* Lam	Bordginaceae	Grey leaved saucer berry
45	*Crossopteryx fabrifuga* Hutch & Dalz	Rubiaceae	African bark
46	*Cyperus difformis*	Cyparaceae	umbrella sedge
47	*Cyperus eragrostis*	Cyparaceae	Small flower umbrella plant
48	*Daniella oliveri* (Rolf) Hutch & Dalz	Fabaceae	African copia balsam
49	*Delonix regia*	Fabaceae	Flamboyant
50	*Detarium microcarpum* Guill & Perr	Fabaceae	Camel foot
51	*Dialium guineense* Willd	Fabaceae	Velvet tamarind
52	*Dicoma tomentosa C*ass	Asteraceae	Dicoma
53	*Diospyros mespiliformis* Hotcht ex A. Dc	Ebenaceae	Jackel berry
54	*Dombeya quiqueseta* (Planch) Keay	Sterculiaceae	Long horn orchid
55	*Dryopteris filix-mas*	Dryopteridaceae	Fern
56	*Enantia chloranta* Oliv.	Annonaceae	African yellow weed
57	*Erythrina sigmoidea* (Hua)	Fabaceae	Coral tree
58	*Euphorbia heterophylla* L.	Euphorbiaceae	Painted euphorbia
59	*Euphorbia hirta* L.	Euphorbiaceae	Pill-pod sand mat
60	*Euphorbia kamerunica* Pax.	Euphorbiaceae	Cactus
61	*Euphorbia lactea* L	Euphorbiaceae	Mottled spurge
62	*Euphorbia mauritanica* L	Euphorbiaceae	Spurge
63	*Euphorbia milli* L	Euphorbiaceae	Christ thorn
64	*Euphorbia neriifolia* L.	Euphorbiaceae	India spurge tree
65	*Euphorbia tirucalli* L.	Euphorbiaceae	Pencil plant
66	*Euphorbia trigona* L	Euphorbiaceae	African milk Weed
67	*Euphorbia unispina* N.E.Br.	Euphorbiaceae	Candle plant
68	*Fadogia erythrophloea* K. Schum & K. Krause	Rubiaceae	-
69	*Faldherbia albida* Del. Chev.	Fabaceae	Winter thorn
70	*Ficus abutilifolia* (Miq) Miq	Euphorbiaceae	Fig discifera
71	*Ficus aurea*	Euphorbiaceae	Florida strangler fig
72	*Ficus capreifolia* Delile	Euphorbiaceae	River sand paper
73	*Ficus exaperata* Vahl.	Euphorbiaceae	Paper fig
74	*Ficus glumosa* Del.	Moraceae	Mountain rock fig
75	*Ficus platyphylla* Delile	Moraceae	Flake rubber
76	*Ficus sur* Forssik	Moraceae	Broom cluster fig
77	*Ficus sycomorus* (Miq.) C.C.Berg	Moraceae	Sycamor fig
78	*Ficus thonningii* Blume	Moraceae	Common fig
79	*Fimbristylis dichotoma* (L.)Vahl.	Moraceae	Forked fimbry
80	*Garcinia ovalifolia* (Oliv.)	Clusiaceae	-
81	*Gardenia aqualla* Stapf & Hutch	Rubiaceae	Crystal bark
82	*Gloriosa superb* L.	Colchicaceae	Flame liliy
83	*Grewia barteri* Burret	Tiliaceae	-
84	*Grewia flavescens* Juss.	Tiliaceae	Sandpaper raisin
85	*Grewia venusta* Fresen.	Tiliaceae	-

