Bangor University

DOCTOR OF PHILOSOPHY

Parkia biglobosa (Jasq.) benth. in Nigeria : a resource assessment.

Oni, Peter I.

Award date:
1997

Awarding institution:
Bangor University

PARKIA BIGLOBOSA (JACQ.) BENTH. IN NIGERIA: A RESOURCE ASSESSMENT

By

ONI, PETER. I.

B.Sc, M.Sc. Crop Production (University of Ibadan) Nigeria.

A thesis submitted in fulfilment for the Philosophiae Doctor in the University of Wales

School of Agricultural and Forest Sciences

University of Wales

Bangor, UK.

February, 1997.

ABSTRACT

Parkia biglobosa, an important indigenous fruit tree of West African Sudanian woodland, was studied with respect to natural population distribution and structure, regeneration, reproductive biology and phytosociology in Nigeria. As relevant background, a comprehensive range-wide monographic account of the species was assembled. An ecological survey covering the range of *Parkia* in Nigeria was undertaken between 1994-1995. The survey involved four ecological zones ranging from derived to Sudan/Sahel zone transition. In each ecological zone there were two sample sites within each of which there were two land use types.

The survey showed that nearest mature con-specific neighbour distance and corresponding stocking for all individuals ≥ 10 cm dbh ranged from 25.5 m and 15 tree ha^{-1} in the north down to 91.5 m and 1 tree ha^{-1} in the south. A gradual increase in stocking from the lowland forest zone boundary to the Sudan savanna was observed. *Parkia* populations are significantly more concentrated in cultivated fields than in less intensively used areas of the bush fallow. Natural regeneration in *Parkia* in Nigeria was sparse overall - 9.80 individuals ha^{-1} and coppice shoot regeneration was the main form. Bush fallow conditions favour more regeneration than intense cultivation, and to the south there is more regeneration than in the north.

Tree morphological appraisal showed that there tended to be taller trees in the south of the Nigerian range (with a moister climate) but with smaller diameter than in the north. A broader crown diameter typified populations in the northern part of Nigeria range compared with the south. Branching height ranged from 1.7 m in the north to 3.9 m in the south. The tree rarely branched below 1 m anywhere. Two was the most frequent number of primary branches. Individuals with more than two primary branches per tree occur more frequently in the north of the range. For all morphological parameters except the number of primary branches a significant land use effect was detected. In the survey 136 associated woody species were recorded. More woody tree species were associated with *Parkia biglobosa* in the south than in the north of its range in Nigeria.

A reproductive cycle of 135 days was observed at Saki, Nigeria. Capitulum abortion rate was more than 30% and not related to the tree diameter or crown position. Capitulum podding efficiency was about 67%. Open pollinated capitula had the highest number of pods per treatment. *Parkia* displays some degree of self-compatibility. Capitula located >5 m above the ground are more likely to be pollinated than those below.

ACKNOWLEDGEMENTS

First and foremost I wish to express my profound appreciation for the overall supervision and guidance of this work by my supervisor, Dr. J. B. Hall. The field work was supervised by Dr (Chief) Olapade, for which I am most grateful. The support and advice received from Dr Ladipo and Dr Soladoye during the field trips are sincerely appreciated. I sincerely thank all staff of Kew Gardens, Natural History Museum and Oxford Herbarium for their valuable support during my various visits.

I similarly appreciate the support from all members of staff of my Institute (FRIN) during the field work for their valuable suggestions, especially the statistics division. The identification of flora was done by Mr Ariwodo throughout the field work and I would like to express my gratitude. I also wish to thank Dr. J. Williams for assisting in the preparation of the distribution map with the aid of GIS package, and likewise Dee Aebischer for French manuscripts translation.

My studies were funded by the Commission of the European Communities, Contract TS3* CT92-0072 through collaborative project with FRIN to whom I express my profound gratitude. I also wish to thank the Co-ordinator of *Parkia* project, Dr. Z. Teklehaimanot who supervised the financial administration along with the University of Wales Finance office.

My heart-felt gratitude goes to Dr H. Tomlinson whose moral support can not be quantified throughout the period of this work. Her useful suggestions and editorial comments at the final stage of this work are sincerely appreciated. Next I wish to thank my wife, for her love and moral support and for taking care of all the family responsibilities while I was away. All members of my family and my in-laws, I am most grateful for your moral support throughout. Finally I wish to thank all who at one time or the other contributed to this study but were not mentioned. Most importantly the Almighty GOD for HIS protection, safety and good health abundantly showered on me throughout the period of this study; Baba God, thank you.

TABLE OF CONTENTS

CHAPTER FOUR: RESULTS 110

LIST OF TABLES

LIST OF FIGURES

Figures

LIST OF PLATES

Plates

CHAPTER ONE

INTRODUCTION

Parkia biglobosa (Jacq.) Benth, named after Mungo Park by Robert Brown (1826) has long been widely recognised as an important indigenous fruit tree. In anglophone West Africa is commonly known as the locust bean tree and in francophone countries as néré. It is prominent in the Sudanian woodlands of West Africa from Senegal eastwards to Uganda. As a result of age-long association with traditional agriculture and diverse usage, it has attained protective status in many traditional agricultural systems (Keay, 1955; Hagos, 1962; Hopkins, 1983; Cline-Cole *et al.*, 1988). *Parkia biglobosa* is a deciduous tree with a large spreading crown, which produce indehiscent pods, containing edible seeds (Keay, 1955, Irvine, 1962, Hopkins, 1983). The seeds commonly referred to as beans are the most valuable product of the species.

The tree tops the list of acceptable indigenous multipurpose trees identified by farmers in Nigeria (Awodola & Okoro, 1993), and was recently ranked highest of a list of eighteen traded edible forest products in Mali (Gakou *et al.*, 1995). El-Hadji (1985) in Sudan and FAO (1989) in Nigeria indicate its roles as a food buffer and a reliable income source in drought periods, a view supported by the recent work of Teklehaimanot *et al.* (1996) and Gakou *et al.* (1995) in both Burkina Faso, Nigeria and Mali. An array of multipurpose uses has been reported, including food, medicine, manure, gum, tannin, shade, wind-break, bee food, stabilisation of degraded environmental, livestock feed, fuel, fibre, fish poison and several other domestic uses (Keay, 1955; Irvine, 1961; Campbell-Platt, 1980, Kater *et al.*, 1992, Kessler *et al.*, 1992; Hopkins, 1983). According to FAO (1988b), the demand for the seed merits the establishment of plantations in a significant proportion of its range. *Parkia's* adaptation to its natural environment makes it more drought tolerant than many of the exotics grown as alternative tree resources (Oladele *et al.*, 1985; Osonubi & Fasheun, 1987; Ladipo *et al.*, 1990; Otegbeye, 1995).

Despite the significant potential benefits, conscious effort has been made towards organised resource management only within the last two decades, largely prompted by woodland disappearance in the region due to the extended drought of 1968-1973 (Nichol, 1989; Baumer, 1990b). Despite this interest *Parkia,* like many other indigenous savanna fruit trees providing economic benefits is undergoing genetic depletion as population of the species suffers from increasing demographic pressure on land, uncontrolled bush burning, deforestation and extensive cattle grazing (Pullan, 1977; Kio *et al.*, 1985; Kessler, 1992). There is continually increasing demand for fuel-wood energy, especially in Nigeria but also in other parts of West Africa. According to Baumer (1990) 700 g of dry wood per head is burnt every day in the rural areas of Senegal and in West Africa generally fuel wood supply is satisfactory in only five countries (Baumer, 1990a, 1990b).

Degradation of farmed parklands in West Africa is on the increase in terms of decreasing mother trees and the absence of both seedlings and saplings in the parklands (Gijsbers *et al.*, 1994). There is increasing permanent cultivation, but quantitative data on this trend are inadequate (Pullan, 1974; Raison, 1988; Kessler & Boni, 1991; Gijsbers *et al.*, 1994). Approaches in Burkina Faso (Ouagadougou) have indicated the relative scarcity of the smaller diameter classes of *P. biglobosa* and the development of abundant shrubs forming stands in areas formerly occupied by tree species (Le-Houèrou, 1980; Gisjbers, 1994). In Senegal, *P. biglobosa* has all but disappeared in areas within the rainfall range of 400-800 mm, where there were previously close stands (El-Hadji, 1985). Sustainable in-situ conservation and management of this important tree as a future rural resource requires information on the current state of the mother tree populations.

With increasing awareness of the need for a sustainable environment, improved agricultural output and genetic conservation's of the remaining non-timber tree species of economic importance, programmes to conserve and improve *Parkia biglobosa* have been launched in several West African range countries (Okafor; 1980; Ladipo *et al.*, 1990). In Nigeria, provenance collections and screening of fruit trees important for future resource management involves various units of the government sector (Okafor, 1978, FRIN, 1983, Sabiiti & Cobbina, 1992b). Similar initiatives have also been reported for Benin, Gambia and Burkina Faso (Forster, 1983; Agbahungba and Depommier, 1989; Nikiema, 1993). As part of this drive selected indigenous woody species and some exotics (*Leucaena leucocephala* (Lam.) De Wit, *Gliricidia sepium* (Jacq) Walp, and *Senna siamea* (Lam.) Irwin & Barneby) have been tested in alley farming (on station and in field situations) initiatives (Sabiiti & Cobbina, 1992b). Recently, Ezenwa and Alasiri (1991) and Fagbemi. (1994) reported results of field trials on *P biglobosa's* compatibility with cereals intercrop while, improved propagation techniques have been developed for early seedlings establishment (Okafor, 1978; Agbahungba and Depommier, 1989; Teklehaimanot *et al.*, 1996).

At the national level in Nigeria, a collaborative research programme was initiated between the Commonwealth Science Council and the Forestry Research Institute of Nigeria (FRIN, 1986) into gene resources conservation of *Parkia* (Kio, *et al.*, 1985; Ladipo *et al*, 1990). However, the ex-situ conservation activity proved expensive, and stored seed vulnerable to power supply disruption. At the international level, in recognition of the species' importance, *Parkia biglobosa* was added to the Forest Genetic Resources Priority List of the FAO Panel of Experts on Forest Genetic Resources at their 4th meeting. The species was rated a priority for industrial wood and food sources for genecological exploration, provenance trials, utilisation and conservation (FAO, 1988a).

The current interest in in-situ conservation and management of *Parkia* fruit tree has drawn attention to a need for updated information on the reproductive process. To better understand the genetic value of this species and to aid germplasm collection and improvement, there is a need to understand the phenology, including the breeding system (Ladipo *et al.*, 1990). A useful foundation for research in the field of reproductive biology exist. Baker & Harris (1957); Harris and Baker (1959) described pollination and drawn inferences about the breeding systems, highlighting the roles of bats, but taxonomic disagreements have introduced doubts about how widely their findings apply. Hagos (1962) attempted to resolve these, but they persisted until Hopkins (1983) undertook a comprehensive study of the genus as a whole throughout Africa. Nevertheless, even after the work of Hopkins, additional information is still required on the aspects of reproduction, phenology and ecology.

Land use systems vary greatly throughout the range of *Parkia biglobosa* but basically intensive cultivation and bush fallow systems dominate (Babour *et al.*, 1984). In the savanna woodlands where *Parkia biglobosa* is frequent, bush fires form the major weapon of land clearance for cultivation. The situation is progressively changing, the intensity of cultivation and fallow periods have shortening and already are less than five years. In this changing ecological situation (in terms of distribution, regeneration and phytosociological relationships) in-situ conservation of germplasm of *Parkia biglobosa* requires monitoring programmes and provision for restorative intervention. The land use systems in relation to status of *Parkia biglobosa* is considered in this study.

In most of the range, naturally regenerated seedlings remain the principal replacement of *P biglobosa* mother trees, but as these seeds are sought by both the local people and livestock (Fatubarin 1987; Nikiema, 1993), an insufficient quantity remains on the forest floor to rejuvenate ageing populations. Deliberate planting is generally negligible at both farmers level and in government-owned range lands (Adesina 1994; Popoola & Maisanu, 1995). According to Kessler (1992) farmers believe that planting of

P.biglobosa is like tending another crop, the benefit which they cannot immediately appreciate. The regeneration problem is further aggravated by the fact that *Parkia* seeds do not readily germinate compared with those of other savanna species such as *Vitellaria paradoxa* (Etejere *et al.*, 1982). Seed supply has been decreasing despite the intensity of collection, leading to a price upsurge of the processed beans (Kio *et al.*, 1985). According to Kessler (1992), under intensive cultivation, seedlings regeneration no longer get a chance to establish because of complete vegetation clearance and sometimes mechanisation.

In the light of the foregoing, this study of *Parkia biglobosa* has the following major objectives:

- to provide an authoritative and integrated review of available information on the ecology of *Parkia biglobosa* in Nigeria.

- to assess the population distribution and structure under two land use systems, in the species range in Nigeria.

- to investigate the present level of natural regeneration and the impact of land use systems on the current regeneration status in Nigeria.

- to assess the fruiting efficiency, through preliminary breeding work, by pollination experiments.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, available information on the species taxonomy, biology, ecology, husbandry, silvicultural potential, resource role and wood properties is assembled. The first section (2.1) covers the taxonomy, systematics and description of the species. The second section (2.2) outlines the biology with reference to chromosome number, phenology, reproductive biology, dispersal and disease susceptibility. Section 2.3 treats the ecology of the species range-wide, and the next section (2.4) examines husbandry and management. The penultimate section (2.5) is concerned with the silvicultural potential, and the last section (2.6) collates available reports on the resource role, general economic importance and wood properties. All sections are sub-divided as appropriate.

2.1 The species

2.1.1 Nomenclatural history; synonyms and misapplications.

The specific epithet, *biglobosa,* is the correct name for the important and widely distributed African savanna species of *Parkia*. The oldest written record of this species can be traced back to the account of Adanson (1757) (Busson, 1965). Caillié (1819-1828) also described the fruits as very nourishing and of great use to the travellers (Jacques Félix, 1963; Busson, 1965).

The botanical history of the genus *Parkia* dates back to the illustration of a specimen by Jacquin (1763) supporting a circumscription of what is called *Mimosa biglobosa*, It is based on a plant cultivated in Martinique, West Indies, but presumed to have been introduced from West Africa (Bentham, 1875; Hagos, 1962; Hopkins, 1983) (Table 2.1). However unfortunately there is no record of that specimen being preserved.

Twenty years later Persoon (1783) applied the name *Mimosa taxifolia*, to a specimen since destroyed or lost in the herbarium of Antoine Laurent de Jussieu, but published a formal description was only published after another 24 years (1807).

In 1799, Mungo Park included a brief reference to the species in his journal, under the vernacular name "nitta" from what is now the Guinea/Mali border area. In the next stage, attention returned to Jacquin's plant and its generic placement in 1806, Willdenow made the transfer from *Mimosa* to *Inga*, as *Inga biglobosa*. Soon after, in 1816 Palisot de Beauvois extended the use of the Jacquin epithet to Nigerian plants, but unfortunately a specimen of a different species, today's as *P. bicolor*, and confused later workers by publishing a poor description and an illustration mixing features from both species (Beauvois, 1816). Further independent development took place in the West Indies. In 1824, Hamilton drew up a brief description of a plant which he referred to as a new species of *Inga*, *Inga faeculifera*, utilising a name originally attributable to Nicaise-Auguste Desvaux (Hopkins, 1983). In parallel, *Inga* was also the generic placement favoured for West African plants. De Candolle cites the name *Inga senegalensis* (Candolle, 1825) as a revised name for the material Persoon called *Mimosa taxifolia*. Another change in generic name followed when Desvaux (1826) transferred the plants he had called *Inga faeculifera* to *Prosopis*, as *Prosopis faeculifera*.

The foundation of the current taxonomy originated in 1826 with Robert Brown. Brown was responsible for describing the plants of the Denham-Oudeney-Clapperton-Expedition 1822-4, among which was Clapperton's specimen of *Parkia biglobosa* from Bornu, Nigeria. Brown realised the likelihood of several older names being applied to a single species and that a new generic placement would be appropriate. He suggested that *Inga biglobosa*, *Inga senegalensis* and *Inga taxifolia* were all the same, and that reference to "nitta" trees in the dairies of Mungo Park written in 1797 (Park 1797) were to this species too. Accordingly he named the genus *Parkia* after Mungo Park, but introduced a new species epithet 'africana', later to fuel much nomenclatural debate

(Keay, 1955; Hagos, 1962; Hopkins, 1983). At the time, however, the name adopted was *Parkia biglobosa* formally published by George Don in Bentham, 1875.

The next developments were of further collections of *Parkia* and reduction of further old names to synonyms. Confusion still continued, however. Four years later, George Don (Loudon, 1830) described an additional species as *P. uniglobosa*, only for it to be sunk into *P. biglobosa* by Bentham in 1875. Earlier in 1842 Bentham had introduced the combination *Parkia biglobosa* for Asian as well as African plants (Bentham, 1842). Oliver (1871) applies the name *P. biglobosa* to West African plants explicitly giving *P. africana* as a synonym, but, like Bentham (1842), extends the circumscription to Asian material. In addition, Oliver introduced *intermedia* as an epithet in *Parkia* to refer to a specimen (Mann 1099, K) collected by Gustav Mann on Saò Tomé.

In 1875, Bentham finally separated the Asian and African material, using the name *P. africana* for the latter and reducing *Inga faeculifera*, *Prosopis faeculifera* and *P uniglobosa* to synonyms under this name. He divided the Asian material among two species: *P. biglandulosa* and *P. roxburghii.* Entering the present century, Chevalier (1910) reported the occurrence of Oliver's *P. intermedia* on the mainland as well as well as Saó Tomé, also recognising *P. biglobosa.* Like his predecessors, Chevalier had overlooked the view of a western *P biglobosa* and a separate eastern species of West African savanna and *Parkia intermedia* was adopted. But in 1919 Macbride replaced the name *P. intermedia with P. oliveri*, retaining Mann 1099K as the type specimen (Macbride, 1919). One further name was to be introduced when Baker (1930), established s.n (BM) from Kete Krachi in Ghana as the type of a new subspecies of *P. filicoidea* (subsp. *glauca*).

After the second World War, in-depth studies of African *Parkia* were undertaken as the regional West African flora was revised. In this process, for the easternmost species, Keay (1955) introduced the name *P. clappertoniana* to replace *P. africana*, arguing that Brown's use of *africana* contravened the code for botanical nomenclature because valid epithets already existed and some of the descriptions derived from material explicitly associated with these (Keay, 1955). Exell (1956) kept *P oliveri* as a distinct species, but unlike Chevalier (1910), regarded it as strictly endemic to Saò Tomé (Exell, 1956). Keay (1958) in the standard regional flora recognised *P. biglobosa*, *P. clappertoniana* and (by implication) *P. oliveri* as separate species but reduced Baker's *P. filicoidea* subsp. *glauca* to synonymy under *P. clappertoniana* (Hutchinson & Dalziel, 1954). Justus Hasskarl's use of *intermedia* for another species in 1844 (Oliver, 1871). Hagos (1962) rejects Keay's case for replacing the epithet *africana* with *clappertoniana* and restores the former, at the same time extending the range west to the coast of Senegal. Hagos still recognised *P. biglobosa* as a separate species. Finally Hopkins (1983) united *P. africana/clappertoniana* and *P. biglobosa* as one species under *P. biglobosa*, the older name. Hopkins views are followed here. The complex nomenclatural chronology is summarised in Table 2.1.

Table 2.1 *Parkia biglobosa*: chronology of nomenclature, synonyms and other combinations involving the specific epithet *biglobosa*

Year	Authority	Remarks
1763	Jacquin	*Mimosa biglobosa,* described in (Martinique), West Indies. Original description not associated with any known herbarium specimen.
1797	Mungo Park	Records species as "nitta'', a local name.
1806	Willdenow	*Inga biglobosa,* new generic placement.
1807	Persoon	*Mimosa taxifolia,* described further still. a Senegal plant. No link with Jacquin or Willdenow names percieved.
1806	Palisot-de Beauvois	Applied I*nga biglobosa,* for illustration based on specimen of *P bicolor* and the Jacquin desciption.
1824	Desvaux	name *Inga faeculifera* coined. No link with Jacquins or Persoon material perceived
1825	Hamilton	*Inga faeculifera,* formerly described, under Desvaux's epithet.
1825	De Candolle	*Inga senegalensis* :new generic placement and a new specific epithet for Persoon material
1826	Desvaux	*Prosopis faeculifera* : a new generic placement for the Desvaux specimen.
1826	Robert Brown	Genus *Parkia* established. and specific epithet *africana* introduced. Suggested that *Inga biglobosa* , *I senegalensi*s and *Mimosa taxifolia* were synomyms
1830	G. Don	*Parkia uniglobosa,* combination *Parkia biglobosa* formally published; described.
1842	G. Bentham	*Parkia biglobosa,* circumcribed broadly as African and Asian.
1783	Persoon	Coins name *Mimosa taxifolia* for a specimen since lost.. Not aware of similarity with Jacquin plant.
1871	Oliver	Describes *P. intermedia,* as Sao Tomé endemic, treats *P biglobosa* as synonyms.
1875	Bentham	Revises circumcripton of African plants *Parkia* material with *P biglobosa, P uniglobosa* and *Prosopis faeculifera* as synonyms
1910	Chevalier	Revises use of the name *P biglobosa,* extends range of *P. intermedia* to mainland Africa.
1919	Macbride	Points out use of *P intermedia* for African plants is invalid , introduces *P oliveri* as valid alternative.

1930	Baker	describes *P filicoidea* subsp. *glauca* from Ghana.
1955	Keay	argues that the name *P africana is* invalid and published *P. clappertoniana* as replacement.
1958	Keay	reduces *P filicoidea* subsp *glauca to* synonym under *P clappertoniana.*
1962	Hagos	Replaces name *P clappertoniana* ,with *P africana* retaining *P biglobosa* as a separate species; reduces *P oliveri* to synonym under the *P africana* .
1983	Hopkins	Unites *P biglobosa* and *P africana/clappertoniana* as one species with *P. africana* and *P. clappertoniana* treated as synonyms.

2.1.2 Systematic position

2.1.2.1 The Tribe *Parkieae*

When Brown first described *Parkia,* he concluded that it was a legume in the tribe Mimosoidea displaying a character (imbricate calyx aestivation) suggesting affinity with the Caesalpinioideae (Hopkins, 1986). A few years later the sub tribe *Parkia* was created by Robert Wright & George Arnott (1834) to separate it from all other genera of tribe Mimoseae, which Wright & Arnott referred to subtribe *Acaciae.* As more mimosoid legumes were described, a more complex systematy has developed with *Parkiae* raised to tribal rank, reorganized to accommodate *Parkia* and *Pentaclethra.* In the past, *Erythropleum* and *Dinizia* have been included at times. Modern thinking is reflected by the view of Elias (1981). There are five tribes of legumes (Figure 2.1).

Parkieae is distinguished from the other tribes by imbricate sepals which are united. It consists of only two genera: *Pentaclethra* with (two species) and *Parkia* with about 35 species. According to Elias (1981), the principal character linking the two genera is the imbricate aestivation of the sepals; otherwise the two have little in common and Hopkins (1986) questions whether the two genera are closely related. The two genera are separated from each other by *Pentaclethra* having monomorphic bisexual

MISSING PAGE REMOVED ON INSTRUCTION FROM THE UNIVERSITY

2.1.2.2 The genus *Parkia*

The genus *Parkia* is pantropical, distributed in tropical Africa (four species), the Newtropics (10 species) Asia (10-15 species) and the East Indies (four to five species) Hopkins, 1983, 1986). It consists of about 35 species (Hopkins, 1983) divided among three sections. Separation of section within the genus has been revised by Hopkins (1986). Section *Parkia* is distinguished from the other sections by the presence of neuter staminodal flowers at the base (proximal end) of the inflorescence: such flowers are lacking in *Platyparkia* and *Sphaeroparkia.* The last two sections are separated from each other on the basis of whether the inflorescence are pendent in *Platyparkia* but not in *Sphaeroparkia*) and whether the flowers within an inflorescence display similar sexuality (basal fertile flowers and apical modified nectar-secreting flowers in *Platyparkia*) but all flowers are fertile in *Sphaeroparkia.* Chevalier (1910) stated that in reality, a chain of species occur, the separation of which is difficult on the shared border of their ranges.

Chevalier (1910) suggested division of what today is section *Parkia* (then calling this ''section *Euparkia*'') into subgenera, but for only three of the species accepted today. *Parkia biglobosa* and *P filicoidea* are referable to subgenus *Euparkia* because the endocarp completely fills the gap between the seeds within each pod. In *P. bicolor*, however, gaps are not completely filled by the endocarp until the seeds mature and reappear as they ripen. This feature was the criterion for assignment in a separate subgenus, *Parkopsis.* As the seeds of *P madagascarensis* are unknown, the placement of this species according to Chavlier's subgenera is not possible and Hopkins (1983) concludes that there is no justification for referring the African species to subgenera.

Table 2.2 Summary of differences which separate the African species.

Characters	*bicolor*	*biglobosa*	*filicoidea*	*madagascarensis*
Pairs of pinnae	10-25	up to 17	4-12	7-22
Disposition and pairs of leaflets per pinna	opposite 20-25	usually subopposite 13-70	opposite to subopposite 13-32	opposite to alternate ; number of pairs not reported
Leaflets	5-15 mm long, 1-2.5 mm wide; main nerve usually sigmoid	8-30 mm long , 1.5-10 mm wide; straight main nerve	14-35 mm long, 3.5-13 mm wide; straight or sigmoid main nerve	5-11 mm long, 2-2.5 mm wide; sigmoid main nerve.
Primary rhachis	pubescence, ferruginous; no awn	pubescence greyish; caducous awn	pubescence ferruginous or absent; no awn	not reported
Petiolar gland	single, elliptical, slightly above petiole base	single orbicula at petiole base	double or 2 lobed between petiole base and first pair of pinnae	single, ellipitical between petiole base and first pair of pinnae
Fertile flowers	corolla 8-12.5 m long; corolla lobes > 0.5 total corolla length	corolla lobes 10-17 mm long corolla lobes <0.3 total corolla length	corolla 12-20 mm long; corolla lobes >0.5 total length	corolla 10-14 long; corolla lobes <0.3 total corolla length
Basal flowers	filaments of basal flowers far exserted	filaments of basal flowers not or only slightly exsterted	filaments of basal flowers not or only slightly exserted	character uncertain
Basal part of capitulum, with exserted filaments	ca 40 mm diameter	*ca* 15-20 cm diameter	constricted, *ca* 15 mm diameter	apparently constricted, *ca* 15 mm diameter
Capitulum colour	Pinkish red to yellow	deep bright red	bright red to creamy white	unknown
Pods	growing to 250-450 mm long including stipe , 115-35 mm broad ; flattened usually not constricted between seeds surface over seeds shallowly corrugated	growing to 150- 300 mm long including stipe, s15-25 mm broad terete, not constricted between seeds; surface over seeds ± smooth	growing to 250-800 mm long including stipe 15-35 mm broad; flattened constricted or not between seeds flat and smooth or shallowly corrugated	50-90 mm broad flattened; surface reticulate
Seeds form and maturity	ovoid, 11-15 mm x 7-10 mm	somewhat flattened 12 mm x 8-10 mm x 4-5 mm	somewhat flattened 16-25 mm x 7-9 mm	not reported
Testa	smooth and without pleurogram; detached from cotyledons	with ovate pleurogram, otherwise smooth; tightly enclosing cotyledons	wrinkled and without pleurogram; detached from cotyledons	not reported
Cotyledons	smooth or wrinkled, olive-green	smooth, whitish or yellowish	smooth or wrinkled olive-green	not reported

Key to African/Malagasy species of *Parkia*

1 Corolla lobes of fertile flowers > 0.5 total corolla length:

2 Petiolar gland single and elliptical; filaments of basal flowers far exserted: *P. bicolor*

2 Petiolar gland two-lobed or double; filaments of basal flowers not exserted or only slightly exserted *P. filicoidea*

1 Corolla lobes of fertile flowers <0.3 total corolla length:

3 Petiolar gland single and orbicular, located at base of petiole; main nerve of leaflet straight *P. biglobosa*

3 Petiolar gland single and elliptical, located between base of petiole and insertions of first pair of pinnae; main nerve of leaflet sigmoid *P madagascarensis*

2.2 DESCRIPTION

2.2.1 Seedling

Germination is prominently described as cryptogeal by Hopkins (1986; 1989) Upon germination, the cylindrical, glabrous testa splits open, remaining partially to the cotyledon. The seedling is phanerocotylar, with pinnate eophylls (Polhill & Raven 1981) the minutely puberulous hypocotyl pushes the cotyledons, still within the testa, only to soil level. The epicotyl is 7-11 cm long and bears scale leaves. The cotyledon is thick, fleshy pale-green and from 1.3-1.8 mm long by 0.8-1.2 mm wide, acting as the principal storage organ (Hopkins, 1983). It persists until the first set of true leave expand. These are opposite and bi-pinnate. Subsequent leaves are alternate.

2.2.2 Mature tree

Habit, size and form.

Reported heights for mature individuals of *Parkia biglobosa* usually fall within the range 10-20 m. However, the species is present in widely differing habitats and in seasonally stressful sites of shallow soils with little water holding capacity and at these low rainfall limits of the range it may reach only 7 m (Hopkins, 1983). Unusually tall individuals occur in some areas e.g. patches of ancient dry forest in Senegal (Hopkins, 1983) and in southern Nigeria (Okpala, 1989). Hagos (1962) and Okpala (1989) both state a maximum height of 30 m.

Old individuals may be 1-1.5 m diameter at breast height and the bole being short, usually less than 4 m and rarely of good form. The bark is thick and fibrous with distinct scales of dark brown or greyish colour separated by deep fissures. The blaze is reddish brown (Irvine, 1961; Maydell, 1986) and exudes amber coloured gum.

The crown is very wide in large vigorous individuals, extending as much as 8-10 m outward from the bole (Ouédraogo, 1992). At young stages the branching is more erect and the crown generally more compact. But as the tree ages, the foliage progressively becomes more discontinuous within the crown as major branches die and are not replaced, leading to stag-headed old individuals. The sequence of crown development has been described in detail by (Ouédraogo, 1992).

The mixed axes do not show inherent dorsi-ventral organisation throughout the sequence of differentation. Phyllothaxy is spiral from the juvenile to the mature stage. In some cases the petioles on the distal branches are twisted so that the leaves lie in the same plane. Some trees show anisophilly, resulting in the tendency to a dorsi-ventral arrangement, but this secondary plagiotrophy (Hallé *et al.*, 1978) is not shown systematically. In addition to the reiterative growth of the mixed axes, by which the trunk and branches are formed by the proximal and distal parts of the axes, *Parkia* also exhibits branching from the lateral meristems.

Large roots spreading beyond the crown are features of large individuals and often reach 10 m (Maydell, 1986) and exceptionally 20 m in length (H. Tomlinson,. pers. comm.) There are also vertical roots.

Foliage

In fully mature *Parkia* leaves, the lamina of the leaflet is dark green, but flushing leaves are sometimes pinkish or yellowish green (Maydell, 1986). The pinnae are alternate or subopposite and are often swollen at the base, arranged in up to 17 pairs along a leaf rhachis, 30-40 cm long. with a caducous apical awn. The petiole (the distal end of the rhachis) is 9-10 cm long, and slightly ribbed, bearing a single orbicular gland at the base (Hagos, 1962; Hopkins, 1983). There are 14-30 pairs of leaflets on each side of the rhachis of each pinna, usually in a subopposite arrangements. The individual leaflets are glabrous, linear-oblong, obliquely pointed or rounded at the apex, and usually with more or less parallel margins. At the base they are asymmetrical being obtusely subauriculate with a small triangular flap on the lower margin. The size varies, the length ranging from 8-30 mm within pinnae, the middle leaflets are longer and larger than the terminal and basal leaflets, especially in young trees and coppice stems (Maydell, 1986, Keay, 1989). There is also variation from west to east of the range, in the form of a gradual and continuous increase in size which Hopkins (1983) regards as clinal.

Inflorescence, flowers and flower buds

The most distinctive feature of *P. biglobosa* is the bright red capitula when the flowers are open and fresh (Berhaut, 1967; Chapman, 1970). The capitula are in form of pendulous heads, each at the end of a long stalk peduncle and are mostly at the periphery of the crown but sometimes within the crown if it is fairly open (Baker & Harris, 1957; Hopkins, 1983). The main inflorescence axis is unbranched and terminal or axillary from a shoot of the previous year. The capitula are organised into compound inflorescence racemes of about 10 capitula on alternate peduncles. Each capitulum is about 4.5-7.0 cm long and 2.5-6 cm in diameter (Hopkins, 1983).

Developing capitula are protected by a ring of orbicular bracts inserted at the base which are abscised as the bud enlarges (Hopkins, 1983). Bracts are free or connate, shed separately or together and are circum sessile at the base. Capitula buds are initially spherical but become clavate or pyriform later (Hopkins, 1983). In colour they appear brown and are densely pubescent showing a rhomboidal pattern from the overlapping apices of the bracts subtending the individual flowers.

In the capitulum, the larger distal upper globose part, consists of bisexual (hermaphrodite) flowers and the smaller proximal part consists of male flowers and neuter flowers. A nectar ring where nectar from some of the male flowers accumulates is present between the proximal and distal parts of the capitulum,. occurring at the top of the fertile part of the capitulum as a depression. Here there is an abrupt change to the nectar flowers. Staminodial flowers are present at the proximal end of the capitulum. The number of individual flowers types are indicated (Table 2.3).

MISSING PAGE REMOVED ON INSTRUCTION FROM THE UNIVERSITY

Pod and seed

Parkia fruits are pods hanging in clusters or bunches, at the end of the club shaped fruit base. Pod numbers per peduncle/head usually range from 1-20 but there are rarely up to 25 (Baker & Harris, 1957; Ladipo *et al.*, 1990, Hopkins, 1983). The pod is thick, indehiscent and fleshy, light to dark green in colour (while immature) later changing to light/pink brown and finally to dark brown or grey as it matures but never black (Aubreville, 1950; Bonkoungou, 1987; Hopkins, 1983; Chowdhury *et al.*, 1984; Some *et al.*, 1992). Within a cluster they are usually identical, but vary from tree to tree-from 10-30 cm in length and from 1.5-2.7 cm in breadth (Keay, 1989; Irvine, 1962). The form is linear, straight, falcate terete or elliptic in cross section and unconstricted between seeds, and there is a short stipe (Hopkins, 1983).

The two indehiscent valves enclose the mesocarp (a mealy yellow pulp) which is sweet tasting and edible, surrounding and clinging to each seed, except in the area bounded by pleurogram (Hopkins, 1983; Some *et al.*, 1992). When dry, the mesocarp is floury and powdery and sometimes slightly crumbly, filling the space between the seeds and the fibrous pod shell (Bonkoungou, 1987; Chatterton, 1990; Some *et al.*, 1992).

The seeds are small, dark brown to black, and applanate with the hard testa adhering closely to the cotyledons (Gill & Bamidele, 1981; Maydell, 1986). They are ovoid/oval to oblong, compressed and reniform. Etejere *et al.* (1982) indicated two seed types in the pods of *P biglobosa*: reddish-brown and dark brown, occurring in a ratio of 1:10. However this colour difference is distinctive only with new, mature non dried seeds (Ladipo *et al.*, 1990).

Each seed is attached by a funicle, 5-10 mm in length, to the wall of the testa. Seeds in the middle of the pod tend to be larger than towards the two ends. Seed numbers per pod are directly related to pod length. The usual range is 5-20 per pod but occasionally may be as many as 30 (Sabiiti & Cobbina, 1992b). The size ranges between 0.6-1.5 mm by 0.6-1.00 mm. There are 2700-6700 seeds per kilogram. The cotyledon accounts for about 70% of seed weight (Sabiiti & Cobbina, 1992a). As with leaflet size, there are some suggestions of clinal variation: mean seed thickness was indicated to decrease from Senegal to Chad (Lengkeek, 1992).

2.3 BIOLOGY

2.3.1 Chromosome number

There is some uncertainty about the chromosome number. A value of 2n = 24 was reported by Mangenot & Mangenot (1957) and has often been cited since. Goldblatt (1981), however reports counts of 2n = 26 as well as 2n = 24 in the species and favours 2n = 26 because the most prevalent base numbers in the subfamily are n= 13 and n= 14.

2.3.2 Life cycle

Except when it is planted, the spread and persistence of *P. biglobosa* depends on naturally dispersed seed. If condition are favourable, a small proportion of seeds (5-20%), (the red brown) soon germinate once the associated pulp is removed, since there is lack of any dormancy mechanism (Etejere *et al.*, 1982). The remaining seeds (dark brown) display seed coat dormancy. For these, germination may take place some time later when the effect of the inhibiting factors have diminished and suitable conditions arise.

There are no reports of seed banks which contain *P. biglobosa,* even though it has been confirmed that seed can be stored for at least five years (Bossut, 1986; Forster, 1983). In typical savanna conditions, growth is rather slow and trees are usually 10 years old or older before they fruit. Under experimental conditions, growth is faster (around 1 m $year^{-1}$ in height), and reproductive activity may begin in as little as seven years. Even after fruiting starts, it is some years before the full production potential is achieved. Bonkoungou (1987) has suggested that trees 30-50 years old are at this stage. The time to full production could probably be reduced with well-tended trees.

Reports of age and height relationships in the species indicate that a 22 year old tree can have a diameter at breast height (dbh) of 17-20 cm (Maydell, 1986; FAO, 1988), while a tree grown under nursery conditions was 7 m tall after six years of establishment in Burkina Faso (Nikiema, 1993). Longevity reports are few but 100 and 300 year-old trees have been reported from Nigeria and Burkina Faso (Nikiéma, 1993; Timmer *et al.*, 1996).

2.3.3 Phenology

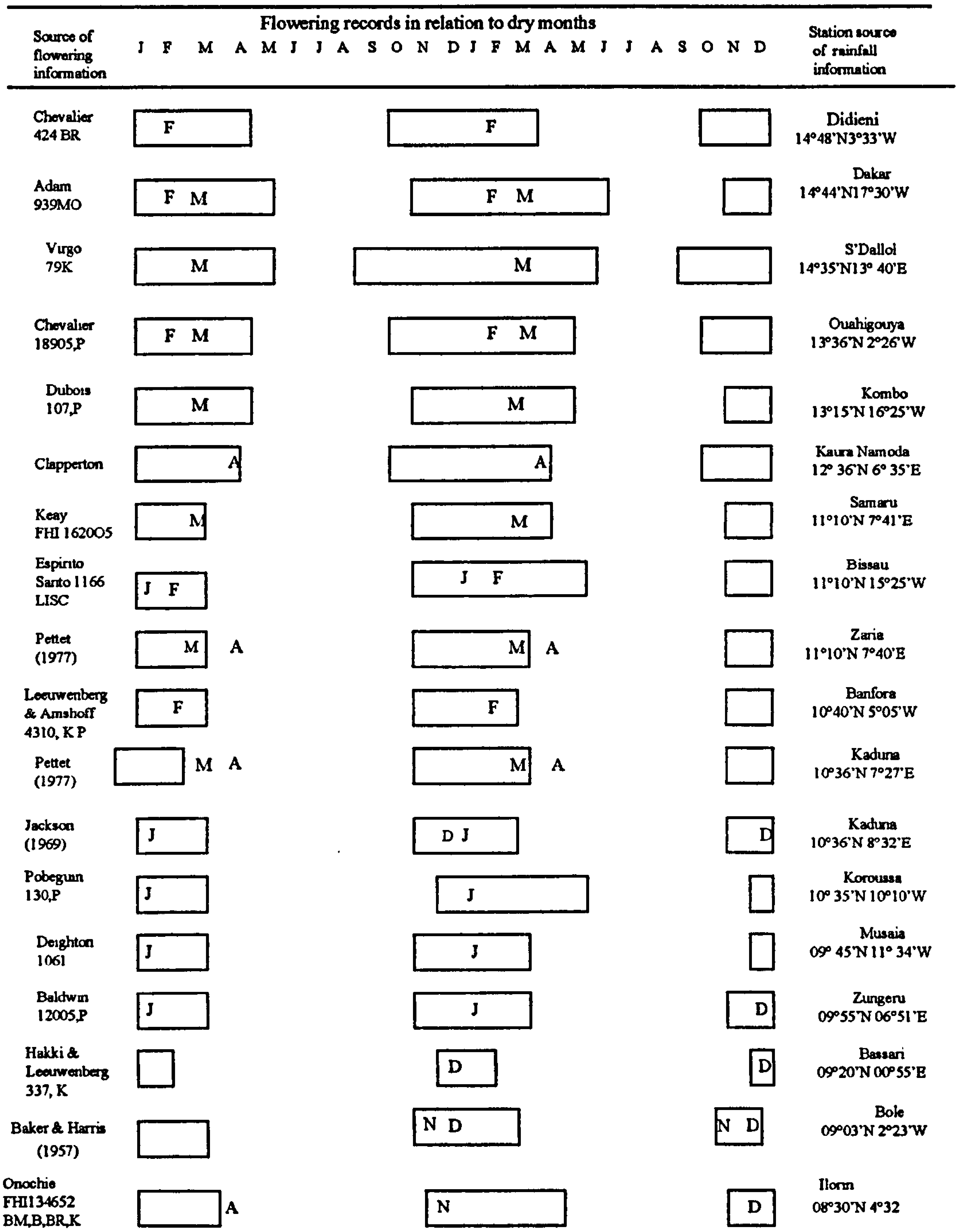
Parkia sheds its leaves during the dry season, but pre-rain flushing is characteristic (Baker & Harris, 1957; 1959; Ayensu, 1974). Leaf shedding is erratic, however. The shedding pattern varies from to tree to tree and may be uneven within a single crown. There is a variation from complete absence to partial or complete shedding (Baker & Harris, 1957; Hopkins, 1983). In most cases flowering occurs during this period.

In most parts of the range flowering is reported as dry a season event (Figure 2.2), lasting four to five months and coinciding with a period of high mean daily temperature and low mean monthly rainfall (Pettet, 1977; Fagbemi, 1989). Onset of flowering occurs later in the year with increasing latitude. Within a distance of 80 kilometres apart an average of seven days interval was reported in Nigeria (Kaduna, 10° 36'N, 7° 27'E and Zaria, 11° 16'N,7° 40'E). It has been suggested that it may be photo-periodically controlled (Pettet, 1977), but presumably modified by other environmental and soil factors, including burning, other land disturbances events, and drought (Hopkins, 1962; Fatubarin, 1987). When flowering is ending, a vigorous development of leaves takes place (Baker & Harris, 1957).

Instances of two flowering periods early, (November-March) and late (May-June) in some Nigerian locations have been indicated (Ladipo *et al.*, 1990) and of spasmodic flowering outside the months of the main flowering season in Ghana and Nigeria (Baker & Harris, 1957, Hopkins, 1983). In the equatorial condition of Saó Tomé, however, flowering is reported to occur throughout the year (Exell, 1944; Hopkins, 1983). According to Hopkins (1983) within a given population, two periods of flowering may occur each lasting 3-4 weeks, with good synchrony between trees. Range-wide flowering spans over a five-month period (November-March, Figure 2.2).

Specifically localised herbarium and literature reports (Figure 2.3) support the view of flowering in the second half of the dry season in the drier parts of the range, but relatively early in the shorter dry season of the moister parts of the range. Fruiting appears as an event taking place during the change from dry the season in drier parts of the range but early in the wet season in the moister parts (Figure 2.3).

Collating information from herbaria specimens and collectors' notes and associating this with climatic data from nearby meteorological stations has enabled a more comprehensive picture of seasonality in flowering and fruiting across the species range to be constructed (Figures 2.2 & 2.3).


Flowering records in relation to dry months
Source of flowering information
J F M A M J J A S O N D J F M A M J J A S O N D
Station source of rainfall information
Chevalier 424 BR
F
F
Didieni 14°48'N3°33'W
Adam 939MO
F M
F M
Dakar 14°44'N17°30'W
Virgo 79K
M
M
S'Dalloi 14°35'N13° 40'E
Chevalier 18905,P
F M
F M
Ouahigouya 13°36'N 2°26'W
Dubois 107,P
M
M
Kombo 13°15'N 16°25'W
Clapperton
A
A
Kaura Namoda 12° 36'N 6° 35'E
Keay FHI 162005
M
M
Samaru 11°10'N 7°41'E
Espirito Santo 1166 LISC
J F
J F
Bissau 11°10'N 15°25'W
Pettet (1977)
M A
M A
Zaria 11°10'N 7°40'E
Leeuwenberg & Amshoff 4310, K P
F
F
Banfora 10°40'N 5°05'W
Pettet (1977)
M A
M A
Kaduna 10°36'N 7°27'E
Jackson (1969)
J
D J
D
Kaduna 10°36'N 8°32'E
Pobeguin 130,P
J
J
Koroussa 10° 35'N 10°10'W
Deighton 1061
J
J
Musaia 09° 45'N 11° 34'W
Baldwin 12005,P
J
J
D
Zungeru 09°55'N 06°51'E
Hakki & Leeuwenberg 337, K
D
D
Bassari 09°20'N 00°55'E
Baker & Harris (1957)
N D
N D
Bole 09°03'N 2°23'W
Onochie FHI134652 BM,B,BR,K
A
N
D
Ilorin 08°30'N 4°32

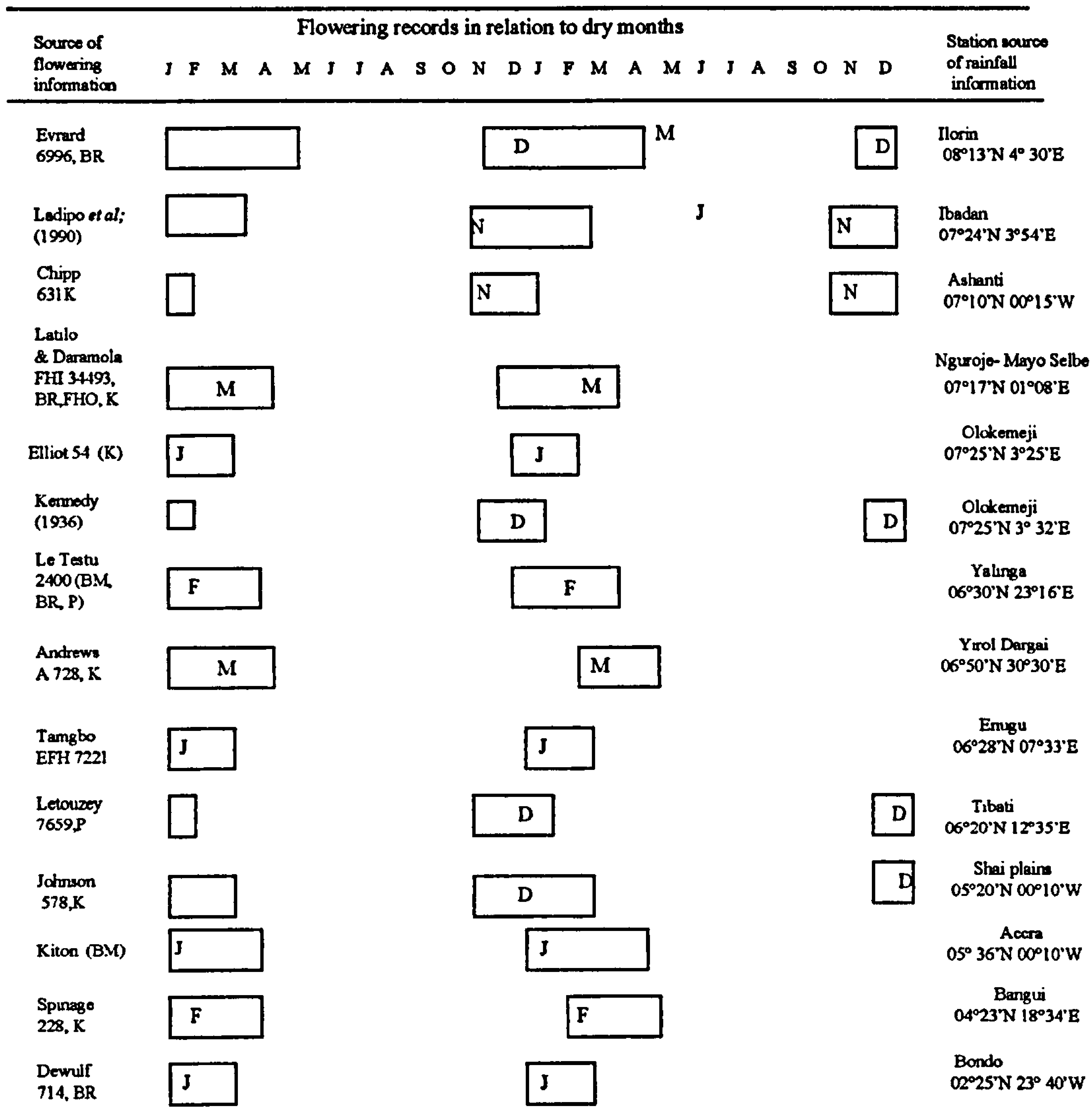
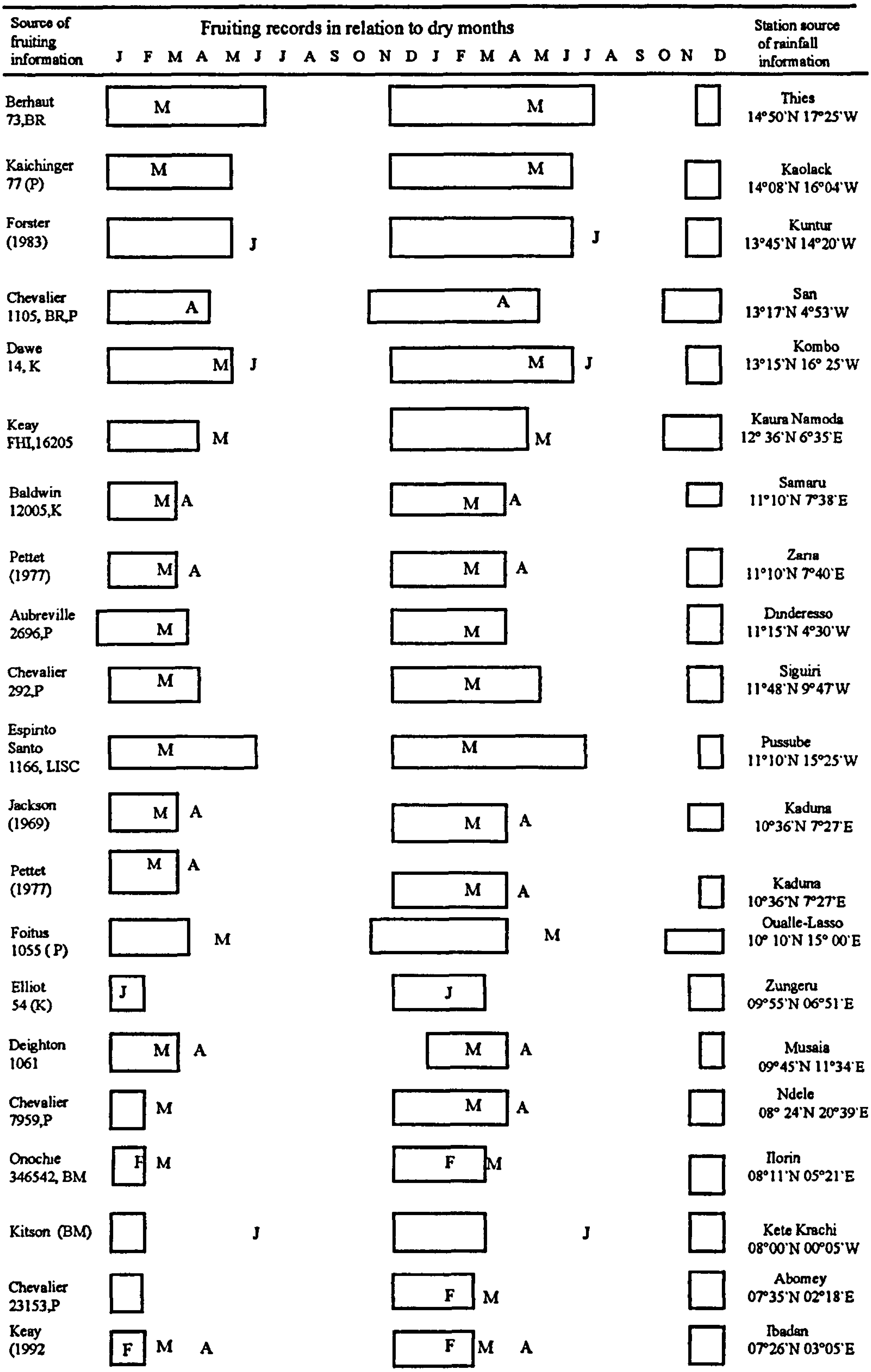


Figure 2.2 Summary of information on flowering in *Parkia biglobosa* in relation to dry months (mean rainfall <50 mm). Records are associated with meteorological station within the same area, the sequence of dry months being enclosed in by a frame. A 24-month cycle is adopted to emphasise climatic seasonality and meteorological stations are listed in a north-south sequence. Entries of the initial letters indicate when flowering was recorded in each case.


Source of fruiting information
Fruiting records in relation to dry months
J F M A M J J A S O N D J F M A M J J A S O N D
Station source of rainfall information
Berhaut 73,BR
M
M
Thies 14°50'N 17°25'W
Kaichinger 77 (P)
M
M
Kaolack 14°08'N 16°04'W
Forster (1983)
J
J
Kuntur 13°45'N 14°20'W
Chevalier 1105, BR,P
A
A
San 13°17'N 4°53'W
Dawe 14, K
M J
M J
Kombo 13°15'N 16° 25'W
Keay FHI,16205
M
M
Kaura Namoda 12° 36'N 6°35'E
Baldwin 12005,K
M A
M A
Samaru 11°10'N 7°38'E
Pettet (1977)
M A
M A
Zaria 11°10'N 7°40'E
Aubreville 2696,P
M
M
Dinderesso 11°15'N 4°30'W
Chevalier 292,P
M
M
Siguiri 11°48'N 9°47'W
Espirito Santo 1166, LISC
M
M
Pussube 11°10'N 15°25'W
Jackson (1969)
M A
M A
Kaduna 10°36'N 7°27'E
Pettet (1977)
M A
M A
Kaduna 10°36'N 7°27'E
Foitus 1055 (P)
M
M
Oualle-Lasso 10° 10'N 15° 00'E
Elliot 54 (K)
J
J
Zungeru 09°55'N 06°51'E
Deighton 1061
M A
M A
Musaia 09°45'N 11°34'E
Chevalier 7959,P
M
M A
Ndele 08° 24'N 20°39'E
Onochie 346542, BM
F M
F M
Ilorin 08°11'N 05°21'E
Kitson (BM)
J
J
Kete Krachi 08°00'N 00°05'W
Chevalier 23153,P
F M
Abomey 07°35'N 02°18'E
Keay (1992
F M A
F M A
Ibadan 07°26'N 03°05'E

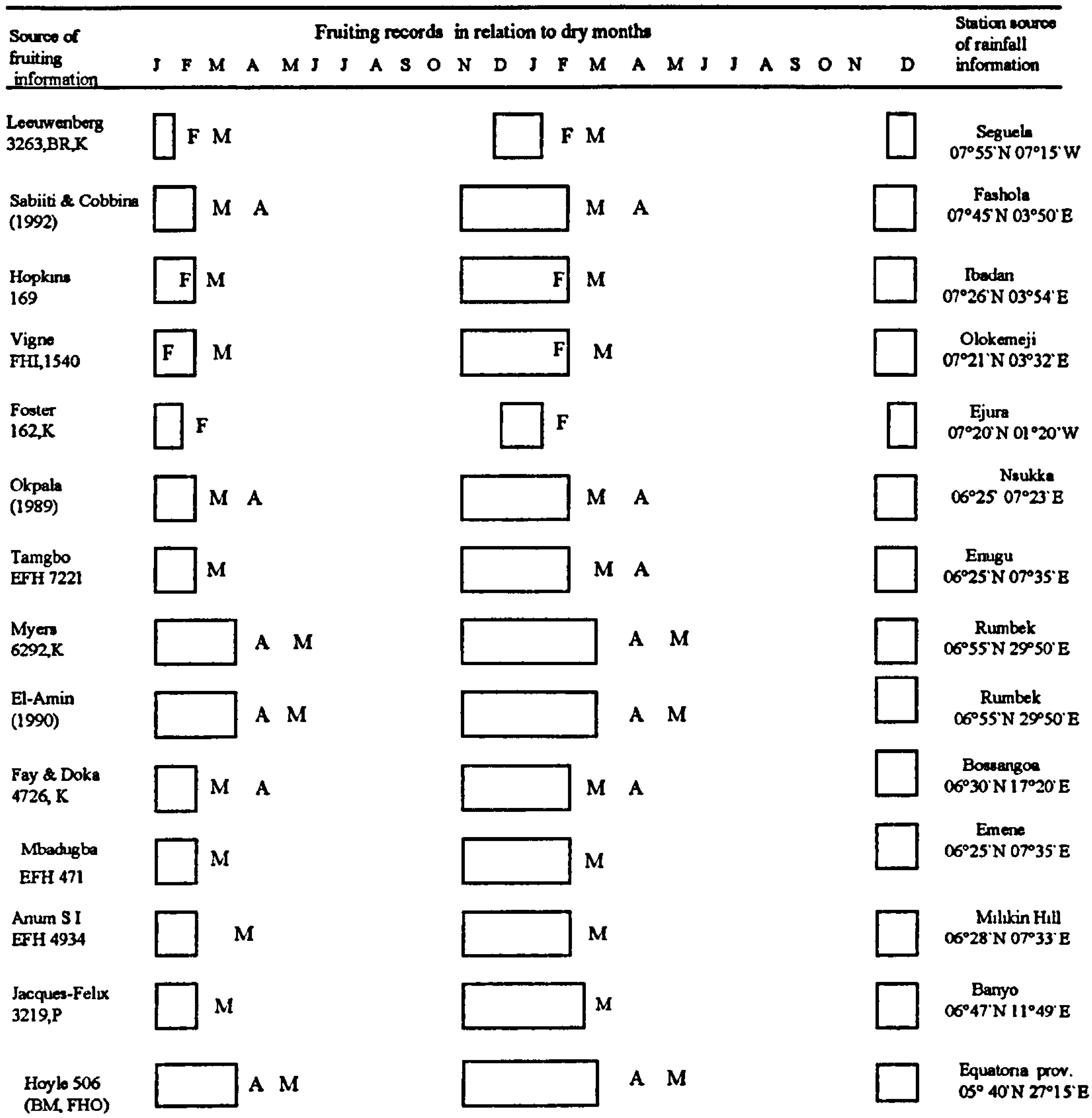


Figure 2.3 Summary of information on fruiting in *Parkia biglobosa* in relation to dry months (mean rainfall <50 mm). Records are associated with meteorological station within the same area, the sequence of dry months being enclosed in by a frame. A 24-month cycle is adopted to emphasise climatic seasonality and meteorological stations are listed in a north-south sequence. Entries of the initial letters indicate when fruiting was recorded in each case.

2.3.4 Pollination and anthesis

The reproductive process in the species has been described in detail by Baker & Harris (1957, 1958; Hopkins, 1983). *Parkia biglobosa* is chiropterophilous; *Eidolon helvum* Kerr, *Epomophorus gambianus* Jentink and *Micropteropus pusillus* (Peters) are recorded visitors (Baker & Harris 1957, Hopkins, 1983). Some degree of self-compatibility and seed set in the absence of pollen visitors has been speculated however, (Baker & Harris, 1957; Hopkins, 1983). The pollination unit is the biglobose capitulum which hangs freely at the periphery of the crown. (Baker & Harris, 1957; and 1959; Hopkins, 1983). The capitulum emits a weak fruity-foetid smell, and between 5-10 ml of creamy nectar are produced per night by the flowers of the nectar ring (Baker & Harris, 1957).

The spherical capitulum may contain upwards of 2000 flowers, forming a major attractant to both daylight visitors and pollen thieves,: bees, wasps, ants and butterflies (Ayensu, 1974; Hopkins, 1983; Booth & Wickens, 1988). The approach of anthesis becomes apparent during the afternoon, as the corolla lobes emerge from behind the flower bracts and the capitulum assumes a pale pink colour (Baker & Harris, 1957). By the end of the afternoon the red corolla of the flowers and the anthers give the capitulum a deep bright red colour. Anthesis commences at dusk with anther dehiscence and exposure of the yellow polyads of pollen, which give the capitulum a dirty appearance at this stage. Most of the pollen is dispersed or taken by pollen feeders within 12 hours (Baker & Harris, 1957).

There is variation in whether stylar development takes place in parallel with pollen release or later. Baker & Harris (1957) noted that in a few bisexual flowers (up to 24 in a capitulum) on hermaphrodite capitula there was synchrogamy; indicated by style elongation. In many more bisexual flowers, however, the style does not elongate until the pollen has been shed - These are protandrous flowers and the dominant anthers is a protandrous process (Baker & Harris, 1957; Hopkins, 1983). Bakers & Harris's (1957) conclusion that gynoecium development generally occurred 24 h later than androecium development is questioned by Hopkins (1983) who considers that the entire process takes place within the same night.

Where pollination is successful, the capitulum changes from bright red to salmon pink and later to dull brown, while withering of the anthers and filaments follow (Baker & Harris, 1957, personal observation). Withering of the inflorescence may be complete, partial or absent while pods are being initiated. Potentially each hermaphrodite flower is capable of producing a pod, but rarely does any capitulum produce more than twenty (Hagos, 1962). Capitula where all flowers are male in functional term are shed within 24 hours of pollen release, falling intact (Hopkins, 1983)

At the level of the entire crown of the individual, three phases of flowering have been recognised an initial stage when a low but increasing number of capitula mature, a fairly short peak in which most capitula release pollen and are receptive to pollination, and a final phase during which the number of capitula maturing per day decline (Baker & Harris, 1957; Hopkins, 1983). Hopkins (1983) records for a medium-sized tree at Ibadan, Nigeria a 3-4 week period of flowering with about 30 capitula per tree maturing in the peak phase. She notes that inflorescences in different positons of the tree attain maturity at different times- only 1 or 2 in the same inflorescence maturing on the same day. The proximal capitula mature first.

2.3.5 Pollen

The pollen of *Parkia biglobosa* has been described by Sowunmi (1973) and S Feuer in Hopkins (1986). The pollen grains are clustered into polyads of 20, with individuals grains clearly outlined, and sculpturing differences present between the central and peripheral portions of the distal face. The description of Feuer is as follows: Sculpturing elements spherical, rounded to elliptical, closely appressed, occasionally fused, becoming significantly smaller at the centre of the distal face. Distal ektexine organised into tectum, columellate interstitium and foot layer. Tectum highly perforated, irregularly thickened, reduced to small granules resting directly on foot layer at the centre of distal face. Interstitium composed of numerous though sporadic columellae, the columellae thin, often bifurcating at the base, occasionally discontinuous between tectum and foot layer. Sparse minute foramina occurring throughout tectum and columellae. Foot layer thin continuos, irregularly thickened with uneven upper surface (cited specimen : *Parkia biglobosa* (Jacq.) R. Br., Jacques-Georges 939 (MO), Leeuwenberg 7684 MO).

The number of the monads per polyad is given as 20 by Sowunmi (1973) but this is at variance with the figures of 16, 28 and 32 reported by Guinet (1981). Sowunmi (1973) provides information on the size of certain pollen features and additional descriptive comment. Polyads are polygonal or rounded in shape, the size being $102.5 \pm 3.6 \times 84.7 \pm 5.4$ µm. Individual monads are 3,4 or 5-sided with convex faces and wedge shaped proximal faces. Apertures are indiscernible. There is exine 2.4 µm thick on the distal face. The sexine is generally negatively reticuloid but verrucose in parts. There are sexine islands supported by one or more distinct rows of bacula and thin sexinous strands form connecting bridges to the islands in some places. Tectal part 0.8 ± 0.2 µm, infratectal baculate zone 0.7 ± 0.3 µm. foot layer 0.6 ± 0.1 µm and endexine 0.3 ± 0.1 µm thick.

2.3.6 Seed dispersal

Today, man probably plays the major role in *P. biglobosa* seed dispersal, evidenced by the many seedlings along tracks and foot paths (Nikiéma, 1993; personal observation, 1994). Various other vertebrates have been reported to disperse *P.*

biglobosa. The yellow mealy pulp, which constitutes about 50-80% of the fresh fruit, makes it attractive to potential vectors, while the thick resistant testa protects the seeds which pass through animals gut (Hopkins, 1983; Booth & Wickens, 1988). Parrots (*Poicephalus senegalus*) disperse seed in Northern Nigeria (Hopkins, 1983) and are the major dispersal agent in Burkina Faso (Nikiéma, 1993). Although there is little overlap between the range of *P biglobosa* and chimpanzees, the attraction of this fruit by the animal in Guinea and Nigeria have been reported by Hopkins (1983); Booth & Wickens (1988) and Soladoye *et al.* (1989).

Speculative reports exist for many other primates including baboons, goat, bush-buck, duikers, squirrels and rodents as potential dispersal agents (Fagbemi, 1989, Soladoye, 1989; Tybirk, 1991). Several birds, including hornbills, sun birds, and fruit pigeons have been found attacking the fruit in northern Nigeria, but their activities are not confirmed as dispersal (Ayensu, 1974; Pettet, 1977; Hopkins, 1983). The role of bats in dispersal is not fully understood. More observations are needed to define their possible roles.

2.4 ECOLOGY

2.4.1 Origins and affinities

The *Parkieae* is suspected to be a specialised off-shoot of the *Ingeae* (Elias, 1981). The *Ingeae* is a relatively advanced group of the Mimosoideae, evolved from a more primitive base group represented today by the Mimoseae. Particular features of *Parkia,* taken as indicating an advanced state within the Mimosideae, are the pollen in polyads and a base chromosome number below 14.

Reports of fossil *Parkia* from Africa do not indicate species (Hopkins, 1986) but reveal that *Parkia* or a very similar taxon, was present in Cameroun and Senegal during the Miocene (23-5 MYBP). Other reports (Salard-Chebaldaeff, 1978) indicate older pollen fossils in Cameroun (Mid and Upper Eocene: 50-35 MYBP). The fossil is known by the palynological name *Parkiidites microreticulatus* Guinet & Salard, but is a better match for Section *Sphaeroparkia* than Section *Parkia* (Muller, 1981). *Sphaeroparkia* is not found in Africa today, but is thought to be the most primitive section of *Parkia* (Hopkins, 1986). The question raised by Hopkins (1986) of how Section *Parkia* comes to be present on both sides of the Atlantic, requires the assumption of long distance dispersal across the sea. It remains uncertain which side of the Atlantic the Section originally developed.

2.4.2 Present distribution and range

The range of *Parkia biglobosa* extends from Senegal (14° 50'N, 17° 25'W- Thies, Berhaut 73, BR) and Guinea, to Uganda (3° 5'N, 11° 20' E -Mount Kei, Dale U 858, EA) in the east (Hopkins & White, 1984). It occurs almost throughout the Sudanian Regional Centre of Endemism and the Guineo-Congolian/Sudanian Regional Transition Zone of White (1983). Spread of *P. biglobosa* into the Guinea-Congolian centre is believed to be a result of invasion following vegetation clearance and general land disturbance (White, 1983; Hopkins & White, 1984). In this centre it is found in derived savanna particularly Nigeria and in the Guinea/Sierra Leone border area (Hopkins & White, 1984). *P biglobosa* reaches its northern limit at the southern boundary of the Sahel (Hopkins & White, 1984).

The latitudinal range is from 4°N to 15°N and the longitudinal range from 17°W to 31°E (Hopkins & White, 1984, Okpala, 1989), covering east to west distance of approximately 5600-8000 kilometres and a north to south distance of about 1000 kilometres (Okpala, 1989). *P biglobosa* occurs in Benin, Burkina Faso, Cameroun, Chad, Coté d'Ivoire, Central African Republic, Gambia, Ghana, Guinea, Guinea Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda, and Zaire (Hopkins & White, 1984; Booth & Wickens, 1988; Sabiiti & Cobbina, 1992a). As an introduction, *P. biglobosa* has been reported from the West Indies, Saó Tomé and Annobon (Exell, 1944; Hopkins, 1983). Using herbaria voucher specimens, with collector's location comments and reported locations in published literatures, it has been possible to prepare a range-wide distribution map for the species (Figure 2.4).

2.4.3 Environmental factors in distribution

Elevation

Information with specimens and reported in ecological surveys gives an altitudinal range of between 6-1285 m for *P. biglobosa.* In the west of the range *P biglobosa* is frequent at low elevation (<400 m) but eastwards it is more consistently associated with higher elevation (>400 m). Frequently reported elevations range-wide are indicated in Table 2.5.

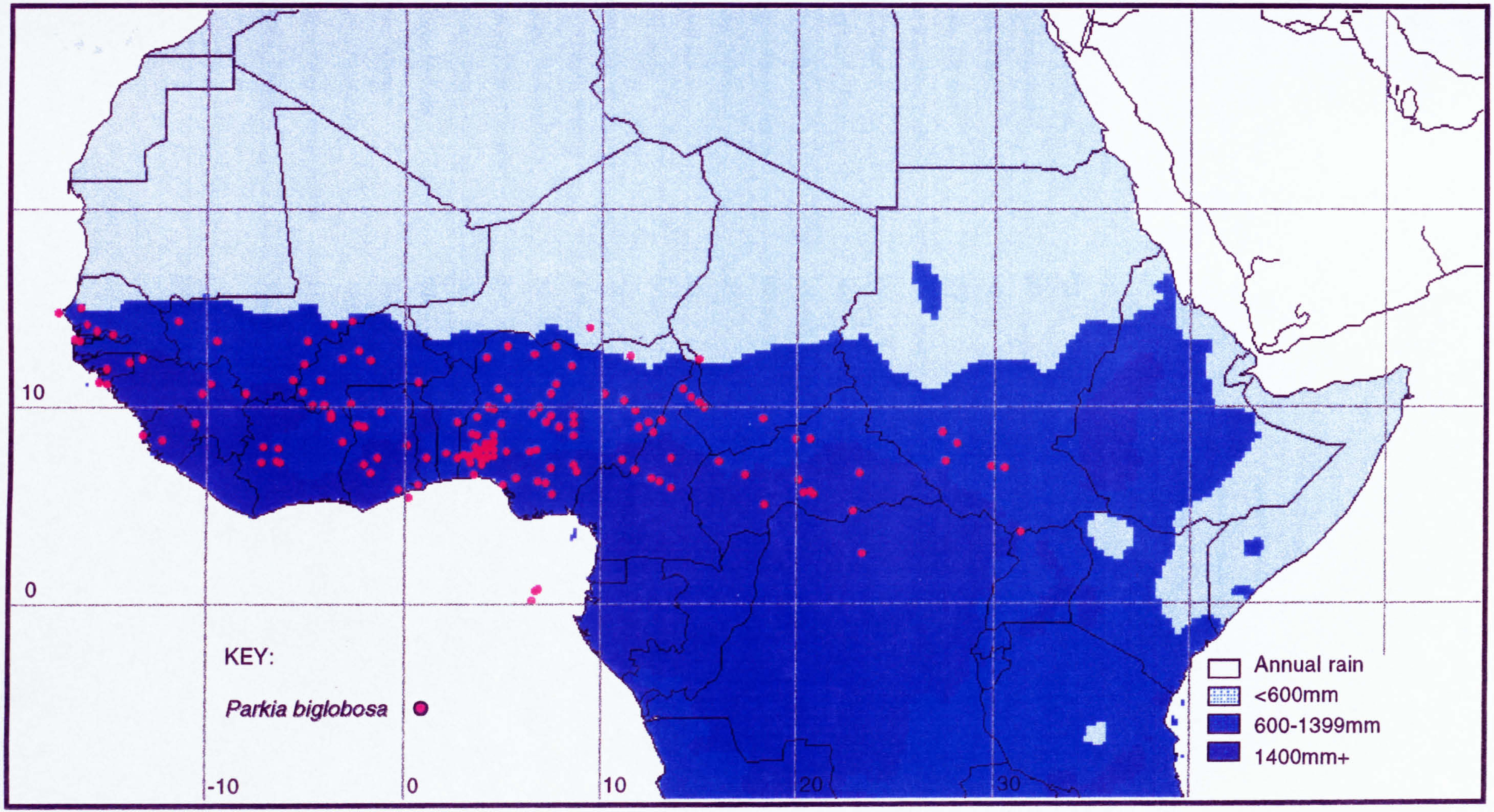


Fig. 2.4 Distribution of *Parkia biglobosa* in relation to mean annual rainfall.

Table 2.5 Elevation of occurrence reported for *Parkia biglobosa* range-wide

Location	Altitude(metres)	Reference
Nigeria, Jos	1285	Batten-Pole 102 K
Cameroun, Wawa	1100	Leeuwenberg 7684, BR, K, MO
Nigeria, Gongola	750-800	Mildbread 9003 BM
Nigeria, Katsina	450-700	Ahmed FHI 26212 BR, FHO, K
Nigeria (Anara forest Reserve)	676	Forest Inventory (Keay 1960)
Central African Rep,. Bangui	400-600	Spinage 288 K
Niger Republic, Magaria	477	Fabregue 3016, P
Burkina Faso, Dinderesso	432	Aubreville 2696, P
Sudan, Yirol-Dirgai	423	Andrews A 728, K
Togo, Sandboden	402	Ern 2961, K
Ghana, Ejura	400	Vigne FHI 1540
Guinea, Koroussa	377	Pobeguin 130 P
Chad Republic, Sarh	365	Foureau 3016, P
Mali, Sikasso	350	Kater *et al.*(1992)
Sierra Leone, Musaia	349	Deighton 5480 K
Benin, Parakou	300-400	Agbahungba & Depommier (1993)
Burkina Faso, Banfora	300	Leeuwenberg & Amshoff 4310, K P
Ghana, Achimota	300	Baker & Harris (1959)
Ivory Coast	300	Leeuwenberg 3263 BR, K
Range-wide	0-300	Derek *et al.* (1984), Hogg (1994)
Nigeria, Okene	300	Maggs OK 31, BM
Cote d' Ivoire, Seguela	300	Leweenberg 3263, WAG
Senegal, Niokolo-Koba	200-300	Tutin 9, K
Nigeria, Kaura Namoda	300	Keay FHI 16205
Nigeria, Ilorin	200	Fagbemi (1994)
Nigeria, Fashola	200	Sabiiti & Cobbina (1992)
Benin, Abomey	167	Chevalier 23153, P
Nigeria, Olokemeji	100	Hopkins (1962)
Guinea Bissau, Bissau Pusube	21	Espirito Santo 1166, LISC
Senegal, Kaolack	6	Raichinger 77 P

Climate

The range of *P. biglobosa* is discussed here in terms of the mean annual rainfall and temperature based on records of site locations of herbarium specimens and available information in the literature. This information is linked to data from meteorological stations (FAO, 1984) and the Meteorological Office (1983). Putting these together presents a more detailed view of the species interactions with the environment, than comparing rainfall and species distribution maps (Figure 2.4).

Rainfall

Except in the Guinea-Congolian centre, and the northern boundary in Mali and Niger Republic regions, *P. biglobosa* occurs principally in areas with mean a annual rainfall of 600-1400 mm (Figure 2.4). In the western part of the range (Senegal, Mali and Burkina Faso) occurrences are associated mainly with a mean annual rainfall of 500-1000 mm (Le Houerou, 1980; Felker, 1981; Kessler, 1992; Kater *et al.*, 1992; Gakou *et al.*, 1995). Moving eastwards, higher mean annual rainfall is reported from locations where the species is found: 600-1500 mm in Ghana, Benin, Nigeria and Cameroun (FAO, 1988; Sabiiti & Cobbina, 1992; Agbahungba & Depommier, 1989).

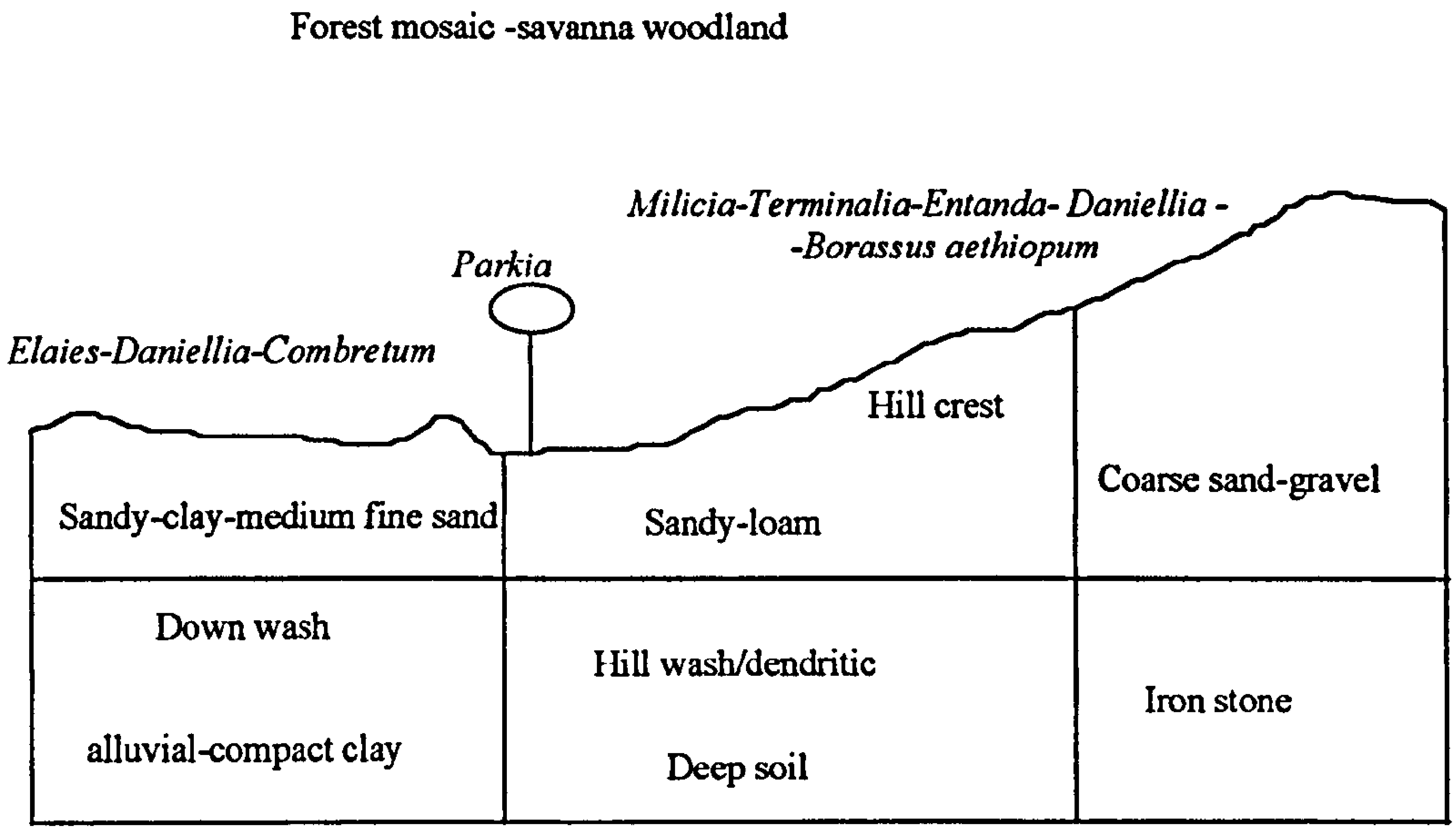
Typically there are 2-7 dry months (months with <50 mm of mean rainfall) (Jackson, 1973, Hopkins & White, 1984; Booth and Wickens; 1988; Kessler, 1992; Agbahungba & Depommier, 1993; Gakou *et al.*, 1995). *P biglobosa* shows adaptations to drought and a prolonged dry season. Deep tap root systems and leaf low stomata conductance were indicated as survival mechanisms for the period of stress (Osonubi & Fasheun, 1987; Oladele *et al.*, 1985).

Temperature

Within the range the mean annual temperature ranges between 20°C-30°C (FAO, 1984). It is generally higher in the west and east of the distribution with an average of about 33°C, but slightly lower in the central part of the range (30-32°C). At the peak of the dry season, the mean monthly temperature reaches 41°C, while in the coldest month, it often drops to about 11°C (FAO 1984; Carlowtiz, 1991). In nowhere in the range is *P biglobosa* exposed to frost (White, 1983b).

Catena and Toposequence

Descriptions of the position of *P. biglobosa* in catenas are few and often difficult to interpret. However, Morison *et al.* (1948) illustrate the toposequence position of *P biglobosa* in Aweil, Sudan (08° 42'N, 27° 20'E) at the colluvial-illuvial transition, where deposits of finer material of sandy-loam, washed down the slope crest of the elluvial region have accumulated. Here *Parkia* occurs with *Khaya senegalensis, Entada africana* and *Borassus eathiopum* (Figure 2.5). From the western state of Nigeria, Adejuwon (1971) described the position of *P biglobosa* in a catena on the rock hill savanna forest in the Guineo-Congolian/Sudanian transition of White (1983a).
P.biglobosa was observed along the crest of the hill on fairly deep soil formed from hill wash.



Morison *et al.* (1948) Sudan (08°42' N, 27° 20'E) Mean annual rainfall 1000 mm
quaternary deposits, Howard (1976) Nigeria, Benue 7 28'N, 835'E Mean annual rainfall 1364 mm
Cretaceous sand stone, Sand stone

Figure 2.5 The position of *P. biglobosa* in the catena.

In the Benue valley of Nigeria (Aliade Plains), in the Guineo-Congolian/Sudanian transition, *Parkia* was absent from the upper slope positions, where there was a mixture of sandstone and shales as the parent materials, and a sandy surface horizon, but occurred at the lower crest region dominated by hill wash sandy-loam soil (Howard, 1976) (Figure 2.5). To the west of the Benue valley, near Ankpa hill, *Parkia* was absent from the upper slope of the crest where the vegetation was *Anogeissus-Terminalia* woodland. However on the lower crest, *Parkia* was observed near the valley zone on sandy-loam, on soil underlain by ironstone parent materials (Howard, 1976). In Zaria (11° 07'N, 07° 44'E) where ironstone pavement is frequent, with gully erosion leading to exposure of the ironpan, an extensive and more or less continuous pavement occurs. At this site, *Parkia* occurs in association with *Combretum glutinosum* and *Entada africana*, but on the upper slopes and ridges, and at the edge of localised plateau, is *Isoberlinia-Annona-Terminalia* woodland (Kershaw, 1968). In the south of Zaria province, where drier slopes with occasional outcrops of ironstone dominate, *Parkia* was absent and the woody species were *Parinari curatelifolia*, *Protea elliotti* and *Terminalia laxiflora* (Kershaw, 1968). In Ghana, in the Gambaga Forest Reserve (10° 32'N, 0° 25'W), *Parkia* was completely absent from the upper slope where the soil was poor with frequent erosion and replaced by stands of *Acacia* species. However Parkia was present in the crest zone where the soil was fertile and well drained. It was also absent from poorly drained parts of the summit ridge (Taylor, 1960).

Geology and soil

P. biglobosa occurs on a wide range of soil types (Adejuwon, 1971; Jackson, 1973; Hopkins & White, 1984; Fagbemi, 1989; Booth & Wickens, 1988; Adejuwon & Adesina, 1992) where the species is considered frequent, however, loamy-sand to loamy-clay 1-4 m deep is typical (Jackson, 1973; Howard, 1976; Fagbemi, 1989; Agbahungba & Depommier, 1989). Texturally soil associated with the tree is variable: fine, medium or coarse in the surface 50 cm, while at a greater depth, good growth is generally where the texture is fine although individuals will survive even if the soil texture is medium to coarse (Howard, 1976; Hopkins & White, 1984; Sabiiti & Cobbina, 1992a; Kessler, 1992). *Parkia* is less frequent, or growth restricted where the soil is shallow (<50 cm) or the water table very deep combined with a prolonged dry season (Hopkins & White, 1984).

Throughout the range, there are occurrences where the underlying geology is the crystalline basement complex, the most widespread geological formation. .*P. biglobosa* is not confined to basement complex rocks. In Senegal it is one of the species retained during formation of the unconsolidated sands (Giffard, 1974)) and has been widely reported from areas of sandstone rock (Hopkins & White, 1984). The general picture is one of concentration on various sandstone's and basement complex rocks and absence or scarce in areas of deep sand deposits and volcanic rocks.

2.4.3 Site

Hopkins & White (1984) described various site conditions range-wide where *P biglobosa* is frequent. Where *Parkia biglobosa* is relatively abundant and grows into large trees, the soil is well drained, but with a good moisture holding capacity. Weathering of basement complex rocks leads to such soils. Although often present on soils with a restricted rooting depth, it is restricted to small sizes in these situations. Poorly drained sites are unsuitable. The toposequence positions where *P biglobosa* is most typical reflect these site requirements. As a savanna species in many parts of the range there are ironstone pavements which reflect quartenary fluctuations in climate. Within the toposequence *P biglobosa* typically occurs on a level area where good soil depth is present above ironstone or on slopes, in places where there has been broken or eroded away. There is nowhere in the range of *Parkia biglobosa* where frost is likely to occur, so it is assumed to be frost-tolerant. Similarly the range does not extend to areas of saline soil and it is probably sensitive to high salinity levels.

2.4.4 *Parkia biglobosa* as vegetation component

Chorology

Along with *Lophira lanceolata* and *Vitellaria paradoxa* with which it is associated, *P. biglobosa* is one of the especially typical Sudannian savanna tree species. None of these, or any member of these genera, occurs in savanna south of the equator. It has been suggested that *P. biglobosa* was part of the original vegetation in almost all parts of the Sudanian Regional Centre (Hopkins & White, 1984). In the Guinea-Congolian/Sudanian transition and Guinea-Congolian centre, however, it is thought to have resulted from secondary invasion or planting (Keay 1959a; Hopkins & White 1984).

Vegetation type

The broad ecological spread of *P. biglobosa* in West Africa is matched by its occurrence in a wide range of vegetation communities. Nevertheless, most reports correspond to vegetation types of White (1983) terms `wooded grassland' and `wooded farmland'. Thus, in White's Sudanian Centre of Endemism, *Parkia biglobosa* is frequently mentioned as a major vegetation component of undifferentiated Sudanian woodland (Taylor 1960; Howard, 1976; Boulvert, 1980; Bourliére & Hadley, 1983; Hopkins & White, 1984; Macmillan, 1991). This is the typical vegetation even at the eastern extreme of the range (Morison *et al.*, 1948; El-Amin, 1990).

In the Guineo-Congolian/Sudanian transition zone, it is a component of Sudanian woodland with abundant *Isoberlinia* (Fagbemi, 1989; Ladipo *et al.*, 1992),. and towards the southern limit of the Guineo-Congolian/Sudanian transition it is a component of the mosaic of lowland rain forest and secondary grassland of White (1983). Illustrative reports of vegetation types where *P. biglobosa* is characteristic are summarised in Table 2.6

Where *Parkia* is typical of wooded farmland this reflects deliberate protection accorded the species, due to its economic importance (Savill & Fox, 1967; Adam, 1968; Kessler, 1992; Gakou *et al.*, 1995). In most parklands, it is dominant in the woody vegetation and often forms a distinctive open *Vitellaria-Parkia* parkland, in association with smaller numbers of other protected woody tree species.

Table 2.6 Major vegetation types and communities associated with *P. biglobosa*

White (1983) vegetation terms	Country, location	Vegetation community	Reference
Sudanian woodland and grassland			
	Burkina Faso	Mixed shrub-tree savanna	Kessler (1994)
	Ghana	Savanna woodland (Thicket)	Jenik & Hall (1966)
	Cameroun	Sudanian dried forest	Aubreville (1950)
	Sierra Leone	Moist savanna woodlands	Savill & Fox (1967); Sharlands (1991)
	Sudan, Maradi	Grass woodland	Tothill (1948)
	Burkina Faso, Petit Samba	Shrub tree savanna	Gijsbers *et al.* (1994)
	Nigeria, Ondo	*Monocymbium* shrub savanna	Adejuwon (1971)
	Nigeria, Benue valley	*Glutinosum-Terminalia* savanna woodland/wooded shrub savanna	Howard (1976)
Savanna wooded farmland	Senegal, Niokolo-Koba	Savanna woodland	Hopkins & White (1984)
	Ghana, Bole	Savanna ecosystem	Baker & Harris (1957)
	Ghana	Derived-Savanna-woodland	Taylor (1960)
	Nigeria, Eruwa	*Parkia-Vitellaria* parklands	Murdoch *et al.* (1976)
	Nigeria, Kontagora	*Detarium-Afzelia-Burkea-* savanna	Valette (1973)
	Nigeria , Katsina	*Parkia*-Diospyros-*Hyphaene-Acacia* savanna	Clayton (1962)
	Nigeria, Ibadan	*Parkia* savanna	Clayton (1958)
	Nigeria, Katsina	Farmed parkland	Clayton (1962)
	Nigeria Benue valley	Economic farm tree	Howard (1976)
	Nigeria (Zaria)	Northern Guinea savanna	Pettet (1977)
	Central Africa Republic	Sudanianwooded savanna/wooded gallery forest	Fay *et al.* (1984)
	Sudan, Aweil	Savanna woodland	Morison *et al.* (1948)

Prominence, population levels and representation

Prominence

The deliberate clearing and cutting of other woody species has made *P biglobosa* prominent in many areas of the farmland in West Africa (Jones, 1963a; Pullan, 1974; Valette, 1973, Hopkins & White, 1984, Kessler, 1992; Gijsbers *et al.*, 1994). *Parkia biglobosa* was used as a descriptor of the farmed parkland reflecting prominence where it was described as *Parkia-Vitellaria paradoxa* and *Faidherbia albida* (Gijsbers *et al.*, 1994).

Population levels

Quantitative reports exist for *Parkia* population levels in some locations in the range, as listed in Table 2.7. However, the approaches adopted and parameters measured by different workers often complicate comparisons. Sampling areas and strategy are variable, and sometimes number of individuals are reported with no reference to minimum values for inclusion. Reported stocking for the species in the range is indicated in Table 2.7.

Table 2.7 Stocking estimates of *Parkia biglobosa* in natural communities

Stocking trees ha^{-1} (representation)	Attribute	Minimum value for inclusion	Location	Basis	Source
0.19	individuals	not indicated	Southern Nigeria	Ecological survey	Forestry Dept (1986)
0.03	individuals	not indicated	Eastern Nigeria	Ecological survey	Forestry Dept (1986)
2	individuals	>10 cm	Kano (12° 05' N, 08°35' E) Nigeria	Ecological survey	Okpala (1989)
0.2 %	individuals	10 cm,	Olokemeji (7° 35'N, 3°25' E) Nigeria	formal inventory 0.25m² plot, >2m height	Hopkins (1962)
0.04 2.20%	stems	not specified	Badeggi (9°01' N,6°08'E) Nigeria	Ecological survey on 0.4 ha	Jones (1963b)
1 individual 0.003%	individual tree	>9.5 cm, 1.30m height	Anara Forest Reserve (10 40' N,7°45' E)Nigeria	0-8 observations on each plot of fifteen 0.2 ha plots	Onochie (1961)
0.14 (9 individuals) 3.6%	trees	not specified	Kwara state (8° 30'N, 04°32' E) Nigeria	Ethnobotanical survey 64 hectares 100% enumeration	Soladoye *et al* (1989)
0.51 0.37%	individuals	>10 cm	Gambaga scarp (10°32'N, 0°2'5W) Ghana	91 observations on 177 ha	Taylor (1960)
3.75 (1.6 %)	trees	not specified	Northern Ghana	48 observations, on composite area 3.2 ha	Vigne (1953)
2-10	trees	>10 cm	Parakou (9°10'N,°2 20' E) Benin	formal inventory	Agbahungba & Depommier (1989)
1 (4%)	stems	>10 cm	Yundum (13°21' N, 16° 40' W) Gambia	formal inventory	Forster (1983)
10 47%	Individual	> 10 cm	Burkina Faso (12°21'N, 01°31' W)	CNSF. harvest inventory	Nikiema (1993)
0.09 3.1 %	sapling	>5 cm and >3m height	Petit Samba (12°45'N, 02°15'W) Burkina Faso	Vegetation survey on 100 ha	Gijsbers *et al.* (1994)
2	Trees	10 cm and 11.7-13 m	Oula (12°20'N, 03°05'W) B/Faso	Field survey	Kessler (1992); 1994
12	Trees	> 15 cm	(Sapone) (12°30'N, 03°10'W) B/Faso	Field survey	Nikiema (1993)
3	individuals	> 10 cm, 11.8 m height	Sikasso (11°21'N 05° 45'W) B/Faso	Agroforestry study	Kater *et al.* (1992)
1-14	individuals	>10 cm	Zaria (11°05'N, 07°42'E) Nigeria	Field survey	Pullan (1974)

Representation

Information on *Parkia* representation in woodland and natural wooded grassland communities generally shows very low values below 5%, but in wooded farmland representation is higher, especially if only relatively large (≥10 cm dbh) woody species are considered. In Kontagora, Nigeria, *Parkia* accounts for upwards of 15% for individuals (dbh >10 cm) (Valette, 1973), and a larger representation of 20-30% was indicated as common for the species in most of the selected parklands of West Africa (Pullan, 1974; Kessler, 1992). Bennett *et al.* (1976) recorded representation of 38% on the Titiale series of Benue Valley in Nigeria.

2.4.5 Interactions with natural or spontaneous plant communities

Influence on soil environment

Quantitative reports on the extent to which *P. biglobosa* influences the soil environment is mainly recent. Previous reports tend to have mainly casual comments. Most reports indicate increased soil fertility within the tree species vicinity and underneath its crown, compared with the open fields (Kessler, 1992, Kater *et al.*, 1992; Sabiiti & Cobbina, 1992b; Tomlinson *et al.*, 1995). Recent studies have indicated that there is no nodulation contrary to the reports published by Allen & Allen (1981). Recently, in Mali, Kater *et al.* (1992) indicated that the average carbon content is higher in soil in the zone covered by *Parkia's* crown compared with open field conditions. There were significant differences for the 0-20 cm soil layer not the 20-40 cm layer. In soil under *Parkia* trees significantly higher levels of available magnesium, potassium and calcium were recorded.

In both Burkina Faso and Mali, *Parkia* tree is reported to increase the soil organic matter and soil carbon, while soil moisture infiltration is improved compared with the open field (Kater *et al.*, 1992; Kessler, 1992; Breman & Kessler, 1995). *Parkia* trees on cultivated field positively affect the soil micro-environment and soil fertility under the tree compared with the open field, due to increased plant-litter-soil recycling, increased moisture availability and also indirect nutrient recycling from the wastes of livestock using the tree as shade (Kater *et al.*, 1992, Sabiiti & Cobbina, 1992; Kessler, 1992; 1994).

Relations with the natural fauna

P. biglobosa interaction with the natural fauna is most noticeable during the reproductive phase, when there are visits by potential pollinators and pollen thieves (Baker & Harris, 1957; Hopkins & White, 1984). Interactions generally with the natural fauna are diverse in terms of the visiting patterns, the parts of the tree visited and available rewards to visitors.

2.4.5.1 Direct consumptive use

Floral visitors/consumers

Floral visitors to *Parkia* have been frequently reported (Baker & Harris, 1957, 1959; Pettet, 1977; Hopkins, 1983) all indicate fruit-eating bats) (*Megachiroptera:Pteropodidae* as the predominant nocturnal visitors attracted by the copious nectar and -birds (Nectariinidae) and a social wasp (a species of *Belanogaster*) as the most common daytime floral visitors. The birds peck and rob the flowers while the wasps feed on the nectar accumulated overnight in the floral depressed ring. Other frequent visitors to *Parkia* inflorescence are crepuscular, honey bees (*Apis mellifica*

Linn), moths and fruit-eating bats. Baker & Harris (1957) note that the bats feed mainly on the nectar, while bees feed mainly on the pollen.

Fruit consumers

P biglobosa fruits with the sugary mealy pulp remain attractive to dispersal agents for some time after maturity, and the thick resistant testa enables seeds to pass through the guts of some animals unharmed. The fruit thus attract various consumers which may also aid dispersal, includingly ungulates tree-climbing mammals and large birds (Hopkins, 1983, Soladoye *et al.*, 1989). Anderson & Pinto (1985), indicates the presence of 0.92-0.95% N in *Parkia* gum (pod) exudates, suggesting that this makes the fruit nutritionally attractive. Hopkins (1983) and Soladoye *et al.* (1989) report of chimpanzees and other animals eating the flowers and fruits of *P. biglobosa.* Various ungulates, primates and birds including ground squirrel (*Xerus erythropus*), Anubis baboon (*Papio anubis)* and wart-hog (*Phacochoerus aethiopicus*), red-flanked duiker (*Cephalophus rufilatus*) and bushbuck (*Tragelaphus scriptus*) have been indicated. Where *Parkia* trees occur in village areas, domesticated animals and pest (sheep, donkeys, horses, bush fowl, goats, antelopes and grass cutters) often browse the seedlings and feed on aborted capitula and naturally dropped fruits (Bayer, 1990; Kessler, 1992; Nikiéma, 1993; Agbahungba & Depommier, 1989).

Organisms eating bark, wood and gum

Forsyth (1966) and Wagner *et al.* (1991) listed arthropods frequently observed feeding on various parts of the tree in Ghana and Nigeria (Table 2.8). In Burkina Faso, bruchid larvae feed on the pulp of pods left un-harvested (Varaigne & Labeyrie, 1981). Fagbemi (1989) and Sabiiti & Cobbina (1992b) observed weevils and Lepidoptera from five families feeding on the fruits, and pyralid and sucking bugs feeding on the leaves in Nigeria. *Parkia,* as an agroforestry species, associates with corn ear-worms and butterflies (*Eurema hercabae* Linn.) from the adjacent maize crop (*Zea mays*), with the larvae feeding on the leaves (Fagbemi, 1989). At the seedling stage in Burkina Faso, rodents and rats (*Malacomys longipes*) bite through the young stalks and consume the leaves (Nikiéma, 1993). Ants are reported frequently especially on pods, possibly feeding on the exuded gum (Hopkins, 1983).

Table 2.8 Arthropods associated with *P .biglobosa*

Arthropods	Location	Reference	Remarks
Insecta			
Lepidoptera: Tortricidae	Ghana	Wagner *et al.* (1991)	Destroy fruits (widely distributed)
Crytophlebia leucotreta MEYR	Ghana	Wagner *et al.* (1991)	Feed on fruits (widely distributed
Anthene amarh GUER.	Ghana and Nigeria	Forsyth (1966)	Attack shoot
Anthene lunulata TRIM	Ghana and Nigeria	Forsyth (1966)	Attack shoot
Orthoptera : Tettigoniidae	Central West Africa	Booth & Wickens (1988)	Attack inflorescence
Crytophelbia peltastica MEYR	Ghana	Wagner *et al.*, (1991)	Bores into inflorescence and fruits
Lepidoptera : Pyralidae			
Mussidia nigrivenella ROGONOT	Ghana	Wagner *et al.* (1991)	Moths, common in green and dry fruits Larvae feed on seed and fruit wall. Cocoons within fruit, breeds continuously
Apis mellifica LINN.,	Ghana	Baker & Harris (1957)	Feed on flowers nectar
Coleoptera			
Alphitobius spp	Ghana and Nigeria	Forsyth (1966)	Attack fruit
Hemiptera: *Planococcoides njalensis* (LAING)	Ghana and Nigeria	Forsyth (1966)	Attack fruit

Dependent use

Trees as habitats

Morison *et al.* (1948) and Tothill (1948) observed the species as frequent on termites mounds at Aweil and Meridi in Sudan. while in Nigeria (Mokwa, Kontagora and Kano) and Burkina Faso (Sapone) similar observation have been made (Josens, 1983;. Nikiéma, 1993; personal observation).

Trees for shelter and protection

The presence of mature trees or developed vegetation often influences animals choice of nest sites or shelter. Soladoye *et al.* (1989) note giant rat burrows very close to *Parkia* trees, especially during fruiting time. Several species of birds roost and nest on the tree. Pettet (1977) provides details for Zaria in Nigeria.

Loranthaceous hemi-parasite associated with *Parkia*

Tapinathus dodoneifolius (DC.) DANSER infests *P biglobosa*, particularly in derived savanna areas such as Saki, Nigeria.

Casual relations with man-including fire

The local importance of *P. biglobosa* and *Vitellaria paradoxa* has been documented repeatedly since the days when the first western European explorers visited the region. The relative abundance, frequency and distribution patterns of *Parkia* in parklands and farmed/fallow lands are indications of this association (Bennett *et al.*, 1976; Pullan, 1974; Kessler, 1992; Gijsbers *et al.*, 1994; Gakou *et al.*, 1995). According to Valette (1973) and Pullan (1974), the presence of a mature *Parkia* tree indicates a long history of human settlement and cultivation, whilst its presence away from existing settlements indicate abandoned land. Regular occurrence of *Parkia* seedlings along cattle tracks and pedestrian routes are further indications of interactions with man (Baker & Harris, 1957, Keay, 1959; Hagos, 1962; J. C. Okafor,. pers. comm.).

P. biglobosa is a fire resistant heliophyte, although apparently to lesser extent than *Lophira lanceolata* and *Crossopteryx febrifuga* (Unwin, 1920; Hopkins & White, 1984). Ogigirigi & Igboanuago (1985) indicate that the deep tap roots, thick bark, and high coppice shoot re-growth are various adaptation strategies to fire and drought

Bush fires largely from intentional human activities are features of savanna woodlands in West Africa (Hopkins, 1962; Fatubarin, 1987). *Parkia* is seasonally exposed to both early and late burning, often coinciding with the flowering, fruiting and regeneration regimes of the species. Unwin (1920) claimed that the fruit-bearing capacity of the species was not reduced by annual grass-fires in localities where it is found. More recent views, however, are that mature *Parkia* trees and seedlings suffer greatly from seasonal bush fires (Gijsbers *et al.*, 1994; Breman & Kessler 1995). Nevertheless the same fire promotes coppice shoot re-growth and pre-rain flushing (Fatubarin, 1987).

***Parkia biglobosa* in successional vegetation change.**

As a new environment is created by seasonal bush burning, the thin-barked thicket species are killed, and fire-hardy savanna species eventually establish themselves in the open grassland. *Parkia biglobosa* has remained edaphically adapted and resistant to seasonal bush fires, especially in Sudanian wooded grassland savanna (Fairbran, 1939; Murdoch *et al.*, 1976; Blair *et al.*, 1977; Hopkins & White, 1984). In the Guineo-Congolian/Sudanian transition zone of White (1983), *Parkia* has invaded and persisted. In this zone it has thrived, favoured by the intensive cultivation, reduced fuel loads and fires intensity, and the selective cutting of competing woody species with less economic values. Clayton (1958) reports that the end product of retrogression can be a park-like landscape dominated by *Parkia* (carefully preserved for its edible seeds). In most anthropic vegetation replacing earlier forest cover, *Parkia* occurs with seral species as a result of secondary succession, probably spreading further over time through planting or dispersal by man (Keay, 1959b; Hopkins & White, 1984). On abandoned farmlands, an initial forb regrowth is succeeded by thicket before woody species including *Parkia*, *Vitellaria* and *Daniellia* invade the vegetation (Stewart & Orebanjo, 1983).

2.5 HUSBANDRY AND MANAGEMENT

This section is concerned with the husbandry and management of *Parkia biglobosa*. The first of its sub-sections highlights traditional and professional management in natural/spontaneous stands. The next sub-section reviews experience from nursery trials and plantations, while the last section reviews germination methods and coppicing in the species.

2.5.1 Traditional management of natural stands

Many workers have reported deliberate protection efforts for both mature and regenerating stands by farmers (Hagos, 1962; Campbell-Platt, 1980; Ghazanfar, 1989; Hopkins, 1983; Gijsbers *et al.*, 1994; Gakou *et al.*, 1995). Traditional management interest in *P. biglobosa* reflects recognition of the importance in sustaining the tree as a nutritious food source, flavouring and source of medicine for the local community and economy. Fuel wood, poles and fodder are secondary benefits. *P. biglobosa* is a key food buffer in many areas, due to its reliable yield and dependable income source (Sene, 1985; Felker, 1990). Not surprisingly, it has acquired a protected status range-wide, even where virtually all other trees are eliminated (Unwin, 1920; Clayton, 1958; Taylor, 1960; Jackson, 1973; Hopkins, 1983; Gijsbers *et al.*, 1994). As a result of this deliberate protection, the tree sometimes appears gregarious on agricultural lands (Jackson, 1973; Nikiéma, 1993).

Nevertheless, deliberate management efforts aimed at natural stands still remain at a most preliminary level (Okafor, 1980; Nikiéma, 1993; Kessler, 1994; Abe, 1995). Growth in the species is slow (Unwin, 1920; Maydell, 1986; Fagbemi, 1989), which appears to be a major set back towards deliberate planting efforts by individuals or groups of farmers. A recent study in Sokoto, Nigeria, however, showed that 60 farmers (30% of those interviewed), planted the species on their farms (Popoola & Maisanu, 1995). Hill (1937), Schery (1952) and Weber (1986) had all previously indicated planting to some extent by farmers, but noted at the same time, that most of the crop came from the wild. In Burkina Faso, Mali, Niger, Nigeria, Benin and Gambia, selected seedlings regenerating naturally are often very deliberately protected with the aid of barriers of thorns, or sometimes even wire mesh, while others are transplanted to open fields (Delwaulle, 1979; FAO, 1988; Fagbemi, 1989; Breman & Kessler, 1995; Popoola & Maisanu 1995). Post-transplanting silvicultural operations are often carried out after planting of the main food crops by farmers at the middle of the rains, and include: watering, weeding and protection against bush fire, browsing and cutting by the use barriers and trees with thorns/wire net (Kessler, 1992; Nikiéma, 1993; Timmer *et al.*, 1996). In the case of the mature trees, pruning is often carried out at the beginning of the rains, when fruit harvesting is over (Timmer *et al.*, 1996) to improve the next season's production. Agbahungba & Depommier (1989) and Kater *et al.* (1992) report pollarding and the removal of dead branches from unproductive old trees for Burkina Faso. Timmer *et al.* (1996) indicate two pruning regimes by farmers (less intensive October-November) and intensive (April-May), although these practices are not applied to *Parkia* in uncultivated fields.

In several parts of the range, legal instruments control exploitation, protecting *Parkia* stands from cutting and pruning for fire wood (Kennedy 1932; Nikiéma, 1993; Gakou *et al.*, 1995). Farmers see formal management of the species as amounting to tending a secondary crop; the advantage of which they cannot immediately appreciate (Kessler, 1994). Timmer *et al.* (1996) summarise the state of knowledge in management of wood tree species and its relevance to *Parkia* (Table 2.9).

Table 2.9 Silvicultural management practices: the current state of knowledge in the Sudan and Sahel zone (adapted from Savenja, 1993; Timmer *et al.*, 1996).

Silvicultural practice	State of knowledge/ need for research[a]	Importance in néré (*Parkia*) case study[b]
Management practices to improve natural regeneration		
Protection of young woody plants	+	0
Manipulation of undergrowth	-	-
Special soil/site treatments (mulching, fertilising)	0	-
Coppice and root re-sprouting techniques	0	-
Artificial regeneration practices		
Seeding	++	+
Impact of micro-site variability	0	-
Plant propagation	0	-
Spacing/planting configurations	0	+
Mixing of species (trees, shrubs, grasses, herbs)	-	-
Special soil/site treatments (mulching, fertilising)	0	0
Management practices for mature woody plants		
Pruning/ branch cutting	0	+
Pollarding/coppicing	0	+
Protection against fire and /or grazing	0	-

a - not studied ; 0 scarcely studied; + much studied; ++ well understood;

b - not applied; 0 rarely applied; + common.

2.5.2 Professional management

When interest in professional management of *Parkia* as an acknowledged resource began, is not very clear. However, evidence available associates this interest as concurrent with the onset of large scale mechanised agriculture in Nigeria in the early 1970's, and possibly also in other parts of the range (Ladipo *et al.*, 1990). The realisation of substantial degradation of the *Parkia* genepool led to co-ordinated management initiatives. The Forestry Research Institute of Nigeria (FRIN), in association with the Commonwealth Science Council, responded by initiating a joint seed collection programme (1985), during which seeds from 280 individual trees (half-sib progenies) from different part of Nigeria were collected and processed for storage (Ladipo *et al.*, 1990). Similar initiatives also took place during this period in the Gambia (Forster, 1983), Burkina Faso (Nikiéma, 1993) and Mali (Cossalter *et al.*, 1988). Various institutions and research organisations continue to show interest in both in-situ and ex-situ conservation and development programmes, including ILCA, IITA, ICRAF, CNSF, FRIN, ENGREF and AFNETA (Sabiiti & Cobbina, 1992a; ANON, 1992; Akinola, 1995).

Chevalier (1910) was apparently the first to propose plantation establishment for the species (Hagos, 1962). Experience has since shown, however, that *Parkia* establishes poorly from direct seeding: usually less than 50% success (Agbahungba & Depommier, 1989; Nikiéma, 1993). Nevertheless, in Nigeria, Fagbemi (1994) obtained a survival rate of 97.33% after one year, while a slight decrease was observed in the subsequent years, with 95.25% success. Potted seedlings, later transplanted, establish better and are ready for the field at 10-14 weeks (Weber, 1986; FAO, 1987; Sabiiti & Cobbina, 1992). For those plantations established, various espacements have been used (2 m x 4 m to 30 m x 40 m).

The determining factor for this variation is whether pure or mixed silvilculture is the aim. A summary of espacements recommended is given Table 2.10.

Table 2.10 Suggested spacing for *Parkia biglobosa.*

Espacement (m)	Locality	Basis	Reference
30 x 40	range	established plantation	Hagos (1962)
5 x 5	Benin	Thinning at 8-10 years to leave 100 stems per hectare (30-40 years)	Agbahungba & Depommier (1989)
4 x 2	Nigeria	mixed silviculture thinning at 3 years, 714 trees per hectare	Fagbemi (1994)
6 x 6	Nigeria	two thinning regimes before 15 years of establishment	FRIN (1989)
7 x 7 to 10 x 10	range	mixed silviculture of maize-sorghum;	Rocheleau *et al.* (1988)
5 x 5	range	thinning at 8-10 years (100 tree per hectare)	Maydell (1986), FAO (1988b, 1989b)
2.5 x 2.5	Burkina Faso	plantation trial (64 trees per hectare)	Nikiema (1993)

Provenance trials had 90% seedlings establishment success with local farmers in Benin (Agbahungba & Depommier, 1989). Sabiiti & Cobbina (1992b) obtained 100% survival on another field in Nigeria, with a similar rainfall pattern to Benin. In Burkina Faso, Nikiéma (1993) reports 41% seedling survival in plantation after 20 months, higher seedling mortality occurring in the dry season. This lower survival value compared with Benin can be explained in terms of shorter rainy season and lower total rainfall in Burkina Faso. *Parkia* seedling survival under field conditions appears to depend greatly on available soil moisture during the dry season.

The growth rate is moderate, attaining a diameter of 17-20 cm and 7 m height after 22 years (Maydell, 1986; Booth & Wickens, 1988). Bonkoungou (1987) indicates height increments of 1 m per year; at 3½ years seedlings were 3 metres tall. Nutritional trials in *Parkia* seedlings show that the species responds better to organic manure mixtures (poultry and sheep dung) than to inorganic fertilisers in a lowland savanna environment (Awodola, 1990; Onuoha, 1995).

Recent research output indicates no nodulation in the species (Halliday, 1984; Workman, 1986; Dommergues, 1987; Faria *et al.*, 1989; Sutherland, 1989; Tomlinson *et al.*, 1995) in contrast to earlier reports (Allen & Allen, 1981). Tomlinson *et al.* (1995) failed to stimulate root nodules development by exposing seedlings to inoculum in the greenhouse. No seedling grown in soil collected from beneath mature *Parkia* trees, or inoculated with cowpea miscellany rhizobial culture, showed any indication of nodulation. They concluded that either no suitable inoculant was provided or that *P. biglobosa* is not capable of nodulating.

Outside the experimental/trial context, comments relating to professional *Parkia* management are linked with agroforestry. Fagbemi (1989) indicates a minimum of 12 months post tree establishment, before crops are introduced to prevent adverse competition effects on the trees. In Mali and Burkina Faso, where tree pruning was employed as a management option, crop performance was better near the trees compared with the open field (Kater *et al.*, 1992; Kessler, 1992). A sustained fodder supply and good coppice shoots were observed in the species under pruning regimes operated with 16-24 weeks intervals (Sabiiti & Cobbina, 1992a). Manipulation can allow the farmer to determine the number of branches left unpruned, and the best pruning regimes for a balance between *Parkia* fruit yield and food crop yield.

2.5.3 *PARKIA BIGLOBOSA* AS A NURSERY SUBJECT

Seed supply and storage

Reports from many parts of the range indicate mature *Parkia* fruits are ready for harvesting at the beginning of the rains, beginning from late March to June/July range-wide (Forster, 1983; Ladipo *et al.*, 1990; Kessler, 1992; Sabiiti & Cobbina, 1992; Guinko & Pasgo, 1994). Harvesting methods range from direct tree climbing by men (Busson, 1965), use of long poles and stakes (Gakou *et al.*, 1995; Sabiiti & Cobbina, 1990) and direct picking of pods, resulting possibly from fruit abscission and disturbances, from the forest floor by women and children (Sharland, 1991; Guinko & Pasgo, 1994). Weber (1986) recommended collection of freshly fallen strong healthy seeds as a seed source for planting. Apart from harvested fruits, viable seeds can also be obtained from local markets. Forster (1983) indicated that the selection of seed of good form is very important if *Parkia* is to be raised for timber production. He suggested that special arrangements could be made with the local population if seed from specific trees is desired.

There are 2800-5000 seeds kg^{-1} (Derek *et al.*, 1984; Carlowtiz, 1991; Booth & Wickens, 1988). Weber (1986) suggested immediate planting of seeds for maximum, percentage germination, but the results of a silvicultural trial in Gambia indicated that seed stored for one year are better than fresh seeds (Forster, 1983). A minimum of 1 year in storage before planting gave 42% germination success, while seeds planted 2 weeks after harvesting had 18% germination (Forster, 1983). Bonkoungou (1986) obtained 61% germination after 1 year storage, but 49.5% after 67 days storage and only 32% after 753 days storage.

Unpreserved seeds soon loose their viability (Ladipo *et al.*, 1990). Forster (1983) and Some *et al.* (1990) report that *Parkia* seeds remain viable for up to 2 years in ordinary plastic containers, sacks and polythene bags, at room temperature. Busson (1965) and Derek *et al.* (1984) recommended air-tight granaries for longer and large-scale storage. High seed viability can be maintained at 0-5°C (Ladipo *et al.*, 1990). Agbahungba & Depommier (1989) observed 80% germination after 5 years of storage.

Nursery activity

It is advantageous if *Parkia* seed is subjected to pretreatment before sowing, to break any dormancy due to the pulp and the hard/thick testa (Oguntala, 1979; Etejere *et al.*, 1982; Sabiiti & Cobbina, 1990; Alabi, 1993). The difference between the red-brown and dark-brown seeds is, however, only discernible when mature non-dried seeds are newly extracted (Ladipo *et al.*, 1990). The red brown seeds germinate readily, and it is the dark brown seeds that are frequently dormant and require pretreatment. In natural conditions, only a small percentage of the seeds germinate due to dormancy problems (Campbell-Platt, 1980; Etejere *et al.*, 1982) and this is a major management problem with implications for both in-situ and ex-situ conservation.

Direct sowing in the field is not favoured in most silvicultural reports (Agbahungba & Depommier, 1989), as it often results in poor germination rates while the delicate young seedlings are frequently attacked by rodents and pests (Bonkoungou, 1986; Alabi, 1993). The nursery should be set up near shade, with adequate light and water, and free from bush fire (University of Ibadan; Forestry Dept, 1986). More robust seedlings can be raised in pots or baskets in the nursery (Agbahungba & Depommier, 1989; Booth & Wickens, 1988). An espacement of 10 cm by 10 cm has been suggested for nursery beds (Ichire, 1993) but pots are preferred alternative. Sowing depth for treated seeds showed that seeds sown at 0 cm soil depth had 20% germination, while at 5 cm and 10 cm depth 100% germination was obtained (Fatubarin, 1987). Pre-treated seed germinates 4-7 days after sowing at a depth of 1 cm. *Parkia* seedlings are intolerant of root pruning, direct lifting, pricking out and stumping (Fishwich, 1964; Agbahungba & Depommier, 1989). Silvicultural recommendations for *P. biglobosa* based on nursery trials in the Gambia (Forster, 1983) are as follows:

- store seeds for one year
- carry out a water floatation test.
- sow in April in polythene tubes.
- sow three seeds per tube.
- sow seeds only superficially
- carry out proper watering.

Table 2.11 Sowing timing for various parts of the range.

Country	Period	Location	Reference
Nigeria	Late March	Sokoto	Fishwick (1964)
	Late March	Katsina	
	Late March	Kano	
	Late March	Bauchi	
Gambia	March-May	Gambia, Fajara	Forster (1983)
	Early April	Nigeria Borno	Fishwick (1964)
Benin	April-May	Benin, Parakou	Agbahungba & Depommier (1989)
Burkina Faso	April-May	Burkina Faso: Ouagadougou	Nikiema (1993)

Out-planting requires seedlings hardened by gradual reduction of the watering rate, which should be ready to plant at the middle of the rains at an age of 10-14 weeks old (Maydell, 1986). *Parkia* seedlings are sensitive to browsing (Bonkoungou, 1978, Booth & Wickens, 1988) and hence require protection from livestock. Seedlings are attacked by leaf blight, fungi and phytophagous insects under field conditions (Roberts, 1969; Fagbemi, 1989), but there is no information on pest and disease control measures under formal management.

Pre-treatment

Seed pretreatment procedures effective for *P. biglobosa* include; acid or chemical scarification, stratification, and cold water (Tables 2.12-2.14). The red-brown seeds germinate more readily than the dark-brown, due to the thinner seed coat, when both are not acid treated before sowing. Etejere *et al.* (1982) obtained 90% and 21% germination success in untreated red-brown and dark-brown seeds respectively. Untreated seeds require 15-24 days for dormancy to be broken naturally but pre-treated seeds germinate after 3-4 days (Oguntala, 1979; Gill & Bamidele, 1981; Alabi, 1993).

Etejere *et al.* (1982), Sabiiti & Cobbina (1992a) and Alabi (1993) report the germination response of *Parkia* seeds to various pretreatment methods (Tables 2.10-2.14). Seeds laid on ordinary moist filter paper failed to germinate after 13 days in both light and dark conditions (Gill & Bamidele, 1981). Broadcasting untreated seeds gave 50% germination after 24 days (Alabi, 1993). Sulphuric acid treatments (exposure to acid for 5-30 minutes) generally led to more than 50% germination within 3 days (Table 2.12). Stratification methods have given more variable outcomes, but are difficult to evaluate as researchers do not always describe the conditions or duration in detail (Table 2.14).

Table 2.12 Reported acids pretreatments, duration and success of germination tests for fresh *Parkia* seeds.

Pre treatments	Duration (days)	Mean germination (%)	Source
Conc. H_2SO_4 in 15 mins	3	75	Derek *et al.* (1983)
Conc. H_2SO_4, 15 minutes (light)	3	90-94	Oguntala (1979)
Conc. H_2SO_4, 15 minutes (light)	5	99	Sabiiti & Cobbina (1990)
Conc. H_2SO_4, 5 minutes (light)	3	60	Gill & Bamidele (1981)
H_2SO_4 10 minutes (dark)	3	94	Gill & Bamidele (1981)
H_2SO_4 , 15 minutes (dark)	3	80	Oguntala (1979)
H_2SO_4 , 30 minutes (dark)	6-8	35-80	Agbahungba & Depommier (1989)

Table 2.13 Reported scarification pretreatments, duration and success of germination tests for fresh *Parkia* seeds.

Pretreatments	Duration (days)	Mean germination (%)	Source
Decoated, micropyle end (partial)	3	73-83	Etejere *et al.* (1982); Alabi (1993
Docoated, non micropyle end (partial)	3	73-88	Etejere *et al.* (1982); Alabi (1993
Decoated (complete)	3	91	Etejere *et al.* (1982); Alabi (1993

Table 2.14 Reported stratification pretreatments, duration and success of germination tests for fresh *Parkia* seeds.

Pre treatments	Duration (days)	Mean germination (%)	Source
Running water ,114 hours	3	89	Alabi (1993)
Hot water 30 mins	5	2	Sabiiti & Cobbina (1990)
Warm water 36 hours	28-70	22	Forster (1983)
Boiling water 3 mins	21-42	29	Forster (1983)
Soak in hot (over night)	not indicated	80	FAO (1987)
Temperature 80 °C,	not indicated	20	Sabiiti & Cobbina (1992)
Temperature 100°C 1-15 minutes	not indicated	0	Sabiiti & Cobbina (1992)

2.5.4 Increment and production

Seedlings and regenerating shoots

Parkia establishes very well from seed and vegetative material (Okafor, 1978; Etejere *et al.*, 1982; Ladipo *et al.*, 1990). Trials conducted in Nigeria have indicated average seedling initial mean height increments of 7 mm per day (Ichire, 1993). Height increment is, however, often influenced by nutrient supply (Awodola, 1993), as well as provenance (Ladipo *et al.*, 1990). Where nutritional requirements are met, and conditions also good in other respects, seedlings attained a mean height of 19.1 cm and diameter of 0.35 cm with 27 leaves in 12 weeks, in Nigeria (Awodola, 1993). In Burkina Faso (Nikiéma, 1993) reported a height of 13 cm at 15 weeks under nursery conditions. Reports of height in relation to age are indicated in Table 2.15.

Table 2.15 Heights of *Parkia biglobosa* in relation to age.

Locality	Age (weeks)	Height cm	Remarks	Reference
Gambia	8	16.2	nursery trial	Forster (1983)
Nigeria	12	19	nutritional trial	Awodola (1993)
Nigeria	12	21.3	nursery trial	Onuoha (1995)
Burkina Faso	15	13	nursery trial	Nikiema (1993)
Nigeria	16	26.7	nursery trial (seed from lowland range)	Oni & Ladipo (1989
Gambia	52	23	nursery trial, mean height for five locations	Forster (1983)
Benin	52	75	transplanted farmers field	Agbahungba & Depommier (1993)

2.5.5 Management of natural and spontaneous stands and height increment

Stands of *Parkia* are reported to have been planted in several parts of the range, including Gambia, Burkina Faso, Niger and Nigeria (Unwin, 1920; Hill, 1937; Forster, 1983; Bonkoungou, 1987; FAO 1988; Kessler, 1994; Popoola & Maisanu, 1995). According to Bonkoungou (1986), branch breakage in the early rainy season from the action of strong winds, and high seedling mortality, have been experienced in the first 3-5 years. Campbell-Platt (1980), FAO (1985) and Fagbemi (1989) indicate that the majority of farmers do not readily propagate indigenous economic trees in plantation, but prefer to protect stands. However, awareness of the species in nursery and plantation afforestation projects by farmers is increasing (Popoola & Maisanu, 1995).

Among the few instances where there are planted trees of known age, Bonkoungou (1987) and Agbahungba & Depommier (1993) indicate a height of 3 m after 3-4 years of establishment while Nikiéma (1993) records a 6 years old tree 7 m tall. Results from agrosilvicultural trials of the species in mixed silviculture with *Gmelina arborea* and food crops (maize and Guinea corn) have shown favourable height increments over the first 6 months following establishment (Fagbemi, 1994), but *Parkia* is nevertheless relatively intolerant of combination with food crops, and seedling height increments are depressed, compared with growth free of crops (Bonkoungou, 1986; Fagbemi, 1994). Six months after establishment, seedlings had attained a mean height of 58 cm in mixed silviculture, but 65 cm when as sole. Corresponding heights after 12 months were 93 cm and 114 cm respectively (Fagbemi, 1994). In mixed cropping with maize (*Zea mays*) and Guinea corn (*Sorghum bicolor*), seedlings were affected differently by the crops (Table 2.16). Maize reduced *Parkia* seedlings by a smaller amount than did sorghum bicolor (Fagbemi, 1989). *Parkia* seedlings without an associated crop at an espacement of 2 m x 4 m, were, by 24 months, 280 cm tall compared with 96 cm in mixed silviculture (Fagbemi, 1994). Survival figures for the same plant in three of the same studies are in Table 2.16

Table 2.16 Heights of *Parkia biglobosa* at different locations

Reference	Locality	Age (months)	Height (cm)	Remarks
1	a	12	86	*Parkia* sole
1	a	18	154	*Parkia* sole
1	a	24	221.7	*Parkia* sole
1	a	12	63	mixed cropping (maize)
1	a	18	97	mixed cropping (maize)
1	a	24	120.3	mixed cropping (maize)
1	a	12	35	mixed cropping (G. corn)
1	a	18	61	mixed cropping (G. corn)
1	a	24	72.33	mixed cropping (G. corn)
1	a	6	0.86	nursery condition
1	a	36	1.93	mixed silviculture
1	a	12	1.21	inter crop
1	a	36	2.70	monoculture
1	a	6	65	monoculture
1	a	12	93	mixed silviculture
1	a	12	114	monoculture
1	a	18	111	mixed silviculture
1	a	18	145	monoculture
1	a	24	150	mixed silviculture
1	a	24	216	monoculture
1	a	30	164	mixed silviculture
1	a	30	243	monoculture
1	a	36	193	mixed silviculture
1	a	36	271	monoculture
1	a	6	58	mixed silviculture
2	b	3	0.19	(trials) optimum nutrition
3	a	3	20-40	nursery condition
3	a	24	2.80	nursery condition
4	d	1.5	15	nursery condition
4	d	1.5	8	nursery condition
4	d	2	20	nursery condition
4	d	2	16.2	Plantation
4	d	12	23	Plantation
4	d	12	27	Plantation
4	d	12	28	Plantation
4	d	12	22	Plantation
4	d	12	15	Plantation
5	e	4	0.13	nursery condition
6	f	12	75	Provenance trial
6	f	44	300	Plantation trial

Source: 1 Fagbemi (1989, 1994) ; 2 Awodola (1993); 3 Oni & Ladipo (1989); 4 Forster (1983); 5 (Nikiéma, 1993) 6 Agbahungba & Depommier (1989). **Localities** (a): Ilorin (08° 29' N 04° 35' E), (b) Sokoto (13° 02'N 5° 25'E); (c) Ibadan (07° 26'N 03° 54'E), (d) Gambia (13° 32'N 14° 46'W), (e) Sapone Ouagadougou (12° 21'N 01° 3'W), (f) Parakou Benin (9° 20'N 2° 50'W).

Table 2.17 Percentage surviving trees reported over time in the range

Treatment	Age (months)	Survival (%)	Location	Remarks
Parkia alone	12	97.50	[1]Nigeria, Ilorin	Agrosilviculture trial
Parkia alone	24	94.50	Nigeria, Ilorin	Agrosilviculture trial
Parkia + maize	12	93.33	Nigeria, Ilorin	Agrosilviculture trial
Parkia + maize	24	86.67	Nigeria, Ilorin	Agrosilviculture trial
Parkia +G/corn	12	84	Nigeria, Ilorin	Agrosilviculture trial
Parkia +G/corn	24	72.78	Nigeria, Ilorin	Agrosilviculture trial
Parkia alone	12	93.75	Nigeria, Ilorin	Agrosilviculture trial
Parkia + Gmelina	12	97.33	Nigeria, Ilorin	Plantation trial
Parkia alone	24	88.83	Nigeria, Ilorin	Plantation trial
Parkia + Gmelina	24	95.25	Nigeria, Ilorin	Plantation trial
Parkia alone	36	88.83	Nigeria, Ilorin	Plantation trial
Parkia + Gmelina	36	95.25	Nigeria, Ilorin	Plantation trial
Parkia alone	12	20	[2] Gambia, Bijilo	Plantation trial
Parkia alone	12	58	Gambia, Furuyar	Plantation trial
Parkia alone	12	53	Gambia, Katilenge	Plantation trial
Parkia alone	12	96	Gambia, Kaiaf	Plantation trial
Parkia alone	12	95	Gambia, Pakala	Plantation trial
Parkia alone	12	90	[3]Benin, Parakou	Plantation trial
Parkia alone	12	84	Niger	Plantation trial

Source: [1]Fagbemi (1989) and (1994), [2] Forster (1983), [3]Agbahungba & Depommier (1989)

Coppice ability and biomass production

Fully established 7 year old *Parkia* trees coppice successfully one week after being cut back and the foliage becomes dense after 3 months (Sabiiti and Cobbina, 1992). High quality fodder can be repeatedly obtained at 16 weeks and 24 weeks cutting intervals without much change in leaf nutritional quality (Sabiiti and Cobbina, 1992). Trials with seeds of provenances from two different ecological zones showed that seedlings produced 34 leaves in 12 weeks (Oni & Ladipo, 1989). A preliminary study on 8 year old trees (Sabiiti & Cobbina, 1992) suggested high coppice shoot regrowth potential in the species, in terms of both total numbers of shoots formed and shoot length, but more studies are required to understand coppice shoot production in the species, and for formulation of proper management systems (Sabiiti & Cobbina, 1992a). Findings in relation to cutting interval are indicated in Table 2.18.

Table 2.18 Effect of cutting interval on coppice productivity in *Parkia biglobosa* in the humid zone of Nigeria (Fashola).

Cutting intervals (weeks)	New shoots (no)	Shoot length (cm)	Leaf biomass kg ha^{-1}	Total biomass kg ha^{-1})
8	6	107		
16	6	170	2474	
24	6	218		3287

Source: Sabiiti & Cobbina (1992b)

Alternatives to propagation from seed

P. biglobosa can be established vegetatively in nursery beds by grafting, budding and adult cuttings (Okafor 1989; Teklehaimanot *et al.*, 1996). Rooting success, however, varies with provenance, and the source of cutting material on the stock plant, in terms of node position, hormonal treatments and propagation techniques (Teklehaimanot *et al.*, 1996). Maximum success has been with severance by diagonal cutting and minimum success by wounding (Teklehaimanot *et al.*, 1996). (O. Oni, pers. comm.), in Nigeria, indicate that juvenile trees, (16-25 years old) responded very well to marcotting and grafting using Indo-butyric acid (IBA), at concentrations of 50 and 100 ppm in Ibadan. Tissue culture studies are currently being extended to juvenile plants in Bangor (Z. Teklehaimanot, pers. comm.).

Teklehaimanot *et al.* (1996) also observed, in cutting trials conducted on seedlings in Bangor, that cutting back plants four months after establishment from seed helps to maintain juvenility in the species, while selection of single node leafy cuttings in May, basal wounding on single node leafy cuttings in September and treating single node leafy cuttings derived from stock plants with hormones in December proved effective in regenerating plants vegetatively. Evaluation of single-node leafy cutting revealed that *Parkia* rooted best from cuttings from the terminal node; while cuttings below the fifth position performed poorly.

Cuttings obtained beyond the fifth position on the nodes were indicated as over-mature for rooting due to lignification, while cuttings from position 1 and 2 subjected to wounding appear to react negatively, possibly due to the delicate nature of the non-woody tissue. Wounding of the severed node with a diagonal cut at its basal end was the most effective treatment for subsequent root regeneration. Among the hormonal treatments, 100 ppm naphthalene acetic acid (NAA) was the most effective in promoting root regeneration (Teklehaimanot *et al*, 1996). Indole 3-butyric acid (IBA) was not as effective as NAA (Teklehaimanot *et al.*, 1996).