86	*Grewia villosa* Wild	Tiliaceae	Mallow leaved cross berry
87	*Harungana madagascariensis* Lam. Expoir	Guitiferae	Praying hands
88	*Hoslundia opposita* Vahl.	Guitiferae	Bird gooseberry
89	*Hyptis suaveolens* Poit.	Lamiaceae	Bush tea
90	*Ipomea carnea (*Mart. Ex Choisy) D. Austin	Convolvulaceae	Gloria Da La Manana
91	*Ipomoea asarifolia* (Desr.) Roem &Schult	Convolvulaceae	Ginger leaf morning glory
92	*Ipomoea involcrata* P. Beauv.	Convolvulaceae	Morning glory
93	*Ipomoea triloba*	Convolvulaceae	Little bell
94	*Isoberlinia tomentosa*	Fabaceae	-
95	*Keetia venosa* (Oliv) Bridson	Rubiaceae	Raisin fruit
96	*Khaya sensgalensis* (Desr)A.Juss	Meliaceae	African mohagany
97	*Kyllinga erecta*	Cyperaceae	-
98	*Landolphia owariensis* P. Beauv	Apocynaceae	White rubber vine
99	*Lantana camara*	Verbaceae	Bush lantana
100	*Laportea aestuans*	Urticcaceae	Tropical nettle weed
101	*Leptadenia hestata* (Pers.) Decne	Asclepiaceae	-
102	*Lonchocarpus laxiflous*	Fabaceae	Senegal lilac
103	*Lophira lanceolata* Tiegh. Ex Keay	Ochnaceae	Meni oil tree
104	*Luanaceae taraxacifolia*	Asteraceae	Yellow Oleader
105	*Mariscus alternifolius* Vahl.	Cyperaceae	Mariscus
106	*Maytenus senegalensis*	Celastraceae	Red spike thorn
107	*Mimos pudica*	Fabaceae	Sensitive plant
108	*Neocarya macrophylla*	Chrysobalanceae	Ginger bread plum
109	*Opuntia dillenii* Haw.	Cactaceae	Prickly pear
110	*Opuntia lindheimeri* Engelm	Cactaceae	Taxas prickly Pear
111	*Opuntia littoralis (*Engelm.) J.M. Coult.	Cactaceae	Coastal Prickly Pear
112	*Parkia biglobosa* (Jac q.)R.Br.ex G.Don	Fabaceae	Locust bean tree
113	*Paullinia pinnata* L.	Sapindaceae	Bread & cheese
114	*Piliostigma thonningii* (DC) Hoschst	Fabaceae	Monkey bread
115	*Pseudocedrela kotschyi* (Schweinf.) Harms	Fabaceae	Dry zone cedar
116	*Psidium guajava*	Myrtaceae	Guava
117	*Psychotria pshychotriodes* (DC)Roberty	Rubiaceae	-
118	*Ptercarpus erienaceus*	Fabaceae	Senegal rosewood tree
119	*Rhus natalensis* Bernh.ex Krause	Anacardiaceae	Natal rhus
120	*Rytigynia senegalensis* Blume	Rubiaceae	-
121	*Sarcocephalus latifolius (*Smith)Bruce	Rubiaceae	African peach
122	*Securidaca longipedunculata*	Polygalaceae	African violet tree
123	*Senna tora* Linn.	Fabaceae	Sickle senna
124	*Sida rhombifolia*	Malvaceae	Cuban jute
125	*Sporobolus pyramidalis*	Poaceae	Drop seed
126	*Sterculia setigera* Del.	Sterculiaceae	Karaya gum tree
127	*Syzygium guineense (*Willd) D.C.	Myrtaceae	-
128	*Tacca leontopetaloides* (I) Kuntze	Dioscoreaceae	Arrow root
129	*Tamarindus indica* L.	Fabaceae	Tamarind
130	*Tectona grandis* L.F.	Verbenaceae	Teak

131	*Terminalia albida* Scott Alliot	Combretaceae	-
132	*Terminalia glaucescens* Planch ex. Benth	Combretaceae	-
133	*Terminalia mollis*	Combretaceae	-
134	*Terminalia avicennioides* Guill & perr.	Combretaceae	Large leave Terminalia
135	*Urena lobata*	Malvaceae	Caesar weed
136	*Vernonia thomsoniana*	Asteraceae	-
137	*Vitellaria paradoxa* Gaertn F.	Sapotaceae	Shea butter tree
138	*Vitex doniana* Sweet	Verbenaceae	Prune finger leaf
139	*Vitex simplicifolia* Oliv.	Verbenaceae	-
140	*Ziziphus abyssinica* A.Rich	Rhamnaceae	Jujube tree
141	*Ziziphus mauritania* Lam.	Rhamnaceae	India jujube
142	*Ziziphus mucronata* Willd	Rhamnaceae	Buffalo thorn