MISSING PAGE REMOVED ON INSTRUCTION FROM THE UNIVERSITY

Guinko & Pasgo (1992), Gakou *et al.* (1995) and Breman & Kessler (1995) all note that a reliable and dependable income can accrue to farmers; and especially the women, involved in processing and marketing the tree by-products. In practice almost all parts of the tree have been indicated as useful in one way or other (Irvine, 1961; Hagos, 1962; Campbell-Platt, 1980; Hopkins, 1983; Abbiw, 1990; Gakou *et al*; 1995), but it is the seed that is most valued (Holland, 1922; Kennedy, 1936; Irvine, 1961; Hagos, 1962; Campbell-Platt, 1980; Hopkins, 1983; Chambers & Leach, 1989; Some *et al.*, 1990; Abbiw, 1990; Alabi, 1993; Okpala, 1993; Gakou *et al.*, 1995). In Burkina Faso (Zitenga), Mali and Benin the processed seed (*soumbara*) tops the list of edible forest food products locally sold in the market (Fandohan, 1983; Guinko & Pasgo, 1992). In Mali, it accounts for 10% of the total non-timber forest products locally used as food (Gakou *et al.*, 1995).

The rather consistent fruiting time of *Parkia* means that fruit collection is in the March-July period throughout the range. A typical tree yields an average of 13-25 kg fruit (Odunfa, 1985; Bonkoungou, 1987; Agbahungba & Depommier, 1989; Sabiiti & Cobbina, 1992a; Kessler, 1994). Seed extraction from fruits involves separating the seeds from the fruit tissues surrounding them. A seven stage operation is dictated by the nature of the fruit (Some *et al.*, 1990). The stages are (1) shelling (2) pre-drying (3) pounding (4) winnowing, or sieving, (5) washing in water, (6) drying and (7) visual sorting by hand (Some *et al.*, 1990). This yields the processed beans used widely to prepare *iru/dawadawa/soumbala* (Omololu *et al.*, 1986; Bonkoungou, 1987; Soladoye *et al.*, 1989; Sabiiti & Cobbina, 1992).

The traditional conversion of locust bean to *soumbala* or *dawadawa* involves dehulling the seed coat and fermenting the bean. Dulling is achieved by boiling in water for about 12 hours before the hard seed coat is removed. This is followed by washing and later fermentation. At fermentation the original cream to light colour of the bean changes to dark-brown, due to a number proteolytic changes in the substrate as a result

MISSING PAGES REMOVED ON INSTRUCTION FROM THE UNIVERSITY

The fermented seeds constitute a natural nutritious concentrate which features frequently in the traditional diets of the people of West Africa (FAO, 1967; Schery, 1969, Fay, 1984; Okafor, 1980; Fagbemi, 1989). Fetuga *et al.* (1974) indicate the easily assimmilable carbohydrates, high protein, limited sugar and the absence of true starch from the fruit. Ikenebomeh & Ingram (1986), who progressively analysed seeds from raw to the fermented stage, noted increasing fat content and decreasing carbohydrate upon fermentation, and the presence of Riboflavin. In culinary terms, the product is comparable to cheese in the Europeans diet (Aubreville, 1950; Irvine, 1961; Campbell-Platt, 1980; FAO, 1987, 1988).

The estimated average consumption rates of *Parkia* beans per head per day for Nigeria, Togo and Ghana are 10 g, 4 g and 2 g respectively (Campbell-Platt, 1980; Odunfa, 1981; Adewunmi & Igbeka, 1992). The fermented beans are the cheapest source of vegetable protein after groundnut and dried fish, and a major food additive equivalent to soybean (Girgis, 1972; FAO, 1988b; Bayer, 1990; Ford, 1991; Adewunmi & Igbeka, 1992). The processed seed is often used to increase the protein content of carbohydrate based foods such as 'ogi' (an equivalent of custard) and cassava products (Odunfa, 1985). In many urban and rural diets, *dawadawa* or *soumbala* features and compares well with sauce additives based on imported ingredients (Gbile, 1980; Fagbemi, 1989).

Mature fruit consists of 43% exocarp, 39% sweet pulp and 18% seed (Busson, 1965). Holland (1922) speculated on the use of the pulp as a sugar source due to its large proportions of saccharine. Simmons (1976) reported that *dawadawa* supplied 1.4% of the energy and 5% of the total protein in-take of Hausas in northern Nigeria. The yellow mealy pulp contains 60% sugar, 10-24% sucrose, (291 mg /100 g dry matter and (Vitamin C) high energising power (FAO, 1967; Campbell-Platt, 1980; Maydell, 1986; Dearden & Cassidy, 1990), and therefore used a as sweetener in children's' diets and as famine food by the people (Busson, 1965; El-Hadji, 1986; Booth & Wickens, 1988; Abbiw, 1990).

Occasionally the seed is ground into meal and mixed with water to form a gruel used as a drink (Busson, 1965; Abbiw, 1990). Macerated in water the pulp flavoured with honey, provides a soothing drink for infants in a febrile state, having emollient and refreshing properties (Irvine, 1961). Children often suck the fresh flowers for the sugary juice (Irvine, 1961, Szolnoki, 1985). A drink made from the pulp and mixed with tamarind water (dagwado) in Northern Nigeria is very nourishing (Campbell-Platt, 1980) while the paste from the pulp (Dozim) attracts a good price in Ghana (Abbiw, 1990). Fermented pulp is used as an alcoholic beverage (Campbell-Platt, 1980), while in Burkina Faso other forms of processing, give a drink with diuretic properties (Some *et al.*, 1990). The pulp is often mixed with rice or other cereals or soup, or sometimes made into cakes and stored or fried as meal (Booth & Wickens, 1988; FAO, 1989). The young leaves are edible (Watt & Breyer-Brandwijk, 1962, Campbell-Platt, 1980; Sabiiti & Cobbina, 1992), and may be fermented into balls and mixed with cereals or sauces (by the Junkun people) of northern Nigeria. Dietary characteristics and mineral contents are summarised in Tables 2.26-2.28.

MISSING PAGES REMOVED ON INSTRUCTION FROM THE UNIVERSITY

2.6.2 Specialist uses

Parkia biglobosa trees play vital roles in the traditional heath care of local people. Abbiw (1990) lists the presence of many active substances present in the tree which form the basis of its use in curative medicine. As a medicinal plant the active ingredient is referred to as *soumara* in the form of a fat (Covi, 1971; Abbiw, 1990). According to Abbiw (1990), before the advent of Western medicine, the tree components and their extracts were used by fetish priests to treat various illness in West Africa.

Table 2.31 Medicinal uses of *Parkia biglobosa* components parts with/without other materials

Part of tree used	Ailment	Preparation	Geographical origin of reports	Reference
Physical healing Seed	Hypertension	addition of processed seed/ bean in soup/sauce preparation	Nigeria	Olapade (1995) Rendu & Auger (1993)
Injuries/cuts Mixture of pulp bark and lemon	fresh cuts /injury/bites/stings	pounded and mixed together	Ghana	Abbiw (1990)
Seed	snake bites scorpion stings	fermented seed	Nigeria	Olapade (1995)
Internal disorders Blended bark	diarrhoea	infusion of bark	Coté` Ivoire	Irvine (1961)
Transmitted diseases Bark	venereal diseases	Blended and mixed with other products	not indicated	Irvine (1961) Maydell (1986)
Psychological healing Seed	vision and mental alertness	fermented seeds	Nigeria	Olapade (1995)
Other ailments Leaves with petioles	haemorrhoids	grounded	range	Maydell (1986)
Leaves mixed with roots	eye lotion and mouth wash	pounded infusion	Nigeria, Gambia, Ghana, parts of range	Holland (1922) Upholf (1959); Irvine (1961); Hopkins (1983)
Bark	tooth ache and ear complaints	pounded and boiled	Senegal	Porteres (1974)
Bark mixed with other forest trees products	bronchitis, pneumonia, ulcers, colic's, bilharizia, guinea worm oedema, rickets	pounded and blended with other ingredients	range	Irvine (1961), Kerharo & Adam (1962; Porteres (1974); Maydell (1986) Abbiw (1990)
Flower buds/young leaves	measles	mixed with egg yolk/potash and palm oil	Nigeria	Soladoye *et al.*(1989)

Apart from medicinal purposes, different component parts of the tree provide other services (Table 2.32). The ashes from the burnt leaves are exploited in a local soap cottage industry (Pobeguin, 1906; Dalziel, 1937; Abbiw, 1990; Nikiema, 1993). In Senegal, the burnt exocarp (Khata) is added to tobacco to increase its pungency (Hutchinson & Dalziel, 1958), while in the Central African Republic, it is mixed with burnt flower heads to produce a cooking salt substitute (Fay, 1984).

Table 2.32 Reported additional uses of *Parkia biglobosa* in the range

Material	Purpose	Remarks	Geographical origin	Reference
Shell	wall glaze and traditional floor	pounded shells an aqueous extract mixed with cow dung	Ghana, Benin	Irvine (1961); Hagos (1962); Booth & Wickens (1988) Agbahungba & Depommier (1989)
Shell	Cooking pot coating before firing	pounded shells an aqueous extract mixed with cow dung	Ghana	Irvine (1961)
Leaves	plastering and walling of indigo pit	pounded leaves mix with stones	Ghana and parts of range	Abbiw (1990);
Leaves and husk	local soap	burnt leaves and husks	range	Abbiw (1990); Pobeguin (1906), CTFT (1979)
Husk and inflorescence	Salt substitute	Burnt husk and inflorescence	Central African Republic	Fay (1984)
Husk	Pungency improvement of tobacco	Burnt husk	Senegal	
Extract from pod processing	smeared on winnowing trays for strength and porosity reduction	Smearing	Ghana	Abbiw (1990)
Seeds and pulp	water purifier	Placed on top of sieve	range	Booth & Wickens (1988)
pods,	improve the lustre of dyed products	Macerated pods	Ghana, Central African Republic	Fay (1984); Irvine (1961)
Bark	saponins for beautification	processed bark	Senegal; Gambia, Ghana	Porteres (1974)

2.6.3 Opportunistic/emergency uses

Parkia trees have a variety of further traditional uses which may be regarded as opportunistic or emergency uses commonly valued in the traditional resource utilisation. These are summarised in Table 2.33.

Table 2.33 Additional derivable uses from *Parkia biglobosa* tree

Material	Purpose	Remarks	Geographical origin	Reference
Twigs	chewing sticks	consumptive	Senegal and Niger	Porteres (1974); Booth & Wickens (1988)
Young leaves	soup additives/sauce	consumption	range, Ghana	Dalziel (1937), Abbiw (1990)
Pod lining	tough membranous	musical accessories	Nigeria	Campbell-Platt (1980)
Pod lining	Binding	use in arrow making	Nigeria	Dalziel (1937),Holland (1962)
Husk	processed and dyed (ear rings)	decorative use	Ghana	Irvine (1962)
Root	Pounded	use as scubber/sponge	range	Hagos (1962), Campbell-Platt (1980)
Pulp	food drink	famine food	Nigeria	Adewoyc *et al.* (1986

Wood

The sapwood is yellowish white and the heartwood dull brown (Irvine, 1961; Adewoye *et al.*, 1986). The smell is unpleasant when newly felled and it is liable to blue stain but moderately tolerant to termite attack (Derek *et al.*, 1984). It can be preserved by physical air drying. Season is rapid with little tendency to warping (Booth & Wickens, 1988). The softness and poor quality of the wood limit its domestic and commercial exploitation (Irvine, 1961; Allen & Allen, 1981; NAS, 1980; Hopkins, 1983; Abbiw, 1990) and it is of little value as a timber (Adewoye *et al.*, 1986; Booth & Wickens, 1988).

Working properties are poor (Unwin, 1920; Derek *et al.*, 1984) and the wood density varies between 580-640 kg/m². Babajide & Fuwape (1984) and Derek *et al.* (1989) report a specific gravity of 0.72, moisture content 16.3% and maximum heating value of 21087 KJ kg^{-1} while, available heating value is only 16599 KJ Kg^{-1} (Table 2.34). It is easy to work by hand or power tools but splits around knots and nails. It glues, varnishes and paints very well (Irvine, 1961; Roberts,1969; Gotz, 1983; Booth & Wickens, 1988). Insects, fungi and borers (Table 2.34) attack the wood.

Table 2.34 Reported insects and various predators of *Parkia biglobosa*

	Type of damage	Reference
Fungal	cause discoloration	Irvine (1961); Booth & Wickens (1988)
Marine borers	boring of sapwood	Gotz (1983)

Despite the percevied low esteem, various uses have been reported for the wood (Table 2.35) and interest is also growing in its commercial exploitation for the match industries. Utilisation is currently been investigated in the pulp and paper industry in Jebba, Nigeria (Ademiluyi & Okeke, 1977; Fagbemi, 1989). Domestically it is used as firewood in the absence of wood with higher burning energy (Babajide & Fuwape, 1984; El-Hadji, 1985).

Table 2.35 Reported uses of *Parkia biglobosa* wood

Uses	Reference
Joinery	Hopkins (1983), ICRAF (1991); Whitemore (1990); Record & Gotz (1983)
Furniture	Holland, 1922; Allen & Allen (1981);Carlowitz (1986)
Domestic utensils	Kennedy (1932); Irvine (1961); Campbell-Platt (1980); Abbiw (1990)
Others (hoe handles, building uprights, roof slats)	Unwin (1920); Adelodun, (1944); Maydell (1986); Irvine (1961), Adewoye *et al.*(1986)

2.6.4 Use in resource management/exploitation

Crop production

In Ghana ashes from the leaves and pods are used as fertilisers (Abbiw, 1990).

Fishing

The pulp covering *Parkia* seeds inside the pod contains some substances toxic to fish. The pulp has been used as a piscicide in many parts of the range, including Guinea (Fouta Djallon), Gambia, Ghana and Senegal (Chevalier, 1910; Irvine, 1961; Hagos, 1962; Booth & Wickens, 1988; Abbiw, 1990). Bossut (1986) however, doubts if the practice continues.

Fodder

P. biglobosa leaves are not particularly utilised as forage or fodder by livestock (Jackson, 1973) due to the low digestible crude protein, high content of neutral detergent fibre (NDF) and presence of tannins (Zech & Weinstabel, 1983; Sabiiti & Cobbina, 1992) (Table 2.36). However, the foliage is rich in energy, although low in some essential nutrients (including potassium, magnesium and sodium), hence rated as low to medium quality fodder (Zech & Weinstabel, 1983). Gijsbers *et al.* (1994) indicate that livestock browse the seedlings in Burkina Faso and aborted capitula are eaten by livestock in Nigeria, Burkina Faso and Guinea Bissau (Gomes é Sousa, 1929; Ladipo *et al.*, 1990; Bayer, 1990; Kessler, 1992).

MISSING PAGE REMOVED ON INSTRUCTION FROM THE UNIVERSITY

reported the importance of the seed as an article of trade among the Hausas of northern Nigeria for both personal use and barter. Inter-state and inter regional trade is frequent, particularly between the middle-belt and the Sudan zone of Nigeria and between Benin and the Niger the Republic (Soladoye *et al.*, 1989; Agbahungba & Depommier, 1989). A total production of 200,000 tons of fruits was estimated for northern Nigeria in 1977 (Campbell-Platt, 1980). In 1964, the produce from a single tree was valued at £4-5 per annum (Booth & Wickens, 1988). In a recent market survey in Zitenga, in Burkina Faso the seeds attracted 54000 CFA for 1638 kg (ca. 33.00 CFA kg^{-1}or U S $ 0.07 kg^{-1}). In other parts of Burkina Faso, the seed was trading at 550 CFA kg^{-1} (U S $ 1.22 kg^{-1}) (Nikiema, 1993; Gakou *et al.*, 1995). In Nigeria, one 100 kg bag attract 350-400 Naira or (US $ 30-40) (Soladoye *et al.*, 1989). Kessler (1994) indicated an estimated income of 5000 FCFA ($20.00) per hectare from *P biglobosa* seeds based on an average density of two trees per hectare.

Non consumptive uses

The umbrella shape of mature *P. biglobosa* tree crown, offers an excellent and attractive use of the tree in avenues (Kessler, 1992). Abbiw (1990) indicates that the whole tree is used for avenues either in pure or mixed arrangement. In Gonse, Burkina Faso, and in the Gambia the tree is planted in isolated positions at the side of the roads or along firebreaks in the forest (Zech & Weinstabel, 1983; Szolnoki, 1985). Irvine (1962), Adeoye *et al.* (1993) and Aiyania *et al.* (1995) also acknowledge *Parkia* as a useful avenue tree in the drier regions of West Africa.

CHAPTER THREE

MATERIALS AND METHODS

This chapter provides information on study site characteristics within a geographical context (3.1) and explains the procedures followed in data assembly and processing. Investigations of the population distribution, natural regeneration and phytosociology are covered in section (3.2) while the last section (3.3) reports observations on reproductive biology. Sections are subdivided as appropriate.

3. Site characteristics and study procedures

3.1 Geographical context

3.1.1 General context

The study was carried out in Nigeria in four ecozones (Lowland rain forest, Derived savanna, Guinea savanna and Sudan savanna) of the Guinea-Congolian regional centre of endemism, the Guineo-Congolian/Sudanian regional transition zone and the Sudanian regional centre of endemism of White (1983) (Figure 3.1). Nigeria lies in low Africa where altitudes in most places are below 1000 m (White, 1983). The landscape is one of relatively low plateaux, plains and basins, interrupted by residual inselbergs.

In most parts of the country, the underlying geology is basically of Pre-Cambrian rock (White, 1983; Oguntoyinbo *et al.*, 1985) although Cretaceous sediments occur in the Benue valley and Niger basin while, in the coastal plains, the influence of west-east currents has resulted in huge Quaternary/Recent sand bars being deposited between the ocean and the lagoons. At the northern limit of the country, and beyond, superficial deposits of Pleistocene age are common, while at the northern boundary of the Sudanian centre consolidated dunes of wind blown sand known as 'qos' occurs (White, 1983). Both environmental and management systems have underlying effects on soil types. In the south-west ferric luvisols dominate. Further east these are replaced by dystric nitosols (FAO-UNESCO, 1977). In the north-east, ferric acrisols are frequent, while the soils of the north-central plains are predominantly ferric luvisols, eutric regosols and cambic arenosols (FAO-UNESCO, 1977). In the coastal parts there are dystric nitosols with gleysols derived from deltaic deposits dominant in Niger delta area and the lower reaches of other major rivers discharging to the Gulf of Guinea (FAO-UNESCO, 1977) (Table 3.1).

Undoubtedly, rainfall is the most important climatic variable. Rainfall decreases both in amount and duration in a south-north direction (Barbour *et al.*, 1984). In the part of the country within the Guinea-Congolian region, there is an equatorial climatic type, combining high humidity with a bi-modal annual pattern, with 3 dry (< 50 mm of mean rainfall) months. In the Guineo-Congolian/Sudanian transition zone, the climate is of the sub tropical type with 3-5 dry months, while in the Sudanian centre of endemism the climate is tropical (summer rain; 5-7 dry months) in the terminology of Walter and Leith (1960-1967). Mean annual temperature ranges from 24°C to 28°C (White, 1983).

On a regional basis, typical Guinea-Congolian vegetation is high to low forest and woodland. The Guineo-Congolian/Sudanian transition vegetation is typically woodland of scattered trees, bush-land and thicket, and typical Sudanian vegetation is shrub land and wooded grassland (White, 1983). There are extensive anthropic landscapes in the Sudanian centre.

Land use is very complex and correlates with existing vegetation as influenced by mean annual rainfall. Some areas show a distinct orientation towards a particular type of agricultural enterprise, but for the most part there is no clear tendency towards a single land use system (Barbour *et al.*, 1984 , 1985; Berry, 1988). Multiple land use is mostly varying levels of cultivation and bush fallow in different stages of development. In the Guinea-Congolian regional centre, logging and root or tree crops dominate, while in the Guineo-Congolian/Sudanian transition there is a mixture of grains and root crops. In the Sudanian centre there is production of legumes, cotton and grain, and livestock grazing is frequent.

3.1.2 Study areas

3.1.2.1 Location rationale

Parkia biglobosa is distributed across several ecological zones with diverse population densities, different land use systems, cultural differences, differences in existing laws and tree tenure systems, and varying rainfall patterns. For the purposes of comparison, the part of the country where this study was undertaken was divided into four ecological zones. Further, land use systems throughout the country may be categorised into (a) intensively cultivated and (b) semi-intensive/bush fallow, combining levels of pastoralism and fallow-phase duration. To embrace these two major land use categories and the diverse demographic pressures across ecozones, study sites were replicated (2-fold replication). Each pair of sample stands in each study site was identified on the basis of site similarities, but exposure to differing intensity of land use. Paired samples differ on an ecozone basis in floristic composition, land use types and tenure, but are similar in all these respects on a study site basis within the different land use types (Table 3.1). The agroclimatic attributes of the nearest meteorological stations to the study sites are shown in (Figure 3.1).

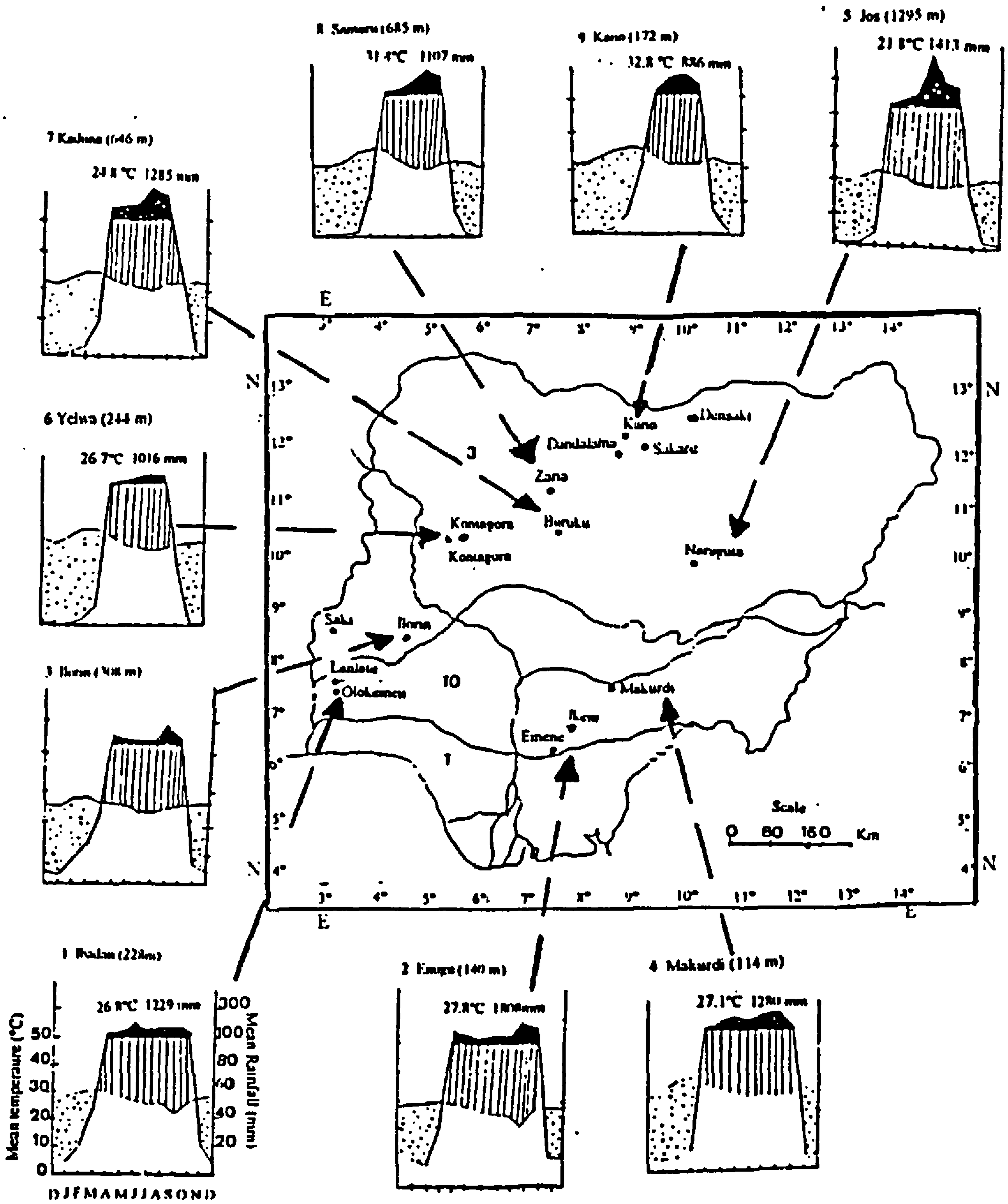


Fig. 3.1 Map of Nigeria showing the study sites within the main phytochoria of White (1983) and in relation to the nearest meterological stations

[1] Guinea-Congolian centre

[3] Sudanian centre

[10] Guinea-Congolian/Sudanian transition

Table 3.1 The physical and vegetation attributes of the paired sample sites in Nigeria.

Ecozones	Ref. Town	Specific pair samples co-ordinates	Within site paired sample distance (km)	Soil types	Geology	Elevation (m) / Terrain
1	Eruwa	Lanlate (7°35'N, 3°25'E)	10	Ferric luvisols	Basement complex	gently undulating (264) 4% gradient
	Olokemeji	Idi-ope (7°35'N, 3° 25'E)		Ferric luvisols	Basement complex	gently undulating (264) 4% gradient
	Enugu	Emene (8° 25'N, 7° 35'E)	40	Eutric nitosols	Cretaceous sand stones and shales	(140) gently undulating
	Nsukka	Ikem (6° 47'N, 7° 43'E)		Eutric nitosols	Cretaceous sand stones and shales	(120) flat > 5% gradient.
2	Saki	Ilorin road (8° 40'N, 3°0'E)	120	Ferric luvsols	Basement complex	(106) gently undulating to flat, rock.
	Ilorin	12 km Ibadan road (8°20'N,4° 25'E)		Ferric luvsols		rock outcrops (308) plains to gent slope.
	Makurdi	Api village (7°40'N, 8°30'E)	250	Gleyic luvisol	Cretaceous dolomite limestone and shale.	(114) undulating to sloppy.
	Jos	Naraguta (10°00'N, 8°55'E)		Ferric acrisols	Basement complex	(1295) Hilly with r outcrops.
3	Kaduna	Buruku (10° 55'N, 7°15'E)	70	Ferric luvisols	Basement complex	(646) flat to gently undulating
	Zaria	Marbargwanda village (11° 10'N, 7° 40'E)				(685) gently undulating to flat.
	Kontagora	Mokwa road (10°25'N, 5°30'E)	15	Ferric luvisols	Basement complex	(400) undulating to flat.
	Kontagora	Sokoto road (10°25'N, 5°30'E)				(400) undulating to flat.
4	Kano I	Dandalama village (12°05'N, 8° 30'E)	10	Eutric regosols	Basement complex	172 Gentle to slop
	Kano III	Jigawa road (12° 05'N, 8° 35'E)				(172) Gentle to slo
	Kano II	Sakare village (12 05'N, 8° 35'E)	200	Eutric regosols.	Basement complex.	(172) Gently undulating.
	Hadejia	Densaki village (12° 30'N, 10°10'E)		Eutric fluvisols	Quaternary alluvial lacustrine deposits	(150) Moderately fl with water draining troughs.

3.1 2.2 Terrain, climate and vegetation

The lowland rain forest ecozone falls within the Guineo-Congolian region with low (120-260 m) gently sloping terrain and high rainfall. Bi-modal rainfall accounts for semi-deciduous high forest species and palms in the south and woodland species to the north. The two sites of this zone are similar in floristic composition and land use but soil and geological differences exist in Site 1 (Eruwa) compared with Site 2 (Nsukka) and the fallow duration is shorter in Site 2, due to the higher population density. The derived savanna of the Guineo-Congolian region and the Guinea-Congolian/Sudanian transition is at altitudes similar to those for lowland rain forest. Here too, the terrain is gently sloping. There are geological differences in the Jos/Makurdi sites. The rainfall is bi-modal and the vegetation a mixture of wooded grassland (White, 1983). The two sites within the pair differ floristically. Land use is broadly similar, but fallow land is more extensive in the bush fallow of Makurdi area compared with the cultivated areas in Jos.

The Guinea savanna ecozone is referable to the Guineo-Congolian Sudanian/transition zone. The terrain is moderately flat to gently sloping in most areas but altitude increases from 400 m in the south to 640 m in the north (Table 3.1). Rainfall is unimodal and the vegetation is wooded grassland. The two sites in this ecozone differ floristically and because of differences in population density and land use intensity. There tends to be a shorter fallow period in Kaduna (Site 6).

The Sudan savanna (Ecozone 4) corresponds with the Sudanian centre of endemism of White (1983). The terrain is flat, with altitudes similar to those in Ecozone 3. Rainfall is lower here, less than (<1000 mm year^{-1}) and unimodal (Table 3.1). Vegetation in most places is wooded farmland, thickets of bushes and grasses. The two sites are similar floristically and also in land use but at Site 7 (Kano) there is more intensive cultivation than at Site 8 (Hadejia).

3.1.2.3 Socio-economic setting

Nigeria's population was less than 20 million in 1921 and increased modestly between 1931 and the 1950s, with an annual growth rate of 2.2%. However by the 1963 census the annual growth rate had increased to 2.5%. By the 1970's the figure had risen to 3% (NEST, 1991) and it is currently thought to be 3-4%. The last census (1992) indicated that the country ranked 10th globally in terms of population. Population density within Nigeria varies greatly ranging from <50 to >200 persons per square kilometre. In the Guinea-Congolian regional centre of endemism with the exception of the major industrial towns (Lagos and Ibadan) and part of the eastern block, population density is 50-200 persons per square kilometre. In the Guineo-Congolian/Sudanian transition centre population is sparser (50 persons per square kilometre). Many parts of the Sudanian centre are, however, moderately to densely populated with some places (including Kano and Katsina) having over 200 persons per square kilometre.

The land tenure system is basically the same throughout the country. Ownership is achieved through inheritance, purchase, lease, pledge, exchange and gift. Of these, inheritance and purchase are the most frequent. In every part of the country, the people have adopted multiple land use systems, growing a variety of crops in the same locality. Today the vegetation types and land use reflect both the irregular distribution of farmlands and the wide-spread practice of bush fallow systems of agriculture.

Within the Guinea-Congolian region (Ecozone 1) consisting of the Olokemeji and Eruwa sample stands, the soils are moderately fertile, possibly due to nutrients release from rock weathering. These permit a medium to high population density to be supported by arable farming with extensive food crops including yams, cassava, maize and beans. Mixed farming and fruit trees, including citrus, kolanut and cashew, are combined with arable cropping. Limited pasture availability reduces livestock husbandry (goats, poultry) and management is extensive. Land tenure is by inheritance in most cases and land per household is <5 ha. In the south east of the ecozone (Enugu and Nsukka sample stands) intensive cultivation of root and tuber crops in compound farms under a multi-storey system is frequent. Individual land inheritance is common. There are about 500 persons per square kilometre and intense concomitant pressure on the land. Fallow periods have been drastically reduced from 5-10 years to 1-3 years over the period of 1970 to 1992. About 90 percent of the farms are less than 5 hectares in extent and 55% are less than two hectares, so that farm size ranges from 1 to 2 hectares per household (Okafor, 1987). Gully erosion is a major problem and has reduced the land carrying capacity.

The Guineo-Congolian/Sudanian transition is characterised by prolonged cultivation, annual burning and intensive cultivation with a short fallow period (Saki and Ilorin). Land tenure is mainly by inheritance. Cultivation is more intensive in Ilorin compared with Saki. In Saki, a modest population operates a longer period of fallow but rock outcrops are prevalent, limiting land available for cultivation in some areas. Semi-intensive cultivation dominates with arable crops, mainly grains (maize and sorghum) and yams featuring prominently. Livestock husbandry is extensive in the area. At the Ilorin sample stand, cultivation is more intensive, reflecting the gentle rather flat terrain. Arable farms produce yams, cocoyams, maize, cassava and vegetables most frequently. Fruit orchards of mango and cashew are common. Livestock husbandry is semi-intensive and mostly undertaken through rotational grazing. Farm size is 3-5 hectares per household with some level of mechanisation.

In the Jos and Makurdi stands, land use is similar to Ilorin and Saki but there is higher pressure on the land due to the high population density. In Jos, rocky topography limits cultivable land. Intensive cultivation is frequent in most places, mainly using horticultural crops and fruit orchards, due to the elevation which brings low temperatures to most areas. The area is noted for unusual farming systems such as terracing, mixed farming and crop rotation. Average land per household ranges from 0.5-3 hectares.

However, a few large-scale company farms exist, and there is some intensive livestock husbandry. Makurdi is an area of medium population concentration, and has moderately gentle topography compared with Jos. Cultivation is of semi-intensive arable farming, especially large-scale yam production. Livestock husbandry is semi-intensive. Land area per household is 2-5 hectares.

In the Kontagora sample stands, inheritance dominates land tenure tradition while land use varies from semi-intensive to intensive cultivation, depending on soil fertility level and the population pressure. The majority of the area is used for arable farming, mainly grain production. However, in recent times, silvopastoralism under an extensive system has become popular. In the north central part of the Sudanian centre, the Kaduna and Zaria sample stands there is permanent cultivation under grains, legumes and fibre crops (cotton). Soil fertility maintenance is through animal remains, human wastes and litter fall (mainly from protected economic trees). Land per household is about 5 hectares. Mechanisation is widely practised. Livestock husbandry is intensive with varying levels of rotational grazing.

The Kano sample stands lie in an area of high population density. Land tenure is by inheritance, communal ownership and purchase (limited to company farms). Intensive arable farming (cereals and legumes) and commercial livestock feature prominently. Land area per household is difficult to estimate due to the communal ownership system involving several members of an extended family which commonly operates over a land area of 3-10 hectares.

3.2 Data collection and processing

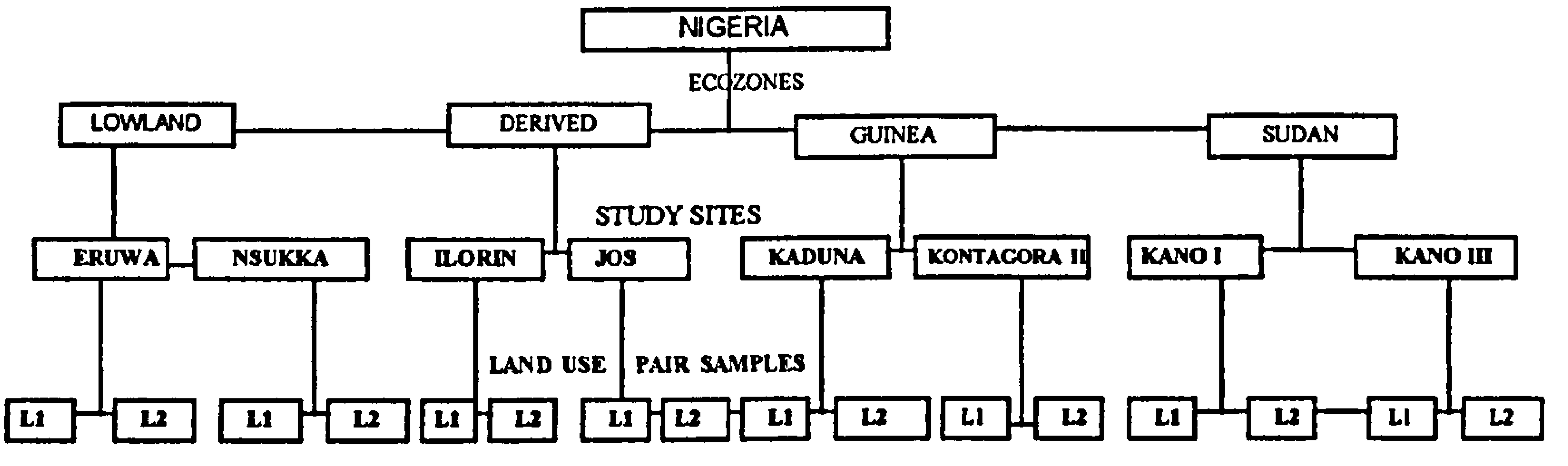
3.2.1 Population status and stand character

Potential field site areas in each of the four ecozones were identified based on an existing *Parkia* provenance collection map of Forestry Research Institute of Nigeria (*Parkia* project field map), Jackson's (1973) map for northern Nigeria and Hopkins (1983) distribution map for West Africa. A reconnaissance field survey followed to identify large *Parkia* stands, taking into consideration varying vegetation types and land intensities. Major towns with forestry offices were used as reference stations. Field station staff were consulted and their knowledge of *Parkia* distribution ascertained and taken into account. Each suggested site was visited and assessed to determine suitability for final selection. Identification and final selection of stands among possible populations was influenced by *Parkia* being dominant in the vegetation. To be acceptable, stands had to meet two criteria: homogeneity and accessibility. Homogeneity was defined as stands with more than 100 mature *Parkia* trees distributed over an area that was considered as uniform in vegetation type and land use. Accessibility was defined as stands with accessible landscape and topography to ensure easy mapping of all the mature *Parkia* trees.

In each of the four ecozones there were two study sites, giving a total of eight sites. At each study site, two land use intensities were represented consisting of; (a) intensively cultivated and (b) semi-intensive/bush fallow thereby giving a total of 16 sample stands (Figure 3.2.1). A sample stand was defined as *Parkia* dominated vegetation on a large expanse of land with ≥100 mature *Parkia* trees. Classification into land use types was based on ≥ 100 mature *Parkia* trees represented within a particular land use type. A mature *Parkia* tree was defined as an individual with diameter at breast height (dbh 1.3 m) ≥ 10 cm (Figure 3.2.2)

For sampling purposes, intensively cultivated land is defined as land where active cultivation of arable crops covers at least half the total. Semi-intensive/bush fallow range land is defined as land of which less than 50% is under active cultivation of arable crops. Areas were considered acceptable for sampling if they supported at least 100 mature *Parkia* individuals. The field work strategy is shown diagrammatically (Figures 3.2.1, 3.2.2 3.2.3).

Regeneration was recorded by source either uninterrupted from direct seed or from stumps/rootstock. Suspected stump/rootstock regeneration was detected by checking the plant base through soil excavation around the shoot concerned, to determine whether there was an expanded base and evidence of previous years' growth. All observed regeneration was classified into seedlings, saplings and poles based on shoot diameter (Figure 3.2.3).



L1 = Intensively cultivated

L2 = Semi-intensive/bush fallow

FIGURE 3.2.1 Flow chart of field work showing the ecozones, study sites and land use pair samples

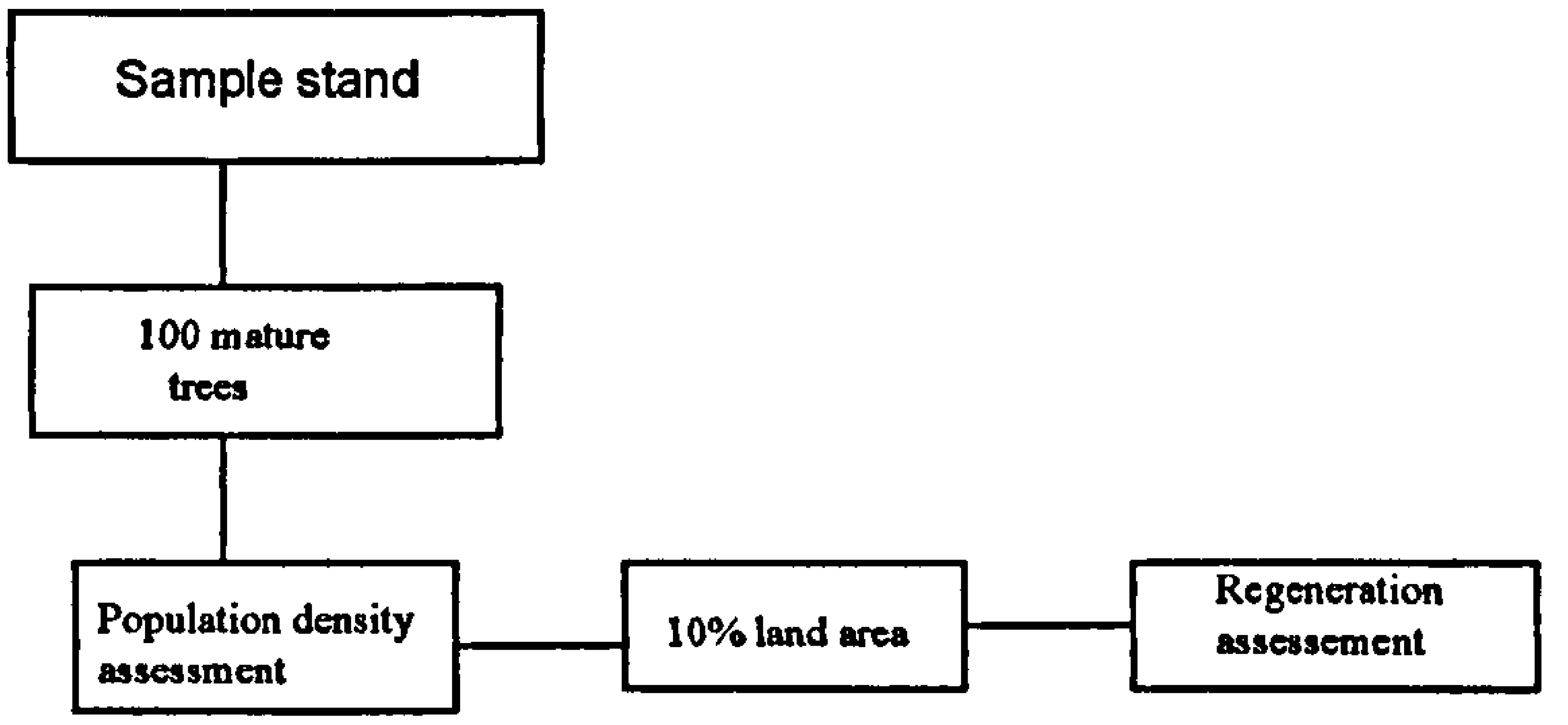


Figure 3.2.2 Population density assessment and regeneration sample size selection

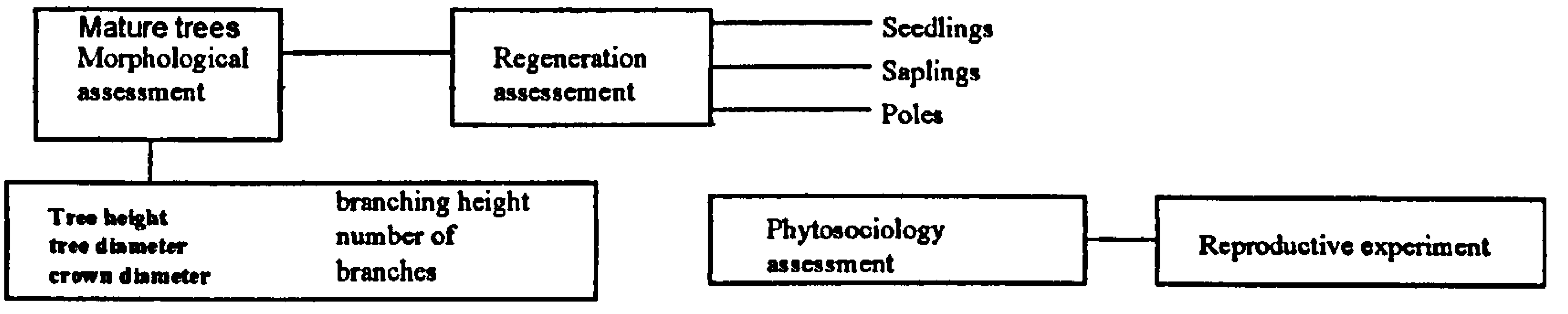


Figure 3.2.3 Flow chart of mature tree sampling, regeneration assessment and reproductive study.

Table 3.2 *Parkia biglobosa*: separation of sites within ecozones.

Ecozones	Intervals between sites (km) within ecozones	
	Minimum	Maximum
Lowland rain forest		
Sites 1 and 2	300	700
Derived savanna		
Sites 3 and 4	500	800
Guinea savanna		
Sites 5 and 6	200	400
Sudan savanna		
Sites 7 and 8	100	300

Table 3.3 Paired stands: approximate distances within each study site.

Sites	Stands name	Straight line distance between stands (km)	Extreme boundaries
	Locations	Minimum	Maximum
Site 1	Eruwa		
	Olokemeji	10	15
Site 2	Enugu		
	Nsukka	40	76
Site 3	Saki		
	Ilorin	45	60
Site 4	Jos		
	Makurdi	185	250
Site 5	Kaduna		
	Zaria	45	76
Site 6	Kontagora I		
	Kontagora II	5	18
Site 7	Kano I		
	Kano II	8	15
Site 8	Kano III		
	Hadejia	65	88

To define a sample stand in terms of the 100 individuals, a starting *Parkia* tree was designated randomly on an area of land supporting at least 100 individuals ≥ 10 cm dbh. From this arbitrary starting point, the nearest other *Parkia* individual ≥10 cm dbh was recorded. Thereafter the group was progressively expanded by adding further individuals but keeping the group compact until the sample reached 100 individuals. All individuals included were closer to each other than to any individuals in another sample stand. All tree positions were mapped and the bearings and the nearest conspecific neighbour horizontal distances were recorded. Stand area and tree density were estimated using the conspecific horizontal distances. From mean conspecific individuals distances were estimated using the Wisconsin distance method of Mueller-Dombois & Ellenberg (1974).

$$\text{Total number of trees} = \frac{\text{unit reference area (I hectare)}}{\text{mean area of trees (m}^2\text{)}}$$

Mean area = (mean distance between nearest conspecific n individuals of a tree species)^2

n = 100 trees for each sample stand in this study.

(MA) = mean area per tree (m^2)

$$\text{Tree density per hectare} = \frac{10{,}000\ \text{m}^2}{\text{mean tree area}^2}$$

All mapped trees were labelled with a serially numbered aluminium tag. Altogether 1600 trees were mapped representing sixteen sample stands. Every tree mapped was also assessed for tree total height, tree diameter, crown diameter, branching height and number of primary branches. Associated neighbouring woody tree species (≥ 10 cm dbh) encountered were recorded on a presence/absence basis using the shortest distance approach in relation to the individual *Parkia* tree mapped (Figure 3.2.3). No other ecological information was recorded for the woody species association study For the individual *Parkia* trees mapped in each sample stand, the following parameters were assessed:

Tree total height : Tree total height was defined as the vertical difference (m) between the ground level and the highest point reached by the tree and was measured with a Haga altimeter.

Tree diameter (dbh): This was measured with a fibre tape at 1.3 metres along the bole from ground level.

Crown diameter (m): This was measured horizontally along two lines at 90 degrees to each other, intersecting at the base of the trunk. The mean of the two measurements was recorded.

Branching height: This was measured vertically from ground level to the point of appearance of a double or multiple leading shoot below the crown base and was determined with a 3 metre metal tape. Bole heights exceeding 3 m were measured with a calibrated stick.

Number of primary branches : this was taken to be the number of branches arising from the distal end of the bole.

Associated woody tree species assessment

A woody tree individual was defined as an erect single or multi-stemmed individual the largest stem of which was ≥10 cm dbh. Using the proximity approach between an associated woody species and two *Parkia* trees each individual associated woody species was recorded as an associate of a given *Parkia* tree, based on the shortest distance between the woody species and any two *Parkia* trees if they were closely positioned (Figure 3.4). A list of commonly reported woody species associated with *Parkia* in the literature (Hopkins & White 1984; White, 1983, Hagos, 1962; Sabiiti & Cobbina, 1992) was compiled, arranged alphabetically and coded to provide a working check list to facilitate recording. As each woody species was encountered, the coded number was recorded against each *Parkia* tree individually mapped. This was used to generate frequency data and species/site similarities for the different study sites and ecozones. The coded list was up-dated as new species were encountered. The stocking density of individuals woody associates was determined using the total land area calculated for *Parkia* by the nearest neighbour approach.

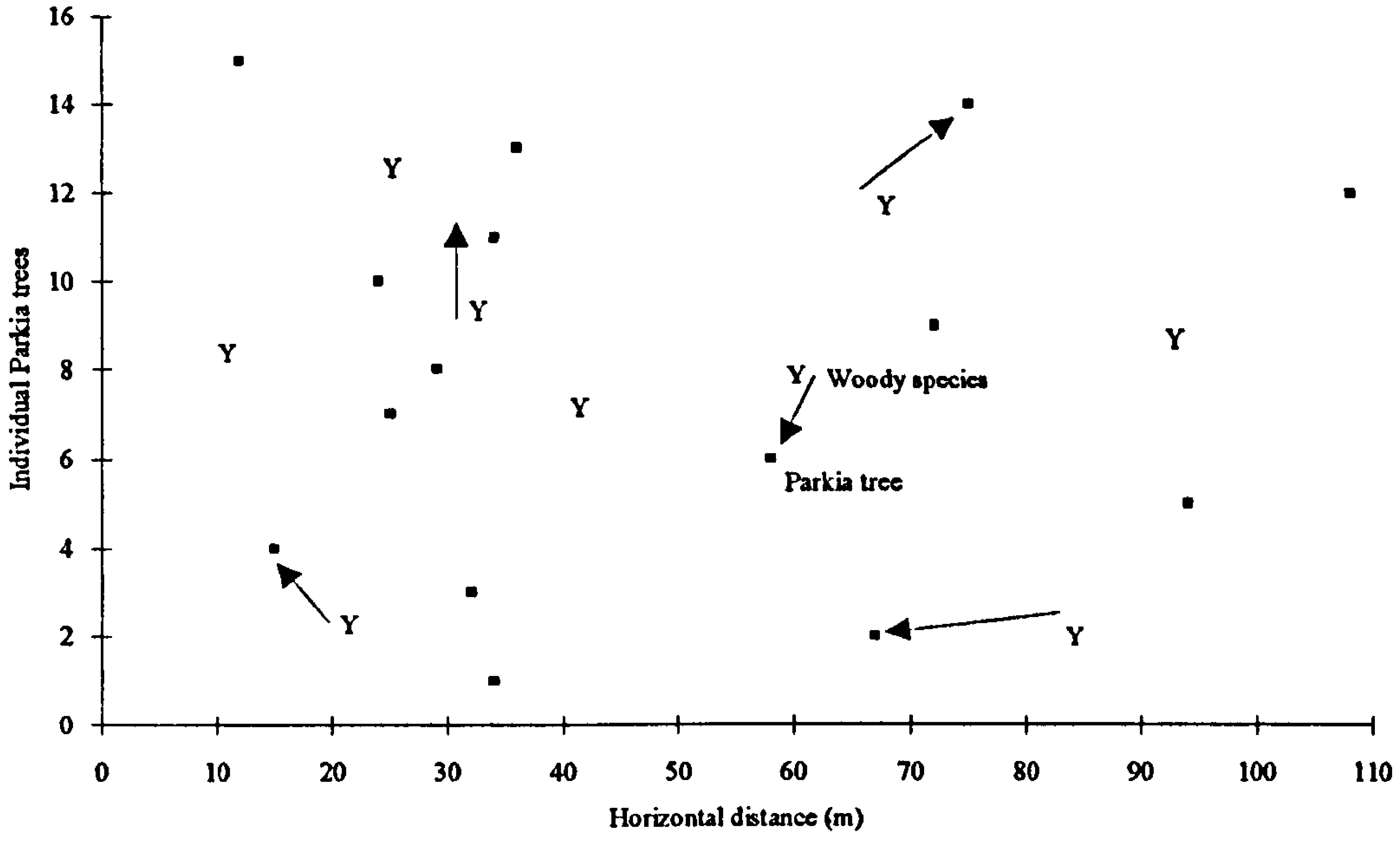


Figure 3.3 Representation of *Parkia* sample stand and nearest woody species scoring procedure based on arrows direction (Y position of a tree of another species). Horizontal distances are hypothetical in relation to individual tree distribution at Saki.

***Parkia biglobosa* regeneration**

Within the frame work of the position of mature *Parkia* trees, each sample stand was assessed for natural regeneration. Categories were defined in terms of seedlings, sapling and poles based on: (a) sources of regeneration either from uninterrupted seed origin or rootstock (b) regenerating plants with the diameter measured at either ground level or at 10 cm above the soil level.

Direct/uninterrupted from seed origin: a plant individual without an expanded base and no signs that the aerial shoot had developed from a rootstock which was older.

Rootstock origin: a plant individual arising from a stump and with evidence of a rootstock with an expanded base.

Seedling: a plant individual arising either from uninterrupted seed or stump/rootstock origin with a diameter ranging between 0.1 cm to 1.0 cm measured at ground level.
Sapling: a plant individual arising either from uninterrupted seed origin or stump/root stock and with no shoot > 5 cm diameter measured at ground level.
Pole : an individual with a shoot of direct seedling origin or from a stump/root stock with diameter > 5 cm at ground level and ≥ 5 cm and < 10 cm at 10 cm above the ground.

The initial land area assessed for mature *Parkia* trees was used in the selection of a ten percent sub-sample area for regeneration (10%). The high sub sample intensity was in response to generally poor regeneration. A single regeneration sample-plot was located close to the centre of each stand. For assessment, the regeneration sample area was subdivided into plots 50 m x 25 m, each of which was scanned for all regeneration categories. The total sub-sample size area assessed for regeneration in each stand was calculated in hectares.

3.3. Pollination observations

3.3.1. Experimental protocol

The degree of self-incompatibility and the roles of pollen visitors (including bats) were examined in relation to tree diameter classes and crown heights. The experiment involved twenty randomly selected trees from a population of >50 mature *Parkia* trees. The twenty trees were part of the Saki stand. For any *Parkia* tree to be selected from the population it had to conform to the following: (a) diameter at breast height (either ≥ 10-39 cm and > 40 cm), (b) tree total height (>10 m) to allow stratification of trees crowns into two heights category, i.e. (0-5 m) from ground level and >5 m, (c) minimum inter-tree distance of 15 m. The low branching habit in *Parkia* allowed stratification of crown into horizontal zones within the crown height. The selected trees, numbered serially, were dispersed through an area of 148 m x 173 m (2.56 ha). Treatments were:

T_1 :-control, open pollinated, all pollen visitors.

T_2 : -capitula inaccessible throughout the flowering to visitors

T_3 : -capitula inaccessible to visitors 18.00-07.00 h local time ;

T_4 : -capitula inaccessible to visitors 06.00-19.00 h local time.

T_5 . -assisted selfing and outcrossing.

Each treatment was applied to between 2-4 capitula on each tree, for the two size classes, and the two crown heights in all directions. The two dbh classes constituted the first factor, the two crown heights the second and the five treatments the third.

Procedure

Selection of the twenty trees was from the Saki stand (Figure 3.4). Initial stages of floral bud development were monitored for the open pollinated treatment. Flowering stages were classified according to Dafni's (1992) four point scale: (1), bud initiation, (2), swollen capitulum, (3), capitula fully developed but flowers not open and (4) capitulum in flower. Capitula for screening were selected before full development. Accessibility to capitula (relative to positions within the crown) and the number of developed inflorescences on each twig were taken into account. Capitula were considered collectively as pollination units of 2-4 capitula monitored/protected for each treatment. Apart from the control treatment, all treatments were protected or bagged with fine mesh nets of (25 cm x 35 cm) prior to capitulum opening. Nets were placed at the end of the peduncle downwards, leaving 10-20 cm space beyond the young capitula for future capitulum size increment and pod development. For assisted pollination (T_5), pollen was collected from the surface of hermaphroditic flower anthers on a donor capitulum with a fine brush and applied on to the entire hermaphroditic section of the capitulum with recipient stigmas daily from the second day to the fourth day. The colour change in capitula from bright red to dark red enabled the recognition of the receptive phase. The experimental unit was covered as soon as dusting was over. Treatments T_3 and T_4 were opened and closed at the specified times. Pollination success was assessed 4-6 days after the anthesis stages for all the treatments. Pistillate anthesis was detected by the change in colour from dark red to dirty brown, followed by the withering of the capitulum structures. Abortion records for the capitula investigated were made six days after pollination. The fine mesh net was removed twenty days after pollination. Fruit development was monitored for all tagged capitula and classified into six stages on Dafni's (1992) 0-5 time scale: (0) no fertilisation, (1), fruit initiation, (2) fruit elongation, (3) green fruits and seed set, (4) fruit maturation (colour change) and (5) mature fruits. Reassessment was undertaken 12 weeks after pollination to check for mature fruits and, at that time, fruits were harvested and data processed. Observations made on the activities and foraging behaviour of floral visitors, were limited to provisional identification without quantification or frequency determination. The positions of the twenty trees investigated and other *Parkia* trees present are indicated in (Figure 3.4)

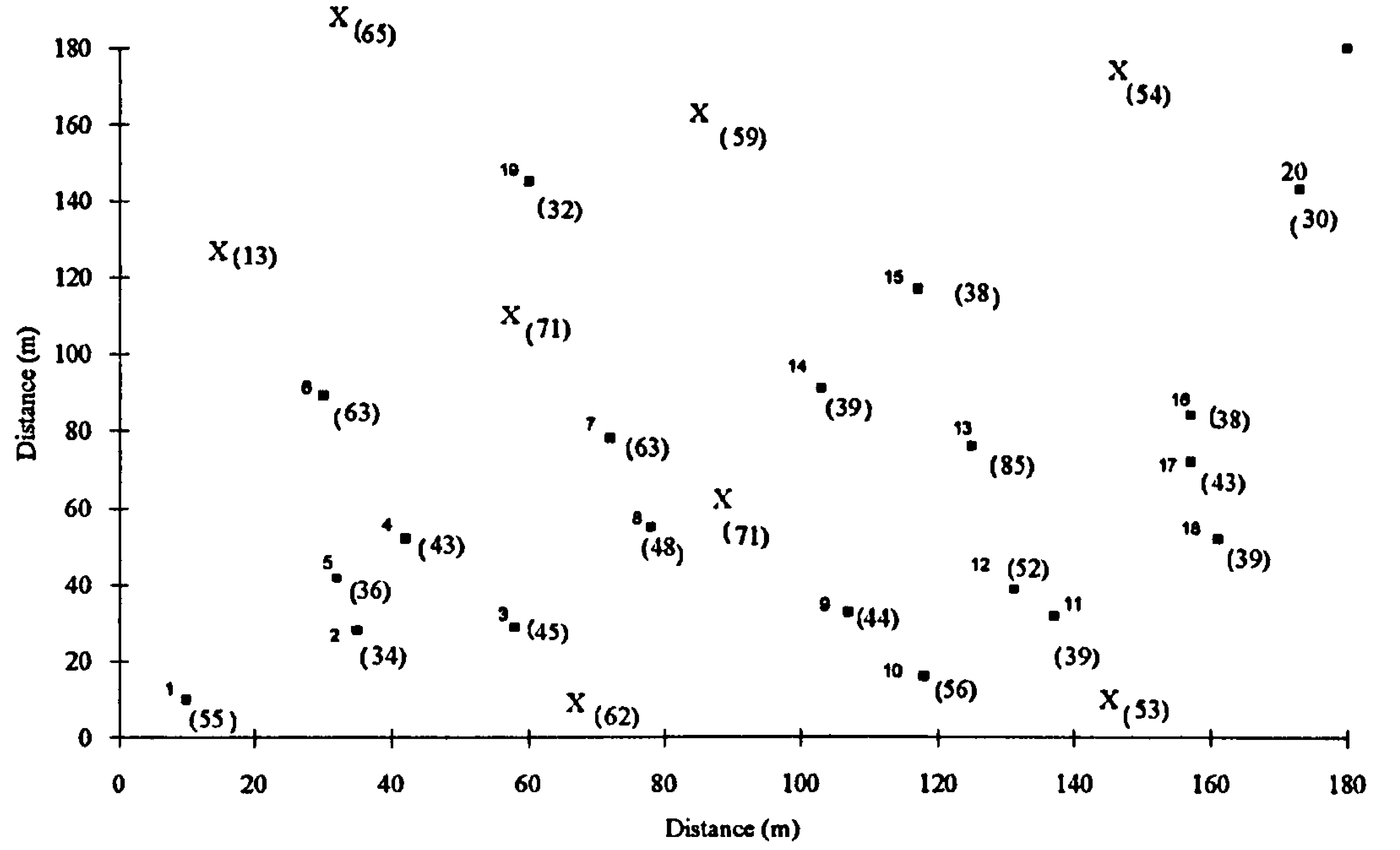


Figure 3.4 Distribution of mature trees at Saki for reproductive study.

(X) Indicates the positions of other *Parkia* trees in the population while, figures in parenthesis represent trees diameter in the population.

Location

The study was conducted at Saki (8°11'N, 3°25'E) Nigeria. Criteria for site selection included unrestricted accessibility (day and night), to the selected *Parkia* population and nearness to a bat roost in five mango trees 300 m away.

Extent /Scale

Twenty trees and a total of 142 capitula investigated.

Species

Parkia biglobosa

Treatments (S) tree sizes (≥ 10 cm -39 cm, > 40 cm), (C) canopy heights (groung level to 5 m, > 5 m), (T) treatments:

$S_1C_1T_1$ - tree size 10-39 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and capitula open to all pollen visitors (8 capitula).

$S_1C_1T_2$ - tree size class 10-39 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and inaccessible to visitors throughout flowering (8 capitula).

$S_1C_1T_3$ - tree size class 10-39 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) inaccessible to visitors 18.00-07. 00 h local time (6 capitula).

$S_1C_1T_4$ tree size 10-39 cm dbh with pollinated capitula in the canopy (at 3-5 m) and inaccessible to visitors 06.00-19.00 h local time (7 capitula).

$S_1C_1T_5$ - tree size class 10-39 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and assisted pollination (6 capitula).

$S_1C_2T_1$ - tree size class 10-39 cm dbh with pollinated capitula in the upper canopy (at > 5 m) and open to all pollen visitors (8 capitula).

$S_1C_2T_2$.- tree size class 10-39 cm dbh with pollinated capitula in the upper canopy (at > 5 m) and inaccessible to visitors throughout flowering (7 capitula).

$S_1C_2T_3$ - tree size 10-39 cm dbh with pollinated capitula in the upper canopy (at >5 m) and inaccessible to visitors 18.00-07. 00 h local time (7 capitula).

$S_1C_2T_4$ - tree size class 10-39 cm dbh with pollinated capitula in the upper canopy (at > 5m) and inaccessible to visitors 06.00-19.00 h local time (7 capitula).

$S_1C_2T_5$ - tree size 10-39 cm dbh with pollinated capitula in the upper canopy (at > 5 m) and assisted pollination (5 capitula).

$S_2C_1T_1$ - tree size ≥ 40 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and open to all pollen visitors (8 capitula).

$S_2C_1T_2$ tree size ≥ 40 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and inaccessible to visitors throughout flowering (7 capitula).

$S_2C_1T_3$ - tree size ≥ 40 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and inaccessible to visitors 18.00-07. 00 h local time (7 capitula).

$S_2C_1T_4$ - tree size ≥ 40 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and inaccessible to visitors 06.00-19.00 h local time (8 capitula).

$S_2C_1T_5$ - tree size ≥ 40 cm dbh with pollinated capitula in the lower canopy (at 3-5 m) and assisted pollination (6 capitula).

$S_2C_2T_1$ tree size ≥ 40 cm dbh with pollinated capitula in the upper canopy (at >5 m) and open to all pollen visitors (10 capitula).

$S_2C_2T_2$ -tree size ≥40 cm dbh with pollinated capitula in the upper canopy (at 5 m) and inaccessible to visitors throughout flowering (6 capitula).

$S_2C_2T_3$ - tree size ≥ 40 cm with pollinated capitula in the upper canopy (at > 5 m) and inaccessible to visitors 18.00-07. 00 h local time (7 capitula).

$S_2C_2T_4$ - tree size ≥ 40 cm dbh with pollinated capitula in the upper canopy (at > 5 m) and inaccessible to visitors 06.00-19.00 h local time (8 capitula).

$S_2C_2T_5$ - tree size ≥ 40 cm dbh with pollinated capitula in the upper canopy (at > 5 m) and assisted pollination (6 capitula).

Date of commencement

13 December, 1994.

Duration

The experiment lasted from 13 December 1994 until 24 March 1995. Observations on capitulum development lasted for 13 days prior to capitula opening but data were collected for 6 days. Anthesis observations lasted 6 days (staminate and pistillate). The abortion rate for each of the pollination unit was assessed after six days on a daily basis after pollination. Fruiting was monitored for 12 weeks.

Table 3.4 Parameter assessment with dates.

Parameters	Days	15/12 1994	17	18	21	24	27	28	29	30	31	4/1 1995	5	6	7	8	9	10	11	19	22
Bud development	6 days	+	+	+	+	+	+														
Staminate stage	2 days							+	+												
Pistillate stage	3 days								+	+	+										
Pollen visitors assessment	5 days						+	+	+	+	+										
Abortion assessment	5 days											+	+	+	+	+					
Fruit initiation	5 days														+	+	+	+	+		
Mesh net removal	1 day																			+	
Mature fruit	10 weeks																				+
Yield data																					

3. 3. 2 Data summarisation and processing

Stocking of mature trees and regeneration

Data were handled on a stand basis. Mean values of conspecific nearest neighbour distance was used for indicating and comparing stocking. Means were computed for morphological parameters and checked for normality. All parameters were summarised by size classes and relative frequencies computed and represented graphically. For tree total height, classes of 4-6 m, 7-9 m, 10-12 m, 13-15 m, 16-18 m, 19-21 m, 22-24 m, and > 25 m were distinguished. For tree diameter, dbh classes of 10-25 cm, 26-41 cm, 42-57 cm, 58-73 cm, 74-89 cm, 90-105 cm, 106-121 cm and >122 cm were distinguished. Branching height classes of 0.0-1.6 m, 1.7-3.2 m, 3.3-4.9 m, 5.0-6.6m, 6.7-8.3 m, 8.4-10 m, 10-11.7 m, 10.8-11.7m and 10.8-13.4 m were used. Mean crown diameter classes were 2-6 m, 7-11 m, 12-16 m, 17-21 m, 22-26 m, 27-31 m, 32-36 m and 37-41 m. Numbers of primary branches were used directly without grouping because variation was within a narrow range.

Differences in the means of parameters were explored through analyses of variance (ANOVAs). Where significant differences were observed, they were further broken down using Tukey's pairwise comparisons test. If significant interactions between factors were found, each land use type was considered separately examining differences between ecozones. The numbers of primary branches were square root transformed in an attempt to force normalisation before analysis.

Allometric relationships were explored between mature tree morphological parameters through linear regression. Mean annual rainfall figures for stations as close as possible to individuals stands were regressed with morphological parameters to seek evidence of strong trends of morphological change with changing mean annual rainfall.

Regeneration data were summarised in tabular form and histograms, and per hectare stocking was calculated for the individual sub-sample areas. After data transformation where necessary, statistical analyses (ANOVAs) were carried out for each regeneration category, to seek evidence of differences in regeneration abundance with ecozones and land use types.

Associated woody species

An ordered incidence table was prepared to display the extent of south-north variation in associated woody species. Stocking per hectare on a stand basis was computed for all the species. The total number of species per stand, ecozones and land use were determined. Sørenson's (1948) co-efficient of similarity (S_S) was calculated as a measure of between site and between stands similarity.

$$S_S = \frac{2a}{2a + b + c}$$

S_S = Index of similarity

a = number of species common to both sites

b = species in site 1 only

c = number of species in site 2 only.

Using the approach of Ramsay (1964), similarity index values were used in the construction of a constellation diagram to show the broad inter-relation between stands/sites.

Pollination biology

Time sequences of flowering and fruiting events were tabulated. Observations made on pollen visitors and their foraging behaviour were summarised descriptively. Mean values and measures of dispersion per pollination treatment were calculated for all quantitative parameters. Abortion numbers per treatment were square root transformed to normalise the data before analysis. Percent abortion per treatment was subjected to angular transformation before analysis following the procedure of Snedecor and Cochran (1976). A three way analysis of variance using the general linear model was employed to check for second order interaction effects of tree diameter class, crown height and pollination treatments on yield components. Fruiting efficiency was computed based on the total number of podded capitula and total pod yield. An Index of self-incompatibility (ISI) was computed and compared among assisted pollinated capitula (Zapata & Arroyo, 1978; Tybirk, 1993). Tukey's multiple comparison test was employed to separate means which were significantly different among pollination treatments. Frequencies of numbers of seeds set per pod were depicted graphically. Evidence of relationships between mean pod length, mean pod diameter and between pod length and mean number of seeds per pod was sought through linear regression presented graphically.

CHAPTER FOUR
RESULTS

The results of research activity undertaken in Nigeria are presented in this chapter. Findings concerning the status of the mature tree populations are reported in Section 4.1 and those relating to regeneration in Section 4.2. In Section 4.3 the results of pollination biology investigations are given. The last section (4.4) summarises the phytosociological aspects of the study.

4.1 Mature trees

During the investigation of population distribution of mature individuals ≥10 cm dbh *Parkia biglobosa* trees in Nigeria, the following parameters were assessed in all the 16 stands mapped.

- nearest mature conspecific neighbour distance.
- tree total height.
- tree diameter.
- crown diameter.
- branching height.
- number of primary branches.

4.1.1 Descriptive statistics

All stand characters parameters considered were checked for normality graphically (bar graphs). Where marked skews were observed transformations were employed to normalise the data. Table 4.1 summarises this process.

Table 4.1 Stand characters and use of data transformation.

Parameters	conspecific neighbour distance	tree height	tree dbh	branching height	no. of primary branches	crown diameter
Appearance	asymmetrical (positive skew)	symmetrical	symmetrical	symmetrical	asymmetrical (positive skew)	symmetrical
Transformation application	Yes	No	No	No	Yes	No
Transformation used	square root, but could not force normality	not applicable	not applicable	not applicable	square root	not applicable

4.1.1.1 Nearest mature conspecific neighbour distance (m)

The mean (± se) nearest mature conspecific neighbour distance ranged from 25.54 ± 1.94 m in Kano III of the Sudanian centre to 91.65 ± 7.54 m in Olokemeji in the Guinea-Congolian centre. The mean distance decreased generally from south to north. Mean distance was greater in bush fallow compared with the cultivated land (Figure 4.1).

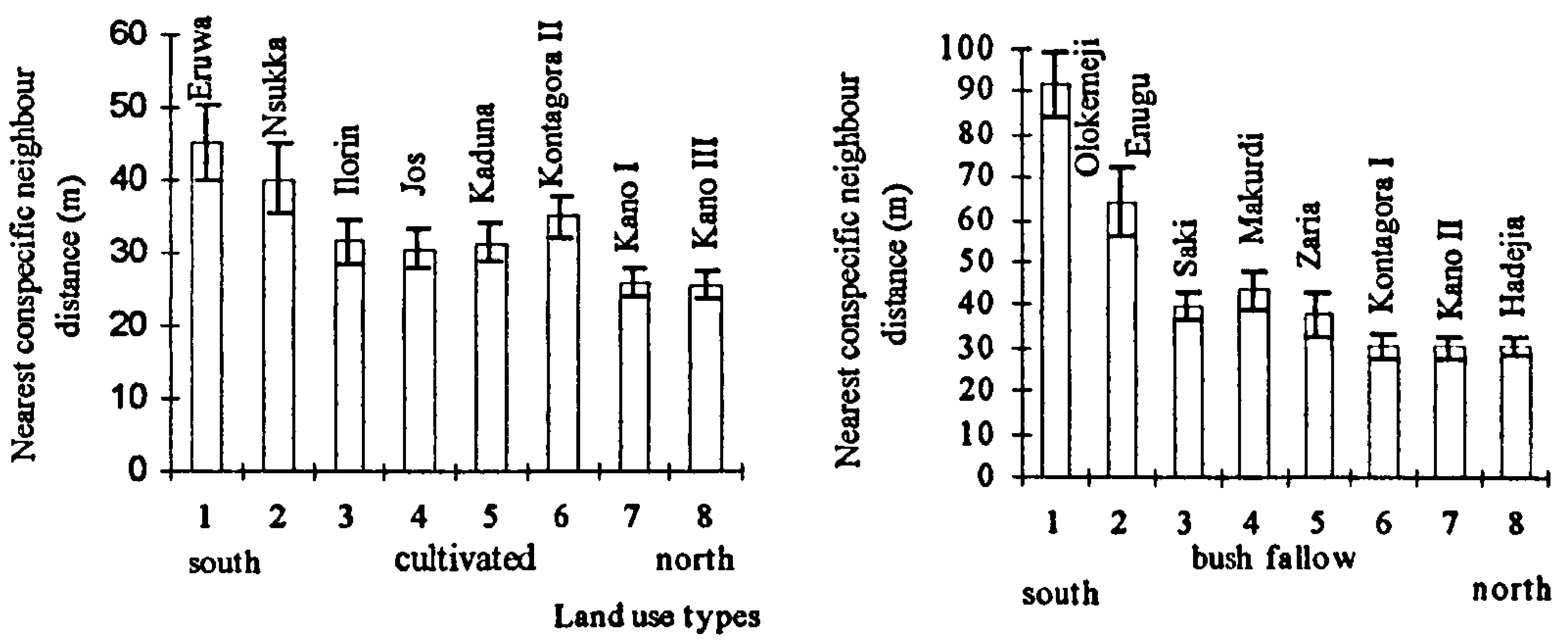


Figure 4.1 *Parkia biglobosa*: mean (±se) nearest mature conspecific neighbour distance for Nigerian sample stands on cultivated land and in bush fallow.

Square root transformation failed to normalise the data set of nearest conspecific neighbour distribution fully. There was some improvement, however, and data in the transformed state were therefore used for analysis of variance.

Anova

Table 4.2 Two way analysis of variance on nearest mature conspecific neighbour distance (square root transformed data)

Source	DF	SS	MS	F
Ecozones	3	484.72	160.60	25.75*
Land use	1	111.75	112.13	17.98*
Ecozones*Land use	3	188.21	62.74	10.06*
Error	1060	6610.31	6.24	
Total	1067	7394.98		

*P <0.05

Since there was a significant interaction betwen ecozones and land use (Table 4.2) breakdown ANOVAs were carried out (Tables 4.3 and 4.4).

Table 4.3 Breakdown anova for conspecific nearest neighbour distance

Source	DF		SS		MS		F	
Treatments	cultivated	bush fallow	cultivated	b/fallow	culti	b/fallow	culti	b/fallow
Ecozones	3	3	43.40	48.59	14.47	16.20	2.78*	0.026*
Error	531	516	2767.74	2739.07	5.21	5.19		
Total	534	532	2811.4	2787.65				

*P <0.05.

Table 4.4 Zonal differences in mean nearest conspecific neigbour distance (m)

Ecozones types	Guinea-Congolian centre	Guineo-Congolian Sudanian transition	Sudanian centre-south	Sudanian centre-north
Cultivated	36.63[b]	30.23[a]	31.30[a]	27.20[a]
Bush fallow	60.64[a]	36.10[b]	26.65[b]	30.48[b]

Values within the same row for land use type with the same following letter do not differ significantly (P <0.05).

Cultivation significantly influenced nearest conspecific neighbour distance in the extreme south of the range, but no interaction to the extreme north (Table 4.3). There were differences in mean nearest conspecific neighbour distance between the southern ecozones with population on cultivated land. Bush falow land use significantly influenced nearest conspecific neighbour distance in the Guinea -Congloian ecozone but not in the transition and the Sudanian centre. (Table 4.4)

4.1.1.2 Tree total height (m)

Mean tree total height (±se) ranged from 8.11 ± 0.28 m in Enugu to 14.84 ± 2.54 m in Nsukka both in the south of Ecozone I (Guinea Congolian centre). Trees >20 m tall were better represented at the more southerly, moister, sites and were rare in the Sudanian centre. There were no consistent patterns of height distribution in relation to land use t..ype.

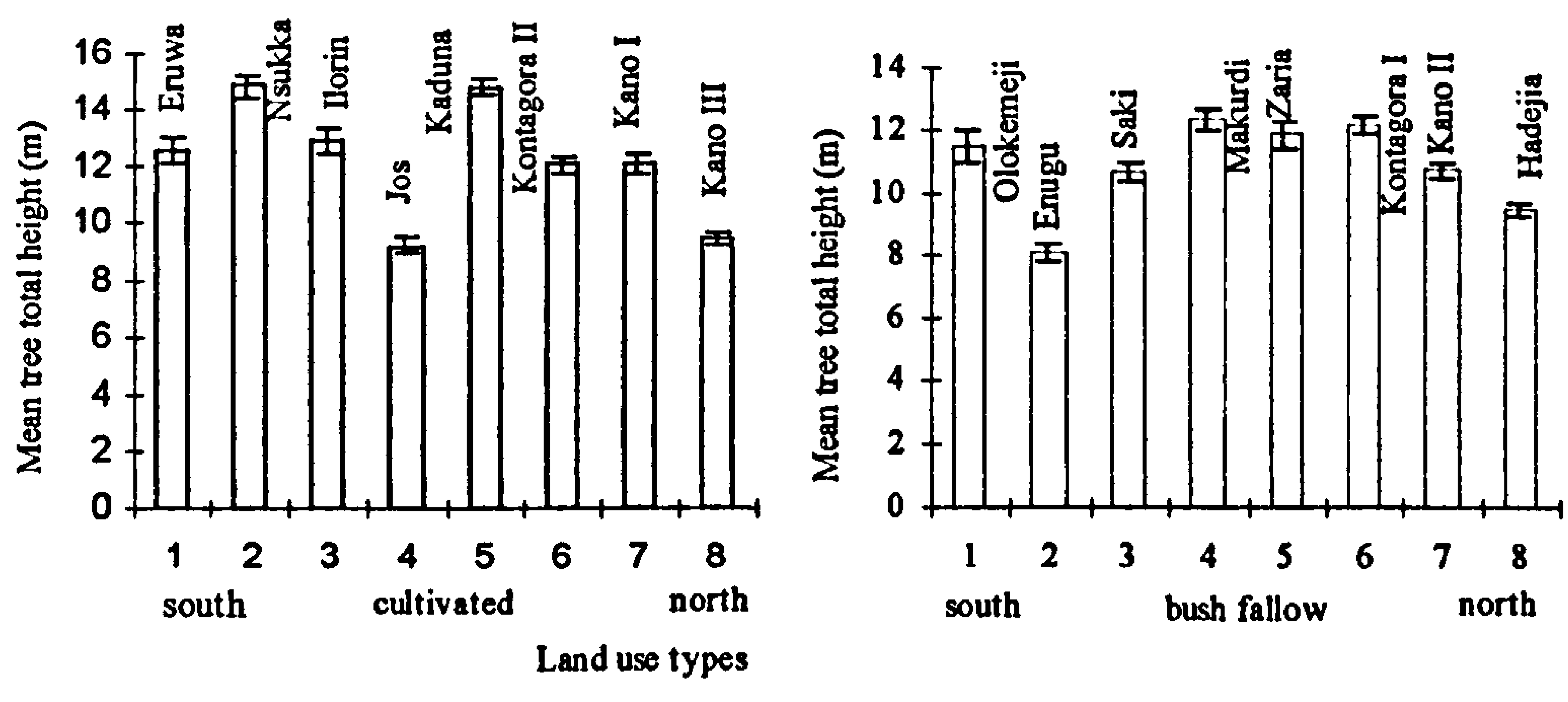


Figure 4.2 *Parkia biglobosa*: mean tree total height (±se) for Nigerian sample stands on cultivated land and in bush fallow.

Tree total height class distribution (cultivated land use)

Figure 4.3a Frequency distribution of tree height in Eruwa

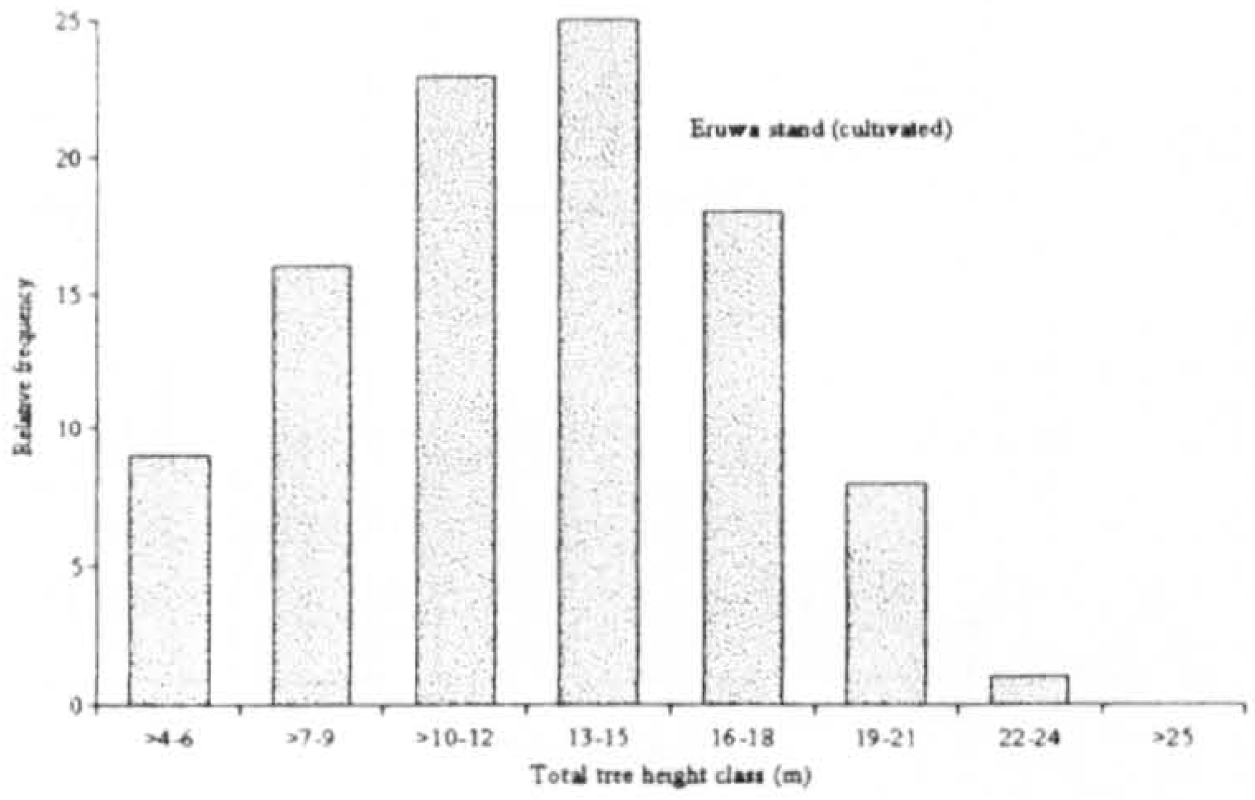
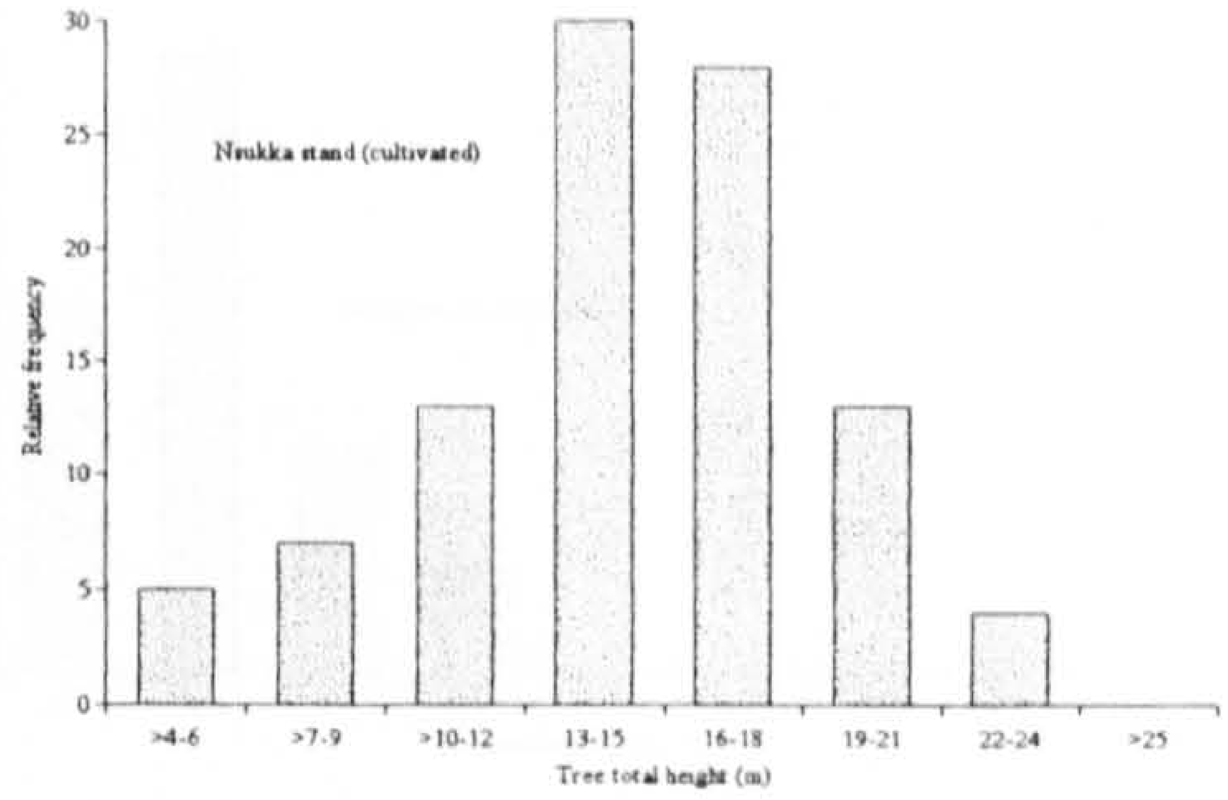
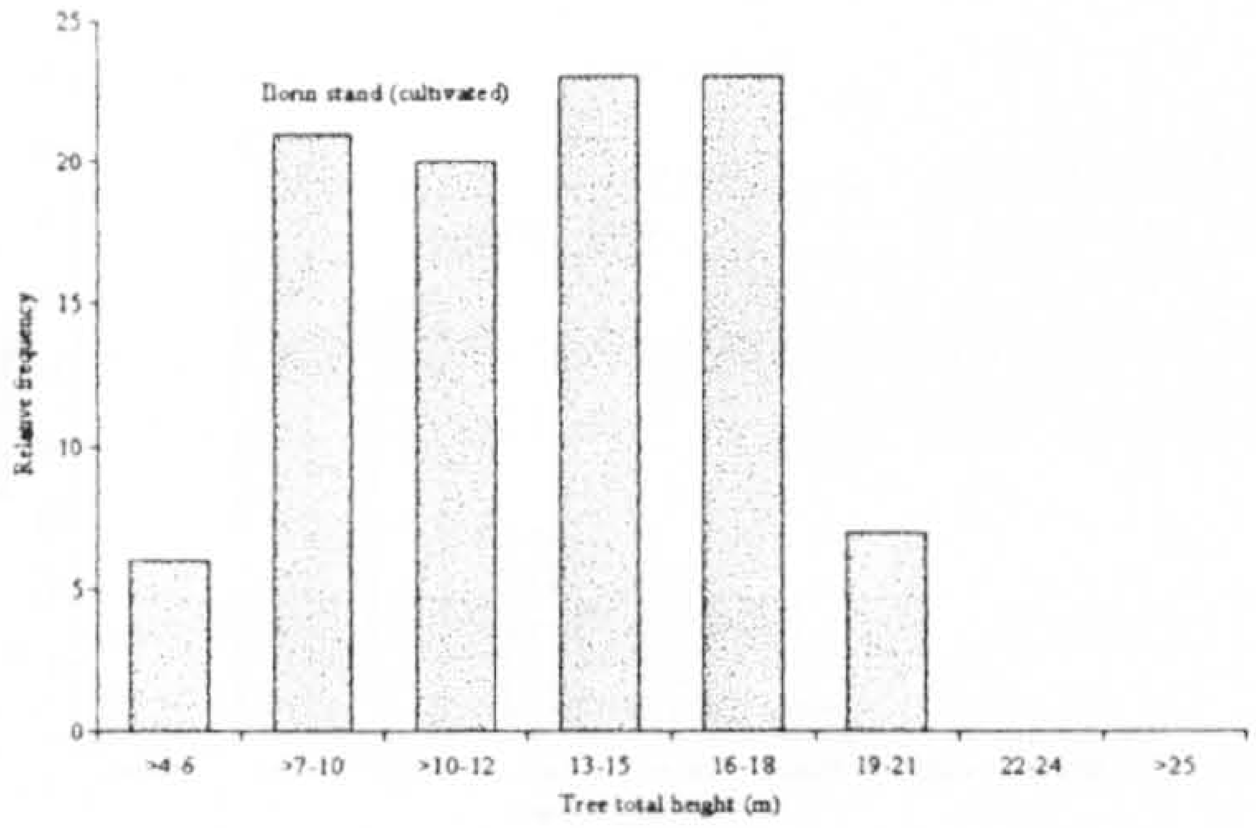


Figure 4.3b Frequency distribution of tree height in Nsukka



4.3c Frequency distribution of tree height in Ilorin



4.3d Frequency distribution of tree height in Jos

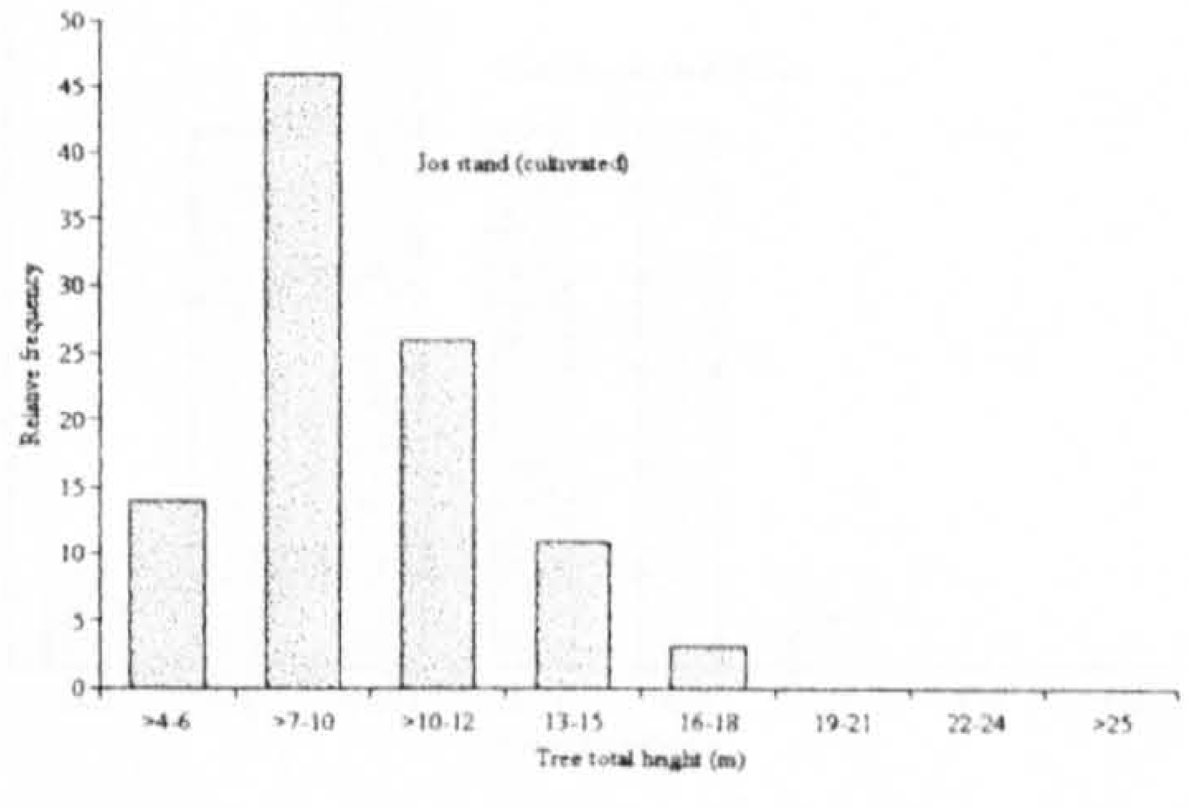


Figure 4.3e Frequency distribution of tree height in Kaduna

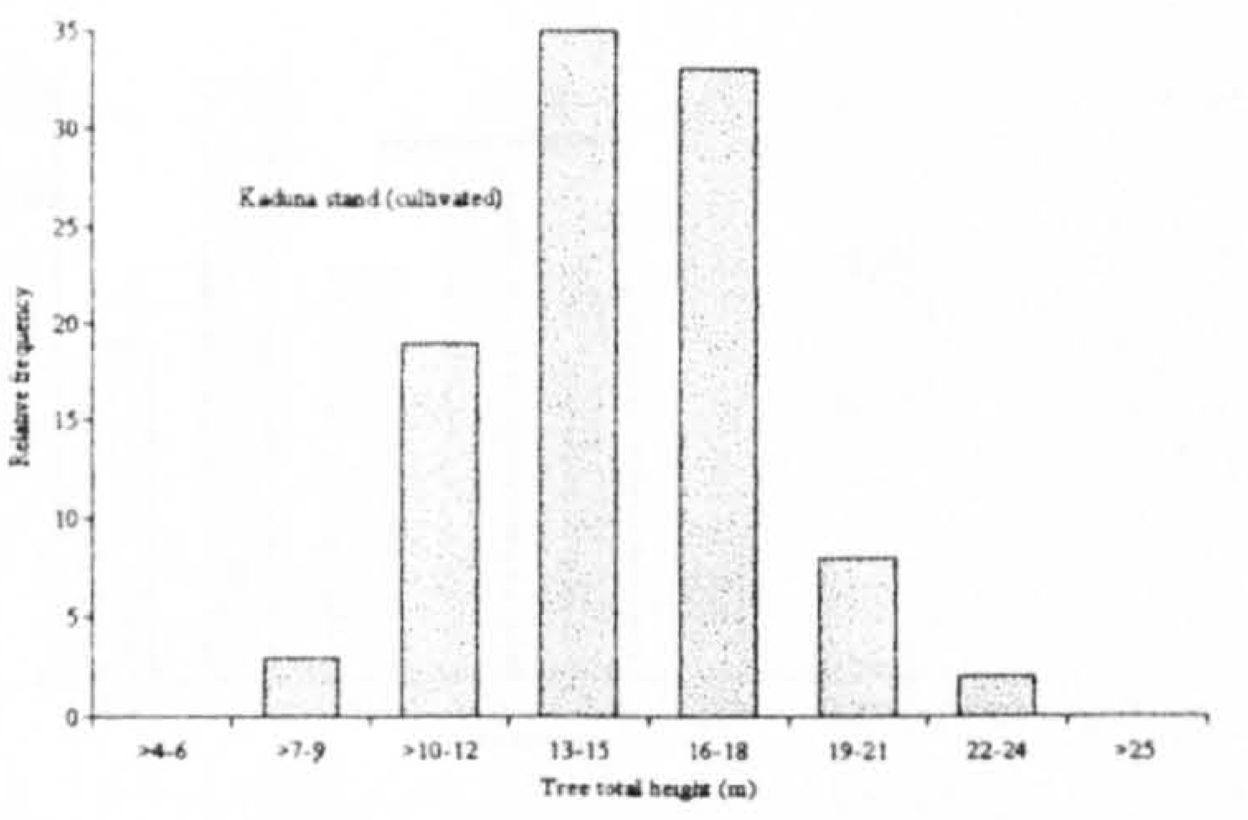


Figure 4.3f Frequency distribution of tree height in Kontagora II

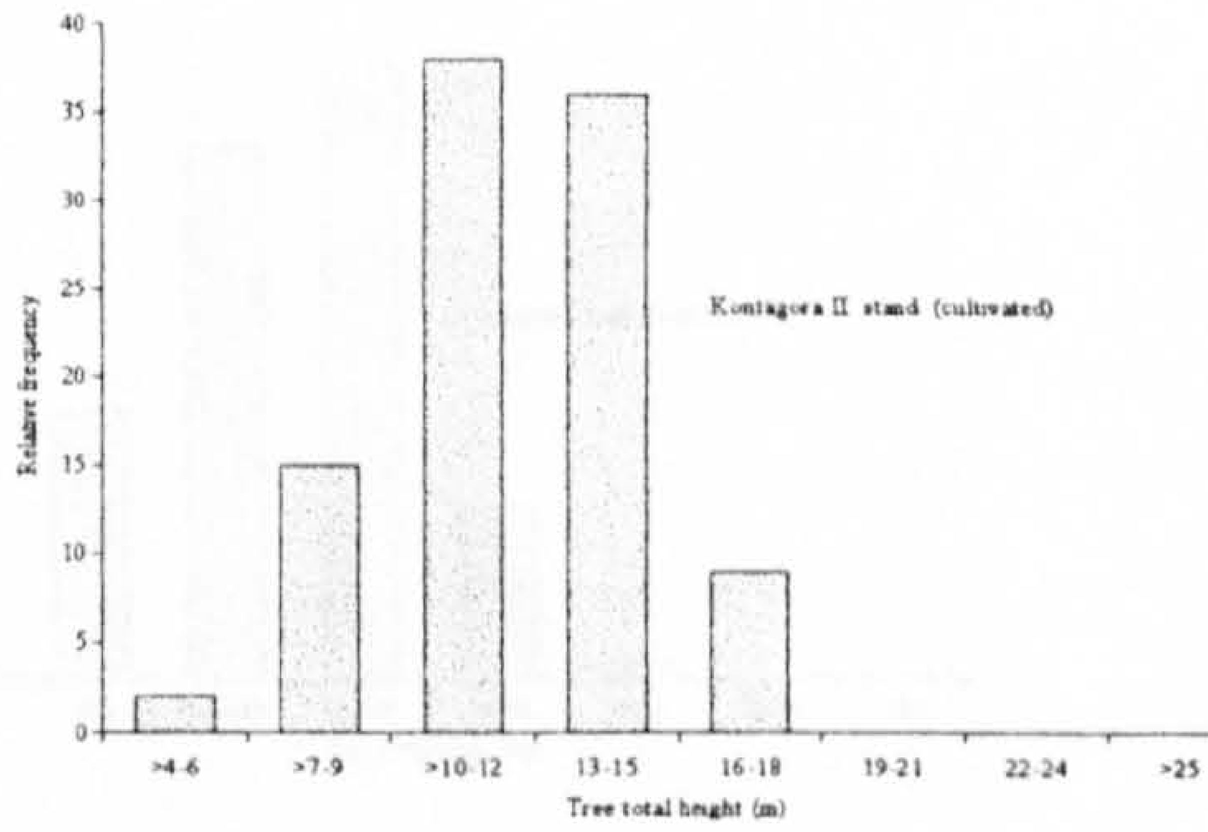


Figure 4.3g Frequency distribution of tree height in Kano I

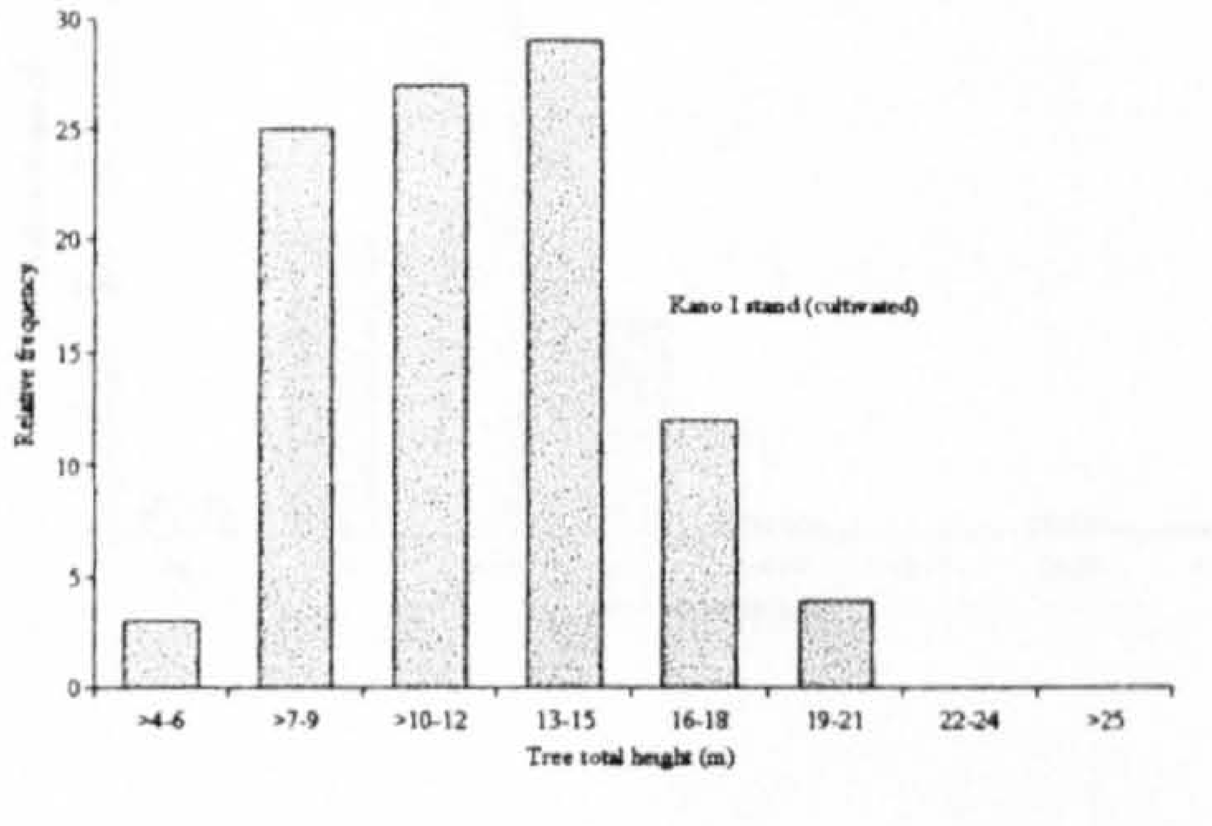
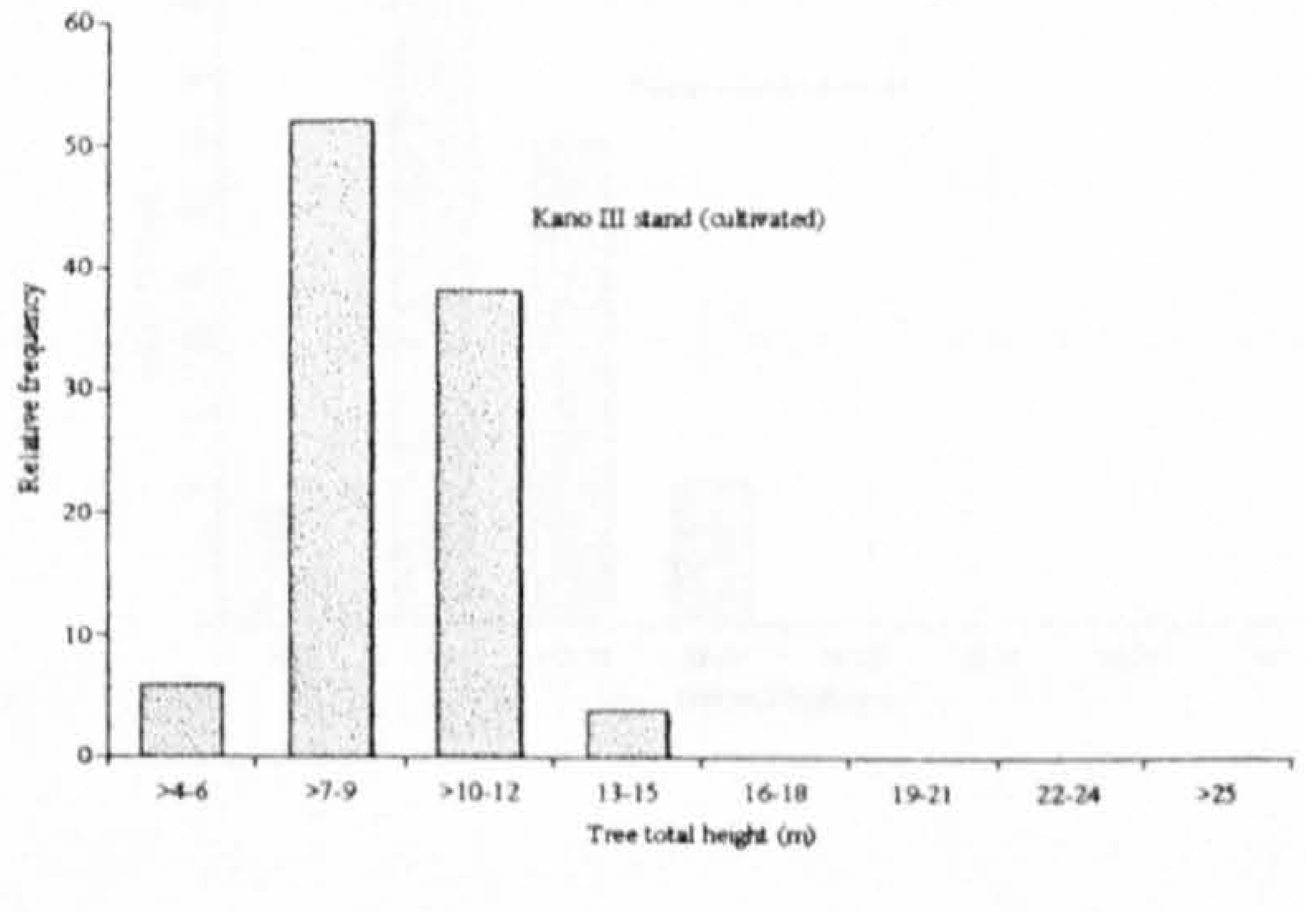


Figure 4.3h Frequency distribution of tree height in Kano III



Tree height class distribution (bush fallow)

Figure 4.3i Frequency distribution of tree height in Olokemeji

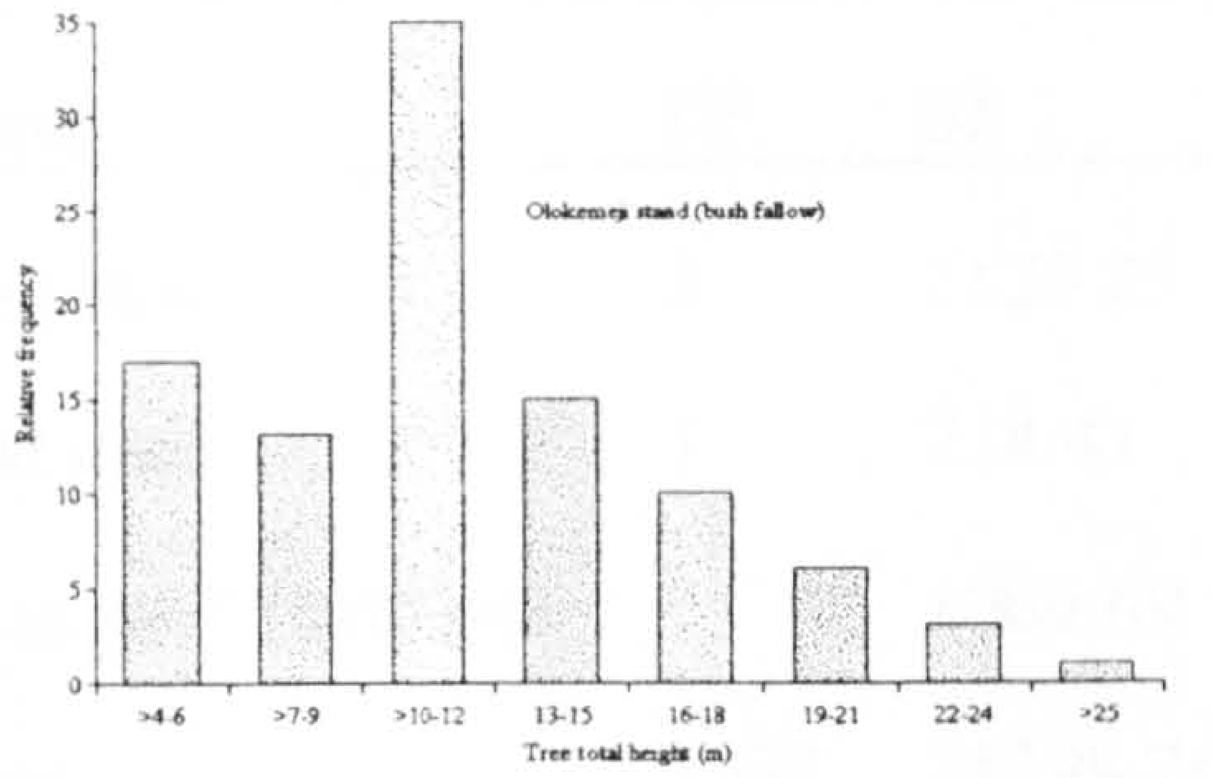


Figure 4.3j Frequency distribution of tree height in Enugu

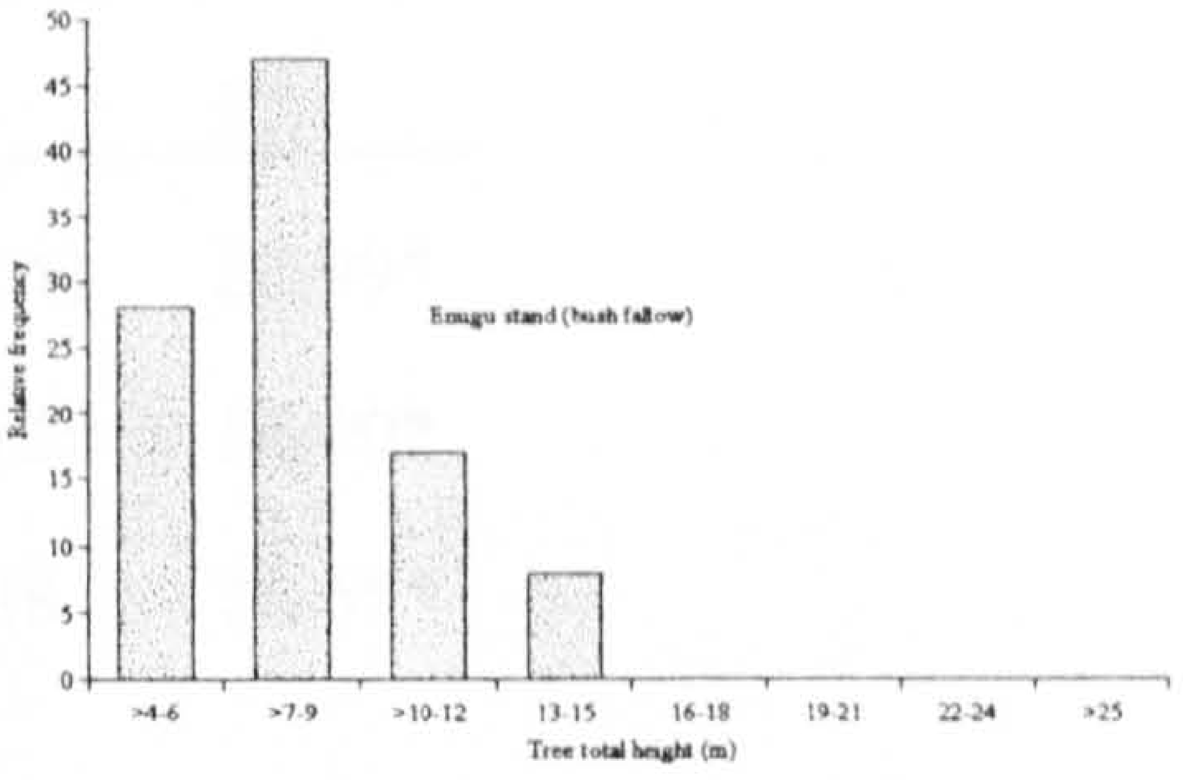


Figure 4.3k Frequency distribution of tree height in Saki

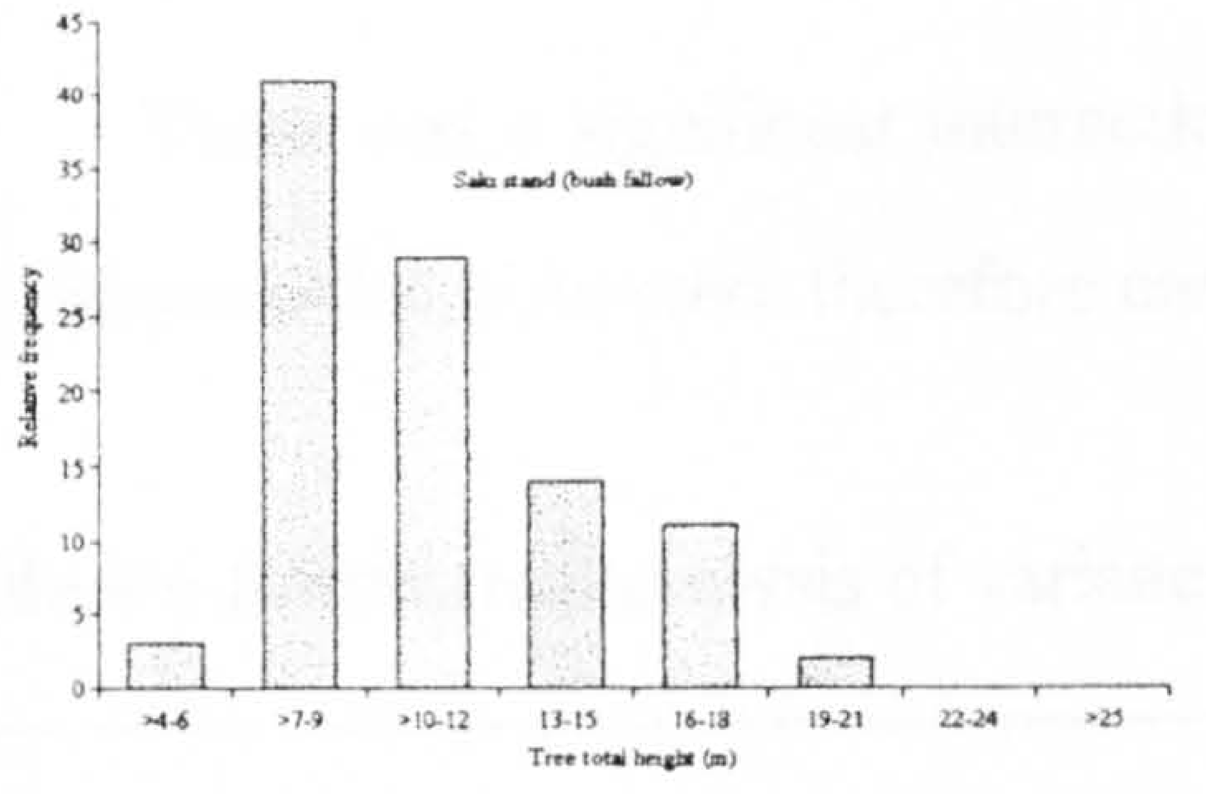


Figure 4.3l Frequency distribution of tree height in Makurdi

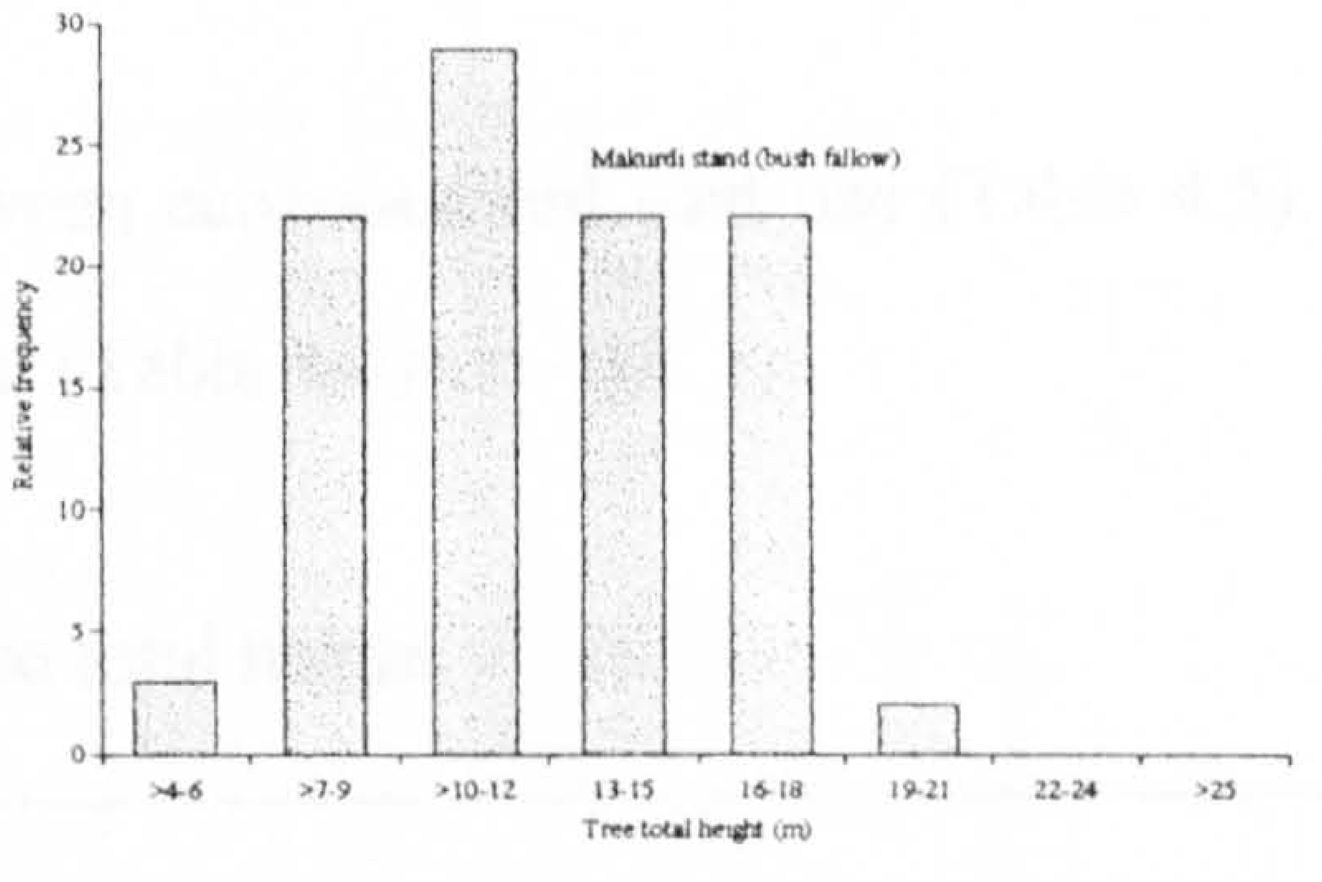


Figure 4.3m Frequency distribution of tree height in Zaria

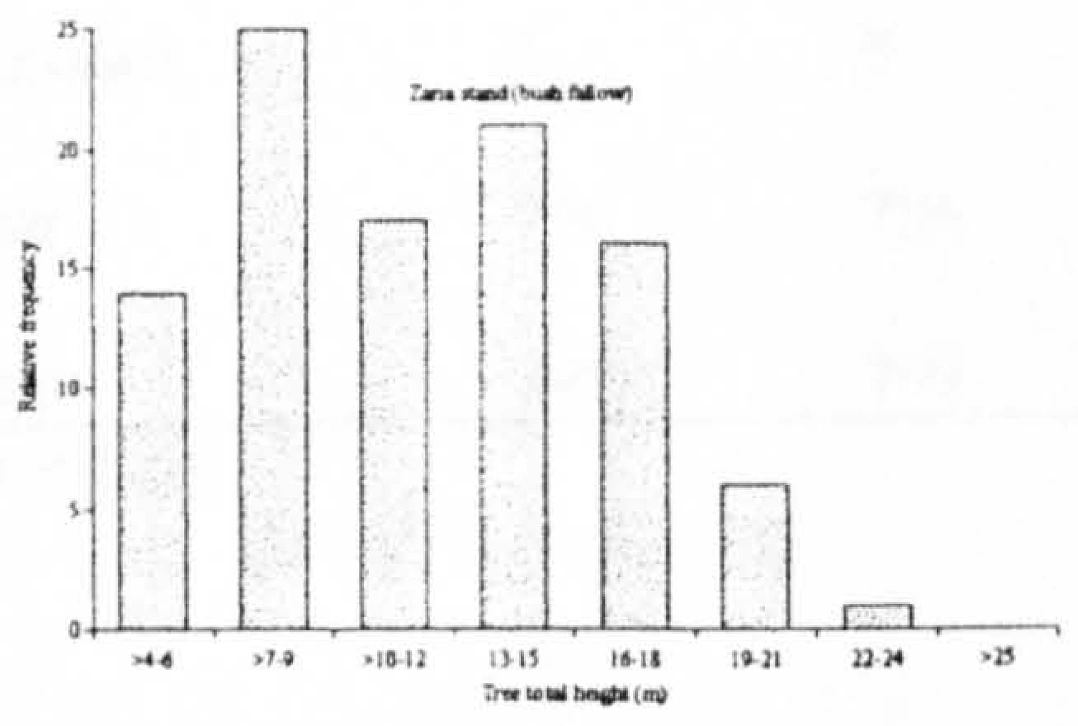


Figure 4.3n Frequency distribution of tree height in Kontagora I

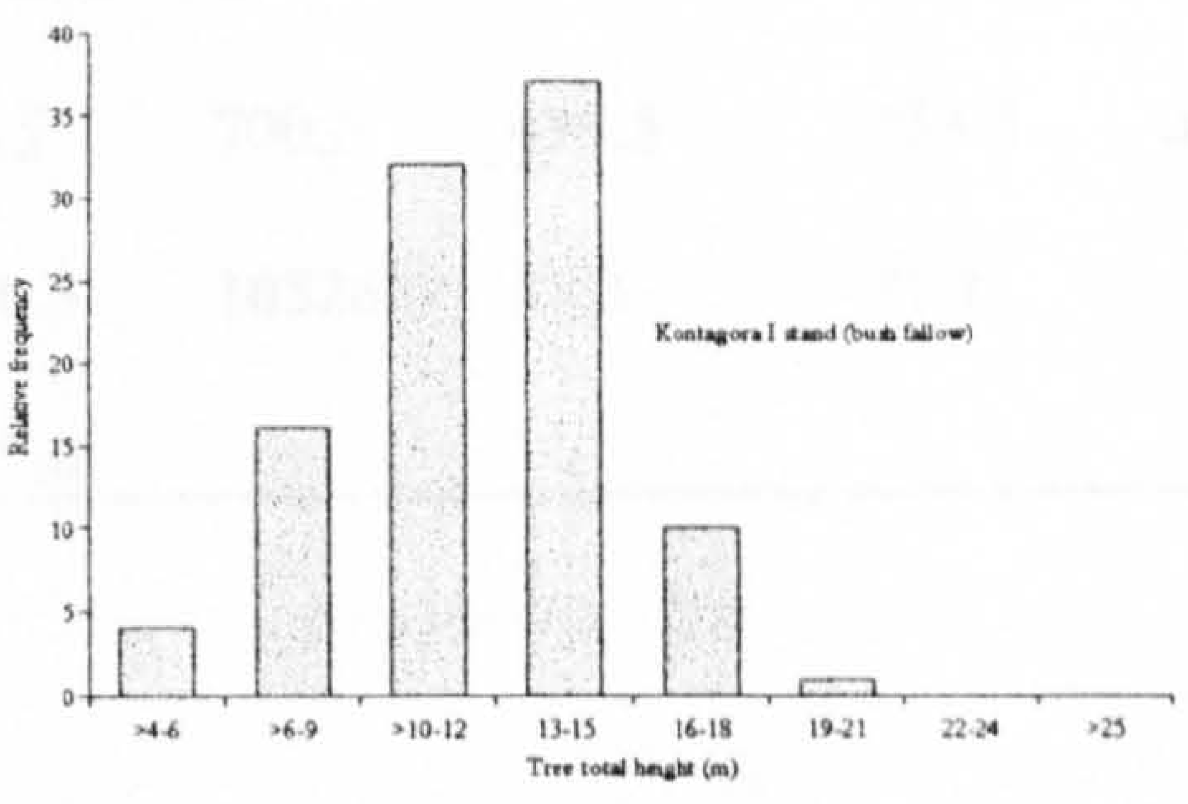


Figure 4.3o Frequency distribution of tree height in Kano II

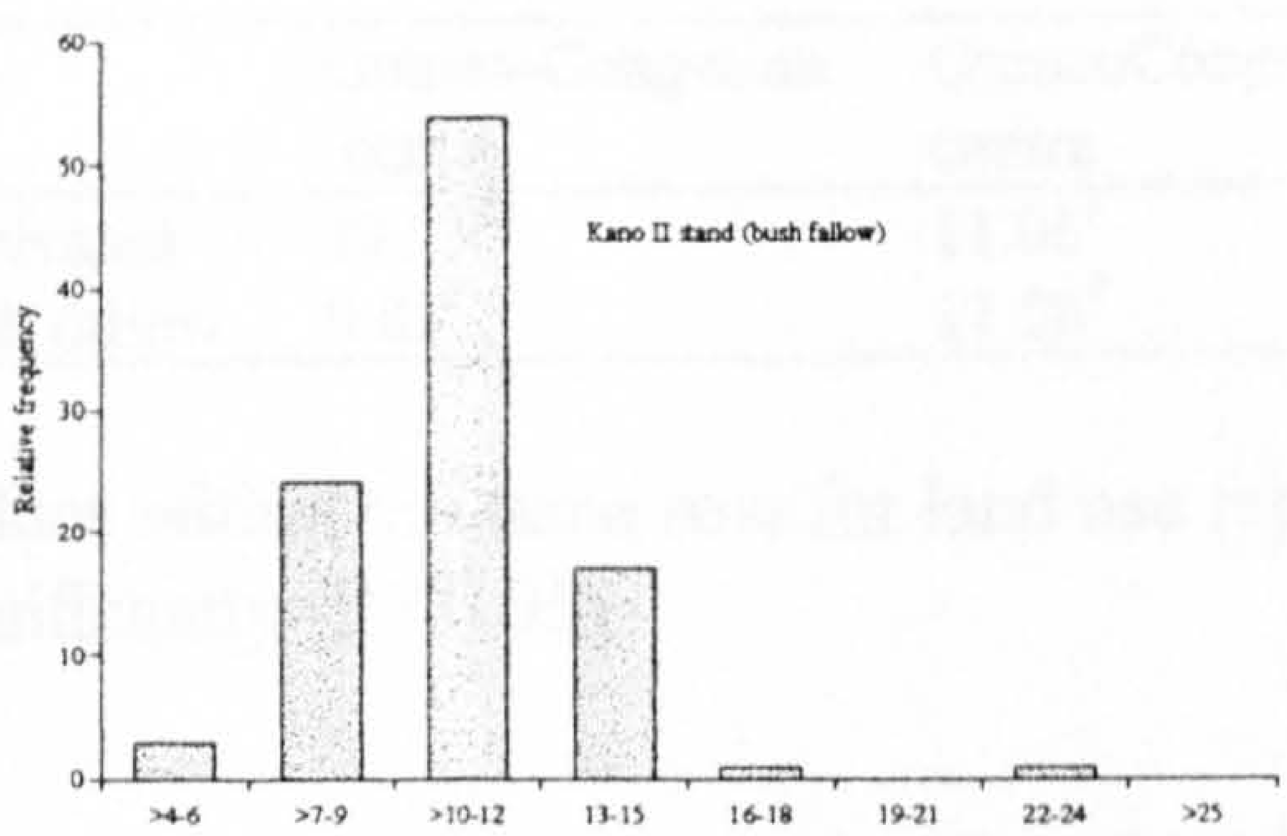
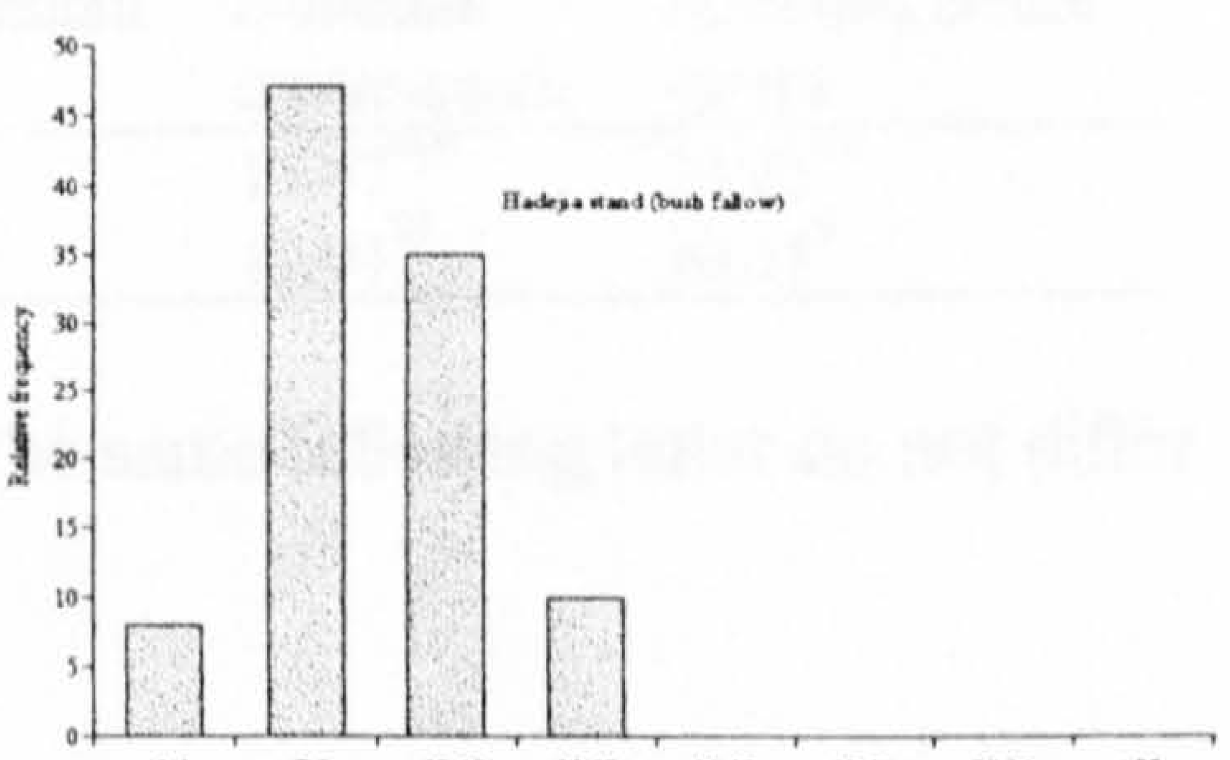


Figure 4.3p Frequency distribution of tree height in Hadejia



Anova

Table 4.5 Two way analysis of variance on tree total height

Source	DF	SS	MS	F
Ecozones	3	1123.23	374.41	27.99*
Land use	1	734.41	356.56	54.90*
Ecozones* Land use	3	1069.69	13.38	26.65*
Error	1592	21298.26		
Total	1599	24225.59		

*P <0.05

There was a significant interaction between ecozones and land use (Table 4.5). Breakdown ANOVAs were therefore carried out (Table 4.6)

Table 4.6 Breakdown analysis of variance on tree total height

Source of variation	DF		SS		MS		F	
Treatment	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow
Ecozones	3	3	1498.5	700.5	499.5	233.5	36.89*	17.66*
Error	796	796	10778.5	10526.6	13.5	13.2		
Total	799	799	12277.0					

*P <0.05

Table 4.7 Zonal differences in mean tree total height (m)

	Guniea-Congolian centre	GuineoCongolian/Sudanian centre	Sudanian centre-south	Sudanian centre -north
Cultivated	13.75^{b}	11.06^{a}	13.47^{bcd}	10.73^{ac}
Bush fallow	9.83^{a}	11.58^{b}	12.04^{bc}	10.14^{a}

Values within the same row for land use type with the same following letter do not differ significantly (P <0.05).

Both land use types significantly influenced tree total height in the extreme south and north of *Parkia* range. However in the transition zone (Ecozones II) intensive cultivation had no significant effect on tree height while in the bush fallow no significant difference was obtained in the Guinea-Congolian centre and Sudanian -north (Table 4.7).

4.1.1.3 Tree diameter (cm)

Mean tree diameter ranged from 29.82 ± 1.49 cm in Enugu stand in the south Ecozone I, (Guinea-Congolian centre) to 69 .95 ± 1.99 cm in Kaduna, Ecozone III to the north (Sudanian centre) (Figure 4.4). More mature trees (>50 cm dbh) were more frequent in the northern part of the range compared with the south. Mean tree diameter comparisons between the two land use types indicated higher tree diameter in the cultivated (50.04 cm ± 3.34 cm) compared with the bush fallow (45.38 cm ± 3.36 cm).