Appendix 2 Plant sample collected in Minna study area (Southern Guinea Savanna) of Northern Nigeria

	Botanical name	Family	Common Name
1	*Acacia hockii*	Fabaceae	-
2	*Acacia kirkii Oliv.*	Fabaceae	-
3	*Adansonia digitata L.*	Bombacaceae	Baobab
4	*Afzelia africana*	Fabaceae	African oak
5	*Albizia lebbeck (*L)Benth	Fabaceae	Woman's tongue
6	*Albizia malacophylla*	Fabaceae	Flood plain acacia
7	Anacardium occidentale	Anacardiaceae	Cashew
8	*Annona senegalensis* Pers.	Annonaceae	African custard apple
9	*Anogeissus leiocarpus* (DC) Guill &Perrs	Combretaceae	African Birch
10	*Asparagus africanus* Lam.	Asparagaceae	Bush asparagus
11	*Azadirachta indica*	Myrtaceae	Neem tree
12	*Borassus aethiopum*	Arecaceae	African fan palm
13	*Bridelia micrantha* (Hochst)Bail	Euphorbiaceae	Mitzeerie
14	*Carissa edulis* Vahl.	Apocynaceae	Simple Spine num-num
15	Chromoleana ordorata	Poaceae	-
16	*Cissus quadrangularis*	Vitaceae	Veld grape
17	*Cleome ciliata*	Capparidaceae	Wild mustard
18	*Cochlospermum planchonii Hook* F.ex. Planch	Cochlospermaceae	Dry plant
19	*Cola laurifolia*	Sterculiaceae	-
20	*Colocasia esculenta*	Arecaceae	Elephant ear
21	*Combretum molle* R.Br.ex G. Don.	Combretaceae	Velvet bush willow
22	*Combretum tomentosum*	Combretaceae	-
23	*Commiphora africana* (A.Rich)Engl.	Burseraceae	African myrrh
24	*Cordia sinensis Lam*	Bordginaceae	Grey leaved saucer berry
25	*Crossopteryx fabrifuga*	Rubiaceae	African bark
26	*Daniella oliveri*	Fabaceae	African copia balsam
27	*Delonix regia*	Fabaceae	Flamboyant
28	*Diospyros mespiliformis* Hotcht ex A. Dc	Ebenaceae	Jackel berry
29	*Dombeya quiqueseta*	Sterculiaceae	Long horn orchid
30	*Enantia chloranta*	Annonaceae	African yellow weed
31	*Fadogia erythrophloea* K. Schum & K. Krause	Rubiaceae	-
32	*Ficus glumosa*	Moraceae	Mountain rock fig
33	*Ficus sur*	Moraceae	Cape fig
34	*Fimbristylis dichotoma* (L.)Vahl.	Cyperaceae	Forked fimbry
35	Gloria superb.L	Colcohicaceae	-
36	*Grewia flavescens*	Tiliaceae	Sandpaper raisin
37	*Grewia villosa*	Tiliaceae	Mallow leaved cross berry
38	*Ipomoea asarifolia* (Desr.) Roem & Schult	Convolvulaceae	Glory Da la manana

39	*Khaya senegalensis*	Meliaceae	Senegal mohagany
40	*Kyllinga erecta*	Cyperaceae	-
41	*Landolphia owariensis* P. Beauv	Apocynaceae	White rubber vine
42	*Lonchocarpus laxiflous*	Fabaceae	Senegal lilac
43	*Neocarya macrophylla*	Chrysobalaceae	Ginger bread plum
44	*Parkia biglobosa* (Jac q.)R.Br.ex G.Don	Fabaceae	Locust bean tree
45	*Paullinia pinnata*	Sapindaceae	Bread & cheese
46	*Piliostigma thonningii* (DC)Hoschst	Fabaceae	Monkey bread
47	*Psidium guajava*	Myrtaceae	Guava
48	*Ptercarpus erienaceus*	Fabaceae	Senegal rosewood tree
49	*Rhus natalensis* Bernh.ex Krause	Anacardiaceae	Natal rhus
50	*Rytigynia senegalensis*	Rubiaceae	-
51	*Sporobolus pyramidalis*	Poaceae	Drop seed
52	*Tacca leontopetaloides*	Dioscoreaceae	Bat flower
53	*Tamarindus indica L.*	Fabaceae	Tamarind
54	*Terminalia albida* Scott alliot	Combretaceae	-
55	*Vitex doniana*	Verbenaceae	Prune finger leaf
56	*Ziziphus mauritania*	Rhamnaceae	Jujube tree

Appendix 3 Plant sample collected from Minna (Northern Guinea Savanna) of Northern Nigeria

	Botanical Name	Family	Common Name
1	*Adansonia digitata L.*	Bombacaceae	Baobab
2	*Afzelia africana*	Fabaceae	African oak
3	*Albizia lebbeck* (L)Benth	Fabaceae	Woman's tongue
4	*Allophulus africanus*	Sapindaceae	-
5	*Annona senegalensis* Pers.	Annonaceae	African custard apple
6	*Cissus araliodes*	Ampelidaceae	-
7	*Cissus populna*	Vitaceae	Edible stemmed vine
8	*Colocasia esculenta*	Araceae	Elephant ear
9	*Combretum tomentosum* G. Don	Combretaceae	-
10	*Commiphora africana* (A.Rich) Engl	Burseraceae	African myrrh
11	*Crossopteryx febrifuga*	Rubiaceae	Ordeal tree
12	*Cyparus eragrostis*	Cyperaceae	umbrella sedge
13	*Cyperus difformis*	Cyperaceae	Small flower umbrella plant
14	*Detarium microcarpum* Guill & Perr	Fabaceae	Camel foot
15	*Gardenia aqualla* Stapf & Hutch	Rubiaceae	Crystal bark
16	*Grewia barteri*	Tiliaceae	-
17	*Grewia flavescens*	Tiliaceae	Sandpaper raisin
18	*Grewia venusta*	Tiliaceae	-
19	*Hoslundia opposita*	Laminceae	Bird gooseberry
20	*Hyptis suaveolens*	Lamiaceae	Bush tea
21	*Ipomoea asarifolia (Desr.)Roem &Schult*	Convolvulaceae	Ginger leaf morning glory
22	*Ipomoea involcrata*	Convolvulaceae	Morning glory
23	*Khaya senegalensis*	Maliaceae	Senegal mahogany
24	*Lophira lanceolata* Tiegh. Ex Keay	Ochnaceae	Meni oil tree
25	*Mimosa pudica*	Fabaceae	Sensitive plant
26	*Parkia biglobosa* (Jac q.)R.Br.ex G.Don	Fabaceae	Locust bean tree
27	*Piliostigma thonningii* (DC) Hoschst	Fabaceae	Monkey bread
28	*Psychotria pshychotriodes* (DC) Roberty	Rubiaceae	-
29	*Sarcocephyllus latifolius*	Rubiaceae	African peach
30	*Sterculia setigera* (Planch) Keay	Sterculiaceae	Karaya gum tree
31	*Tamarindus indica L.*	Fabaceae	Tamarind
32	*Tectona grandis*	Verbenaceae	Teak
33	*Terminalia albida*	Combretaceae	-
34	*Terminalia avicennoides* Guill & perr.	Combretaceae	-
35	*Terminalia glaucescens*	Combretaceae	-
36	*Urena lobata*	Malvaceae	Caesar weed
37	*Verninia thomsoniana*	Asteraceae	-
38	*Vitellaria paradoxa* Happer	Sapotaceae	Shea butter tree
39	*Ziziphus mucronata*	Rhamnaceae	Buffalo thorn

Appendix 4 Plant sample collected from Katsina (Sudan Savanna) of Northern Nigeria