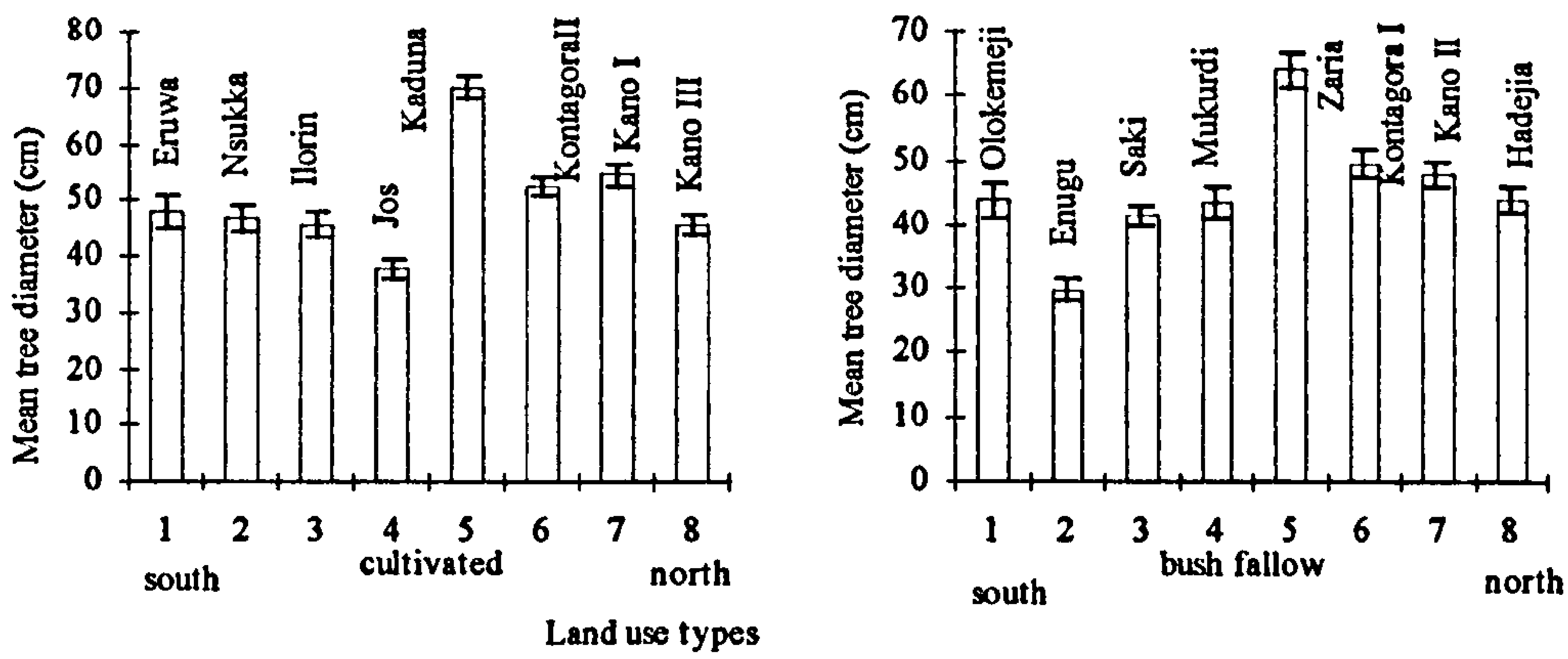


Figure 4.4 *Parkia biglobosa* mean tree diameter (±se) for Nigerian sample stands on cultivated land and in bush fallow.

Tree diameter class distribution (cultivated)

Figure 4.5a Frequency distribution of tree diameter in Eruwa

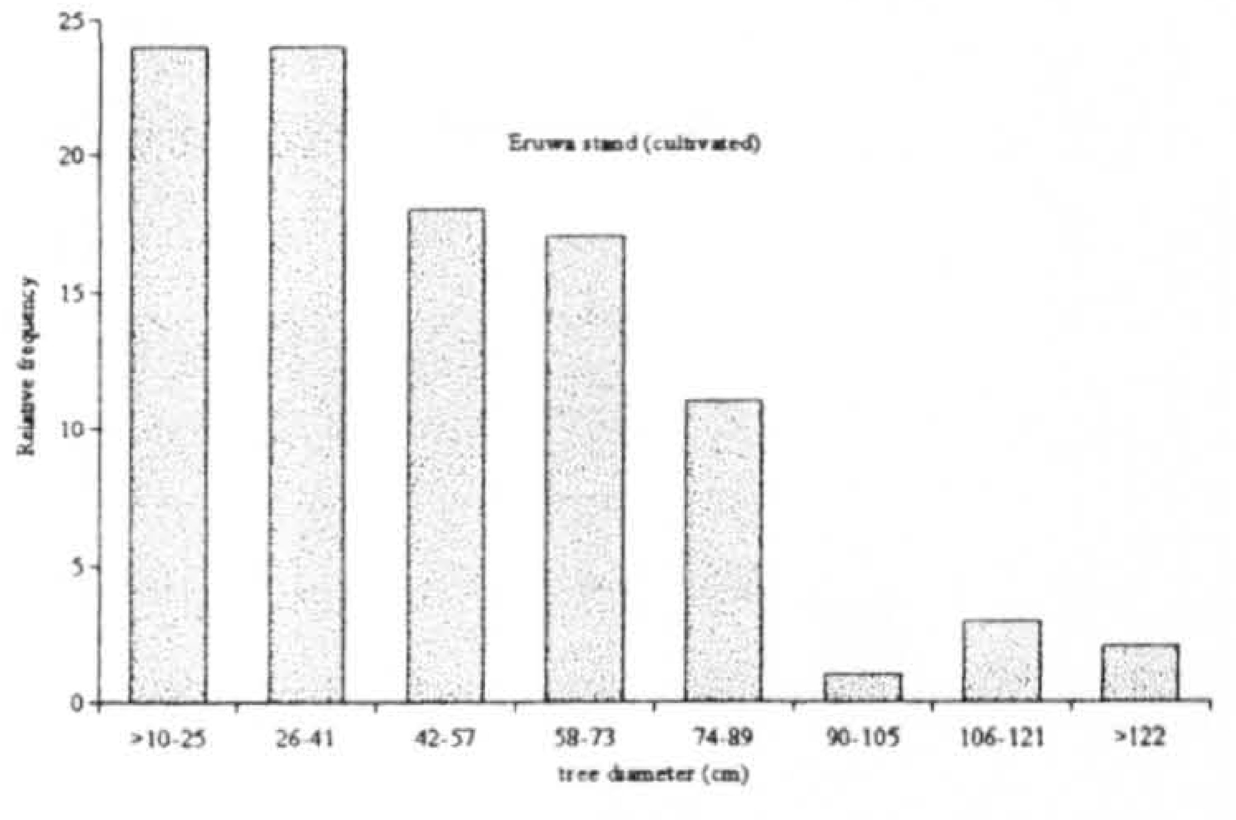


Figure 4.5b Frequency distribution of tree diameter in Nsukka

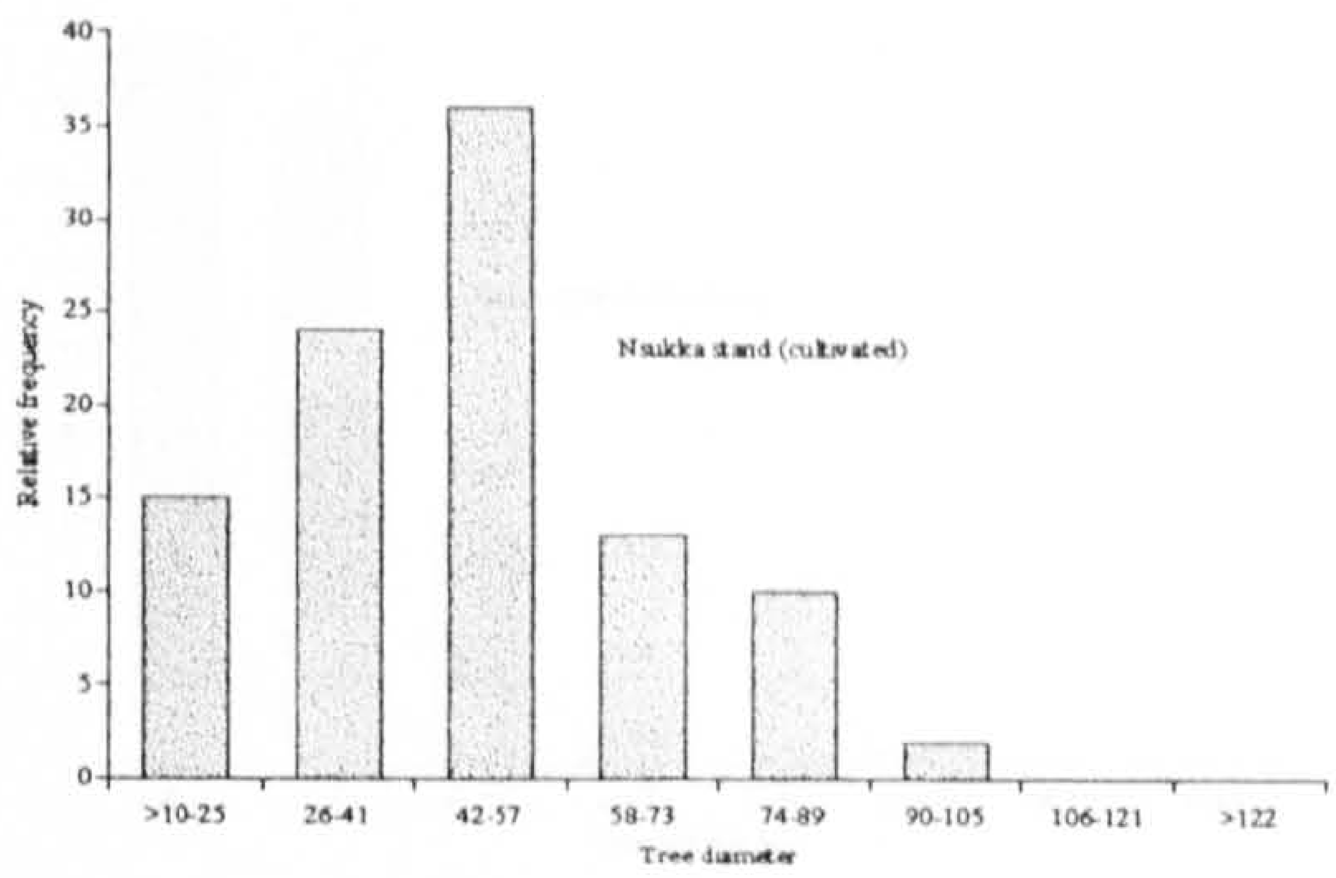


Figure 4.5c Frequency distribution of tree diameter in Ilorin

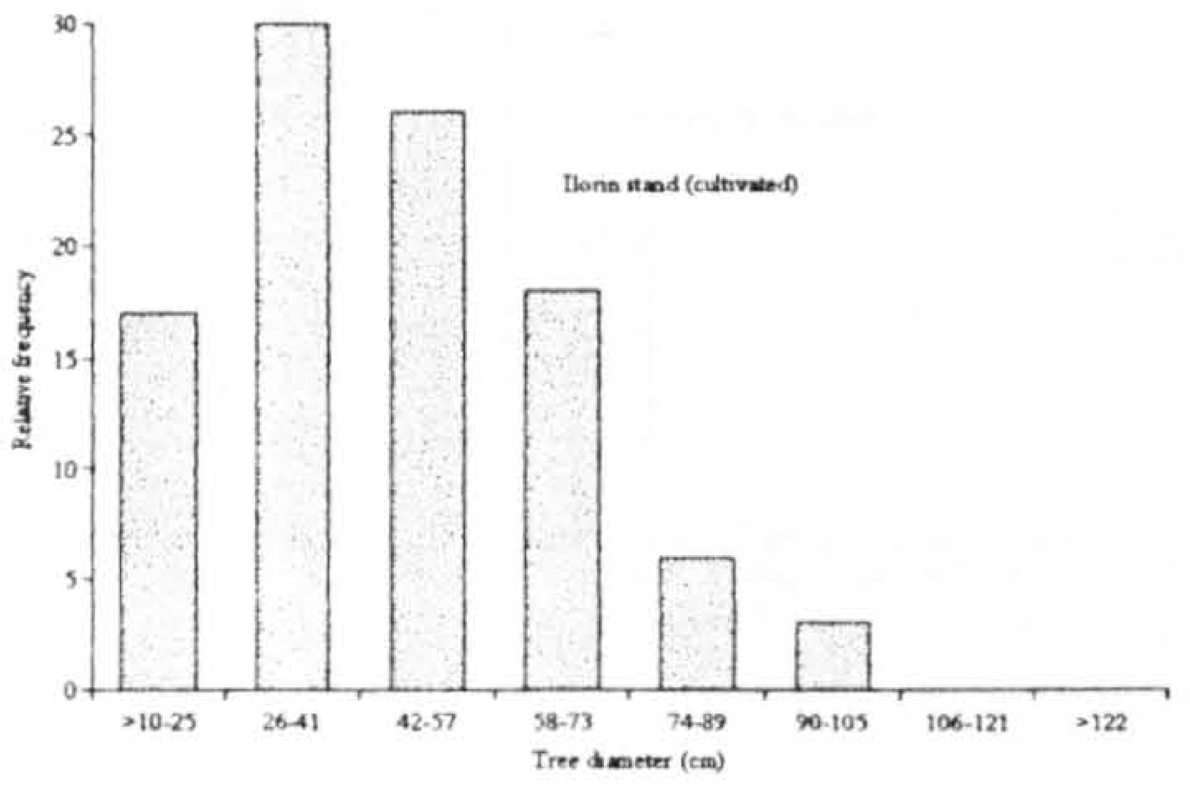


Figure 4.5d Frequency distribution of tree diameter in Jos

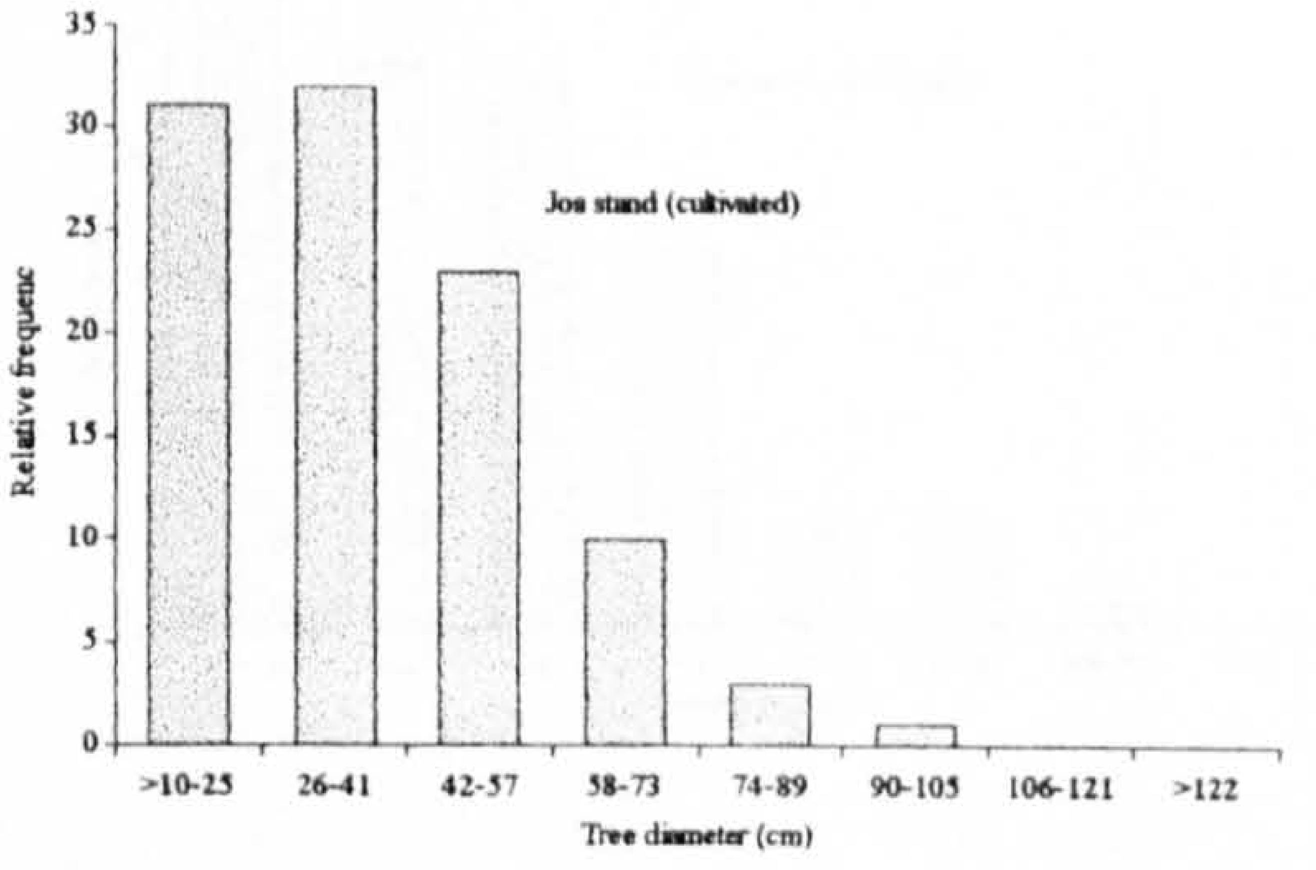


Figure 4.5e Frequency distribution of tree diameter in Kaduna

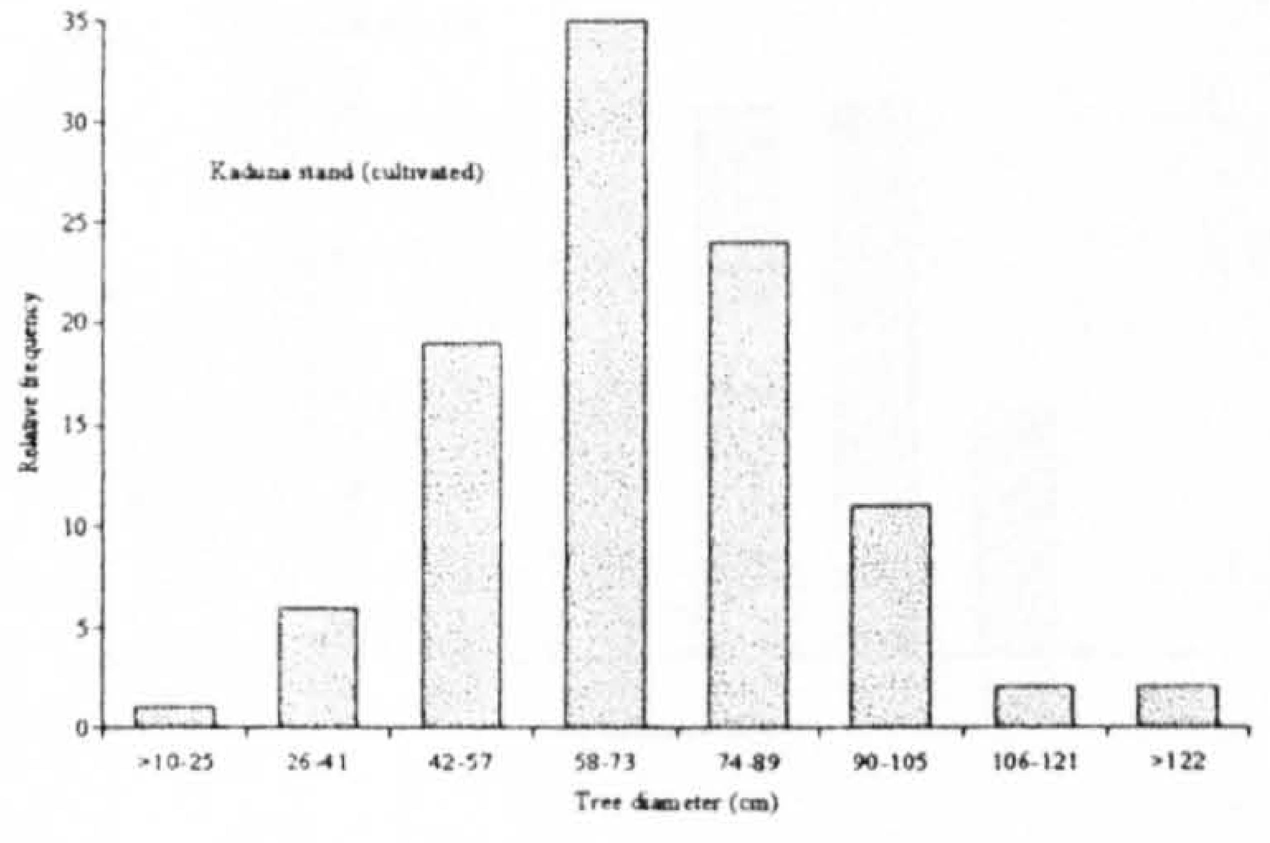


Figure 4.5f Frequency distribution of tree diameter in Kontgagora II

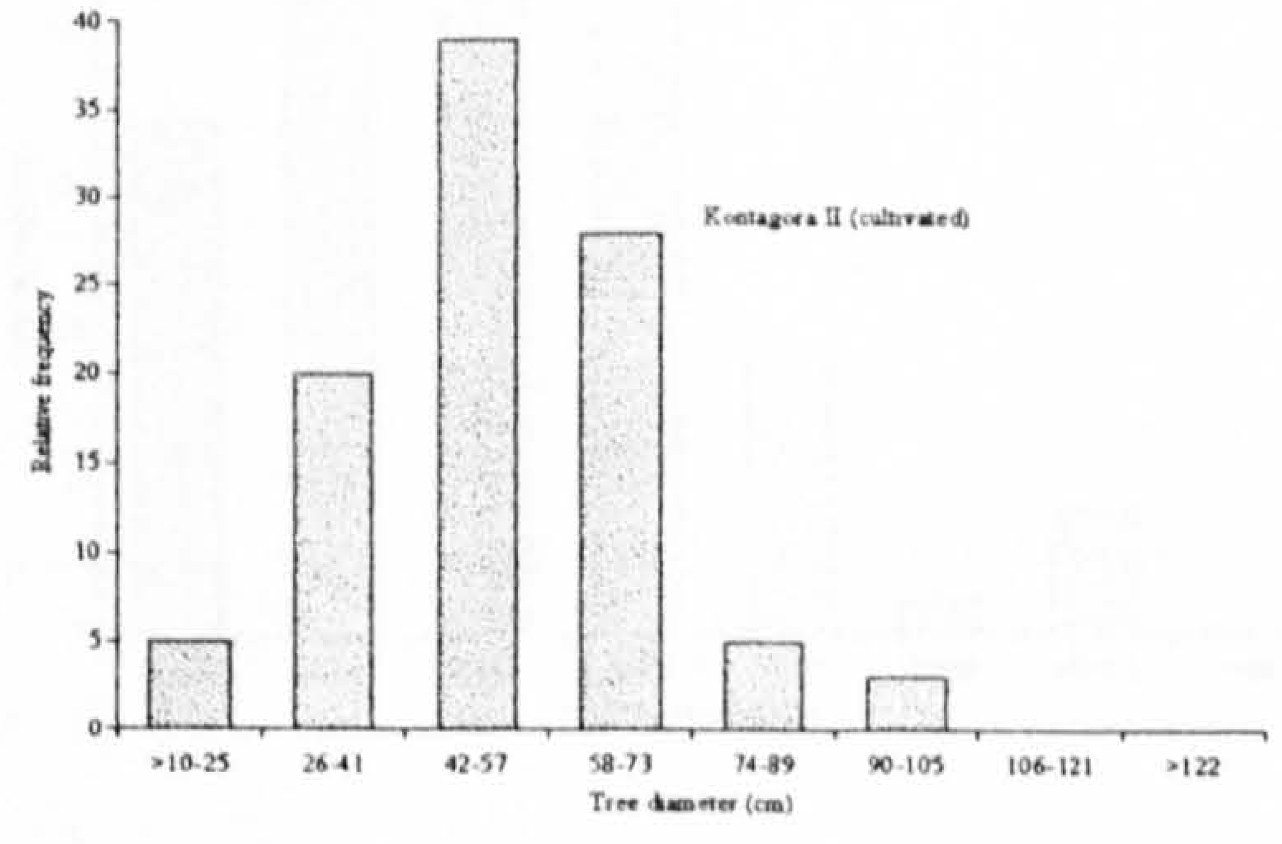


Figure 4.5g Frequency distribution of tree diameter in Kano I

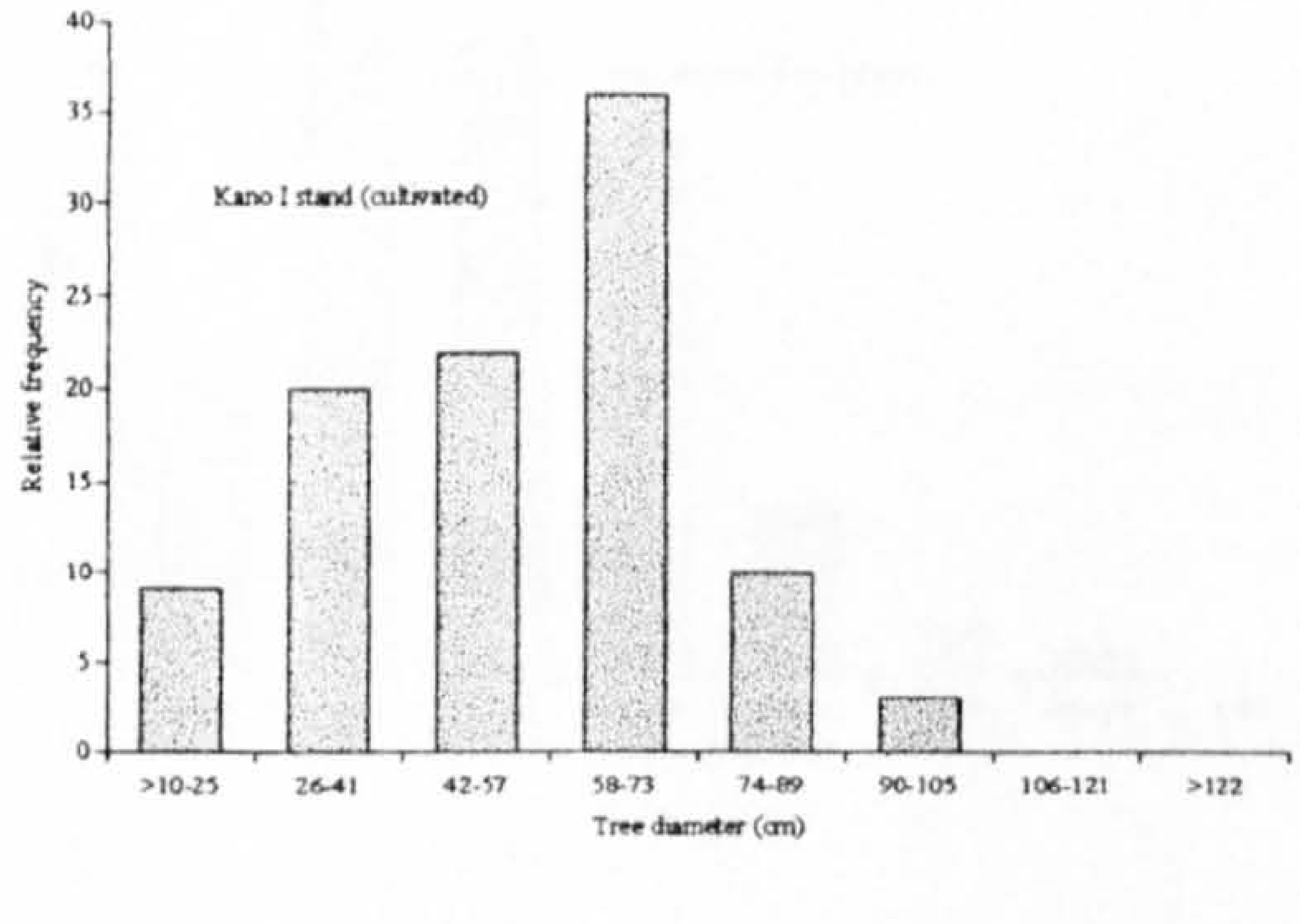
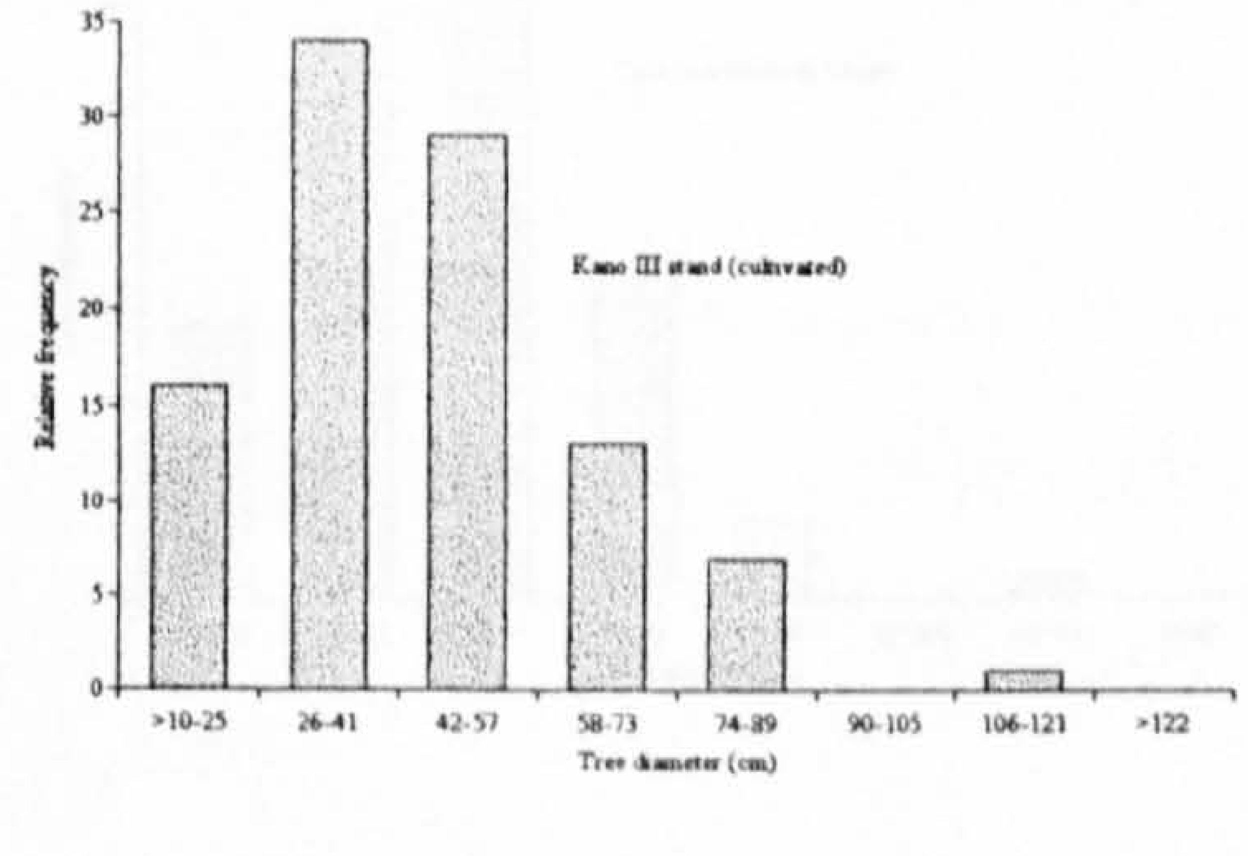


Figure 4.5h Frequency distribution of tree diameter in Kano III



Tree diameter class distribution (Bush fallow)

Figure 4.5i Frequency distribution of tree diameter in Olokemeji

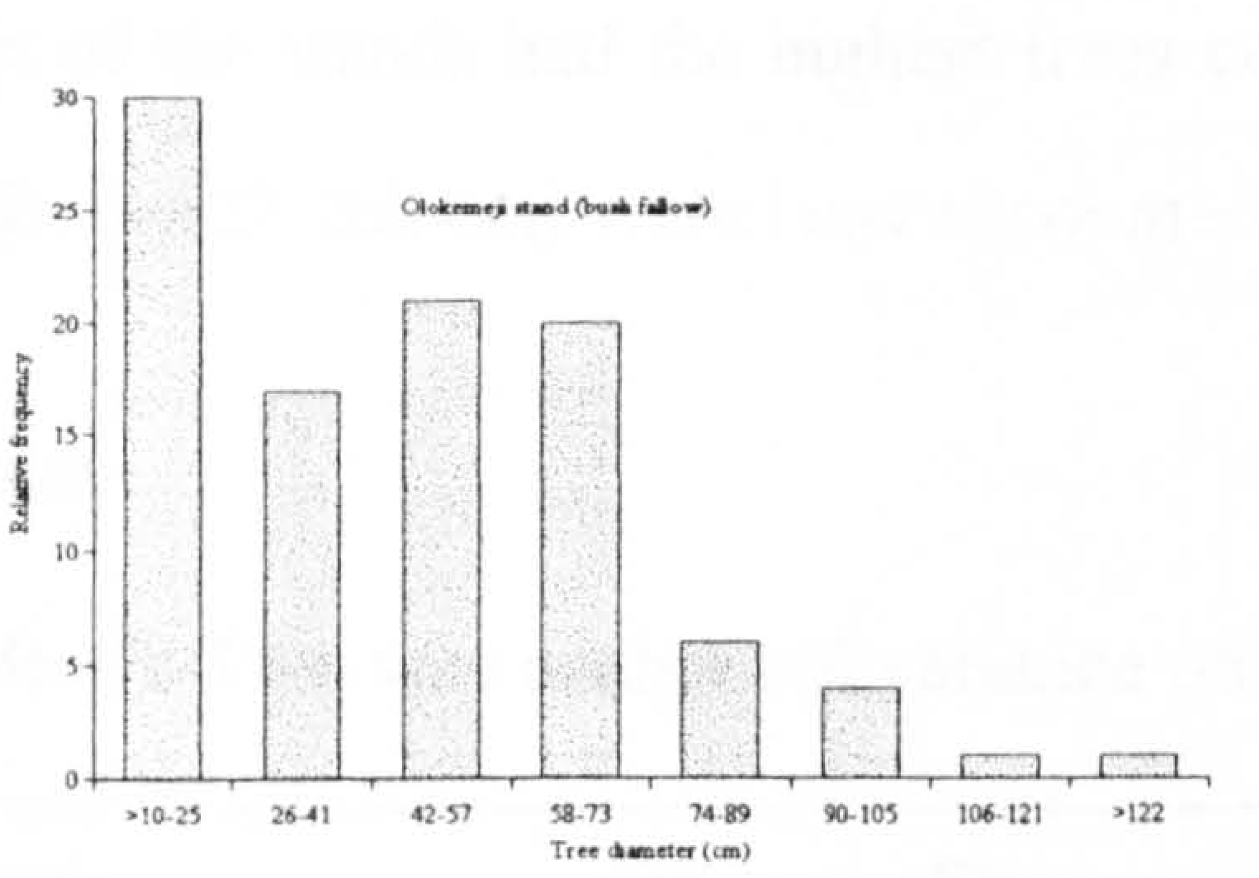


Figure 4.5j Frequency distribution of tree diameter in Enugu

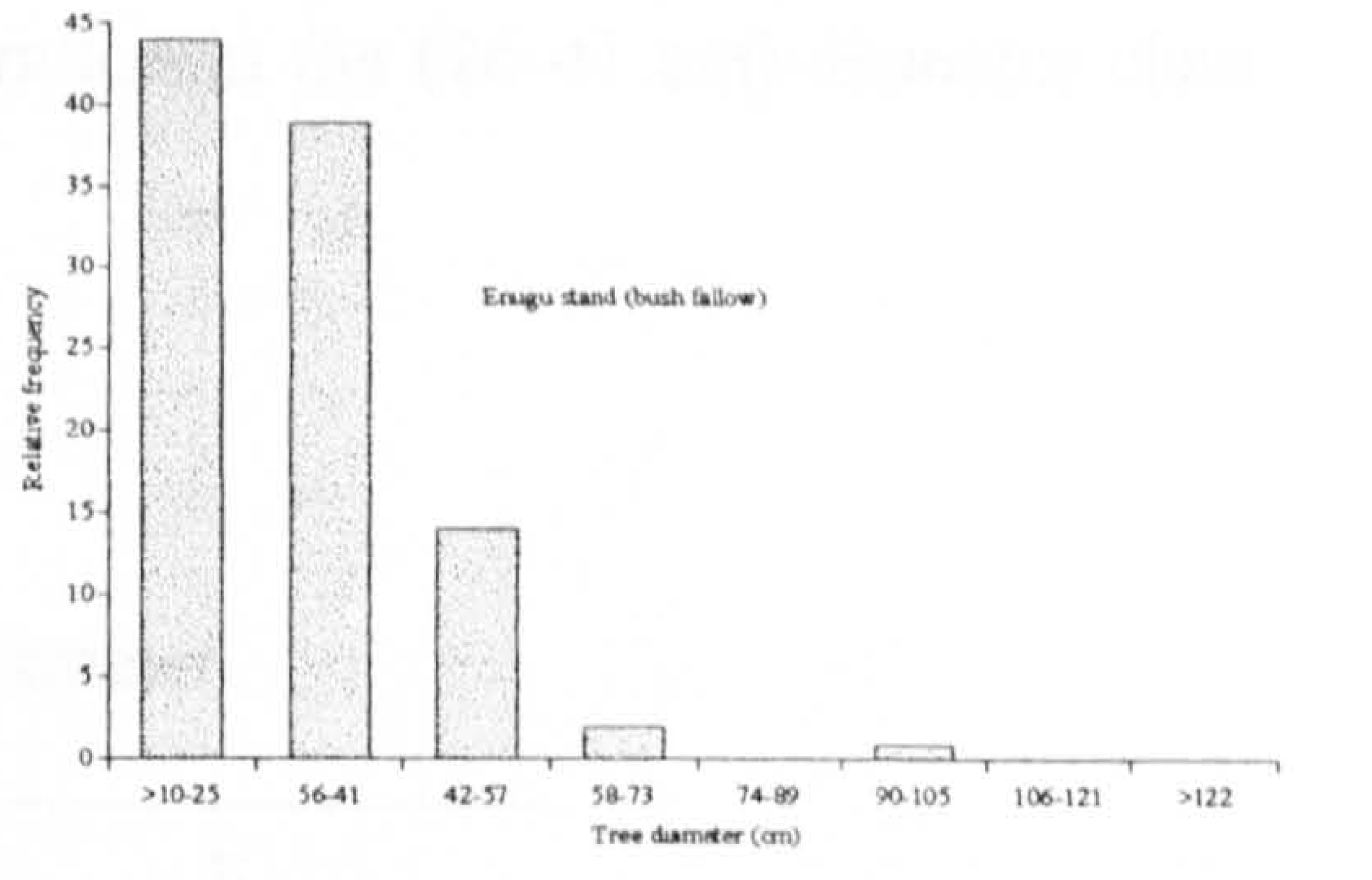


Figure 4.5k Frequency distribution of tree diameter in Saki

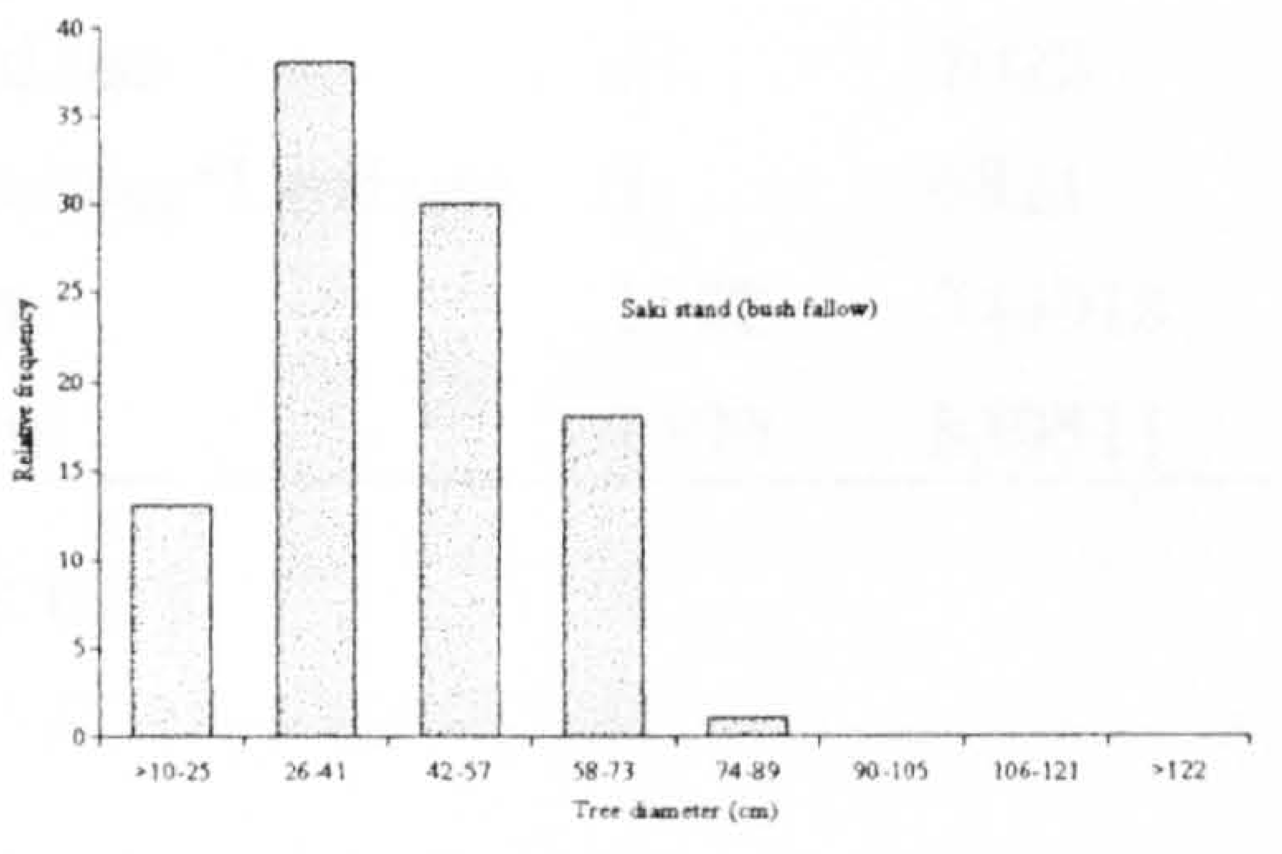


Figure 4.5l Frequency distribution of tree diameter in Makurdi

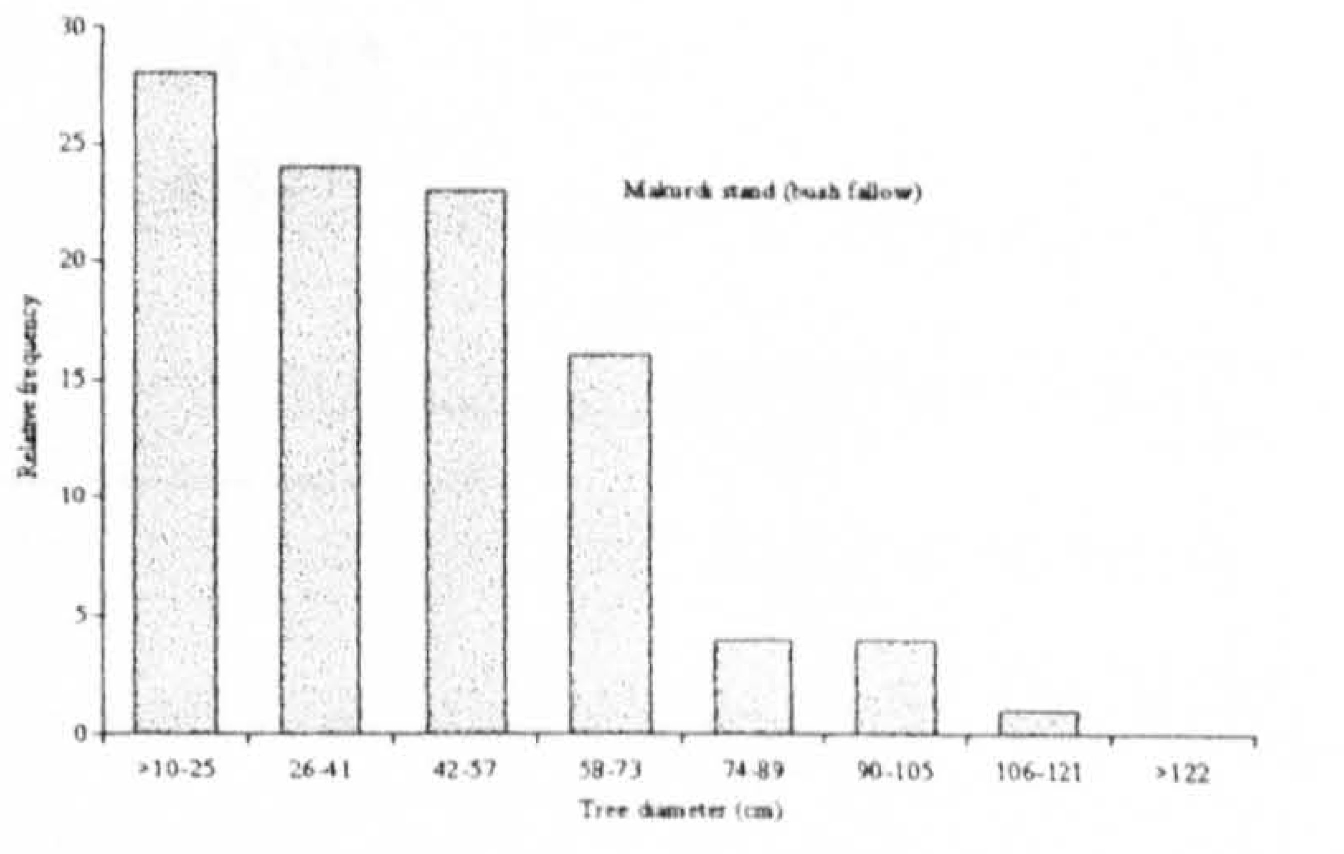


Figure 4.5m Frequency distribution of tree diameter in Zaria

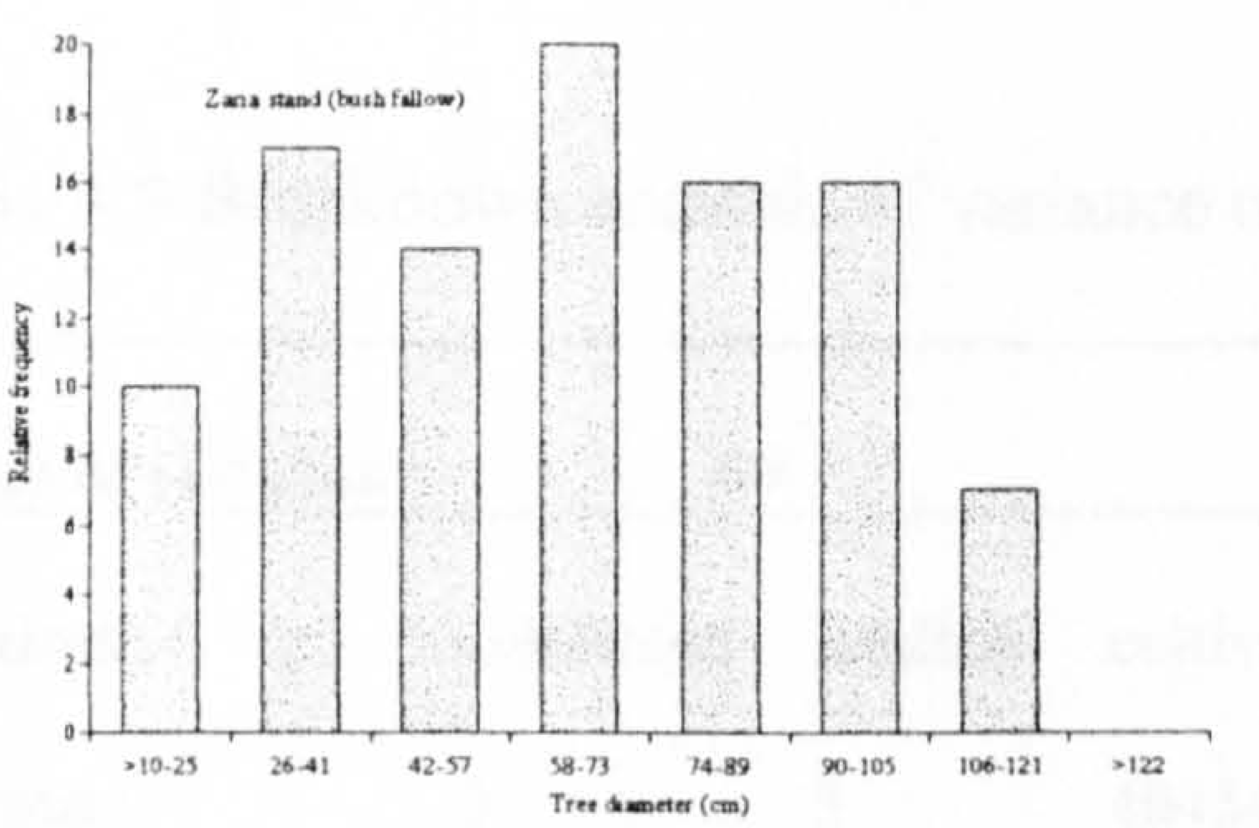


Figure 4.5n Frequency distribution of tree diameter in Kontagora I

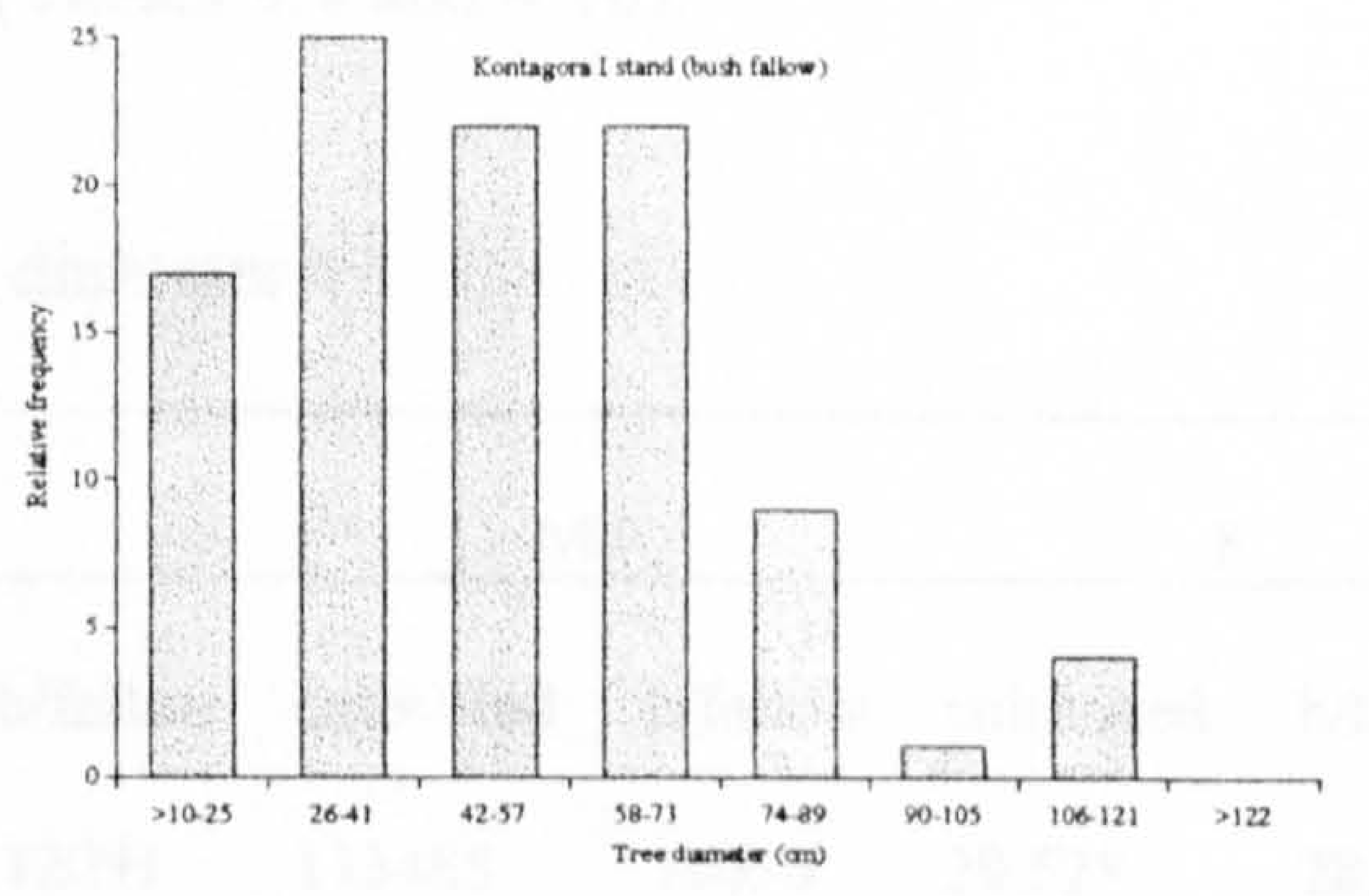


Figure 4.5o Frequency distribution of tree diameter in Kano II

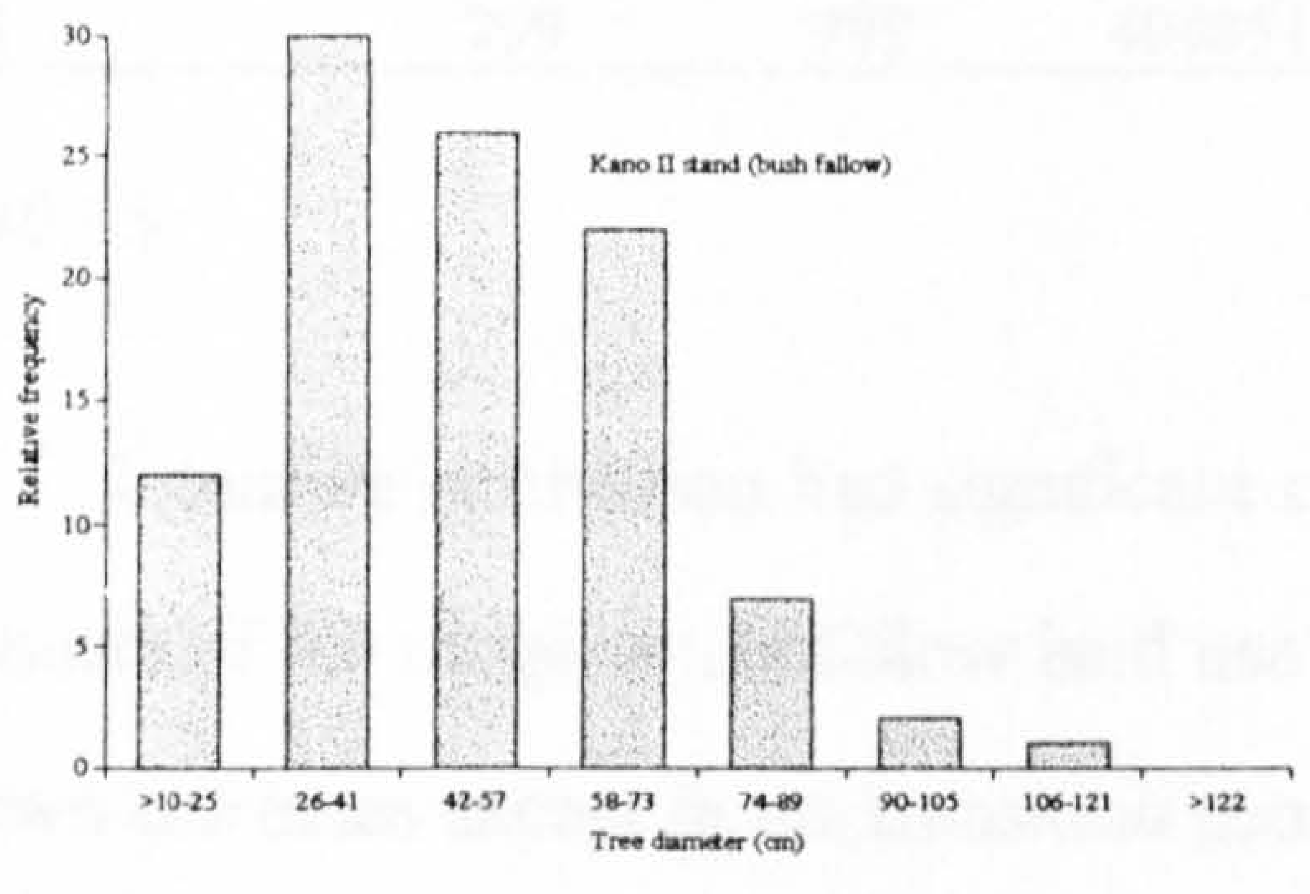
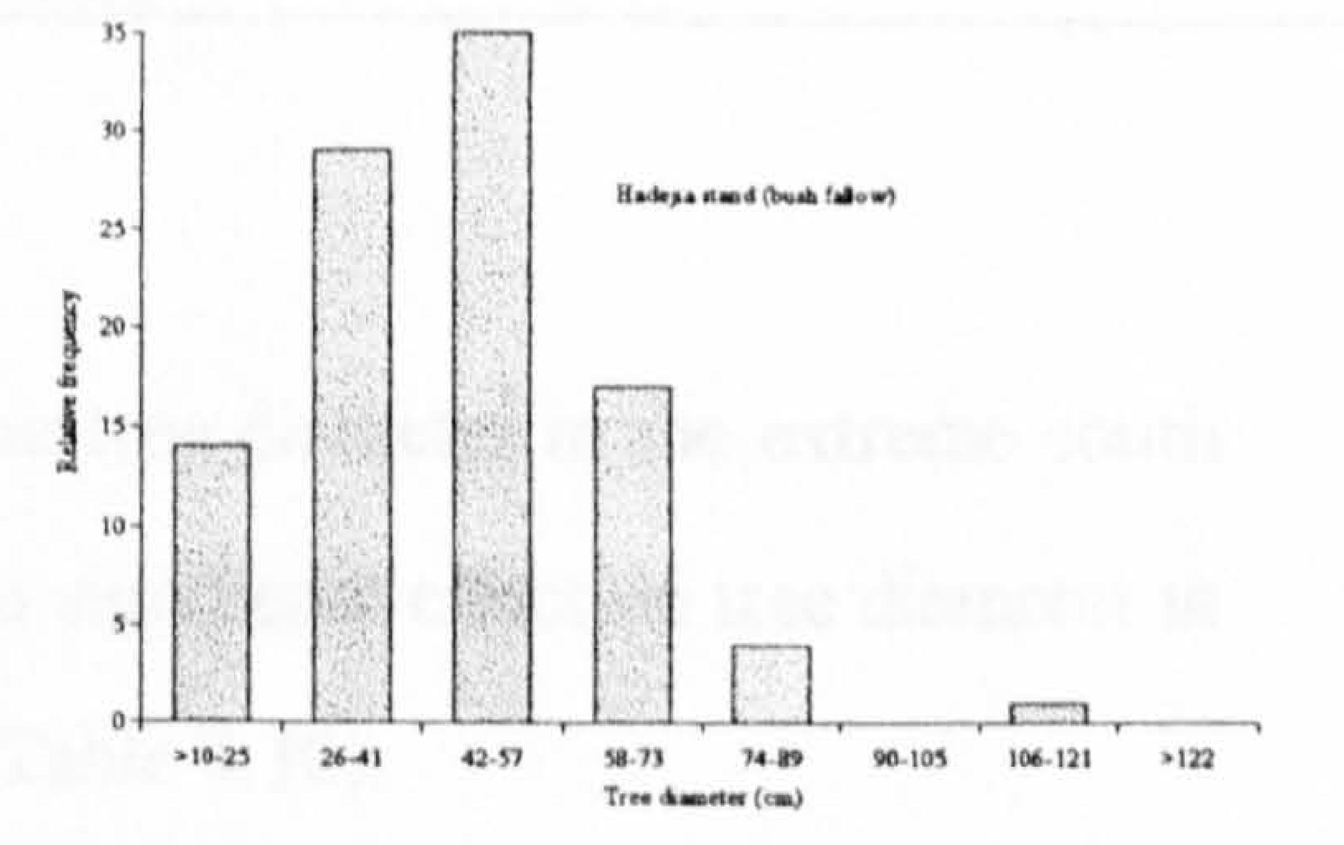


Figure 4.5p Frequency distribution of tree diameter in Hadejia



The distribution of trees to diameter classes indicated increasing number of individuals with increasing diameter classes up to (58-73 cm) diameter class. However most of the stands had the highest trees concentration in the (26-41 cm) diameter class while, (>122 dbh cm) were least encountered.

Anova

Table 4.8 Two way analysis of variance on tree diameter

Source	DF	SS	MS	F
Ecozones	3	75750	25250	53.60*
Land use	1	7022	7022	14.91*
Ecozones*Land use	3	6821	2274	4.83*
Error	1592	749918	471	
Total	1599	839511		

*P < 0.05

There was a significant interaction between ecozone and land use (Table 4.8). Breakdown ANOVAs was therefore carried out. (Tables 4.9 and 4.10).

Table 4.9 Breakdown analysis of variance on tree diameter

Source of variation	DF		SS		MS		F	
Treatment	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow
Ecozones	3	3	40454	42091	113485	14030	29.52*	28.90*
Error	796	796	363597	386394	457	485		
Total	799	799	404051	428485				

*P <0.05

Intensive cultivation had significant effect on tree diameter in the extreme south and north of the range, while fallow land use had no significant effect on tree diameter in the two extremes except in the transition ecozone (Table 4.10).

Table 4.10 Zonal differences in mean tree diameter (cm)

	Guniea-Congolian centre	GuineoCongolian/Sudanian centre	Sudanian centre-south	Sudanian centre -north
Cultivated	47.34[a]	41.62[b]	61.16[cde]	49.21[ac]
Bush fallow	36.79[a]	42.40[a]	56.63[bcd]	46.64[ab]

Values within the same row for land use type with the same following letter do not differ significantly (P <0.05).

4.1.1.4 Crown diameter (m)

Mean crown diameter ranged from 5.42 ± 0.17 m in Enugu to the south, Ecozone I, of the (Guinea-Congolian centre) to 18.68 ± 0.2 m in Kaduna to the north, Ecozone III, of the (Sudanian centre) (Figure 4.6). Crown diameter generally tends to be larger (>12 m) in the north of the range compared with the south. Comparisons between the two land use types indicated higher mean crown diameter in the cultivated (13.58 ± 0.88 m) compared with the bush fallow (12.30 ± 1.12 m).

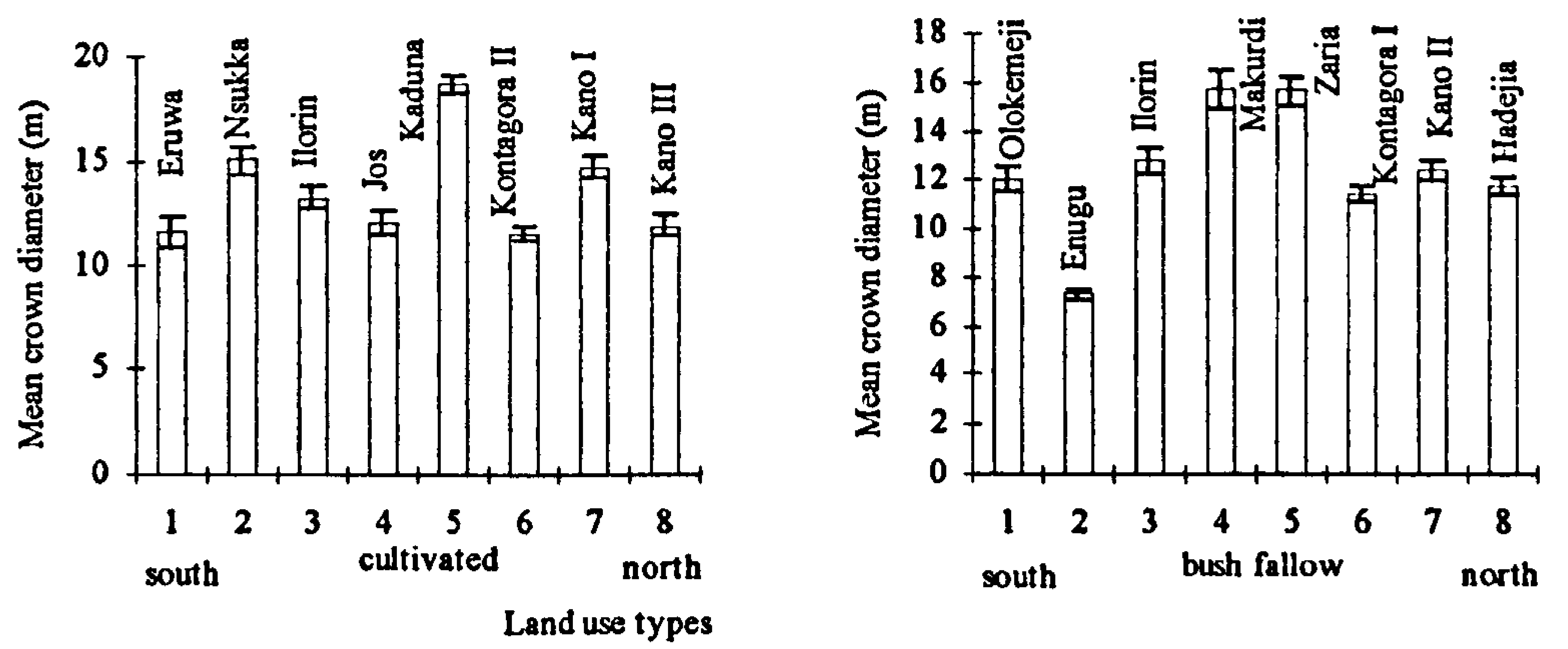


Figure 4.6 *Parkia biglobosa*: mean crown diameter (±se) for Nigerian sample stands on cultivated land and in bush fallow.