	Botanical Name	Family	Common Name
1	*Acacia ataxacantha D.C.*	Fabaceae	Flame thorn
2	*Acacia ehrenbergiana*	Fabaceae	Salam
3	*Acacia kirkii* Oliv	Fabaceae	-
4	*Acacia occidentalis Rose*	Fabaceae	Sonoran tree cat claw
5	*Adansonia digitata L.*	Bombacaceae	Baobab
6	*Annona senegalensis*	Annonaceae	African ccustard apple
7	*Anogeissus leiocarpus* (DC) Guill &Perrs	Combretaceae	African Birch
8	*Balanite aegyptica* (L)Del.	Balanitaceae	Soap berry tree
9	*Capparis fascicularis*	Capparaceae	Zizag capar bush
10	*Colocasia esculenta*	Araceae	Elephant ear
11	*Combretum fragrans* F. Hoffm.	Fabaceae	-
12	*Combretum tomentosum*	Fabaceae	-
13	*Detarium microcarpum* Guill & Perr	Fabaceae	Camel foot
14	*Dialium guineense* Willd	Fabaceae	Velvet tamarind
15	*Dicoma tomentosa C*ass	Asteraceae	Dicoma
16	*Diospyros mespiliformis* Hotcht ex A. Dc	Ebenaceae	Jackel berry
17	*Ipomoea asarifolia* (Desr.)Roem &Schult	Convolvulaceae	Ginger leaf morning glory
18	*Isoberlina tomentosa*	Fabaceae	-
19	*Keetia venosa* (Oliv) Bridson	Rubiaceae	Raisin fruit
20	*Piliostigma thonningii* (DC)Hoschst	Fabaceae	Monkey bread
21	*Securidaca longipedunculata*	Polygalaceae	African violet tree
22	*Senna tora*	Fabaceae	Sickle senna
23	*Vitellaria paradoxa*	Sapotaceae	Shea butter tree

Appendix 5 Plant sample collected from Jos (Montane Vegetation) of Northern Nigeria

	Botanical name	Family	Common name
1	*Acacia ehrenbergiana* Hayne	Fabaceae	Desert acacia
2	*Acacia erythrocalyx* Brenan	Fabaceae	-
3	*Acacia kirkii Oliv.*	Fabaceae	Flood plain acacia
4	*Adansonia digitata L.*	Bombacaceae	Baobab
5	*Albizia lebbeck (*L)Benth	Fabaceae	Woman's tongue
6	*Alchornea cordifolia* Schmach &Thonn	Cactaceae	-
7	*Aloe schweinfurthii*	Aloaceae	-
8	*Annona senegalensis Pers.*	Annonaceae	African custard apple
9	*Anogeissus leiocarpus* (DC) Guill &Perrs	Combretaceae	African Birch
10	*Asparagus africanus* Lam.	Asparagaceae	Bush asparagus
11	*Balanite aegyptica* (L)Del.	Balanitaceae	Soap berry tree
12	*Bombax costatum* Pellg&Vilill	Bombacaceae	Red kapok tree
13	*Boscia angustifolia* A. Rich	Capparaceae	Rough leave shepherd tree
14	*Bridelia ferruginea* Benth.	Euphorbiaceae	-
15	*Bridelia micrantha* (Hochst)Baill	Euphorbiaceae	Candelabra micrantha
16	*Brillantaisia nites* Lindau	Acanthaceae	Spatula Plant
17	*Canarium schweinfurthii* Engl.	Apocynaceae	Bush candle tree
18	*Carissa edulis* Vahl.	Apocynaceae	Simple Spined num-num
19	*Chrysophyllum albidum G.Don*	Sapotaceae	white star apple
20	*Cochlospermum Planchonii*	Cochlospermaceae	Dye plant
21	*Combretum collinum*	Combretaceae	Variable Combretum
22	*Combretum glutinosum* Pers.	Combretaceae	Kantakara
23	*Combretum molle* R.Br.ex G. Don.	Combretaceae	Velvet bush willow
24	*Commiphora africana* (A.Rich)Engl	Burseraceae	African myrrh
25	*Detarium microcarpum* Guill & Perr	Fabaceae	Camel foot
26	*Diospyros mespiliformis* Hotcht ex. A. Dc	Ebenaceae	Jackel berry
27	*Dombeya quiqueseta*	Sterculiaceae	-
28	*Dryopteris filix-mas*	Dryopteridaceae	Fern
29	*Erythrina sigmoidea* (Hua)	Fabaceae	Coral tree
30	*Euphorbia cotinifolia L.*	Euphorbiaceae	Red spurge
31	*Euphorbia heterophylla L.*	Euphorbiaceae	Painted euphorbia
32	*Euphorbia hirta L.*	Euphorbiaceae	Pill-pod sand mat
33	*Euphorbia kamerunica* Pax.	Euphorbiaceae	Cactus
34	*Euphorbia lactea L*	Euphorbiaceae	Mottled spurge
35	*Euphorbia mauritanica L*	Euphorbiaceae	Spurge

36	*Euphorbia milli L*	Euphorbiaceae	Christ thorn
37	*Euphorbia neriifolia L.*	Euphorbiaceae	India spurge tree
38	*Euphorbia tirucalli L.*	Euphorbiaceae	Pencil plant
39	*Euphorbia trigona L*	Euphorbiaceae	African milk Weed
40	*Euphorbia unispina* N.E.Br.	Euphorbiaceae	Candle plant
41	*Fadogia erythrophloea* (R.Schum & K. Kruase)	Rubiaceae	-
42	*Faldherbia albida* Del. Chev.	Fabaceae	Winter thorn
43	*Ficus abutilifolia*	Moraceae	Fig discifera
44	*Ficus aurea*	Moraceae	Florida strangler fig
45	*Ficus capreifolia* Delile	Moraceae	River sand paper
46	*Ficus exaperata* Vahl.	Moraceae	Paper fig
47	*Ficus glumosa*	Moraceae	-
48	*Ficus platyphylla* Delile	Moraceae	Flake rubber
49	*Ficus sur* Forssik	Moraceae	Broom cluster fig
50	*Ficus sycomorus* (Miq.) E.C.Berg	Moraceae	Sycamor fig
51	*Ficus thonningii*	Moraceae	Common fig
52	*Garcinia ovalifolia* (Oliv.)	Clusiaceae	-
53	*Gardenia aqualla* Stapf & Hutch	Rubiaceae	-
54	*Gloriosa superb L.*	Colchicaceae	Flame liliy
55	*Harungana madagascariensis*	Clusiaceae	Praying hands
56	*Ipomea carnea (*Mart. Ex Choisy) D. Austin	Convolvulaceae	Gloria Da La Manana
57	*Ipomoea asarifolia* (Desr.) Roem &Schult	Convolvulaceae	Ginger leaf morning glory
58	*Ipomoea triloba*	Convolvulaceae	Little bell
59	*Khaya sensgalensis* (Desr)A.Juss	Meliaceae	African mohagany
60	*Landolphia owariensis* P. Beauv	Apocynaceae	White rubber vine
61	*Lantana camara*	Verbenaceae	Bush lantana
62	*Laportea aestuans*	Urticcaceae	Tropical nettle weed
63	*Leptadenia hestata* (Pers.) Decne	Asclepiaceae	-
64	*Lophira lanceolata* Tiegh. Ex Keay	Ochnaceae	Meni oil tree
65	*Luanaceae taraxacifolia*	Asteraceae	Yellow Oleader
66	*Mariscus alternifolius* Vahl.	Cyparaceae	Mariscus
67	*Maytenus senegalensis (;-*	Celastraceae	Red spike thorn
68	*Opuntia dellenii* (Ker grawl.) Haw.	Euphorbiaceae	Prickly pear
69	*Opuntia lindheimeri* Engelm	Cactaceae	Taxas prickly Pear
70	*Opuntia littoralis (*Engelm.) J.M. Coult.	Cactaceae	Coastal Prickly Pear
71	*Parkia biglobosa* (Jac q.)R.Br.ex G.Don	Fabaceae	Locust bean tree
72	*Piliostigma thonningii* (DC)Hoschst	Fabaceae	Monkey bread
73	*Pseudocedrela kotschyi* (Schweinf.) Harms	Fabaceae	Dry zone cedar
74	*Psidium guajava L.*	Myrtaceae	Guava

75	*Psychotria pshychotriodes* (DC)Roberty	Rubiaceae	-
76	*Rhus natalensis* Bernh.ex Krauss	Anacardiaceae	Natal rhus
77	*Rytigynia senegalensis* Blume	Rubiaceae	-
78	*Sarcocephalus latifolius (*Smith)Bruce	Rubiaceae	African peach
79	*Sida rhombifolia*	Malvaceae	Cuban jute
80	*Sterculia setigera (*Planch)Keay	Sterculiaceae	-
81	*Syzygium guineense (*Willd) DC.	Myrtaceae	-
82	*Tamarindus indica L.*	Fabaceae	Tamarind
83	*Terminalia avicennoides* Guill & perr.	Combretaceae	-
84	*Terminalia glaucescens Planch*	Combretaceae	-
85	*Terminalia mollis*	Combretaceae	Large leave Terminalia
86	*Vitellaria paradoxa* Happer	Sapotaceae	Shea butter tree
87	*Vitex doniana* C.F.Gaertn.	Verbenaceae	Prune finger leaf
88	*Vitex simplicifolia*	Rhamnaceae	-
89	*Ziziphus abyssinica* A.Rich	Rhamnaceae	India jujube

Appendix 6 Climatological data collected from internet on four study areas representing the four vegetation belts in Nigeria.