Crown diameter class distribution (Cultivated)

Figure 4.7a Frequency distribution of crown diameter in Eruwa

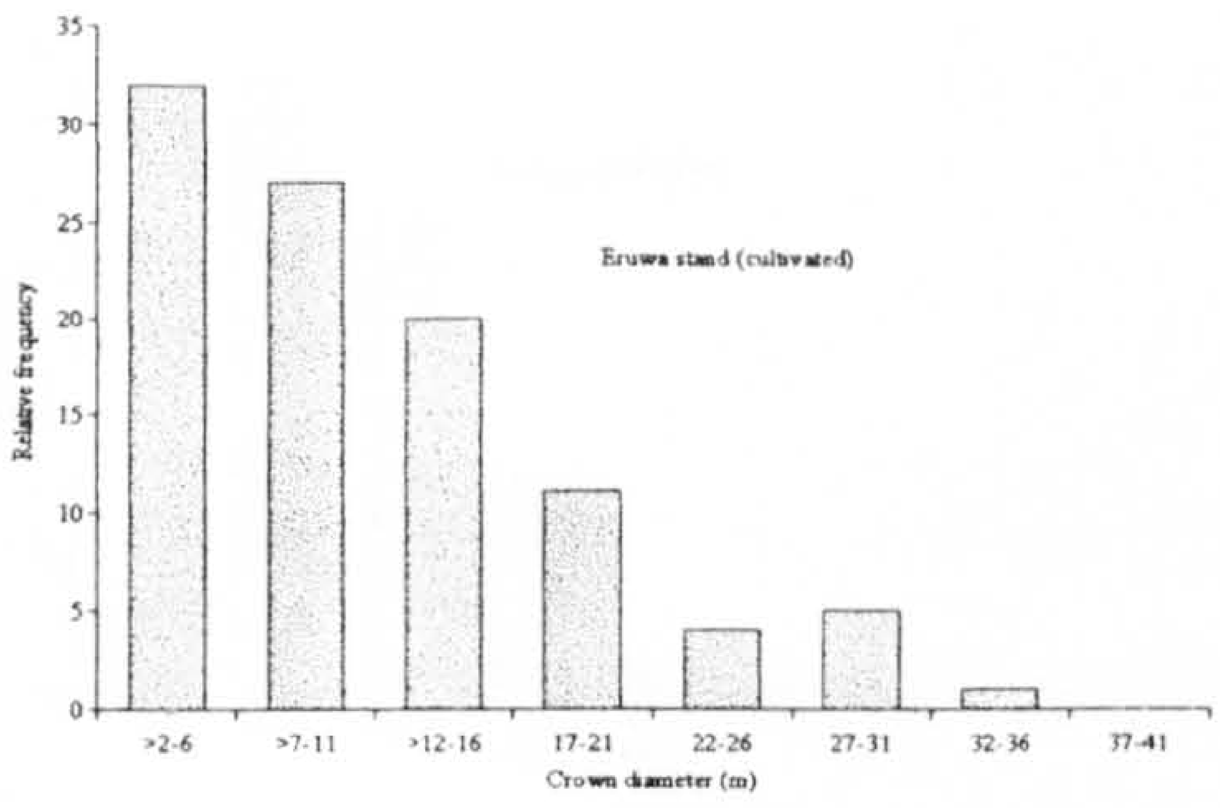


Figure 4.7b Frequency distribution of crown diameter Nsukka

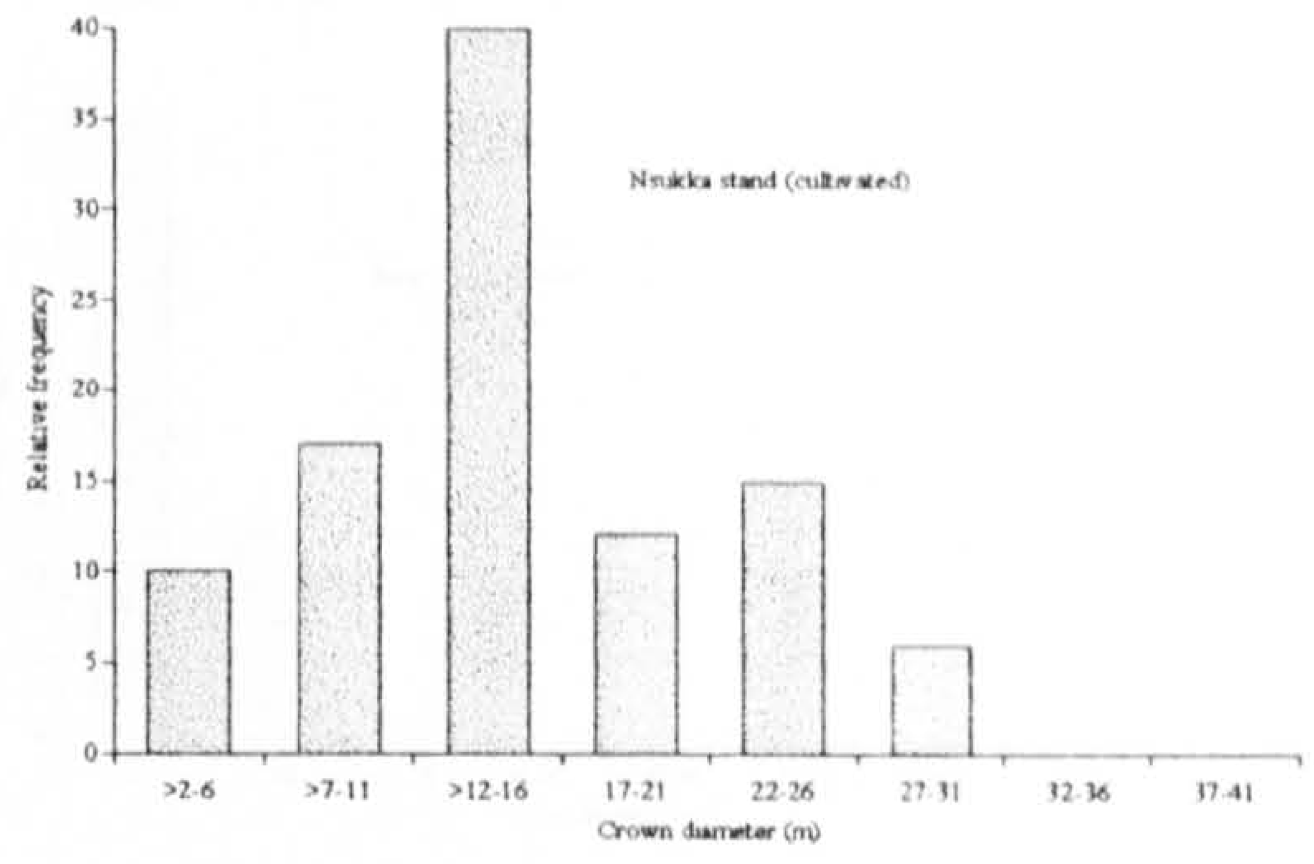


Figure 4.7c Frequency distribution of crown diameter Ilorin

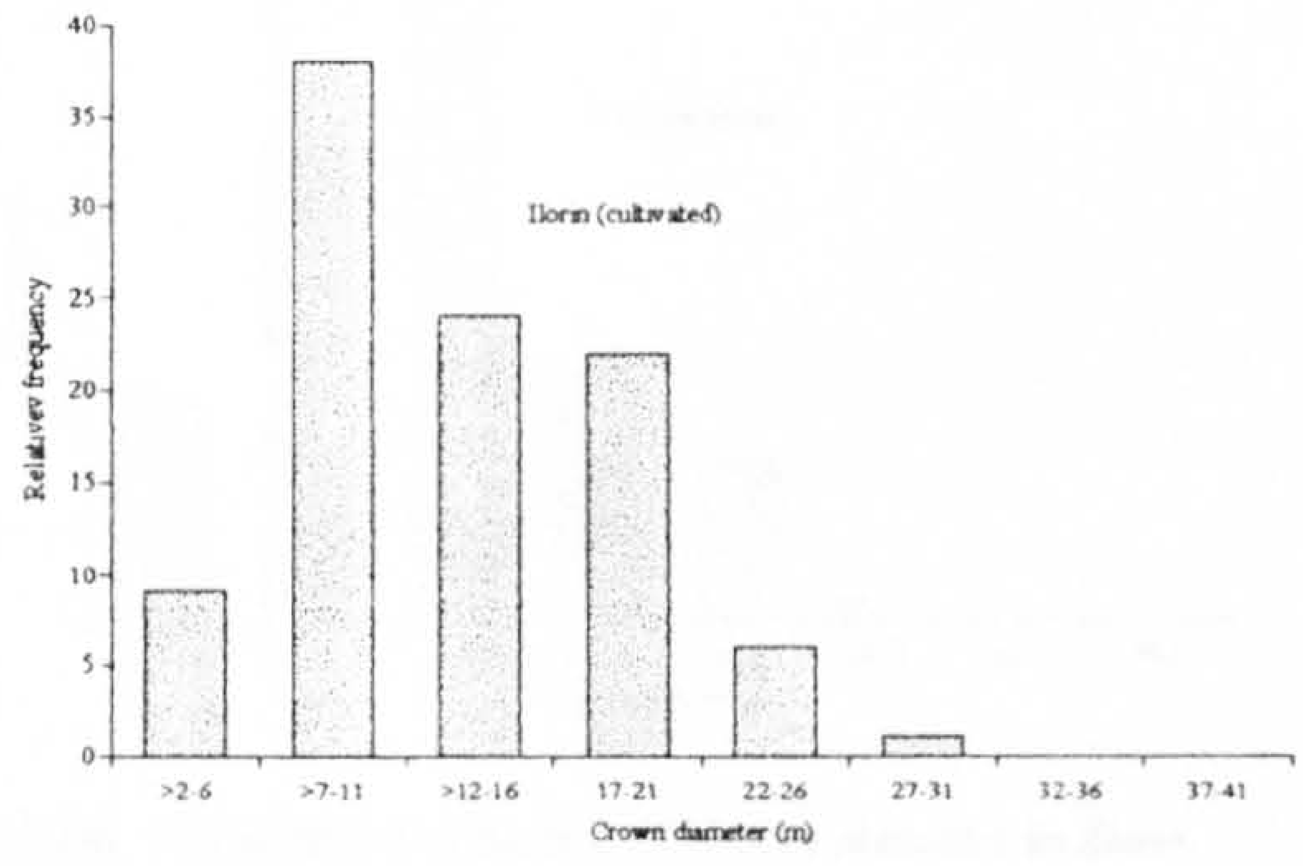


Figure 4.7d Frequency distribution of crown diameter in Jos

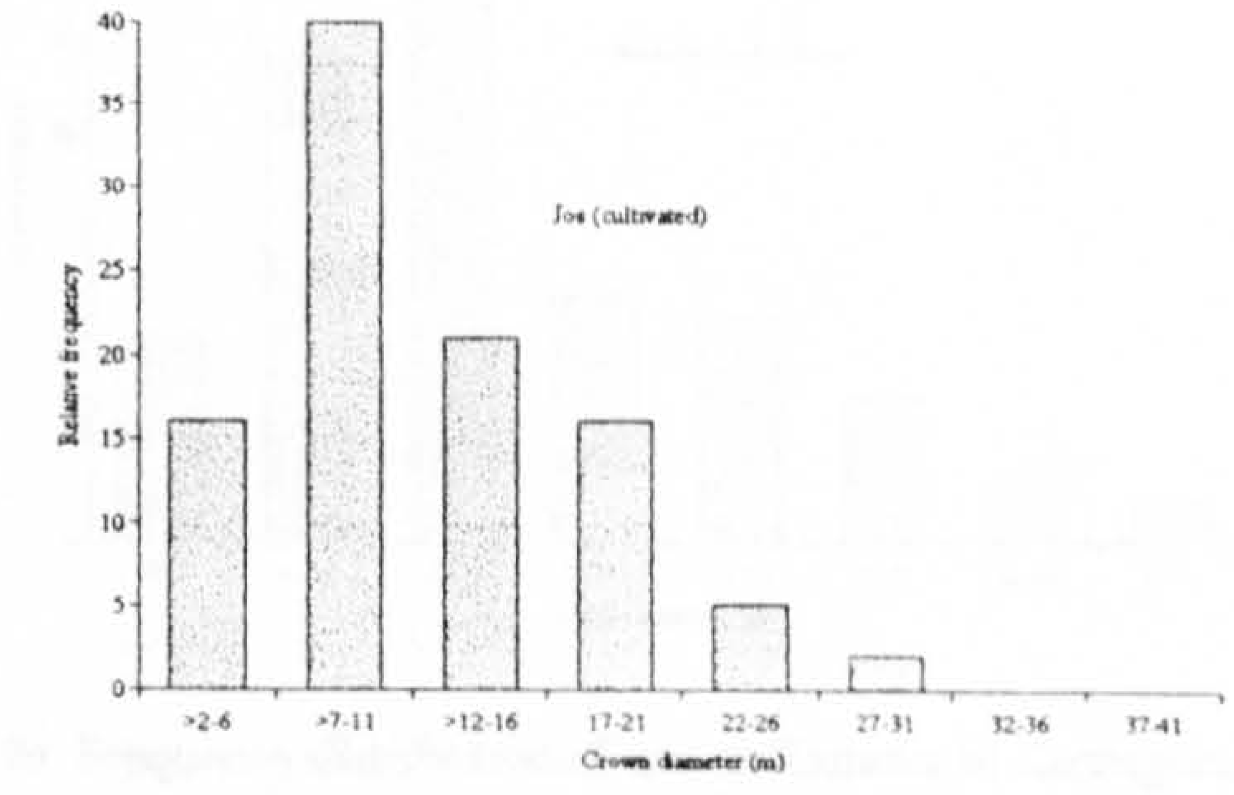


Figure 4.7e Frequency distribution of crown diameter in Kaduna

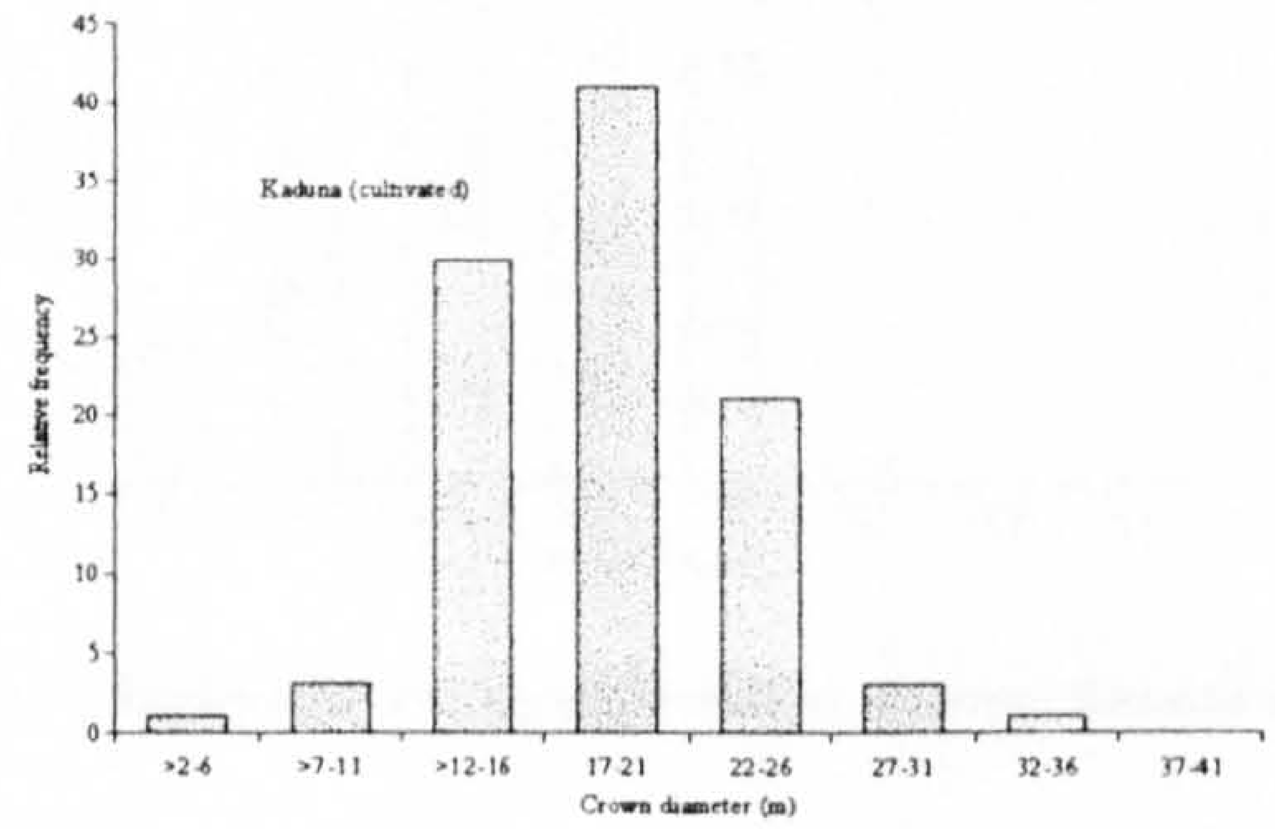


Figure 4.7f Frequency distribution of crown diameter in Kontagora II

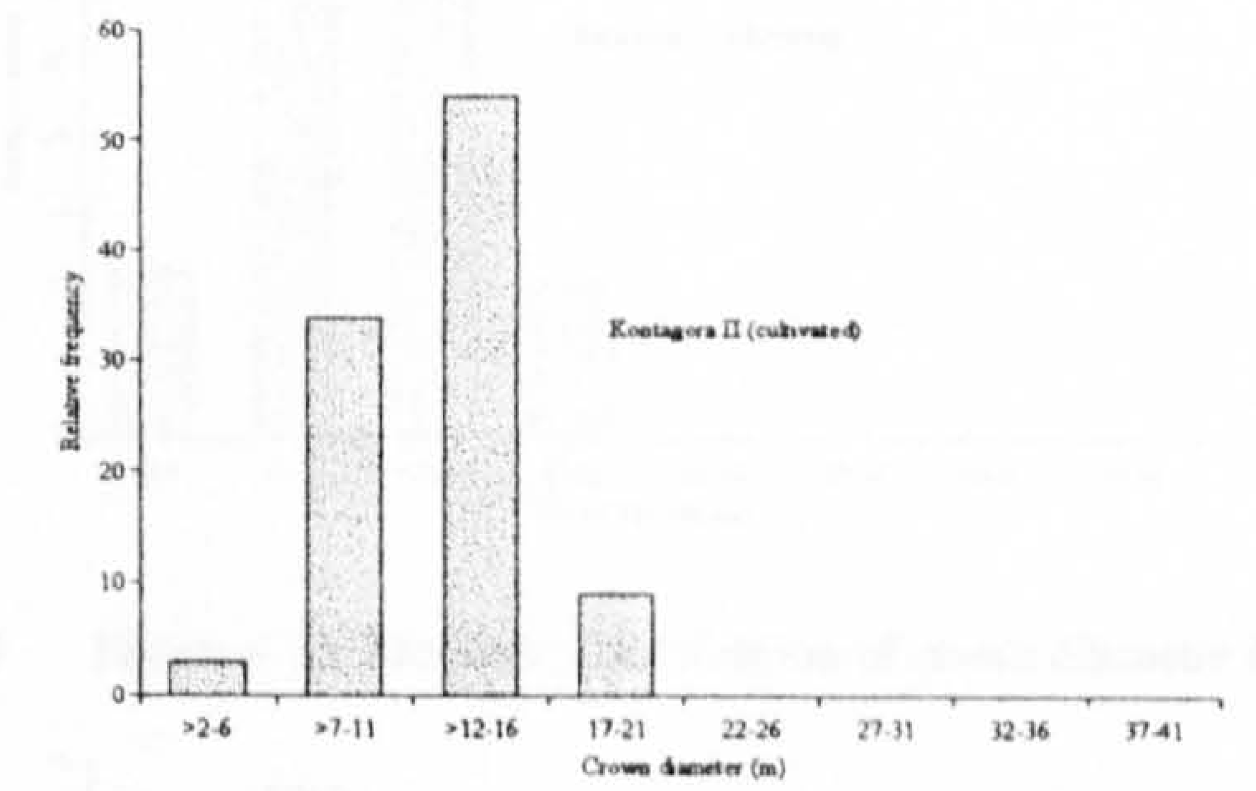


Figure 4.7g Frequency distribution of crown diameter in Kano I

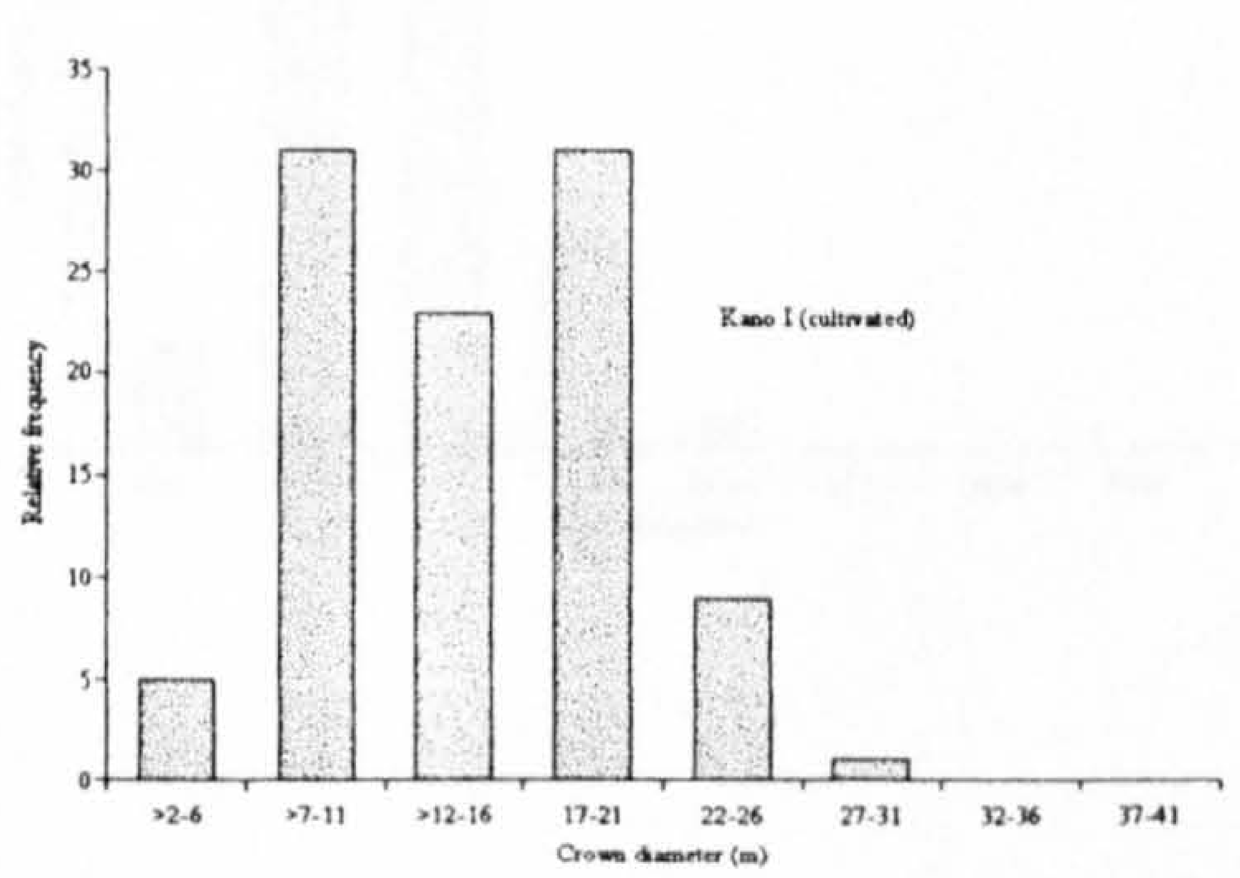
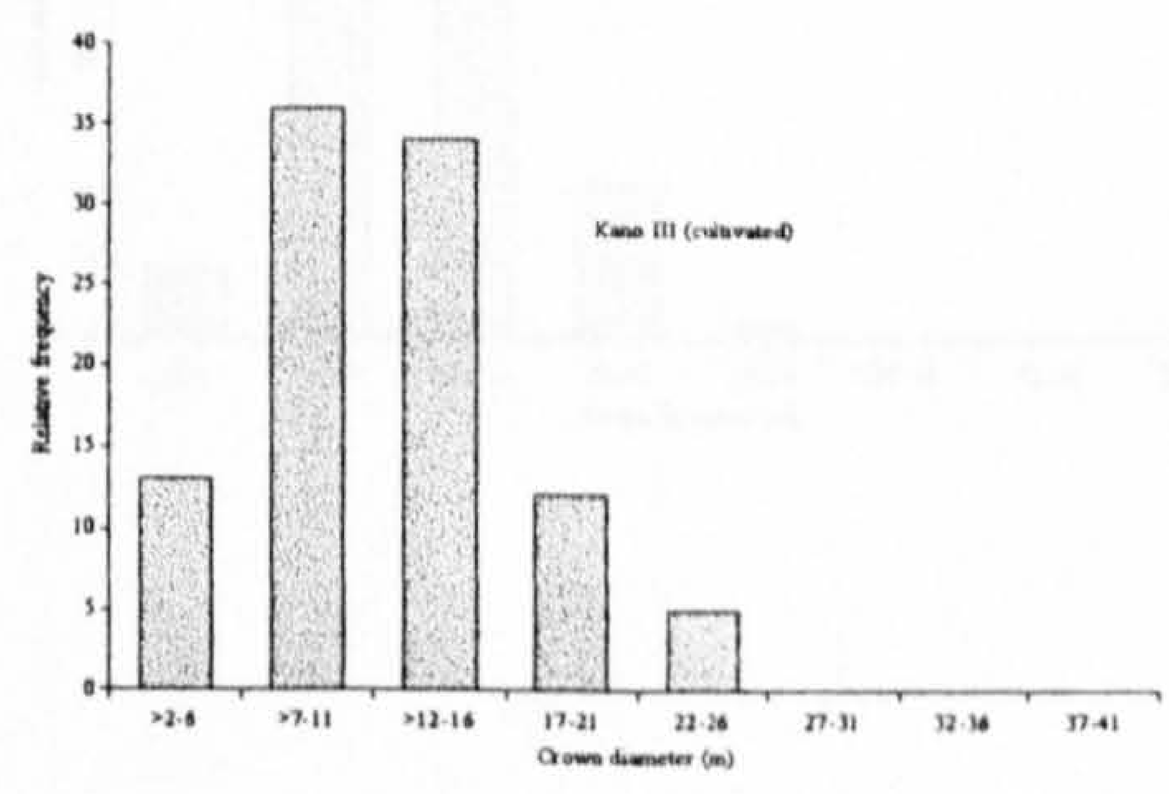


Figure 4.7h Frequency distribution of crown diameter Kano III



Crown diameter (bush fallow)

Figure 4.7i Frequency distribution of crown diameter Olokemeji

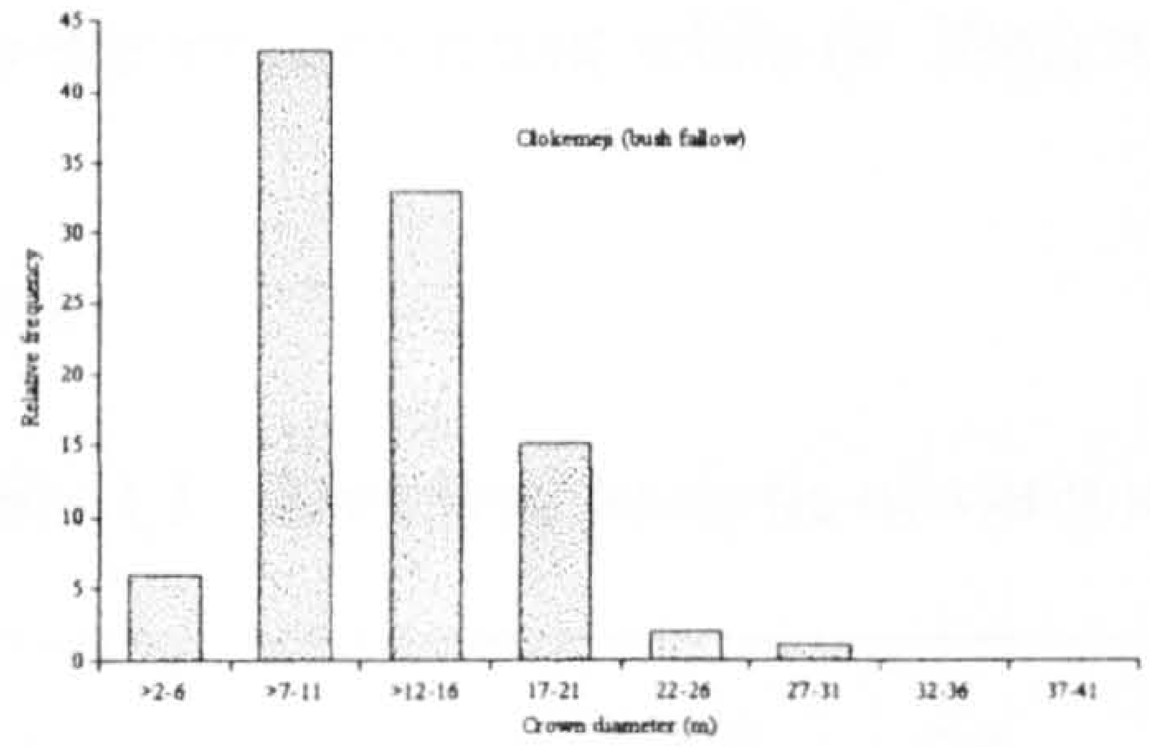


Figure 4.7j Frequency distribution of crown diameter in Enugu

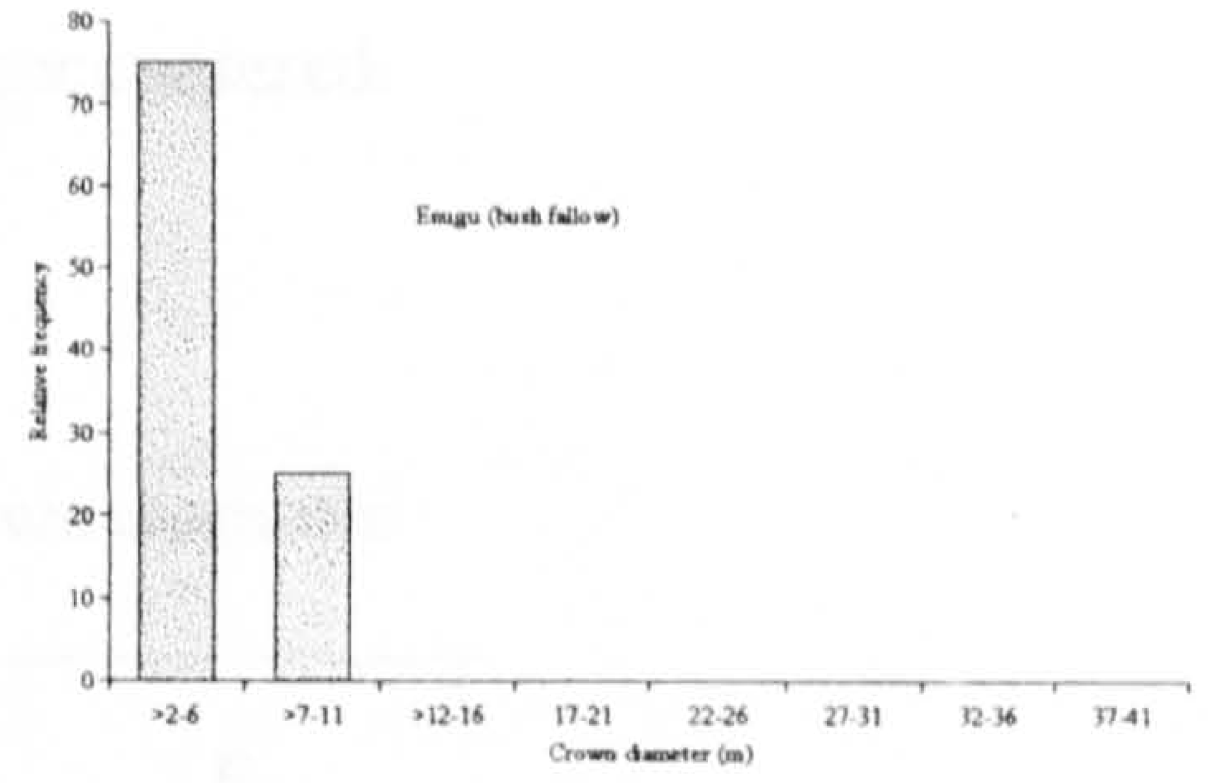


Figure 4.7k Frequency distribution of crown diameter in Saki

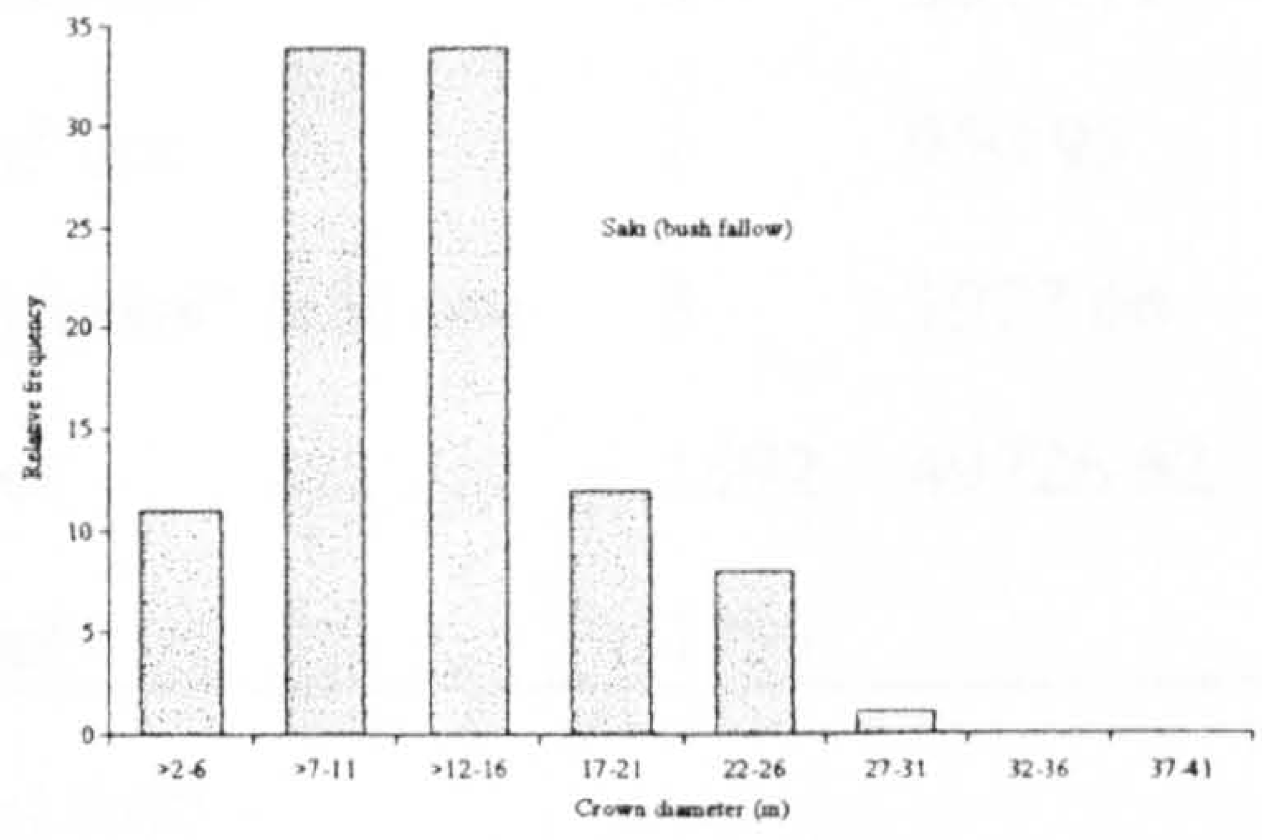


Figure 4.7l Frequency distribution of crown diameter Makurdi

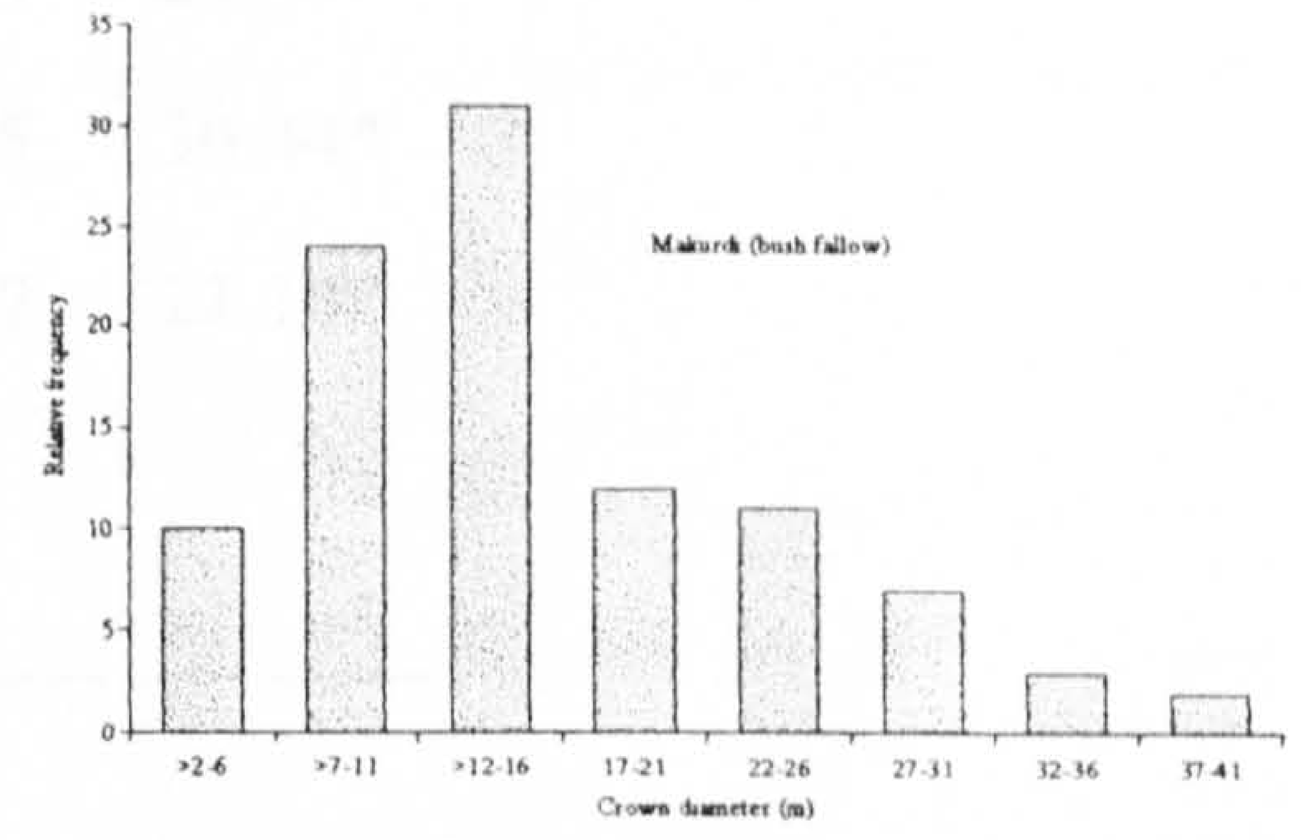


Figure 4.7m Frequency distribution of crown diameter in Zaria

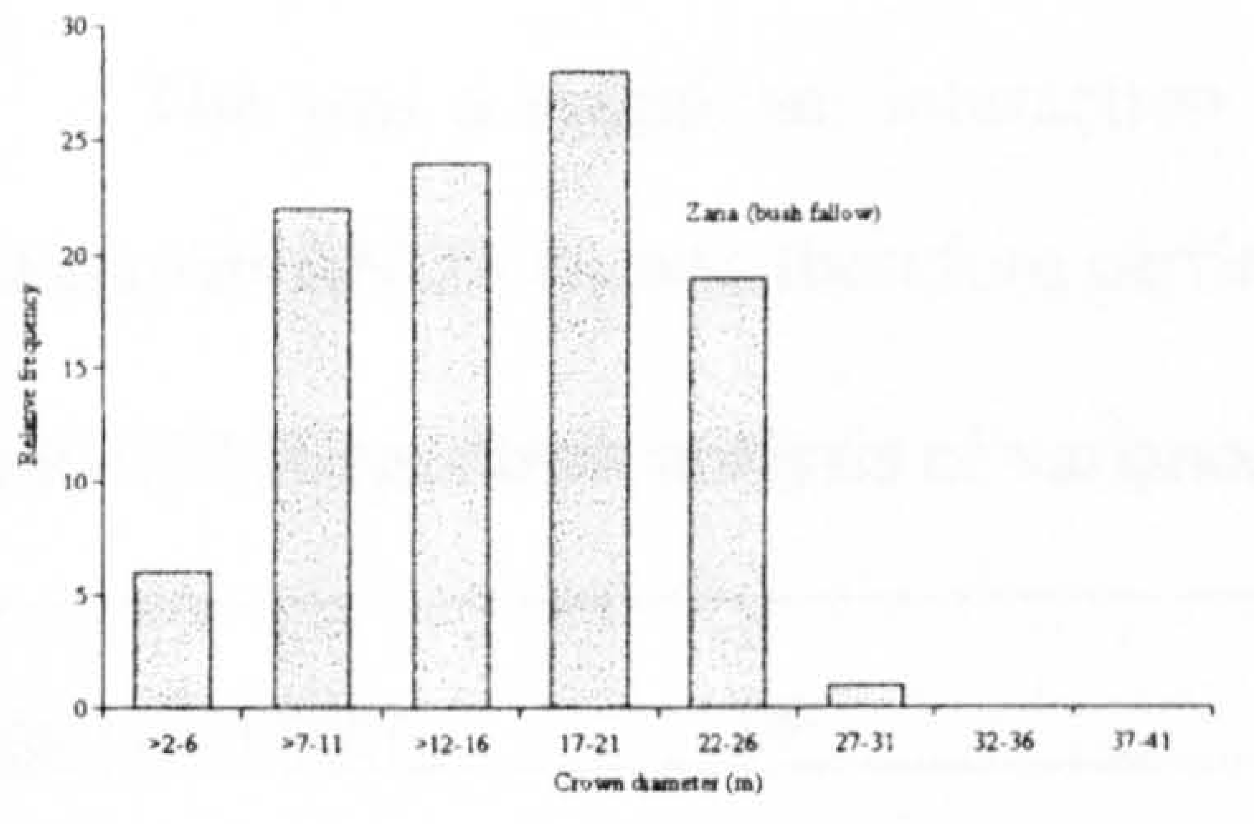


Figure 4.7n Frequency distribution of crown diameter in Kontagora I

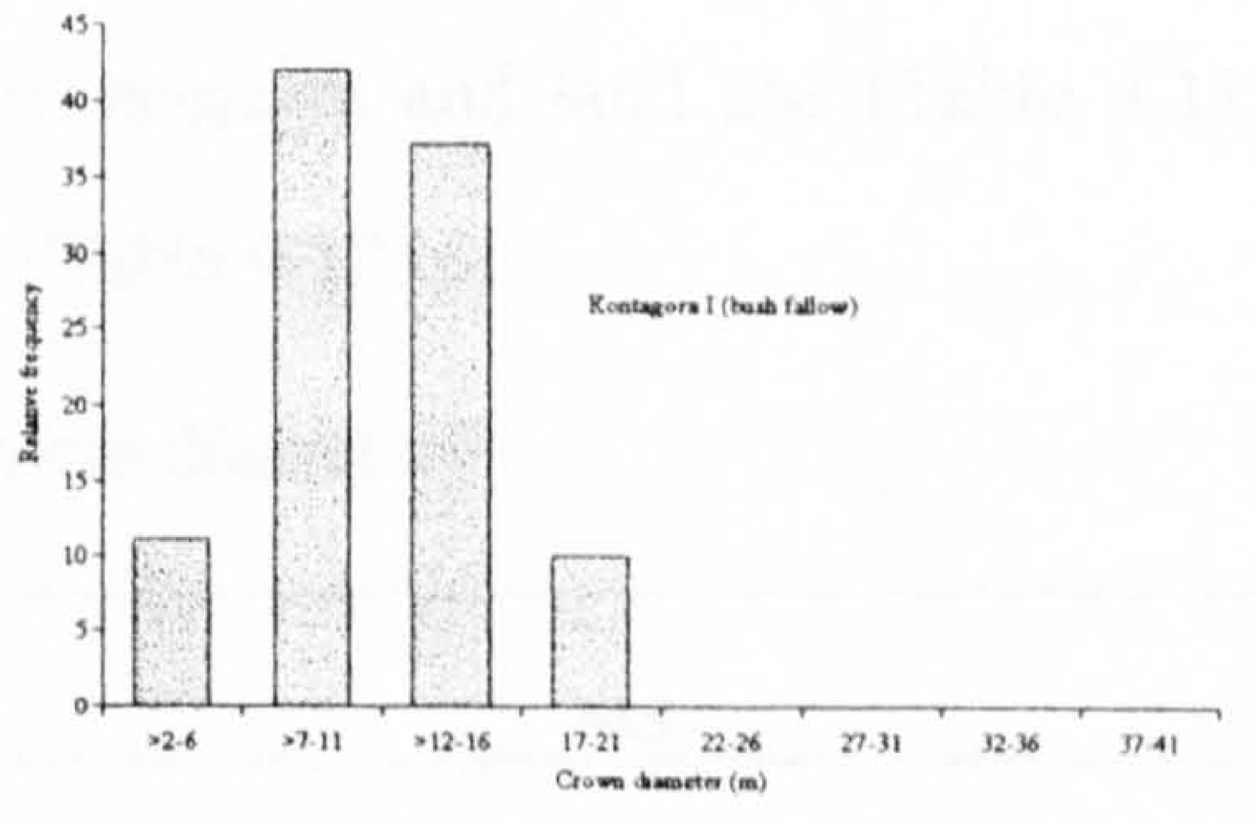


Figure 4.7o Frequency distribution of crown diameter in Kano II

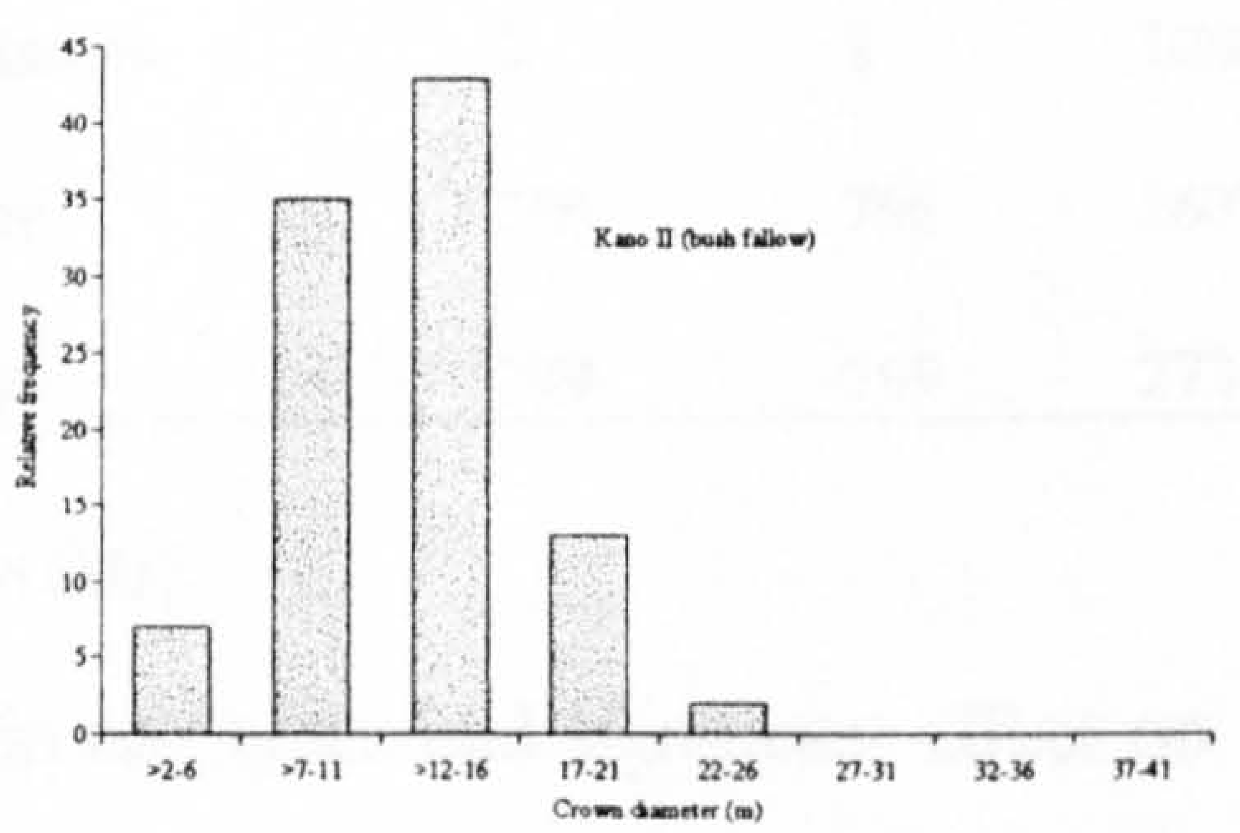
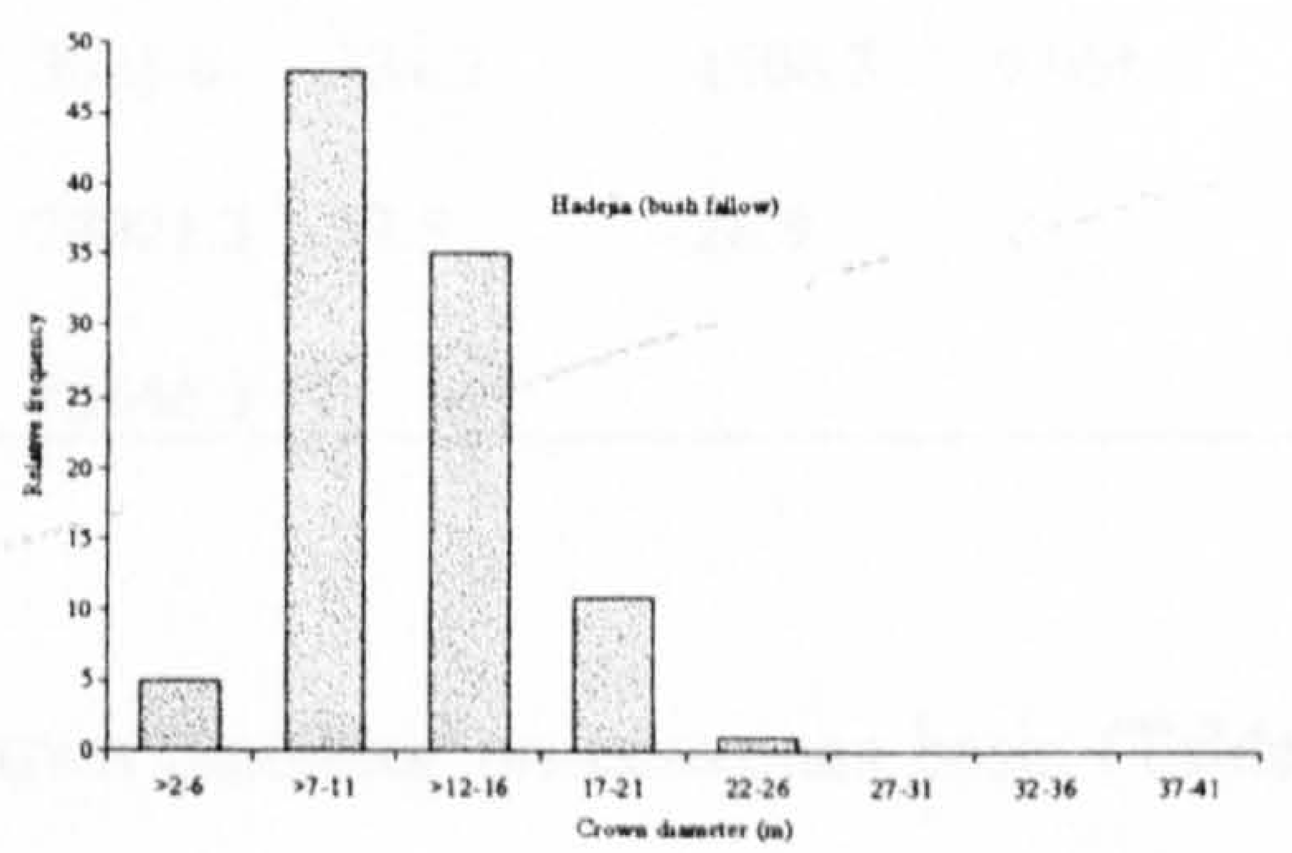


Figure 4.7p Frequency distribution of crown diameter Hadejia



The distribution of individuals to crown diameter classes increased with increasing diameter class up to (17-21 m) crown diameter. The (7-11 m) diameter class was the most frequent while (> 30m) were less encountered.

Anova

Table 4.11 Two way analysis of variance on crown diameter

Source	DF	SS	MS	F
Ecozones	3	2649.11	883.04	28.27*
Land use	1	950.95	950.95	30.44*
Ecozones* land use	3	1977.66	659.22	21.10*
Error	1592	49726.62	31.24	
Total	1599			

*P < 0.05

The was a significant interaction between ecozone and land use (Table 4.11). Breakdown ANOVAs was therefore carried out. (Table 4.12)

Table 4.12 Breakdown analysis of variance on crown diameter

Source of variation	DF		SS		MS		F	
Treatment	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow
Ecozones	3	3	1002.6	3625.0	334.2	1208.3	9.96*	41.78*
Error	796	796	26702.9	23021.3	33.5	28.9		
Total	799	799	27705	26646.3				

*P <0.05

Land use types had significant effect on tree crown diameter on ecozones basis (Table 4.12).

Table 4.13. Ecozones comparisons between the two land use types for crown diameter

Ecozones types	Guinea-Congolian centre	Guineo-Congolian Sudanian transition	Sudanian centre-south	Sudanian centre-north
Cultivated	13.32[a]	12.63[a]	15.58[bc]	13.30[a]
Bush fallow	8.73[a]	14.26[b]	13.55[b]	12.13[bcd]

Values within the same row for land use type with the same following letter do not differ significantly (P <0.05).

Breakdown analysis of variance indicated significant interaction between crown diameter and bush fallow land use in the extreme south, transition zone and to the north of the range. However intensive cultivation had significant effect mainly in the transition zone (Table 4.13)

4.1.1.5 Branching height

Mean branching height in *Parkia* ranged from 1.70 ± 0.072 m in Jos, transition zone to 3.88 ± 0.21 m in Nsukka, Ecozone I of the (Guinea-Congolian centre). The branching height is generally higher in the southern part of the range (Guinea-Congolian centre), moderate in the north (Ecozone III) of the (Sudanian centre), but relatively lower in the transition zone, Ecozone II of the (Guineo-Congolian/Sudanian transition). The branching height between the two land use types indicated a slightly higher height in the cultivated (2.37 ± 0.04 m) compared with the bush fallow (2.33 ± 0.43) (Figure 4.8).

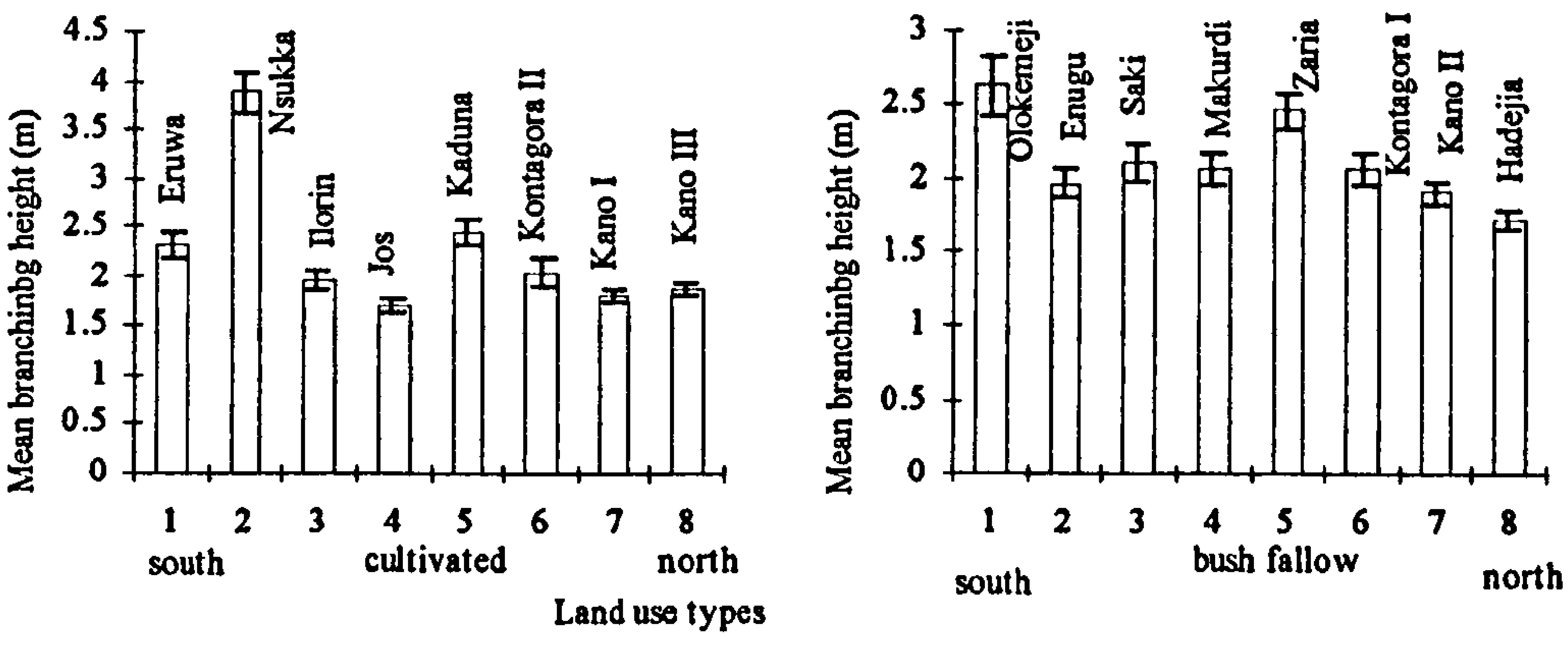


Figure 4.8 ***Parkia biglobosa***: mean (±se) branching height for Nigerian sample stands on cultivated land and in bush fallow.