S/no	Study Area	Temperature Value	Annual Rainfall	Relative Humidity
1	Lokoja	22 -35 ^{o}C	1,100- 1.300 mm	30 - 70%
2	Minna	25-37 ^{o}C	1,000 - 1,200 mm	25 -60 %
3	katsina	26 -40 ^{o}C	600 - 700 mm	13 - 22%
4	Jos	18-22 ^{o}C	1,100 -1,600 mm	26 -51%

Appendix 7 The correlation coefficients of 14 site attributes used for ordination by principal components analysis in the study of latex-producing plants in vegetation belts (Sgs, Ngs, Sds and Mnv) of Nigeria

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	1.000										
II	.846	1.000									
III	-.885	-.655	1.000								
IV	-.472	-.075	.683	1.000							
V	.991	.840	-.906	-.490	1.000						
VI	.430	.070	-.472	-.550	.403	1.000					
VII	.849	.661	-.798	-.550	.827	.447	1.000				
VIII	.259	.179	-.161	.007	.247	-.117	-.026	1.000			
IX	-.078	-.411	-.142	-.483	-.055	.194	.118	-.045	1.000		
X	.237	.425	-.176	.251	.279	-.217	.127	-.118	-.482	1.000	
XI	.495	.611	-.365	.134	.484	.090	.458	-.042	-.421	.671	1.000
XII	.886	.730	-.849	-.545	.923	.296	.733	.223	.068	.364	.440
XIII	-.790	-.565	.676	.602	-.782	-.451	-.527	-.386	-.044	.068	-.195
XIV	.637	.493	-.726	-.452	.669	.147	.708	.050	.313	.285	.359

Appendix 8 The correlation coefficients of 8 site attributes used for ordination by principal components analysis in the study of latex-producing plants in vegetation belts (Sgs, Ngs, Sds and Mnv) of Nigeria

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
Z1	1.000							
Z2	-.117	1.000						
Z3	.194	-.045	1.000					
Z4	-.217	-.118	-.482	1.000				
Z5	.090	-.042	-.421	.671	1.000			
Z6	.296	.223	.068	.364	.440	1.000		
Z7	-.451	-.386	-.044	.068	-.195	-.732	1.000	
Z8	.147	.050	.313	.285	.359	.790	-.280	1.000

Appendix 11 Different steps involving columns in the computation of Shannon Diversity index and Evenness in the 20 plots of the study areas of the vegetation belts of nortnern Nigeria Nigeria.

Plot	Species Total	Natural log.	Proportion of each plot	Shannon Diversity index	Evenness
1	38	3.64	0.076	0.277	0.74
2	26	3.26	0.052	0.169	0.83
3	28	3.33	0.056	0.173	0.81
4	24	3.18	0.048	0.153	0.85
5	23	3.14	0.046	0.144	0.86
6	28	3.33	0.046	0.186	0.81
7	24	3.17	0.048	0.152	0.85
8	29	3.37	0.058	0.195	0.80
9	18	2.89	0.036	0.104	0.93
10	22	3.09	0.044	0.136	0.87
11	13	2.56	0.026	0.067	1.05
12	13	2.56	0.026	0.067	1.05
13	9	2.20	0.018	0.040	1.22
14	9	2.20	0.018	0.040	1.22
15	14	2.64	0.028	0.074	1.02
16	33	3.5	0.066	0.231	0.77
17	36	3.58	0.072	0.258	0.75
18	39	3.66	0.078	0.285	0.74
19	38	3.64	0.076	0.277	0.74
20	35	3.55	0.070	0.249	0.76
	499				

* Natural log. = 2.70 divide by each Nta log of each plot to get evennes