Branching height (Cultivated)

Figure 4.9a Frequency distribution of branching height in Eruwa

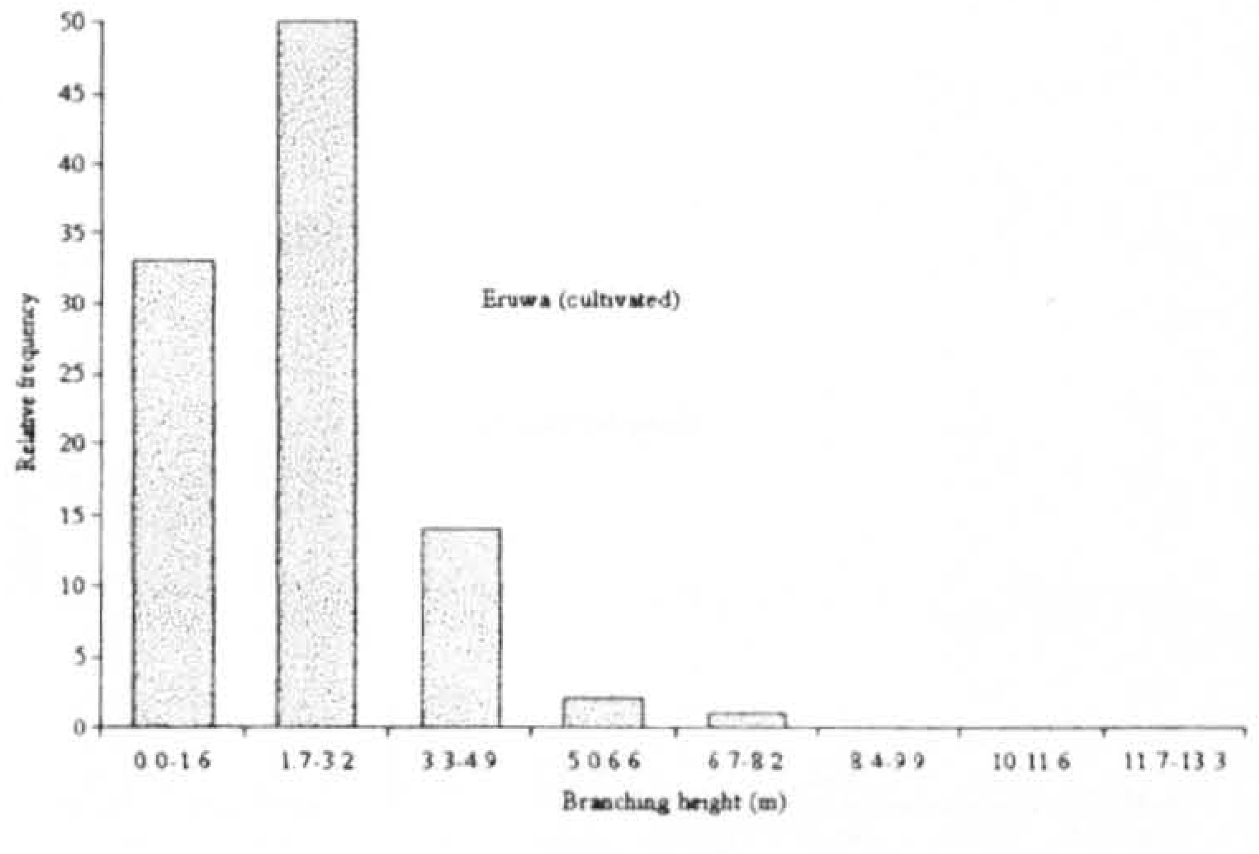


Figure 4.9b Frequency distribution of branching height in Nsukka

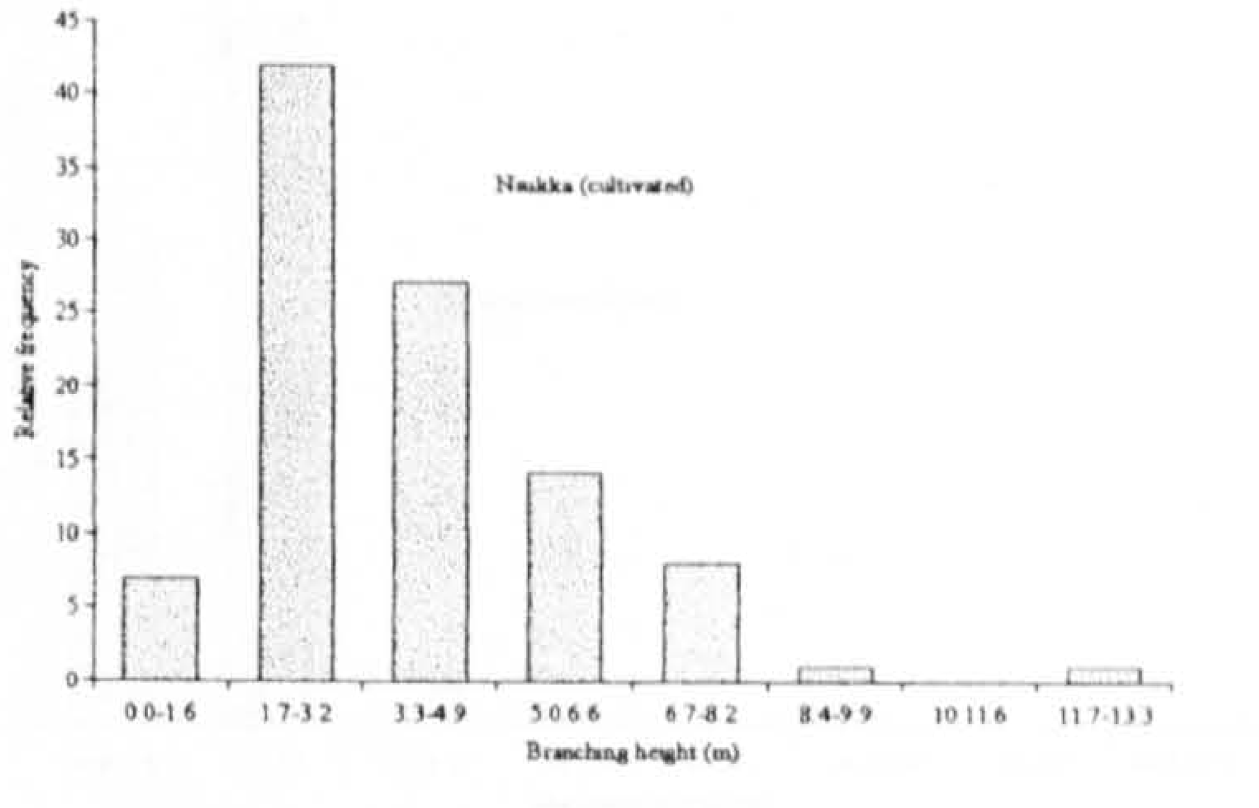


Figure 4.9c Frequency distribution of branching height in Ilorin

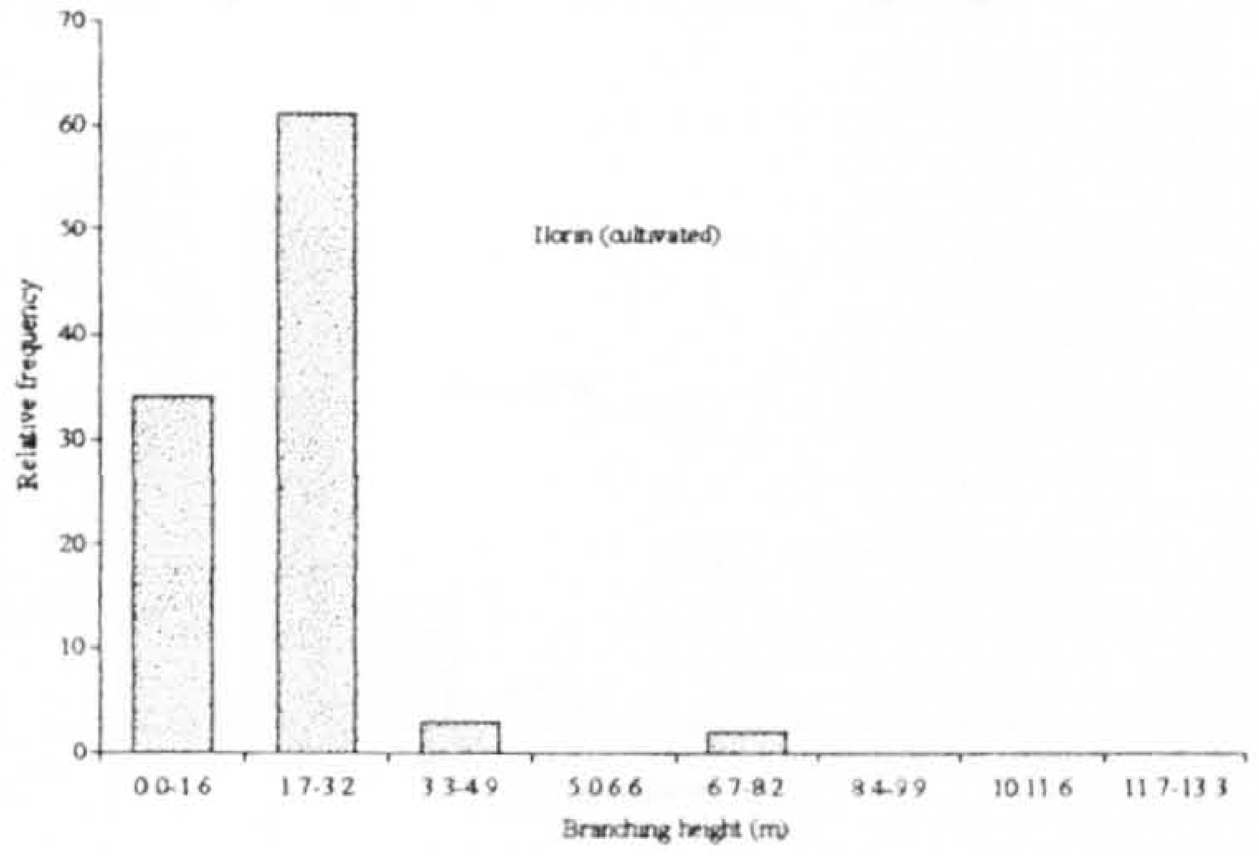


Figure 4.9d Frequency distribution of branching height in Jos

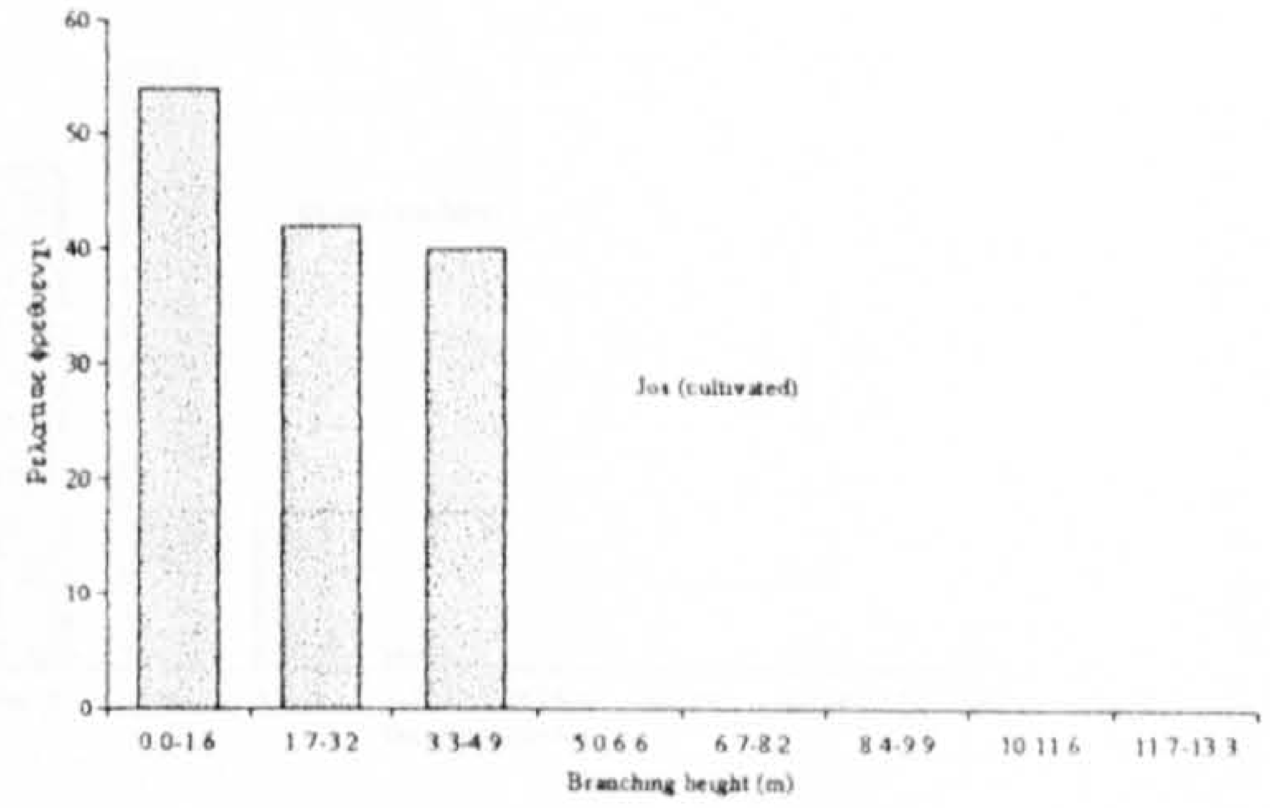


Figure 4.9e Frequency distribution of branching height in Kaduna

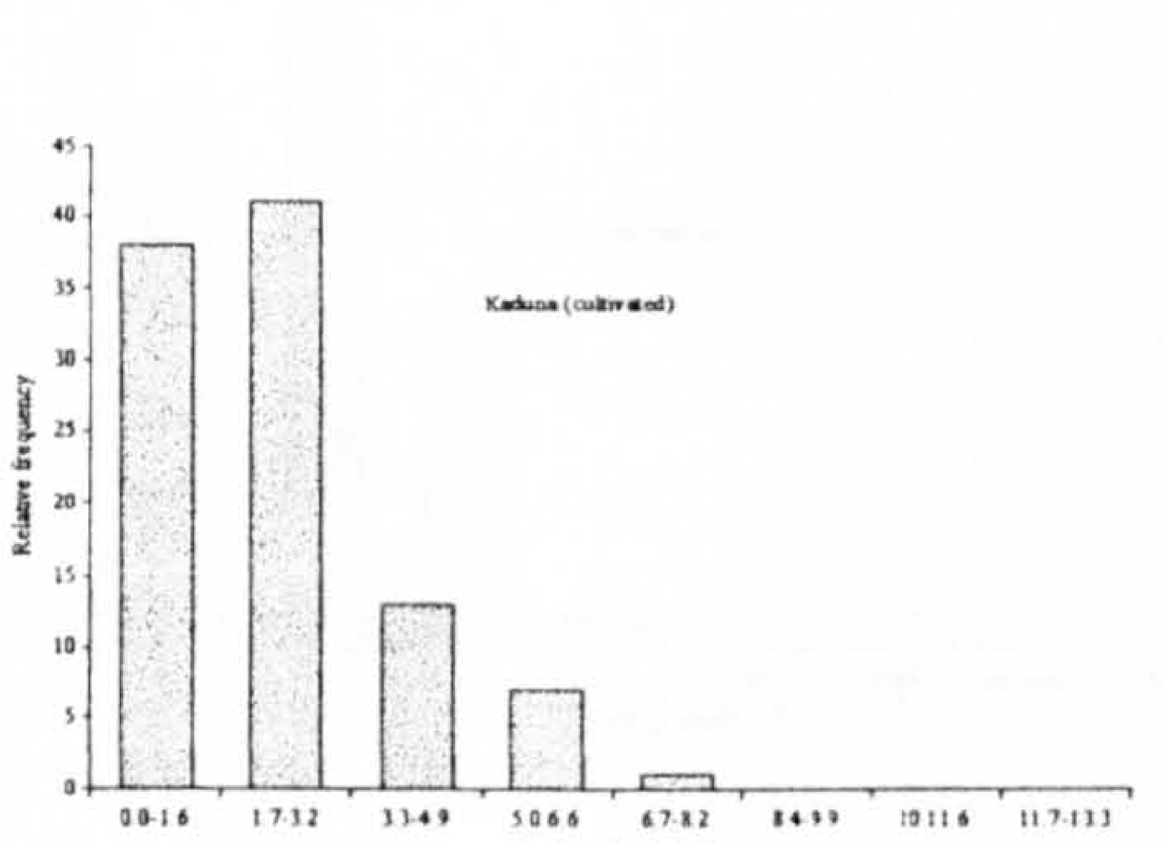


Figure 4.9f Frequency distribution of branching height in Kontagora II

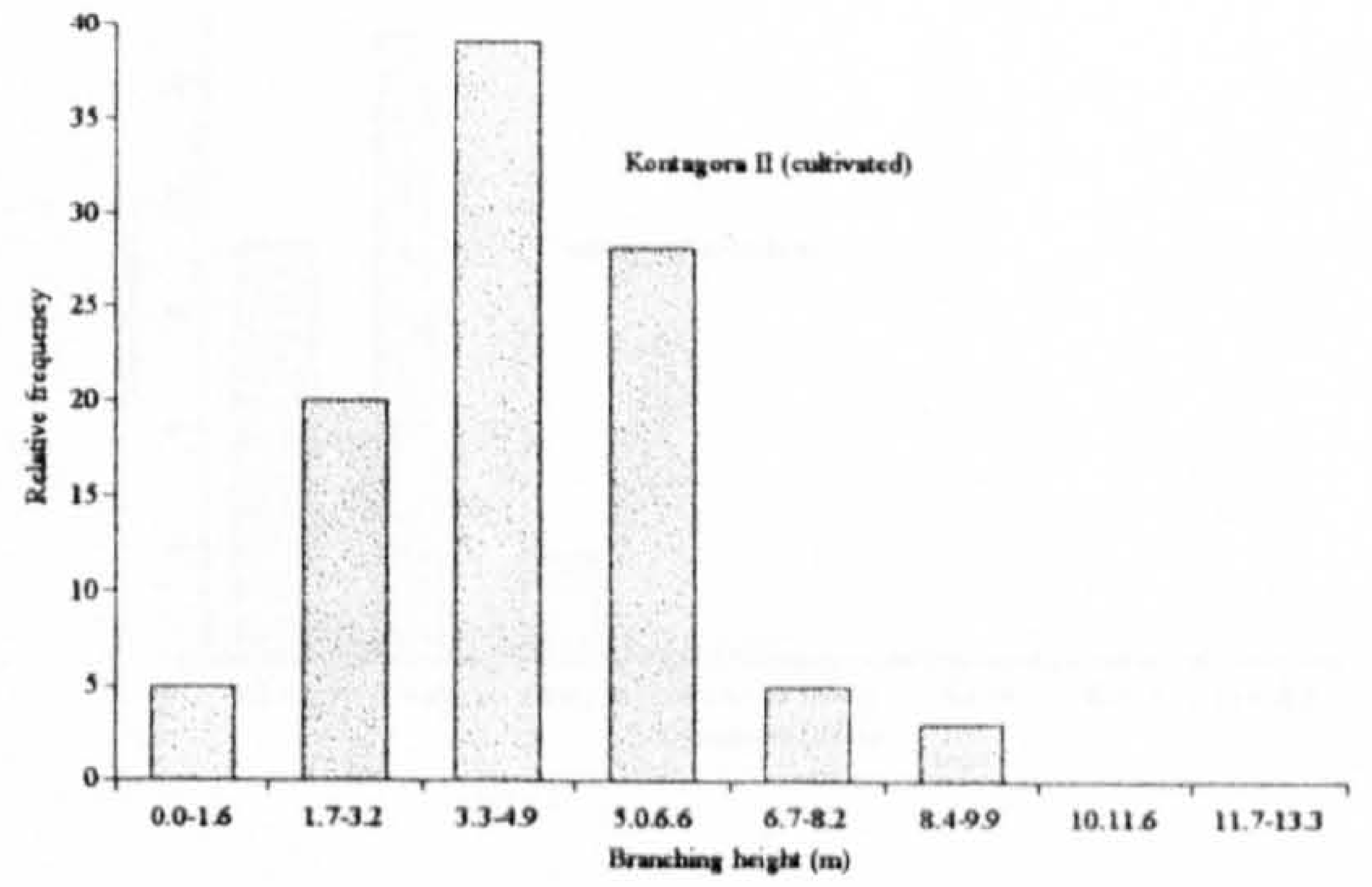


Figure 4.9g Frequency distribution of branching height in Kano I

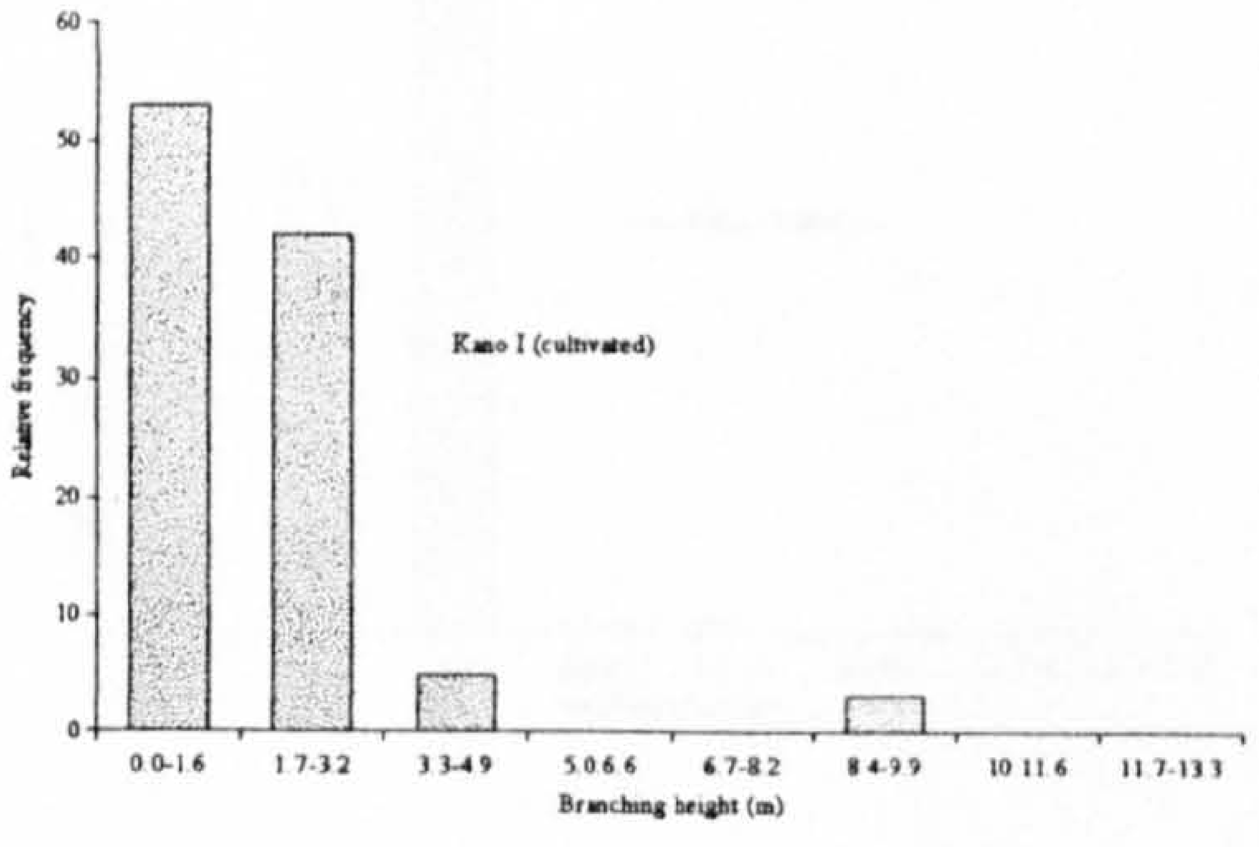
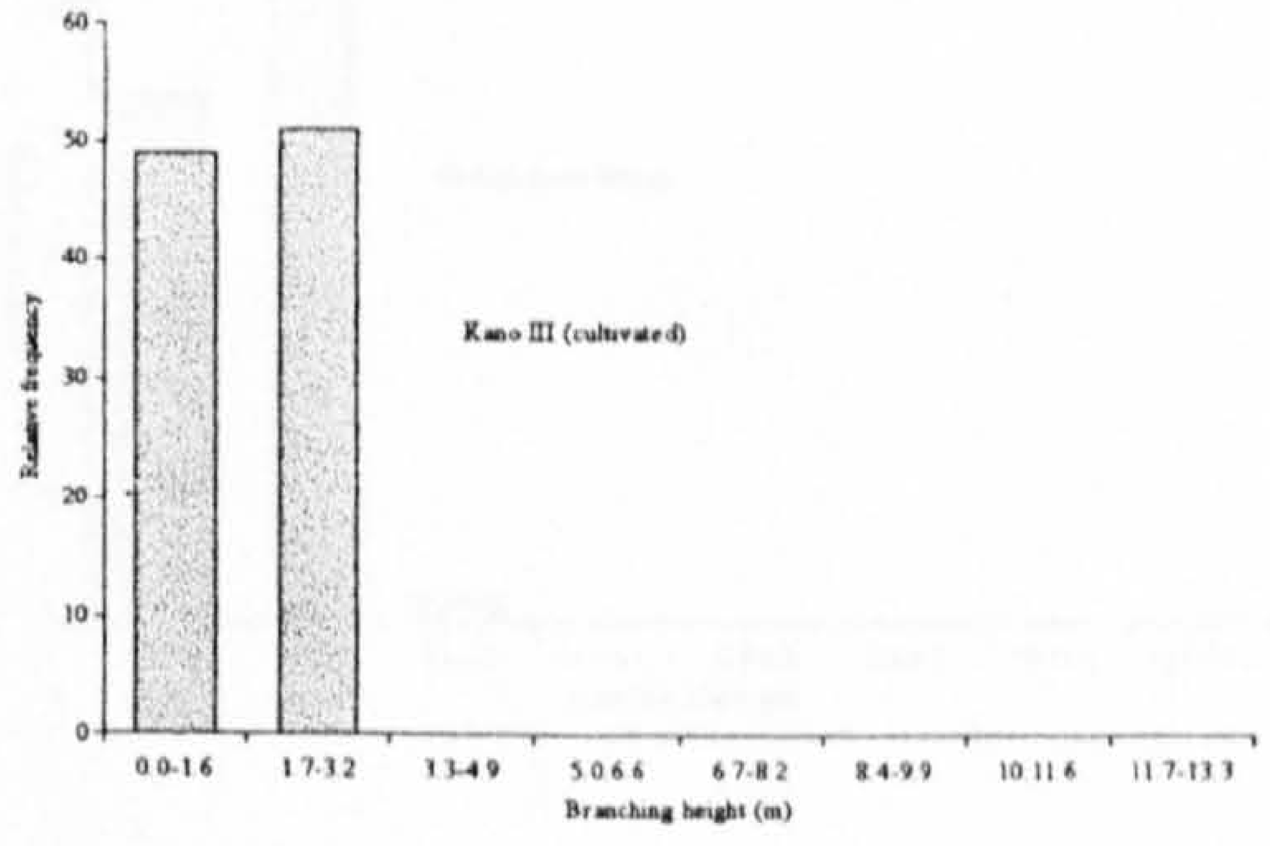


Figure 4.9h Frequency distribution of branching height in Kano III



Branching height (bush fallow)

Figure 4.9i Frequency distribution of branching height in Olokemeji

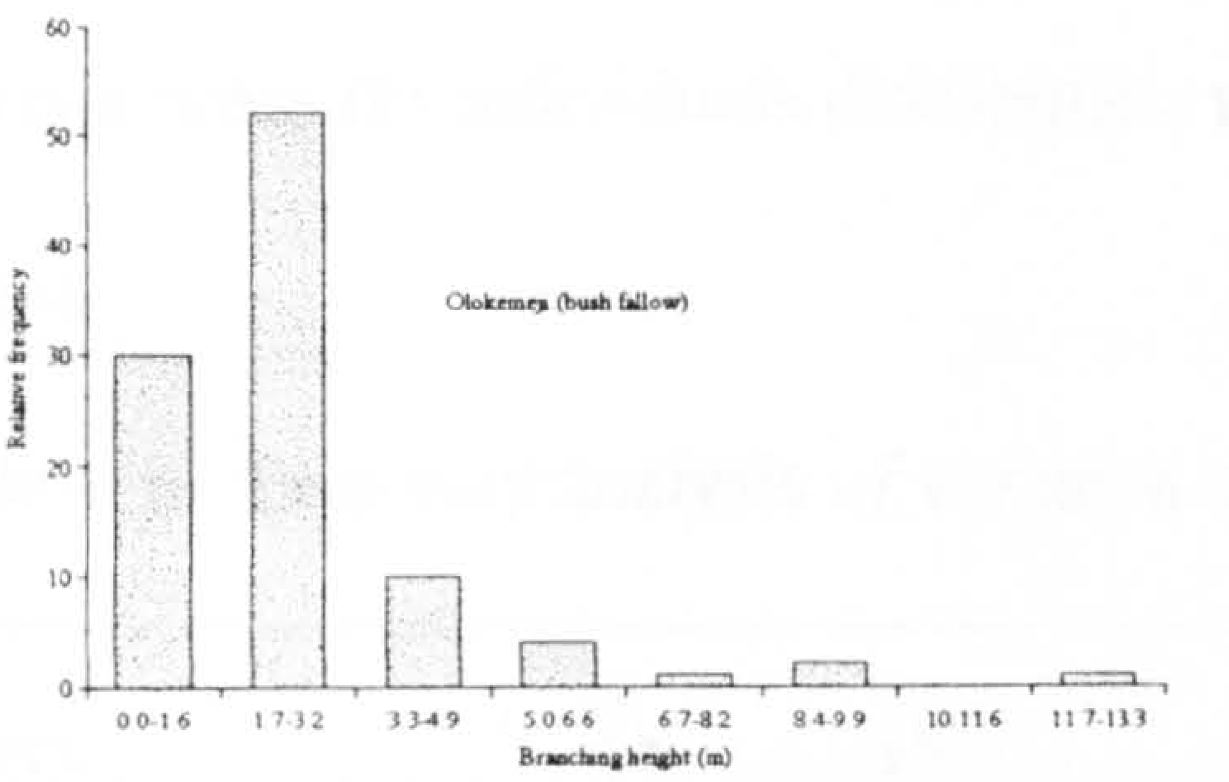


Figure 4.9j Frequency distribution of branching height Enugu

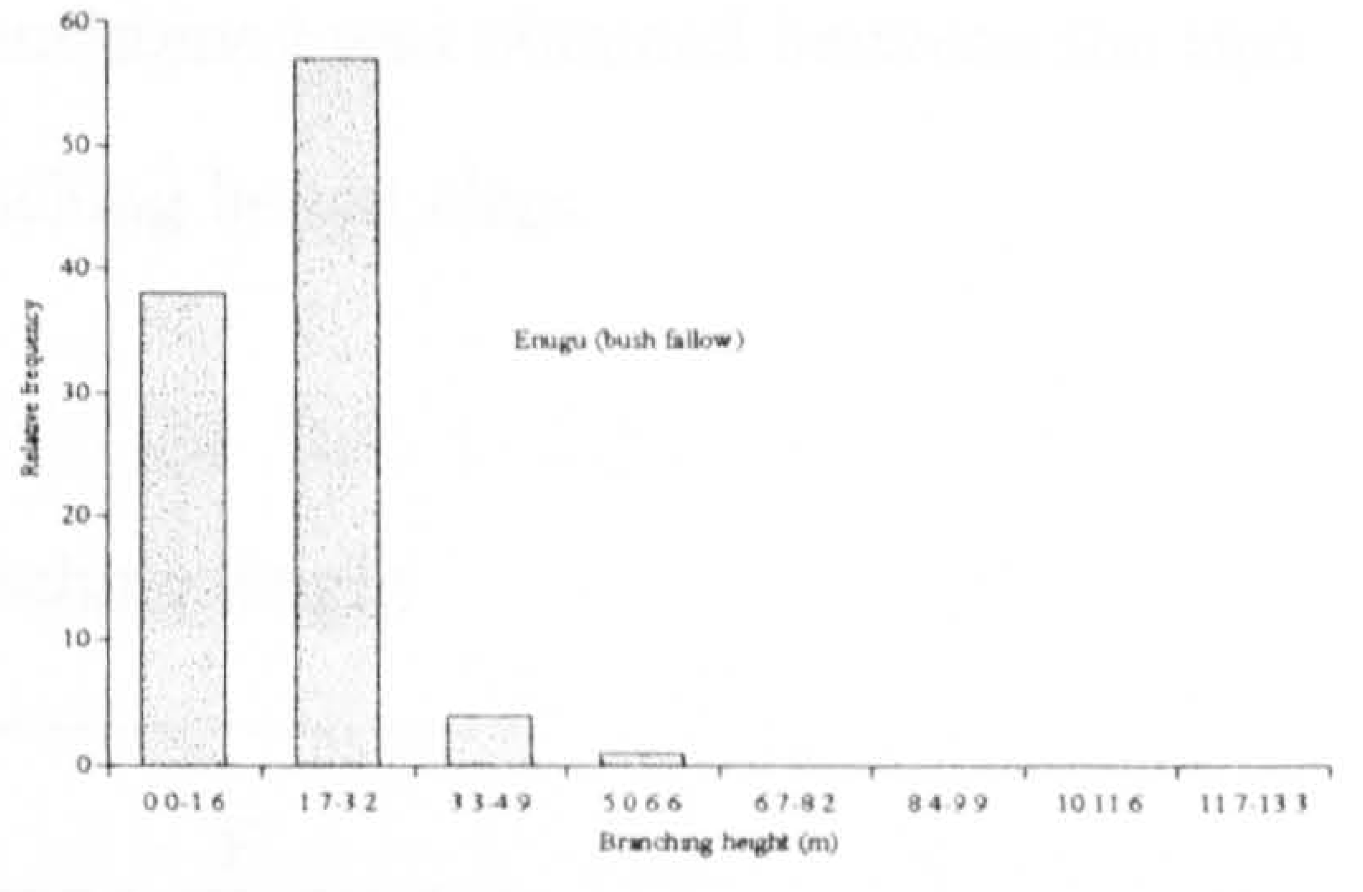


Figure 4.9k)Frequency distribution of branching height in Saki

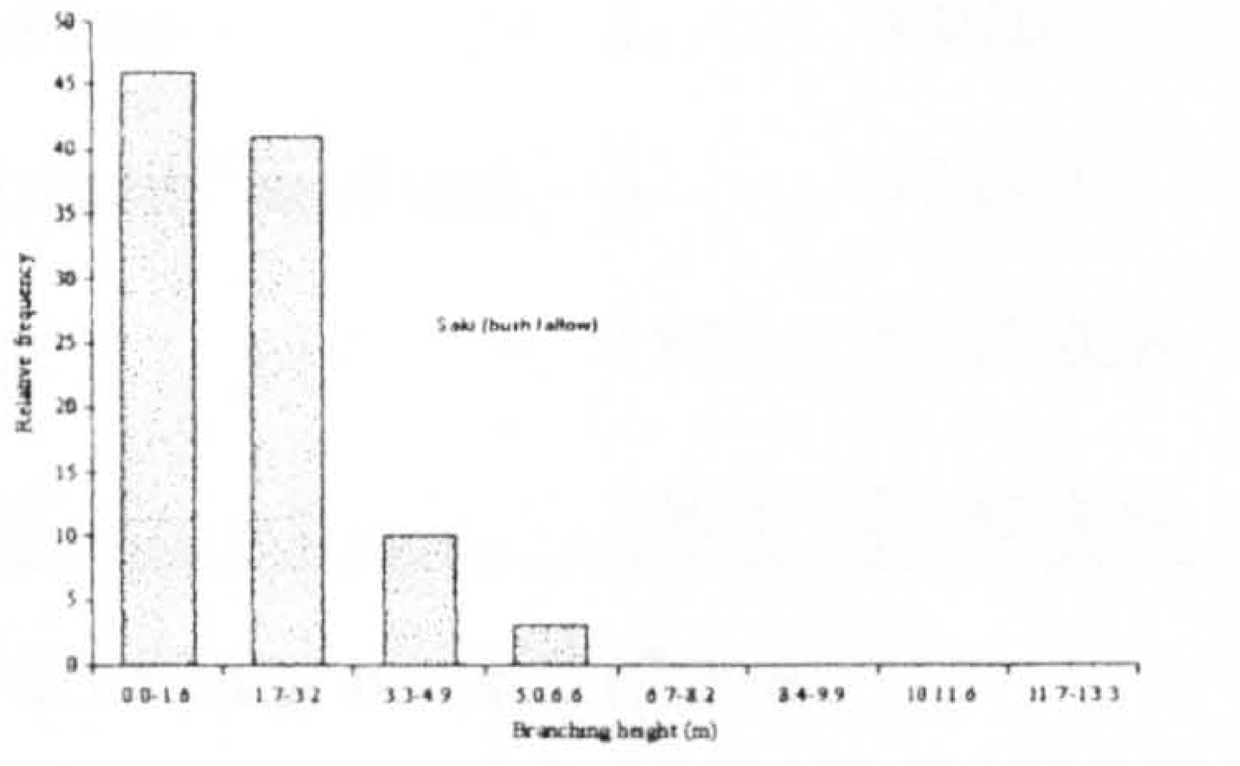


Figure 4.9l Frequency distribution of branching height in Makurdi

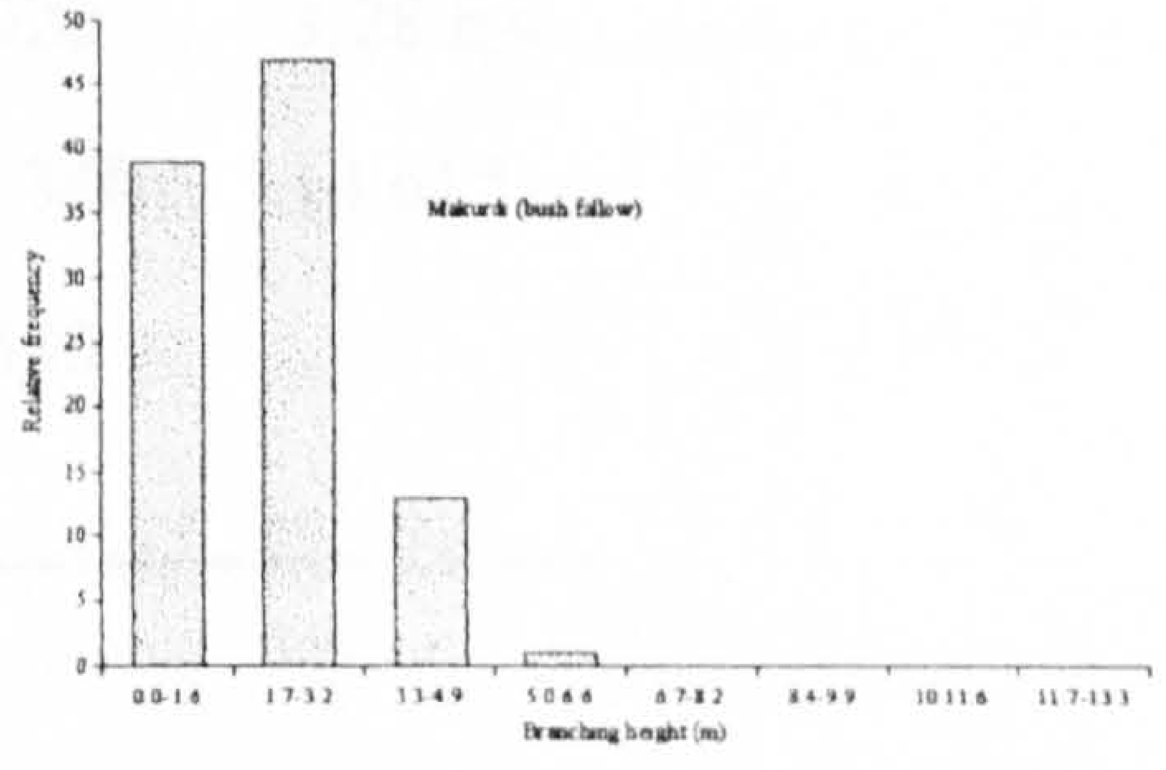


Figure 4.9m Frequency distribution of branching height in Zaria

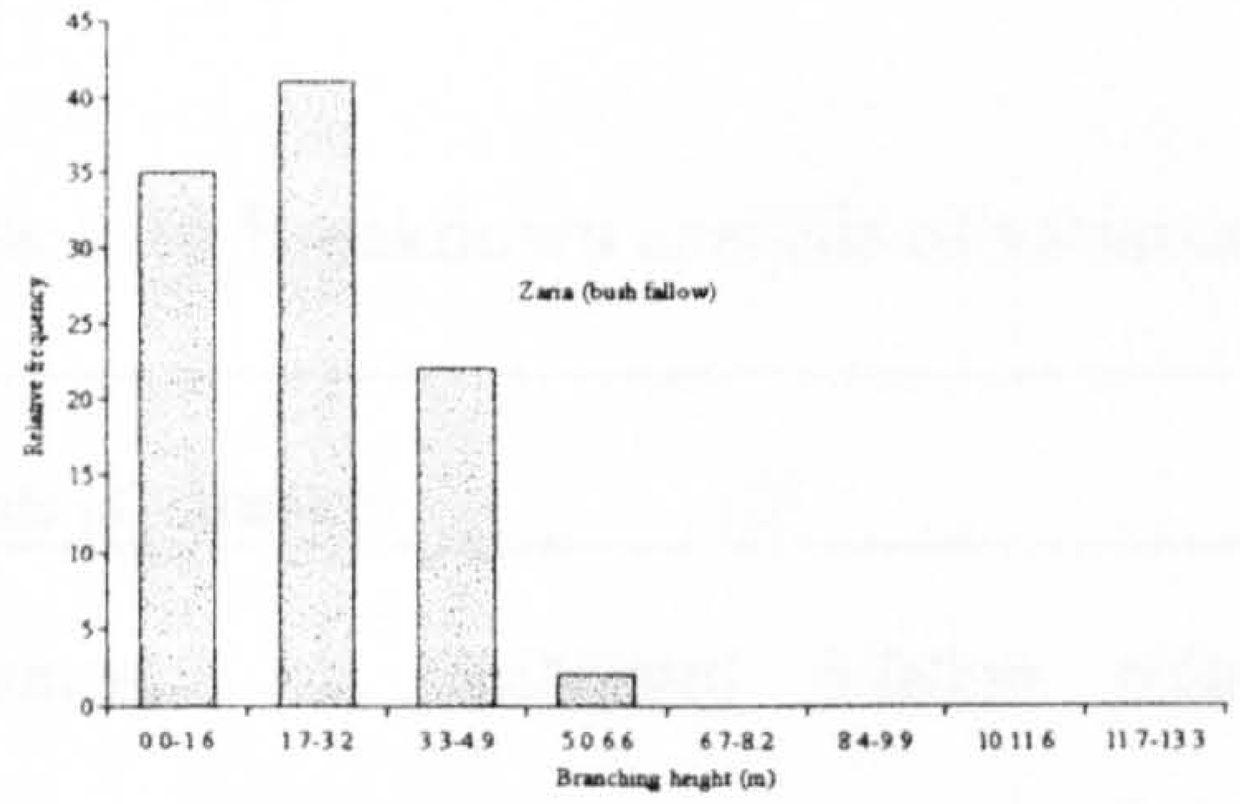


Figure 4.9n Frequency distribution of branching height in Kontagora I

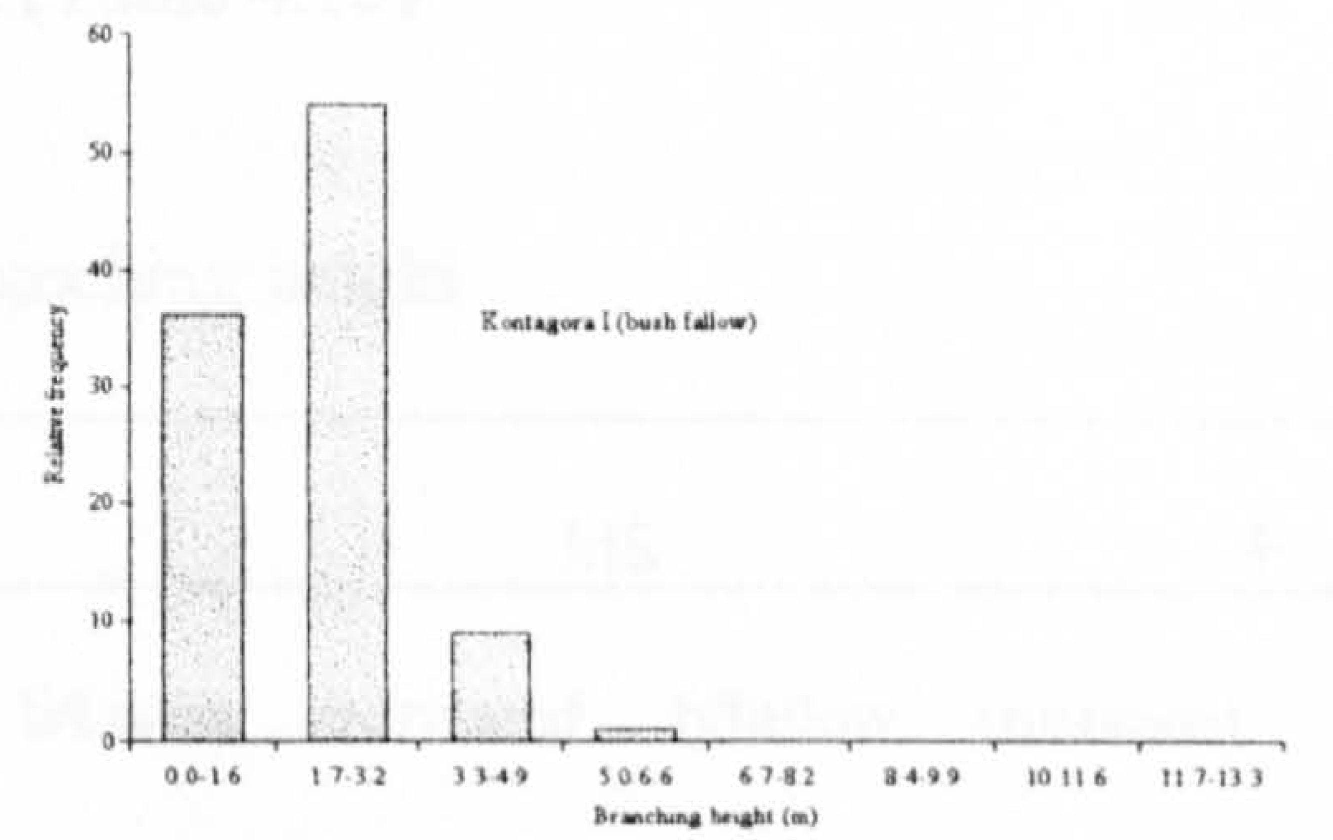


Figure 4.9o Frequency distribution of branching height in Kano II

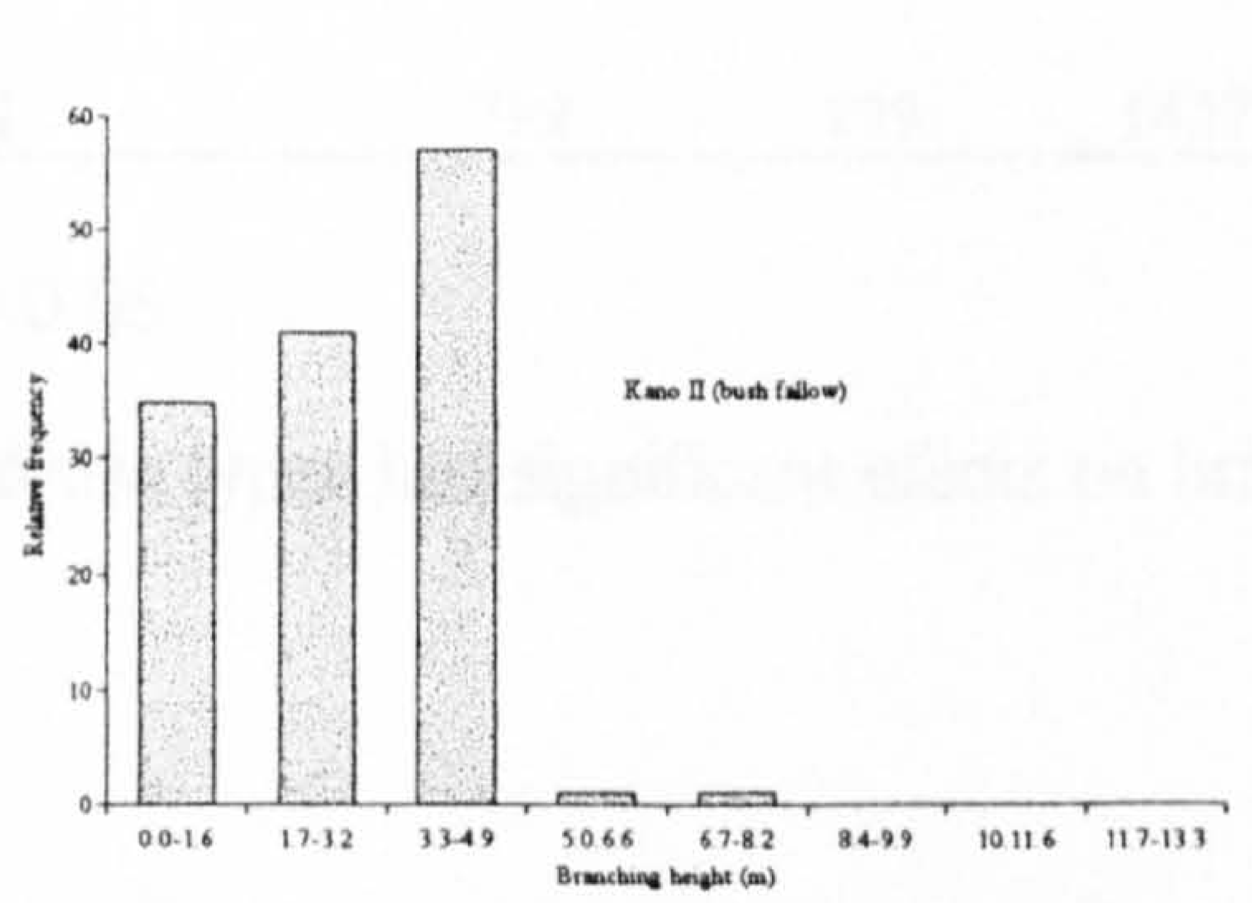
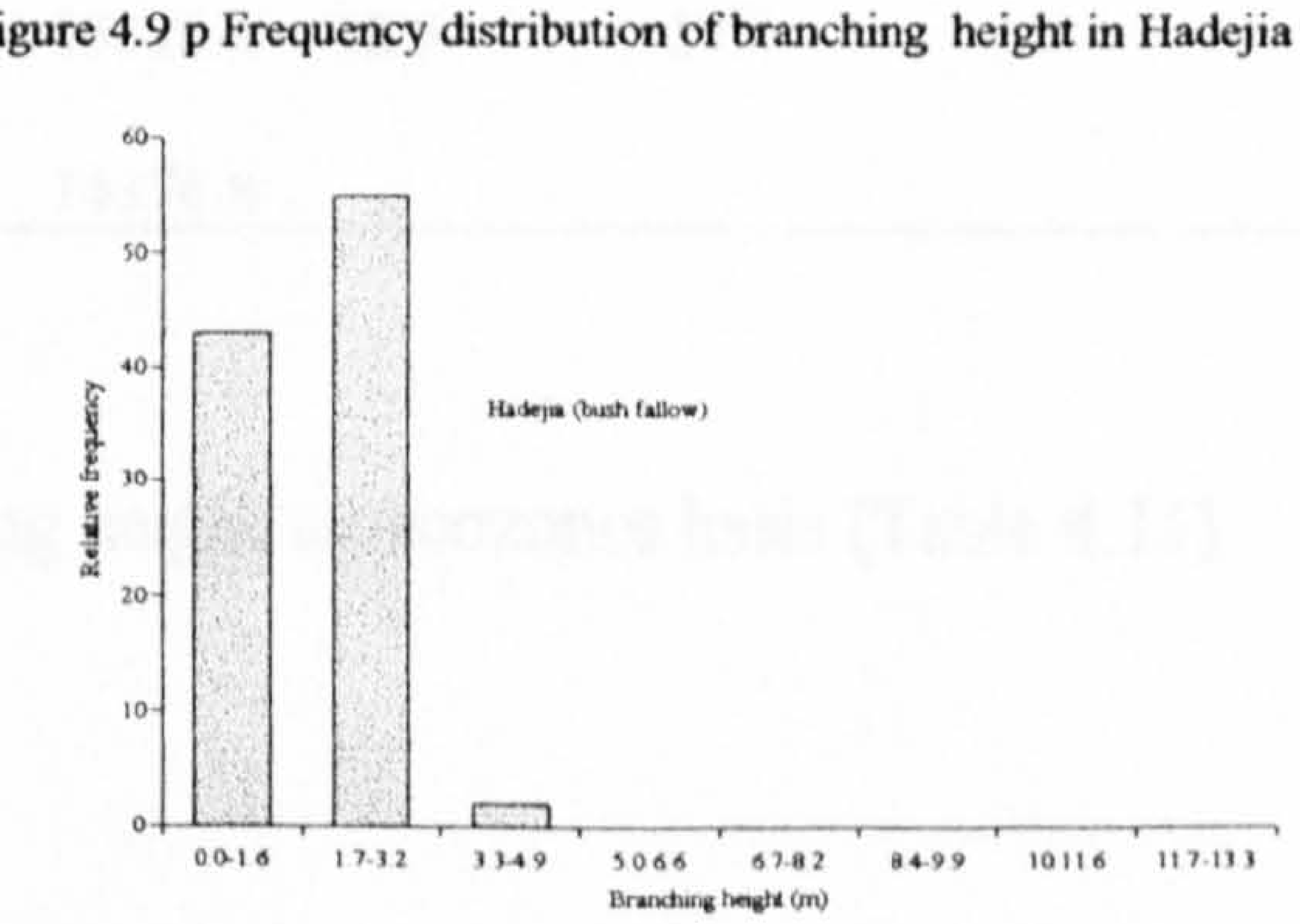


Figure 4.9 p Frequency distribution of branching height in Hadejia



The distribution of individuals to branching height class showed a decreasing number of individuals with increasing size classes, however concentration of branching height was in the (1.7-3.2 m) height class. No consistency was obtained between the two land use types for individuals distribution to branching height class.

Anova

Table 4.14 Two way analysis of variance on branching height

Source	DF	SS	MS	F
Ecozones	3	185.414	61.805	40.39*
Land use	1	5.020	5.020	3.28 n.s
Ecozones* land use	3	67.044	22.348	14.61*
Error	1592	2435.926	1.530	
Total	1599	2693.404		

*P <0.05, n.s. not significant

There was a significant interaction between ecozone and land use (Table 4.14). Breakdown ANOVAs were therefore carried out (Table 4.15)

Table 4.15 Breakdown analysis of variance on branching height

Source of variation	DF		SS		MS		F	
Treatment	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow	cultivated	b/fallow
Ecozones	3	3	4291.2	3252.4	1430.4	1084.1	114.01*	62.30*
Error	796	796	9986.79	13816.9	12.5	17.4		
Total	799	799	14277.9	14376.8				

*P <0.05

Land use types had significant efects on branching height on ecozones basis (Table 4.15)

Table 4.16 Ecozones comparisons between the two land use types for branching height

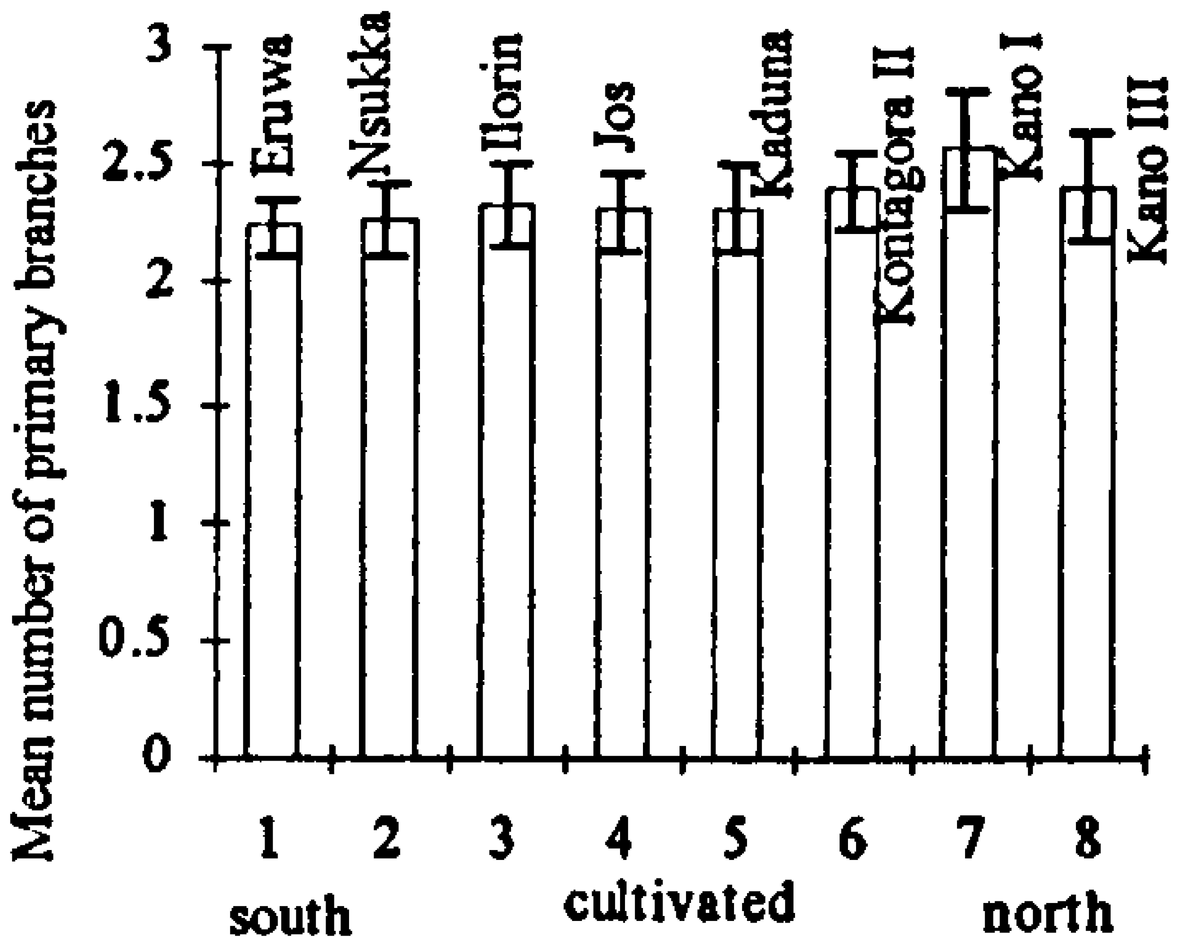
Ecozones types	Guinea-Congolian centre	Guineo-Congolian Sudanian transition	Sudanian centre-south	Sudanian centre-north
Cultivated	3.10a	1.83[b]	2..15[a]	1.83[a]
Bush fallow	2.30[a]	2.07[a]	2.16[a]	1.78[a]

Values within the same row for land use type with the same follwing letter do not differ significantly (P <0.05).

The breakdown analysis of variance indicated that the intensity of cultivation influenced height at branching in the extreme south and north of the range, but not in the transition zone. Whereas fallow land had no significant effect on branching height in all the zones except in the extreme south of the range.

4.1.1.6 Number of primary branches

Two mean number of primary branches (2.35 ± 0.03) was the most frequent in *Parkia*. It however ranged from 2.12 ± 0.02 branches the Guineo-Congolian/Sudanian transition to 2.64 ± 0.02 branches in Sudanian centre (Figure 4.10). The mean number of primary branches per tree tends to be higher in the north than in the south. but there was no diffrence between the two land use types.



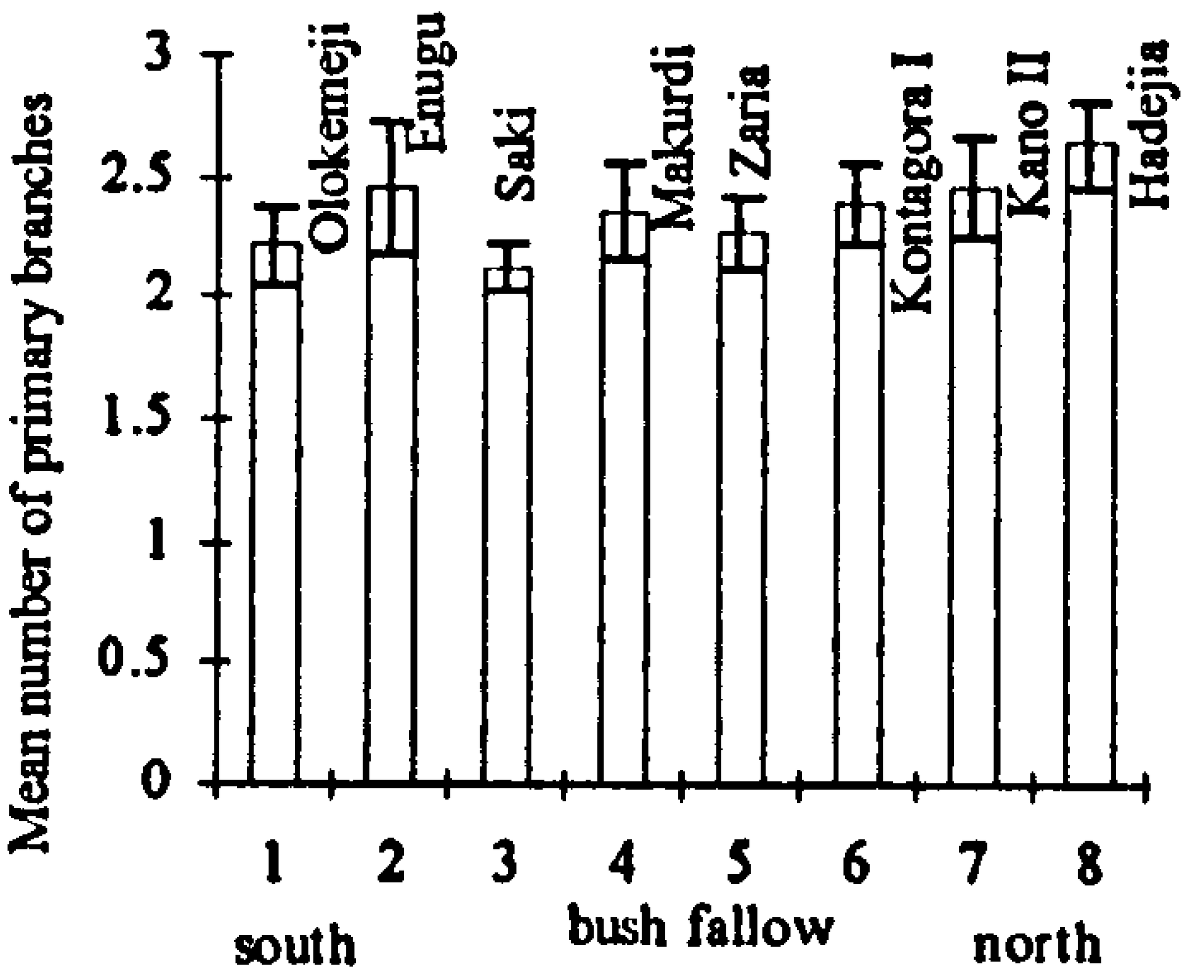


Figure 4.10 *Parkia biglobosa*: mean (±se) number of primary branches for Nigerian sample stands on cultivated land and in bush fallow.

Number of primary branches class distribution (cultivated)

Figure 4.11a Frequency distribution of number of branches in Eruwa

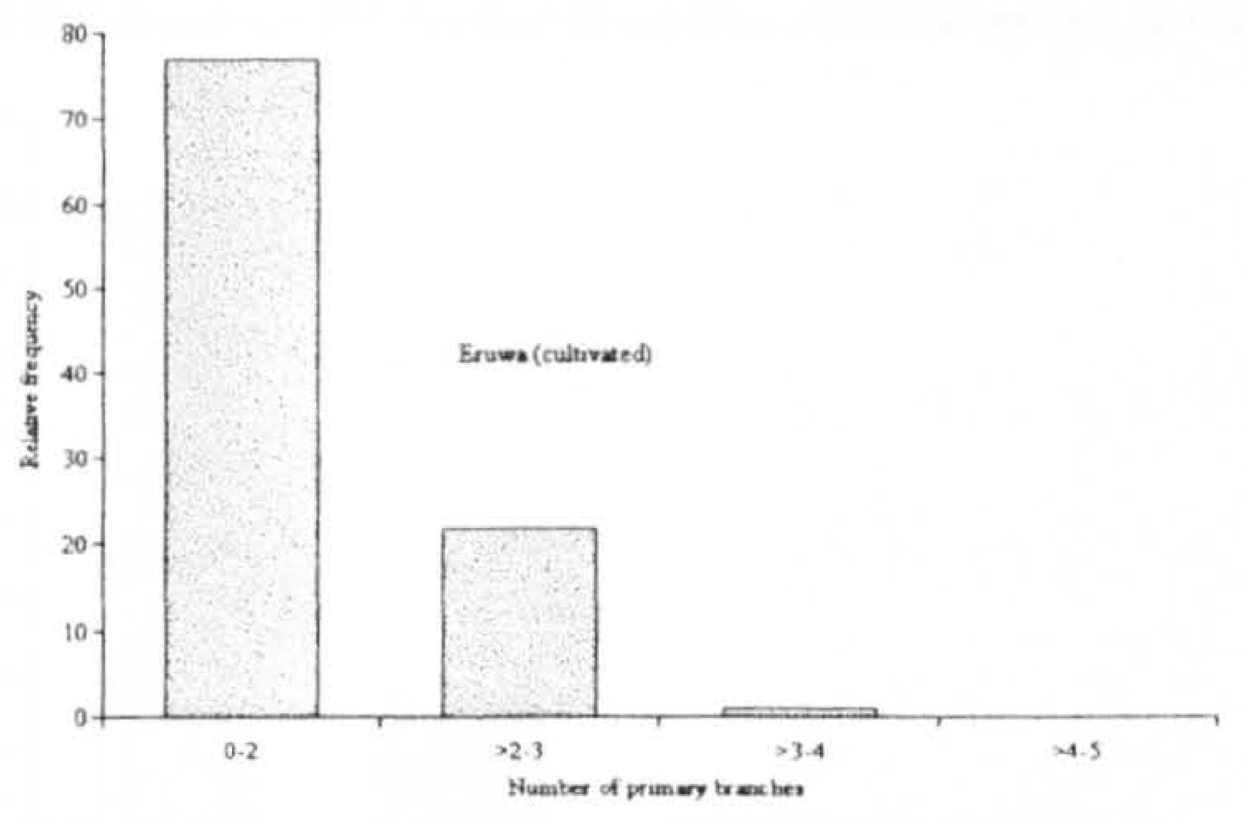


Figure 4.11b Frequency distr. of number of primary branches in Nsukka

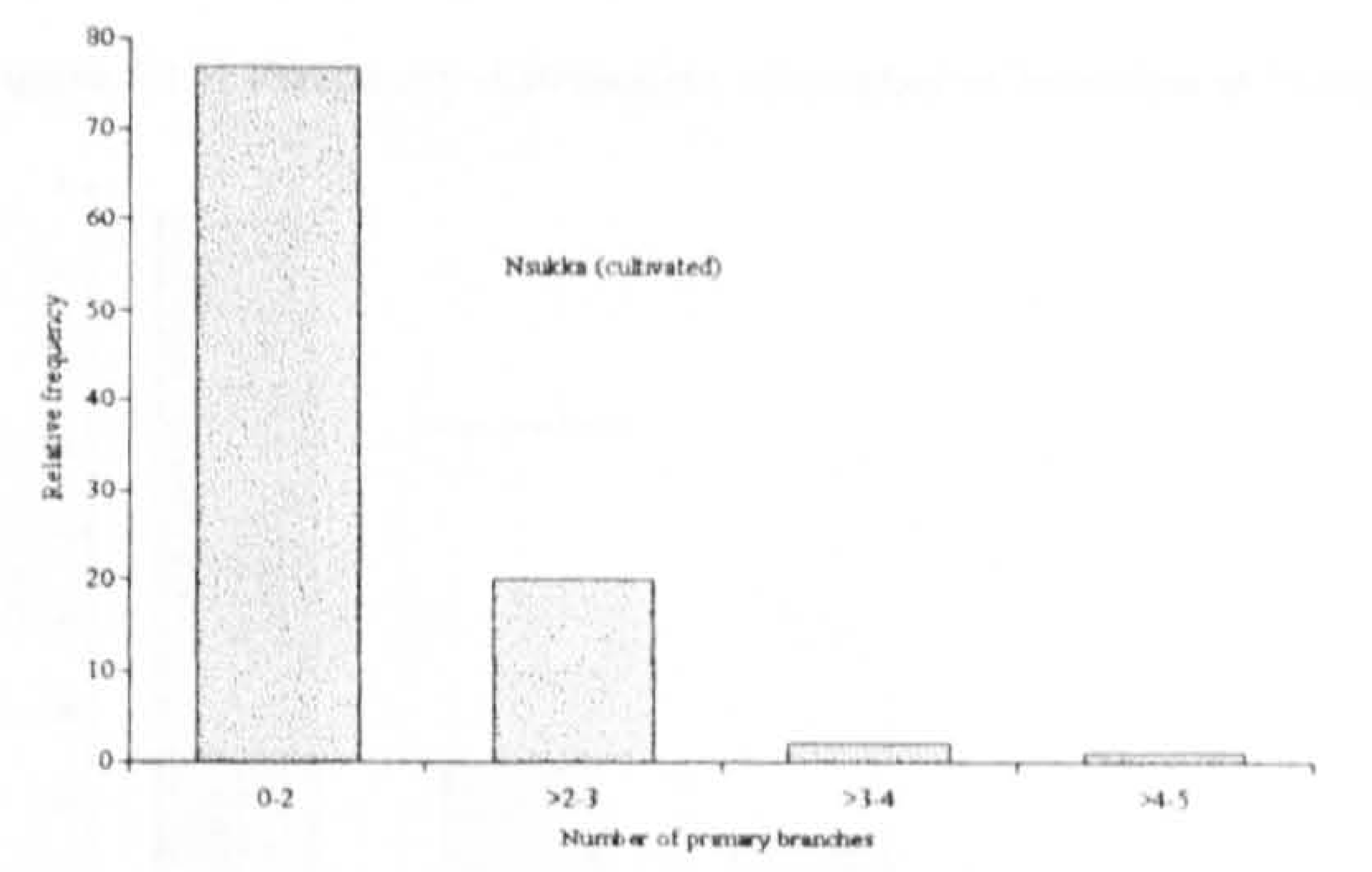


Figure 4.11c Frequency distribution of number of branches Ilorin

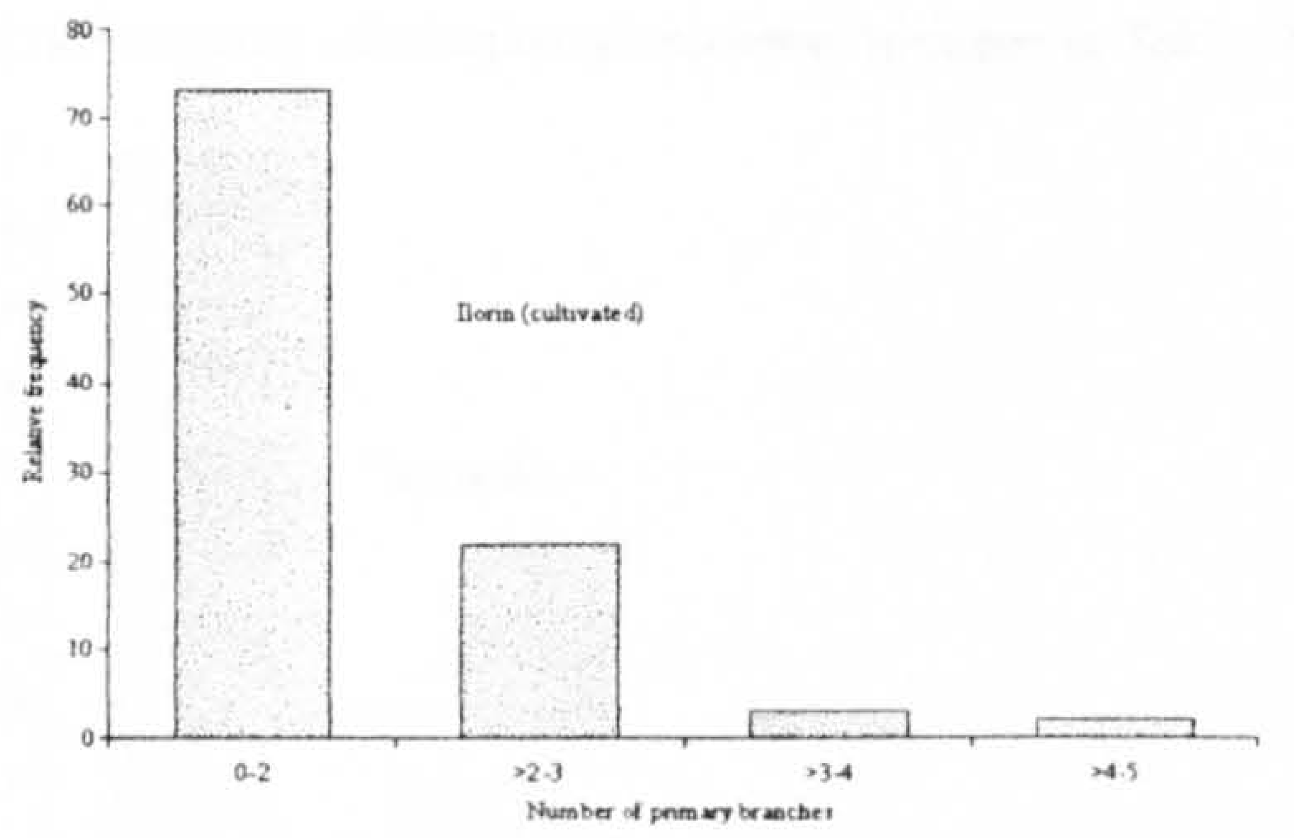


Figure 4.11d Frequency distribution of number of branches in Jos

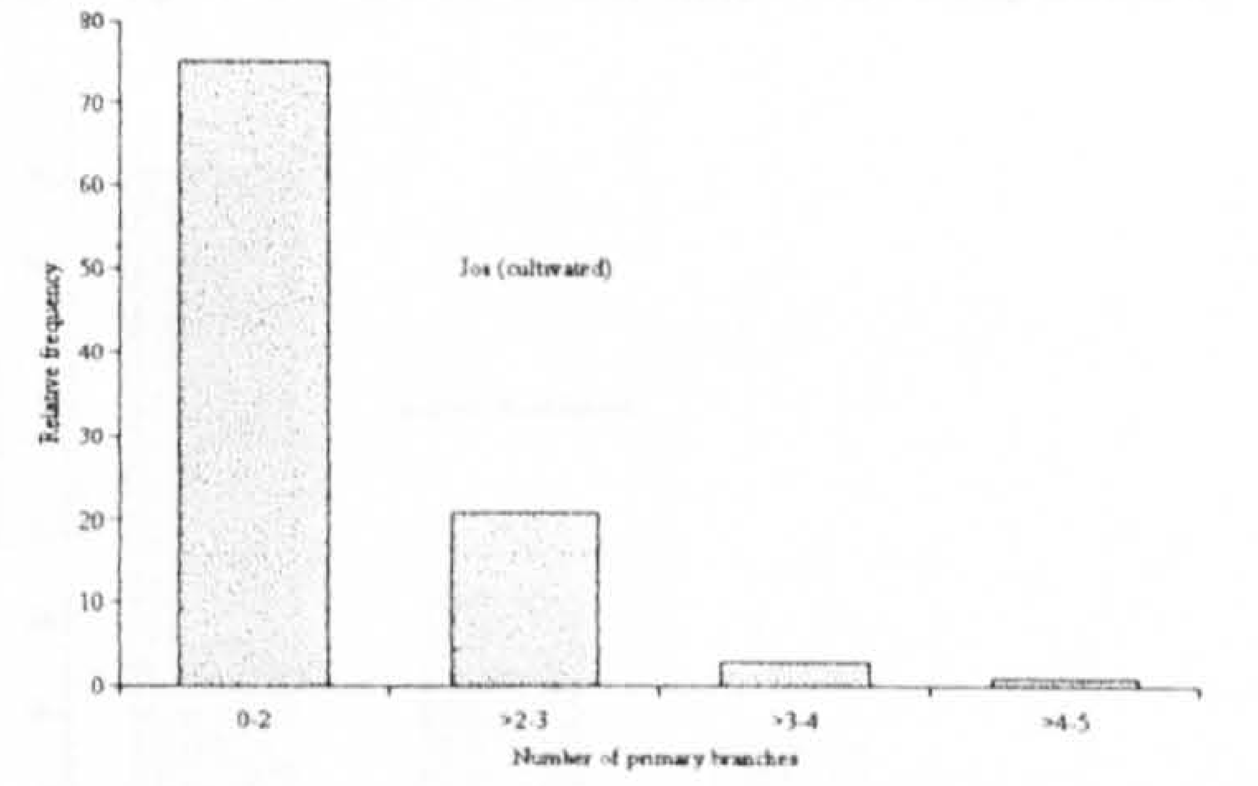


Figure 4.11e Frequency distribution of number of branches in Kaduna

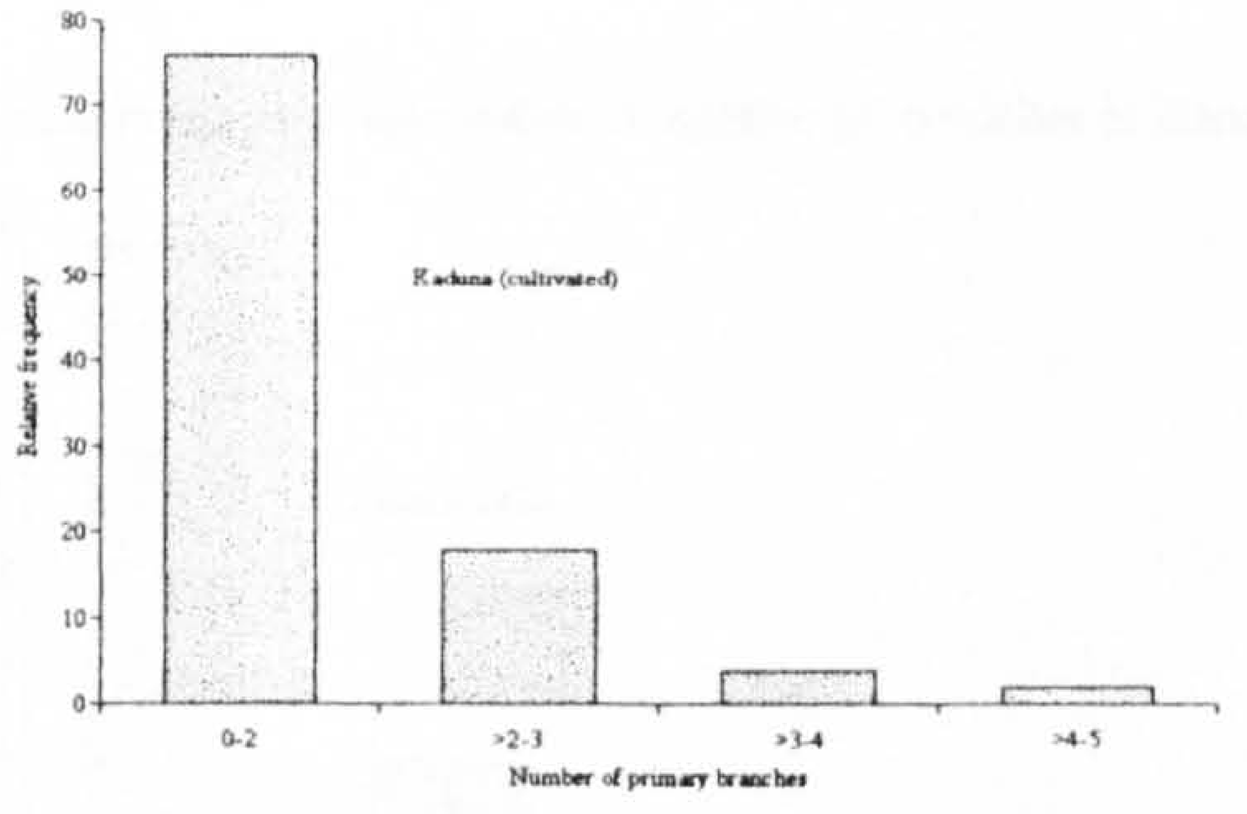


Figure 4.11f Frequency distribution of number of branches in Kontag.ora II

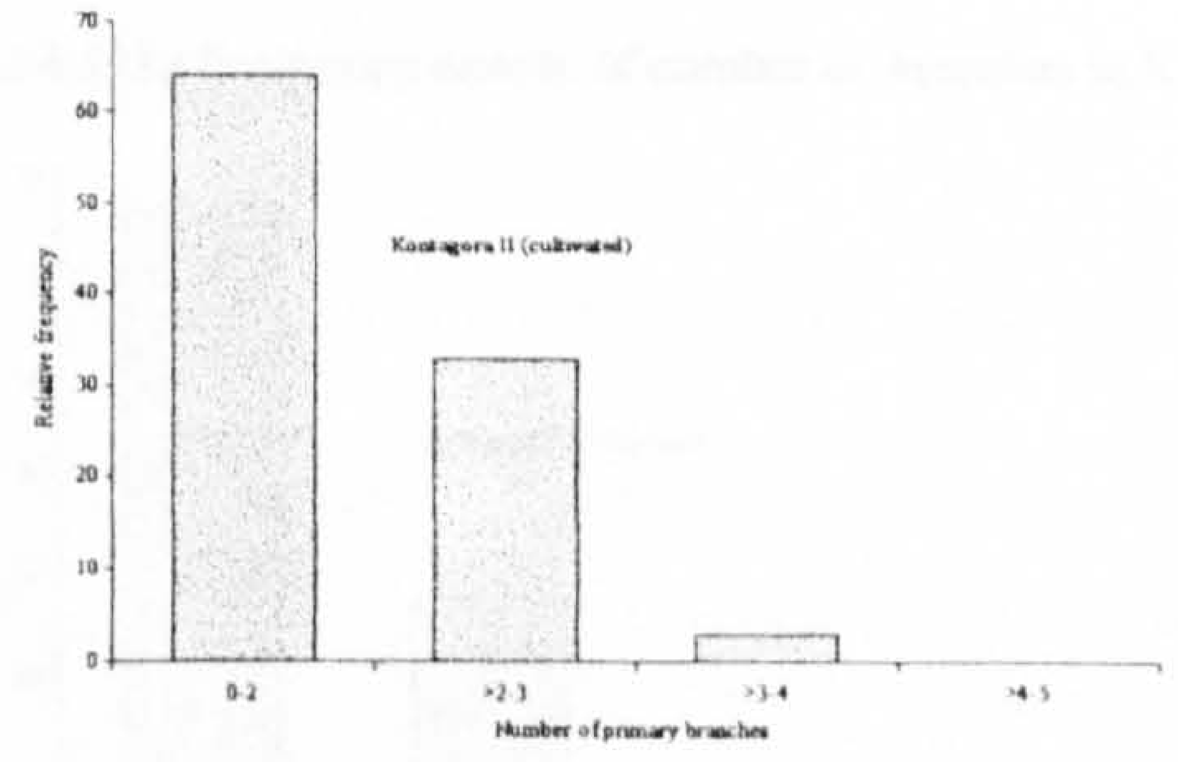


Figure 4.11g Frequency distribution of number of branches in Kano I

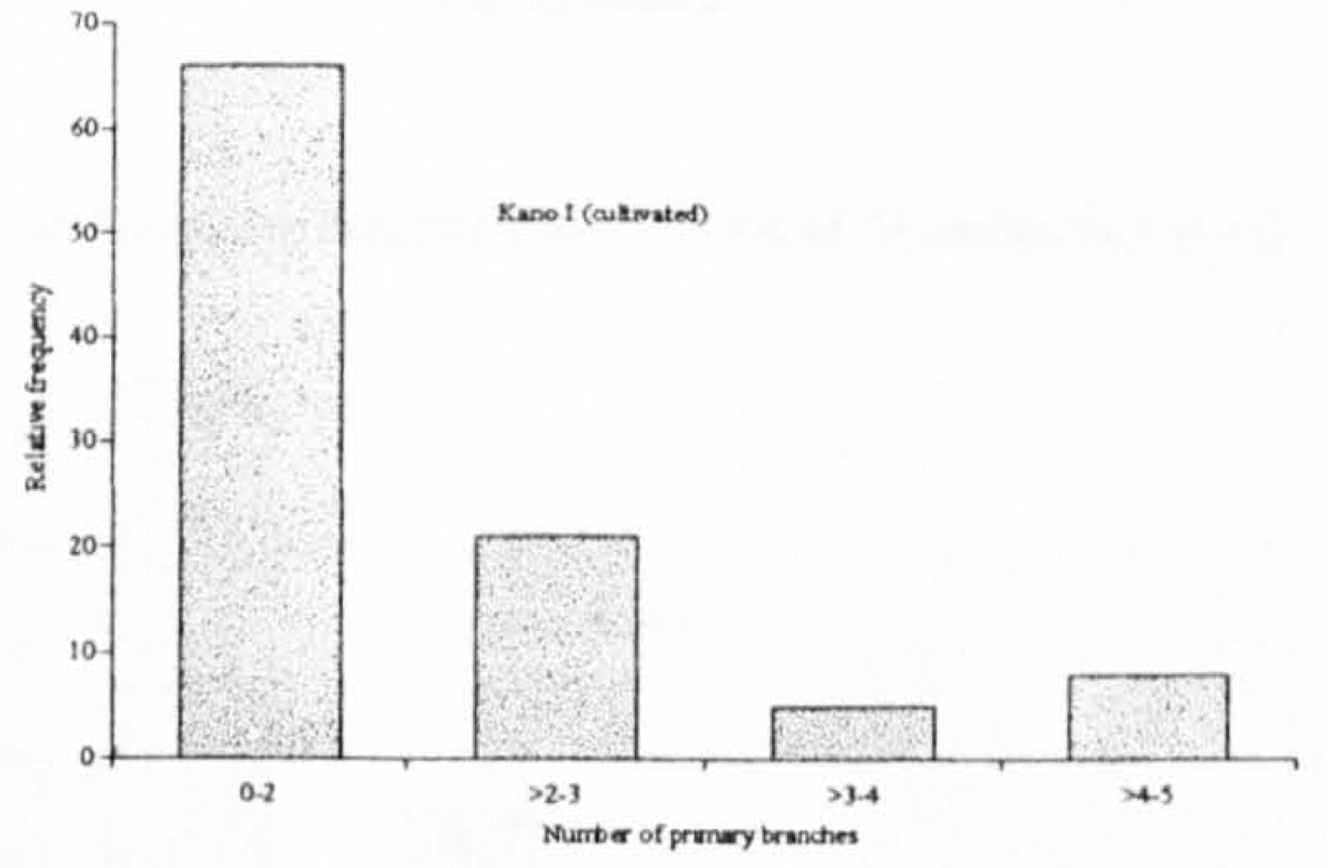
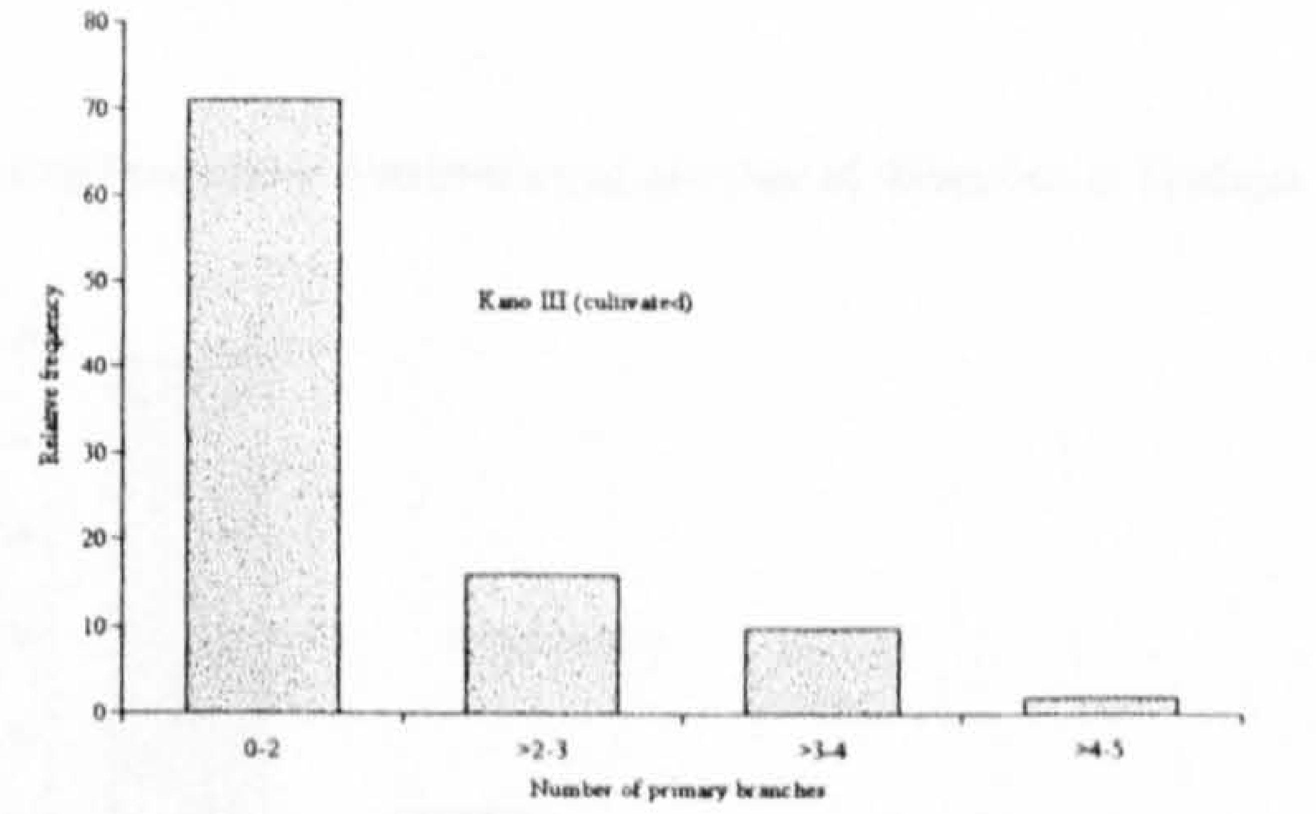


Figure 4.11h Frequency distribution of number of branches in Kano III



Number of primary branches (bush fallow)

Figure 4.11i Frequency distribution of number of branches in Olokemeji

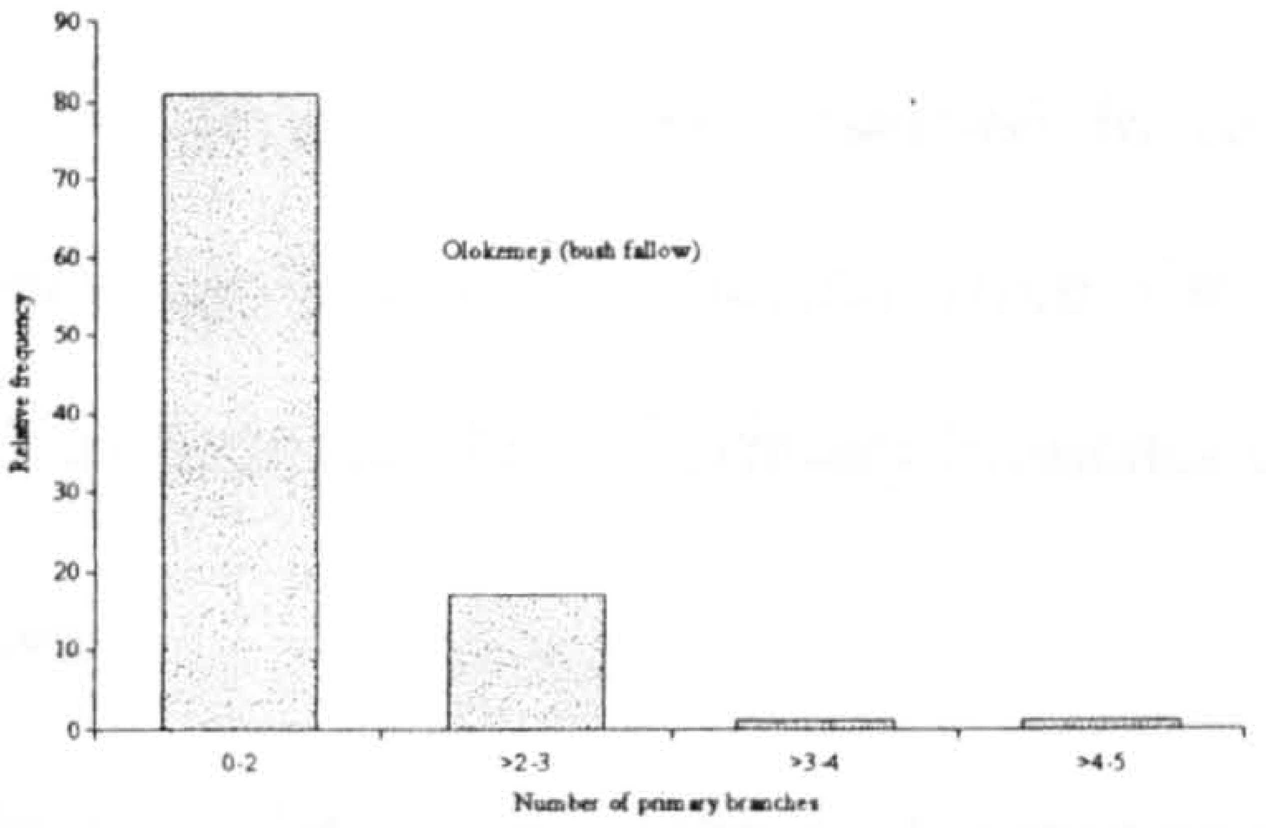


Figure 4.11j Frequency distribution of number of branches in Enugu

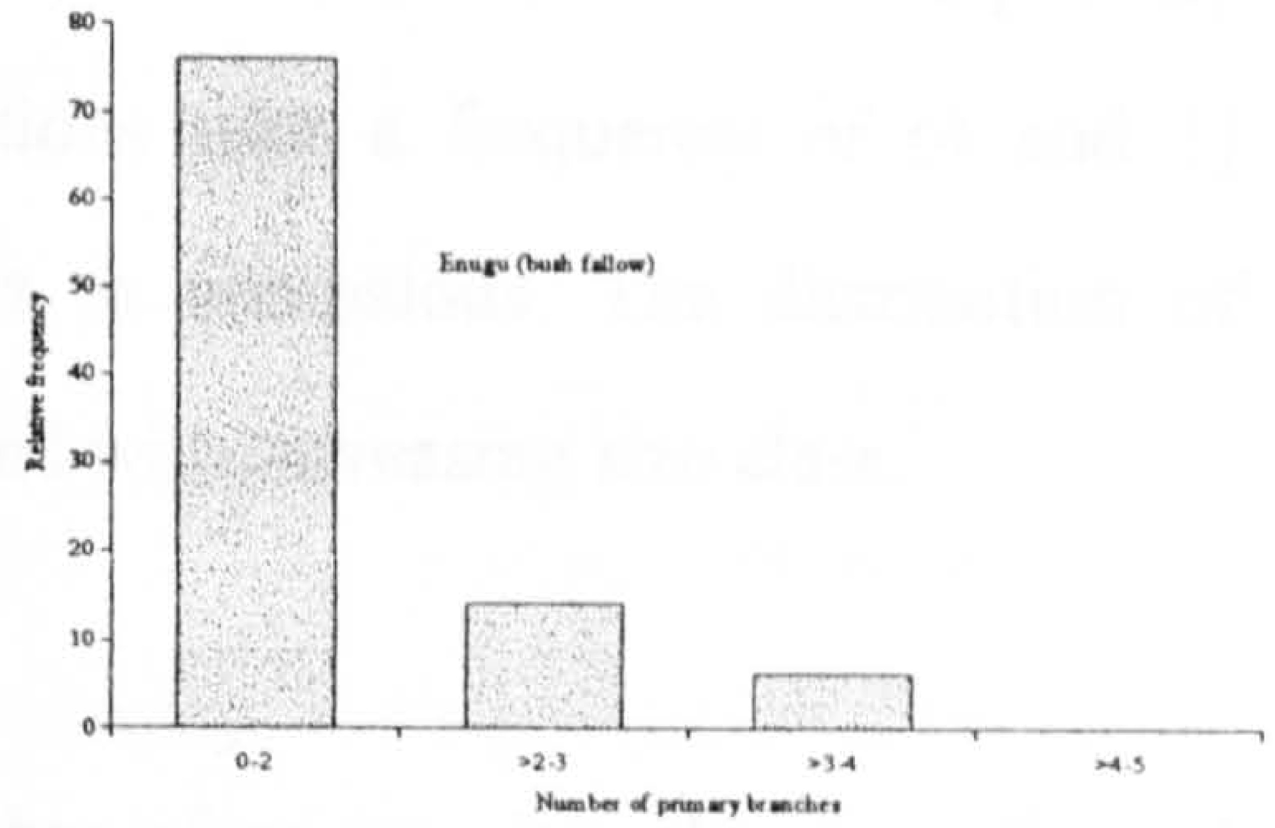


Figure 4.11k Frequency distribution of number of branches in Saki

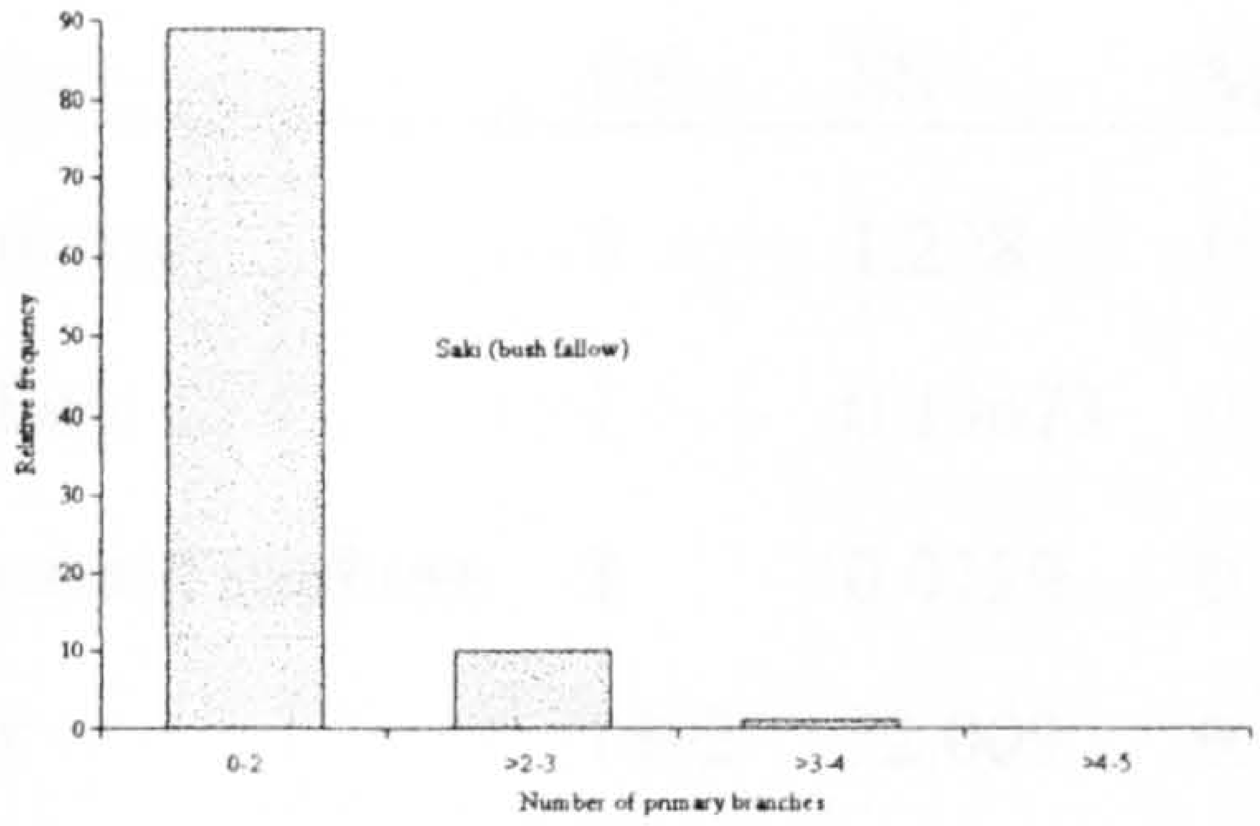
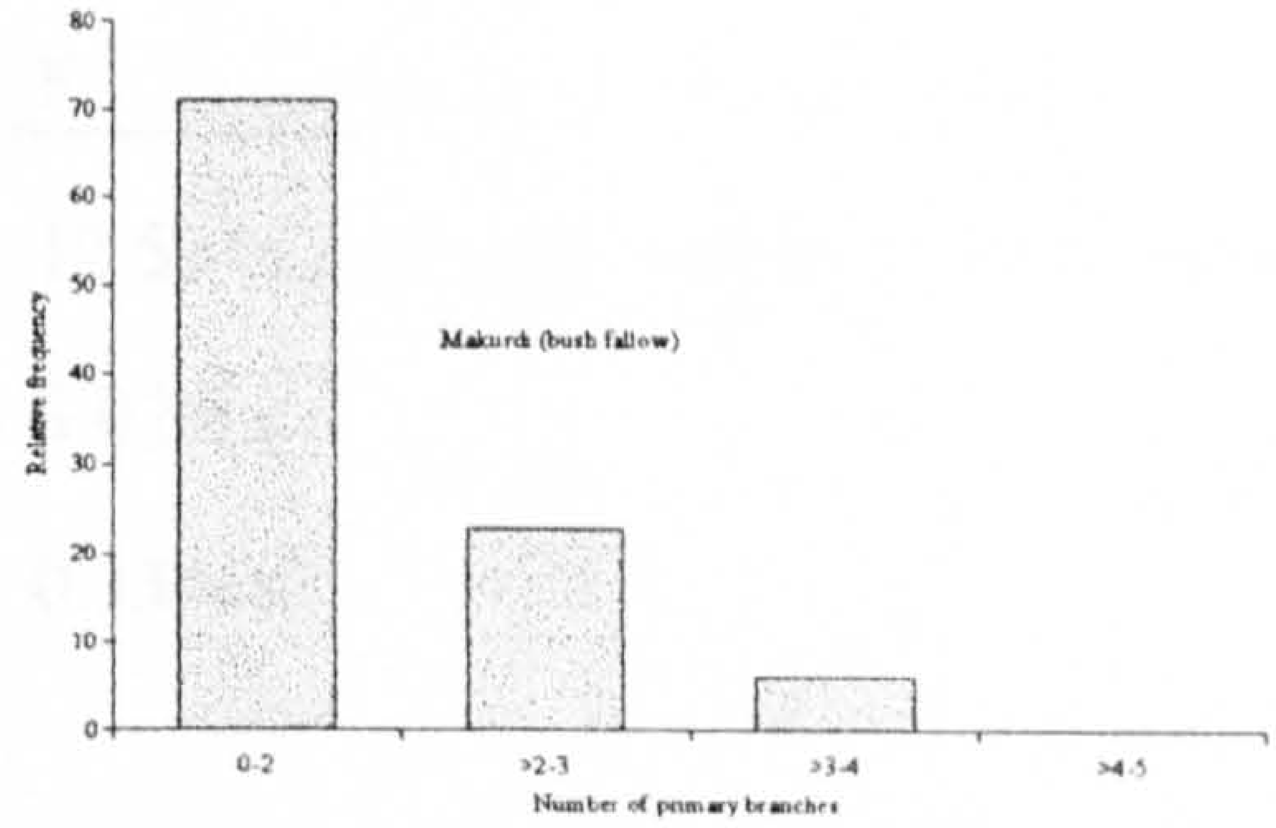


Figure 4.11l Frequency distribution of number of branches Makurdi



.Figure 4.11m Frequency distribution of number of branches in Zaria

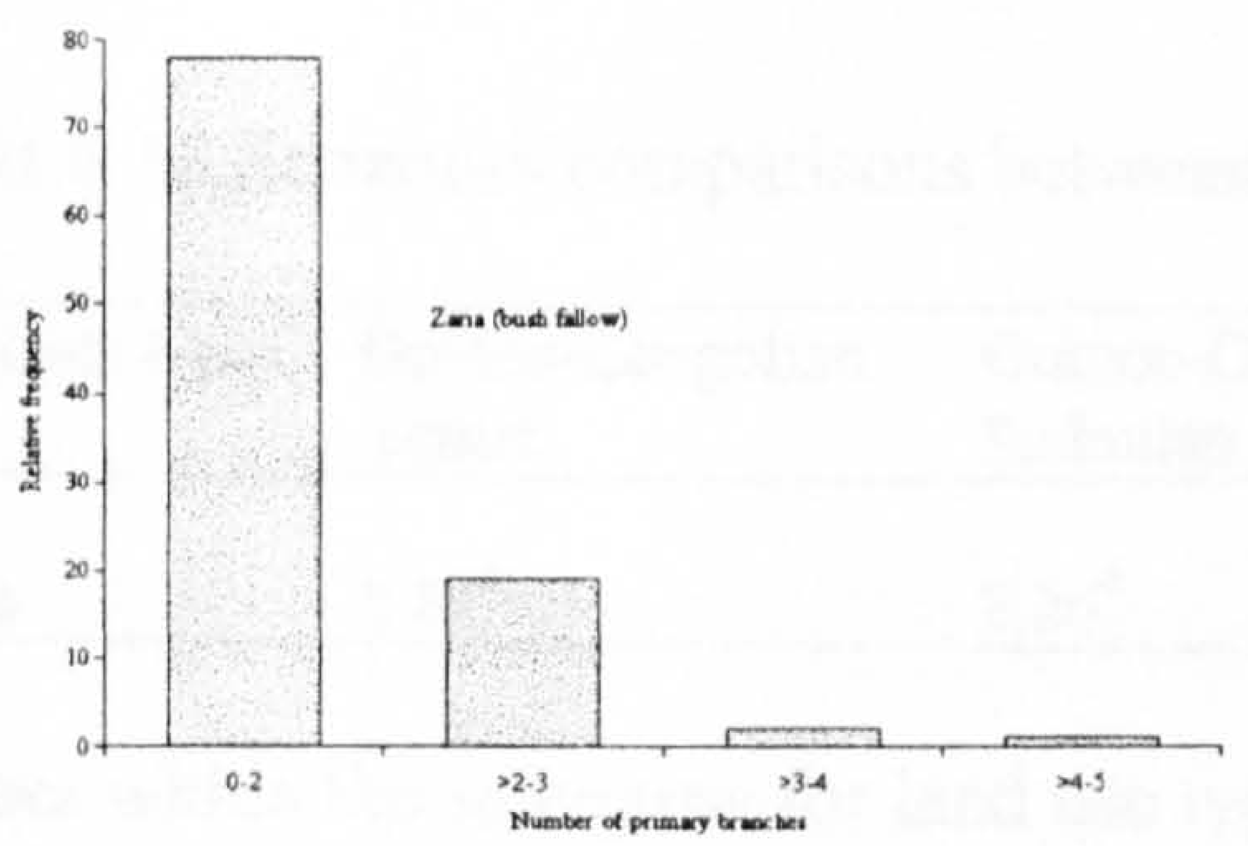


Figure 4.111n Frequency distrib. of number of branches in Kontagora I

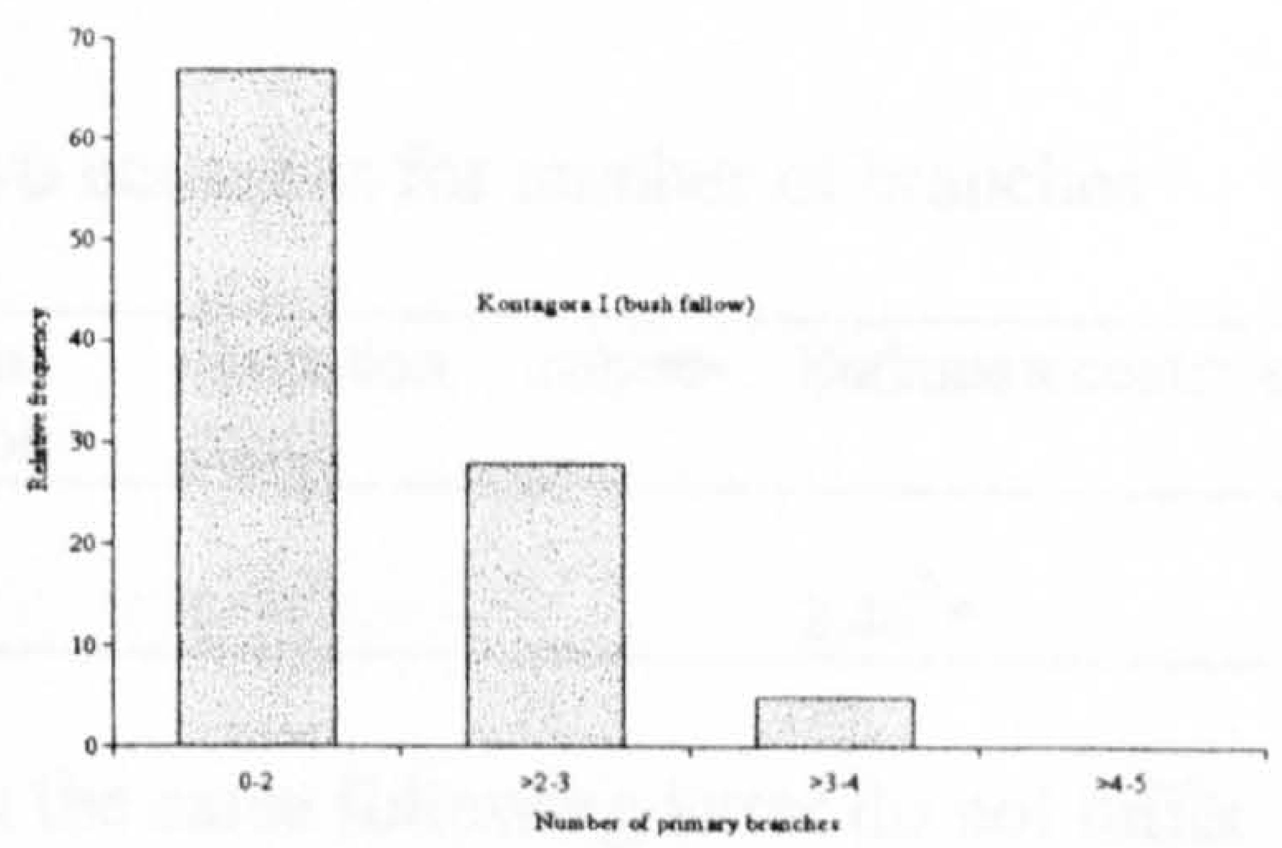


Figure 4.11o Frequency distribution of number of branches in Kano II

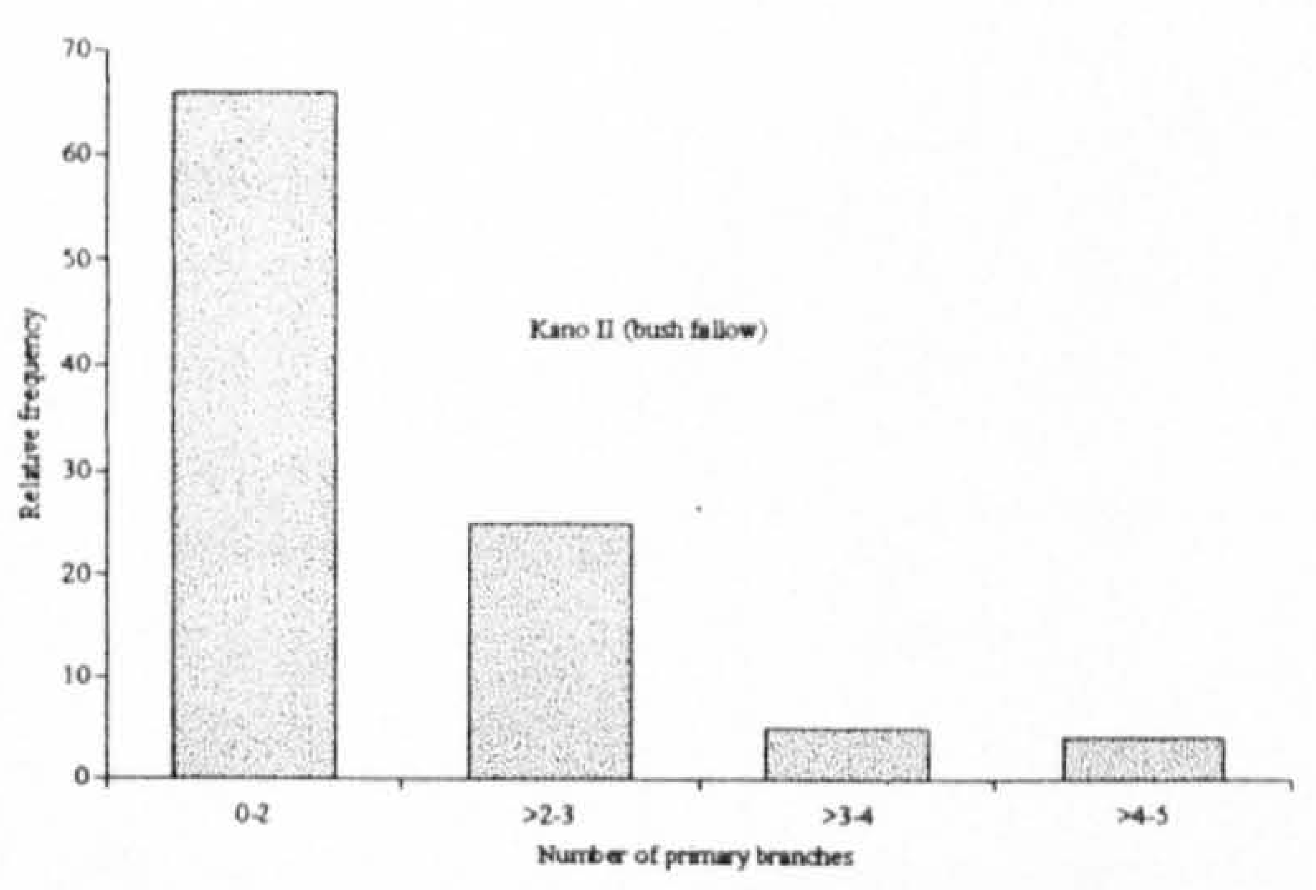
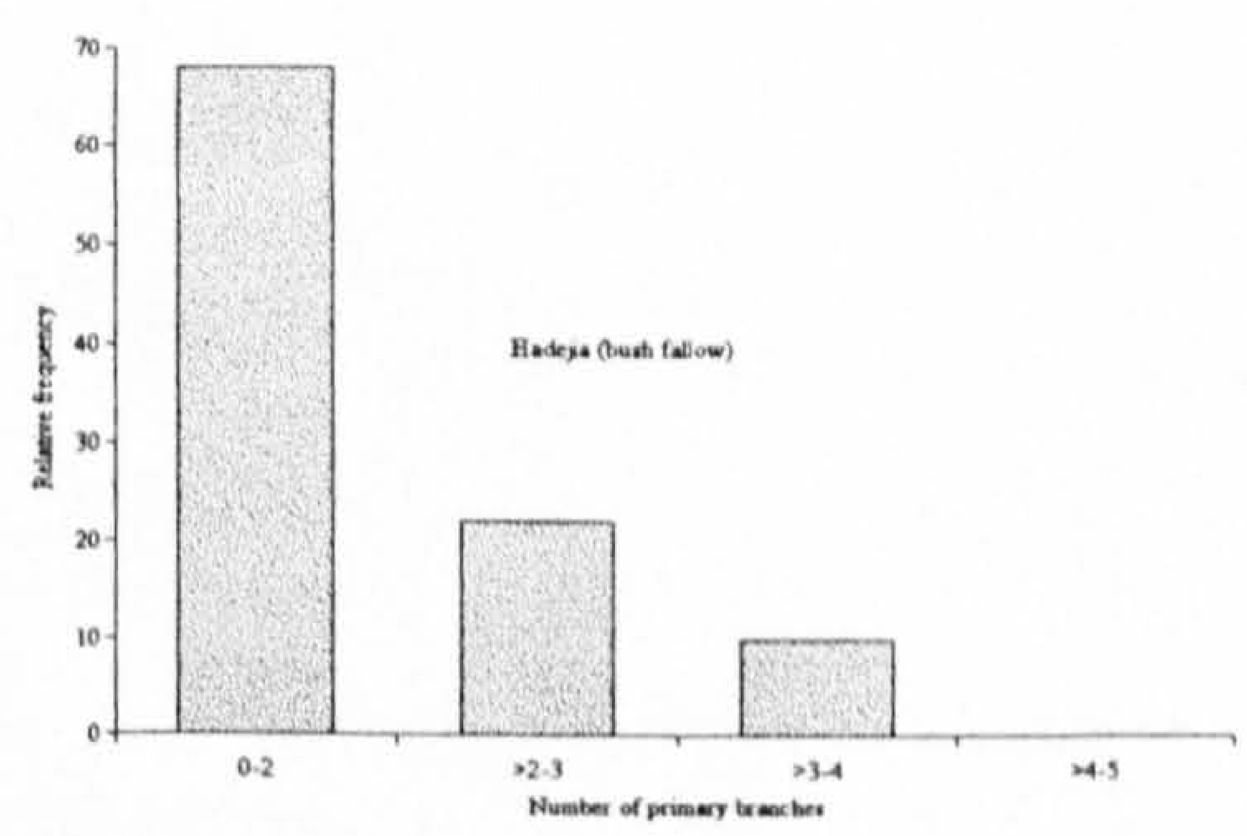


Figure 4.11p Frequency distribution of number of branches in Hadejia



The distibution of number of primary branches showed that trees with two branches were the most frequent (1175 individuals). Two extremes number of primary branches (0 and 6) were observed in two locations with a frequency of (4 and 1) respectively but were rejected from the analysis as anomalous. The distribution of individuals to number of primary branches decreased with increasing size class.

Anova

Table 4.17 Two way analysis of variance on number of primary branches (transformed data)

Source	DF	SS	MS	F
Ecozones	3	1.228	0.409	12.53*
Land use	1	0.19673	0.196	6.02 n.s
Ecozones* land use	3	0.0129	0.004	0.13 n.s
Error	1592	52.009	0.0326	
Total	1599	53.447		

*P < 0.05, n.s. not significant

Table 4.18 Ecozones comparisons between the two ecozones for number of branches

Ecozones types	Guinea-Congolian centre	Guineo-Congolian Sudanian transition	Sudanian centre-south	Sudanian centre-north
Mean	2.25[a]	2.26[a]	2.34[a]	2.46[b]*

Values within the same row for land use type with the same following letter do not differ significantly (P <0.05).

4.1.2. Allometric relationships

4.1.2.1. Relationships between stand parameters

Six regression relationships were all positive and significant. The relationship of crown diameter and branching height was the exception (Figure 4.12e-f). However strongest ($r^2 = 0.591$) relationship between stand characters was obtained between crown and tree diameter. The lowest correlation relationship was between branching height and tree total height with ($r^2 = 0.02$) (Figure 4.12f). The regression relationships between all the stand characters is shown in Table 4.19-4.25. Calculated regression coefficient (b) was not significantly different from zero based on tabulated $t_{(0.05)}$ value.

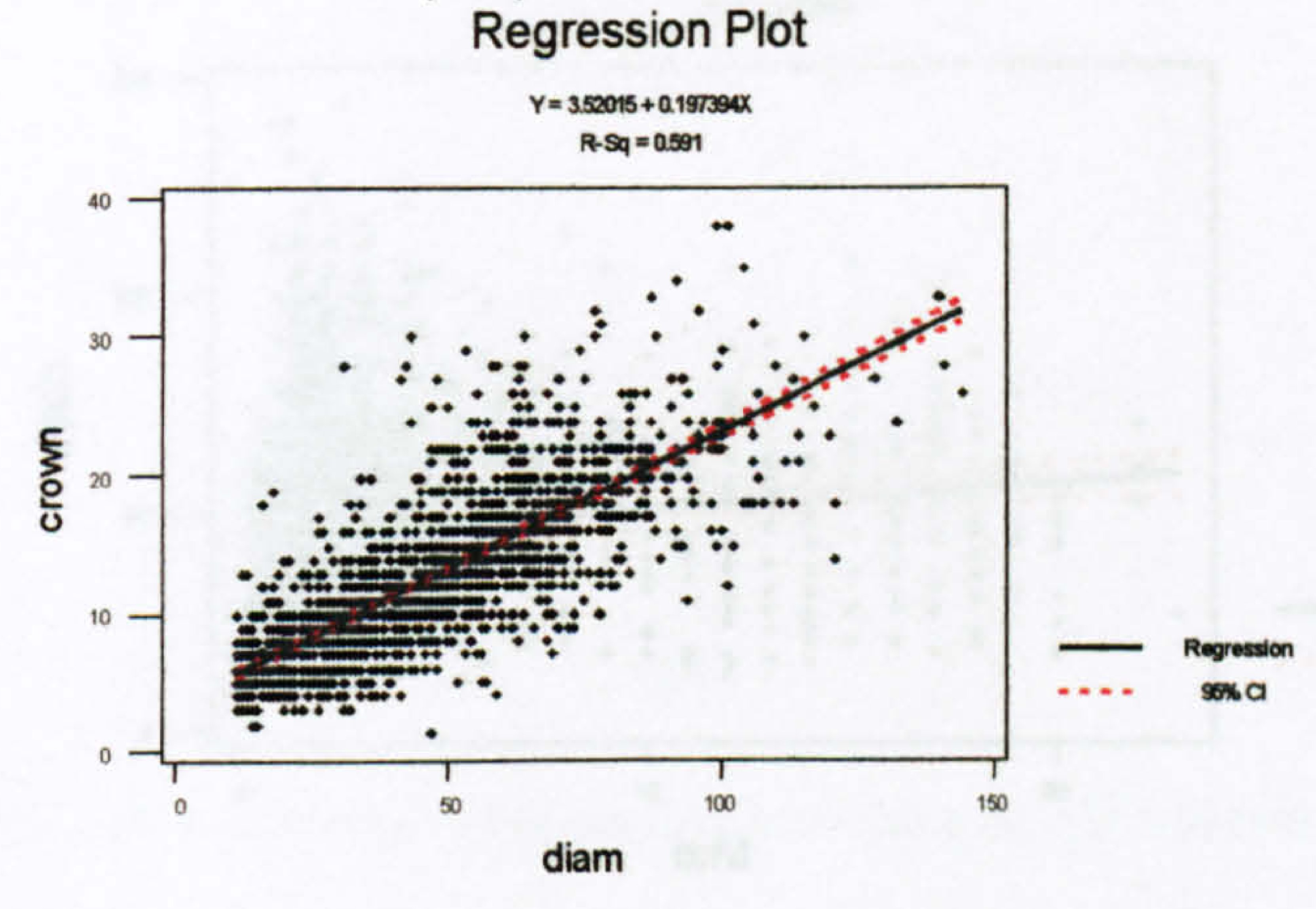


Figure 4.12a Overall regression relationship between crown diameter

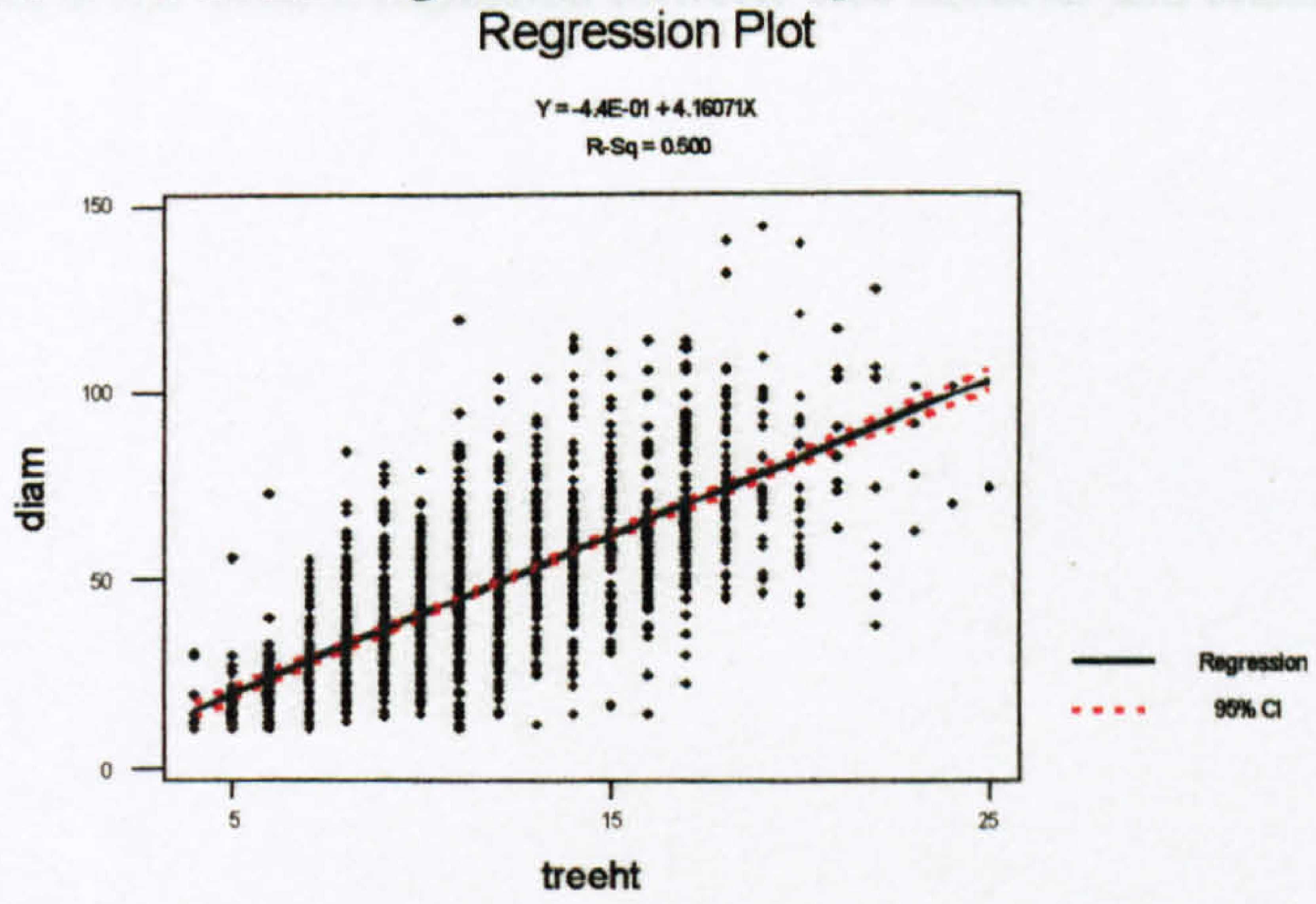


Figure 4.12b Overall relationship between tree diam. and total ht.

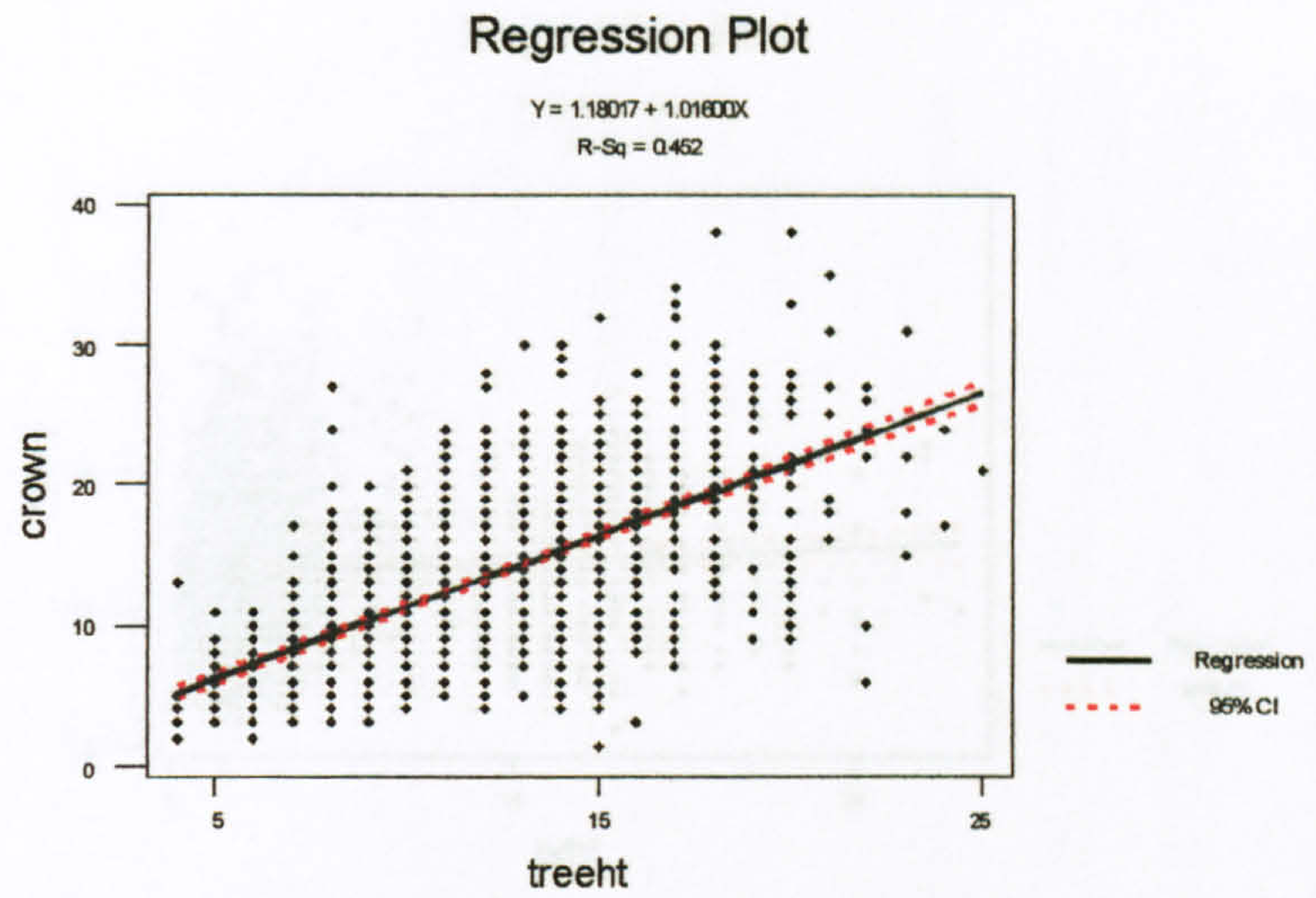


Figure 4.12c Overall regression between tree crown and tree height

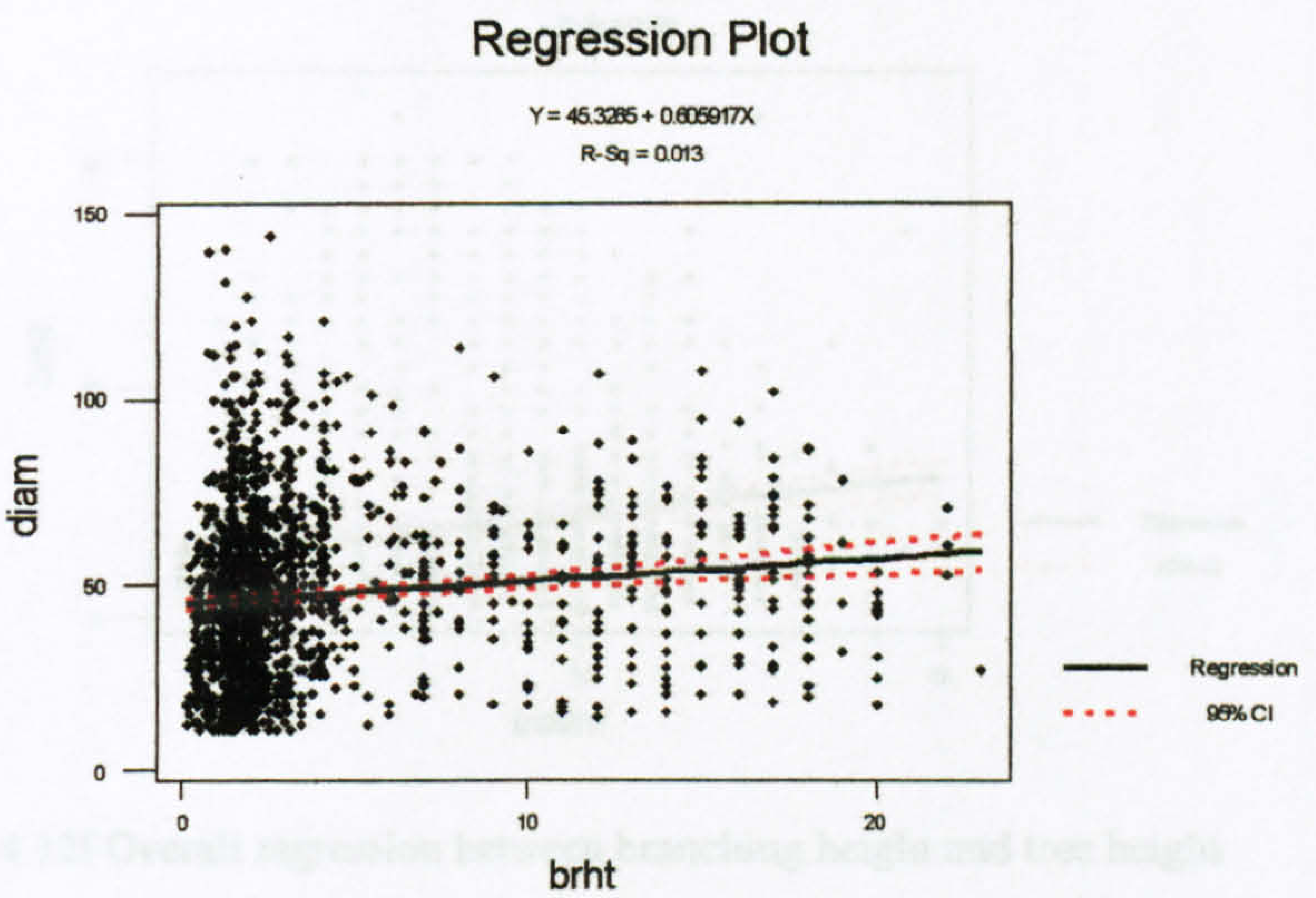


Figure 4.12d Overall regression between tree diameter and branch height.

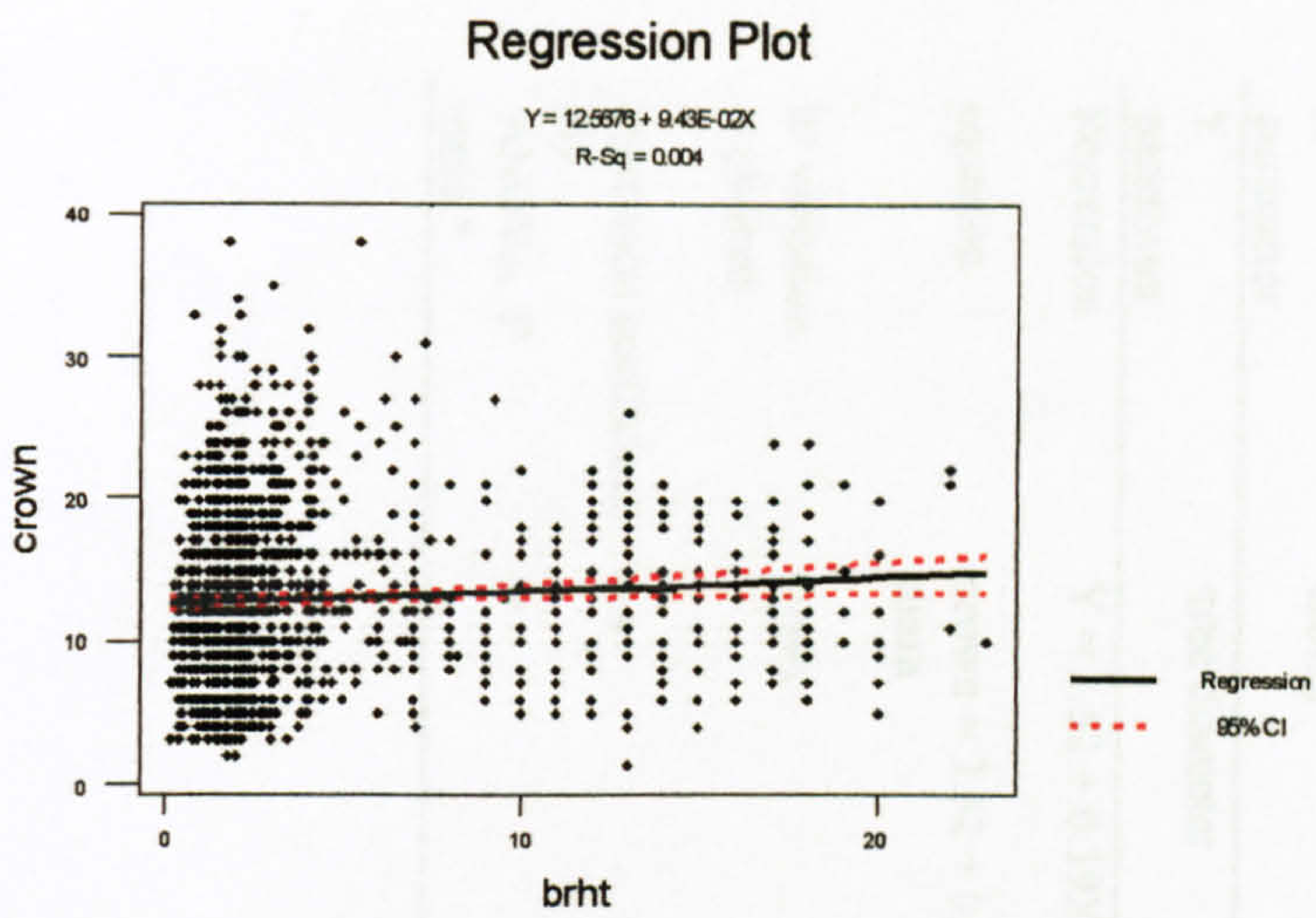
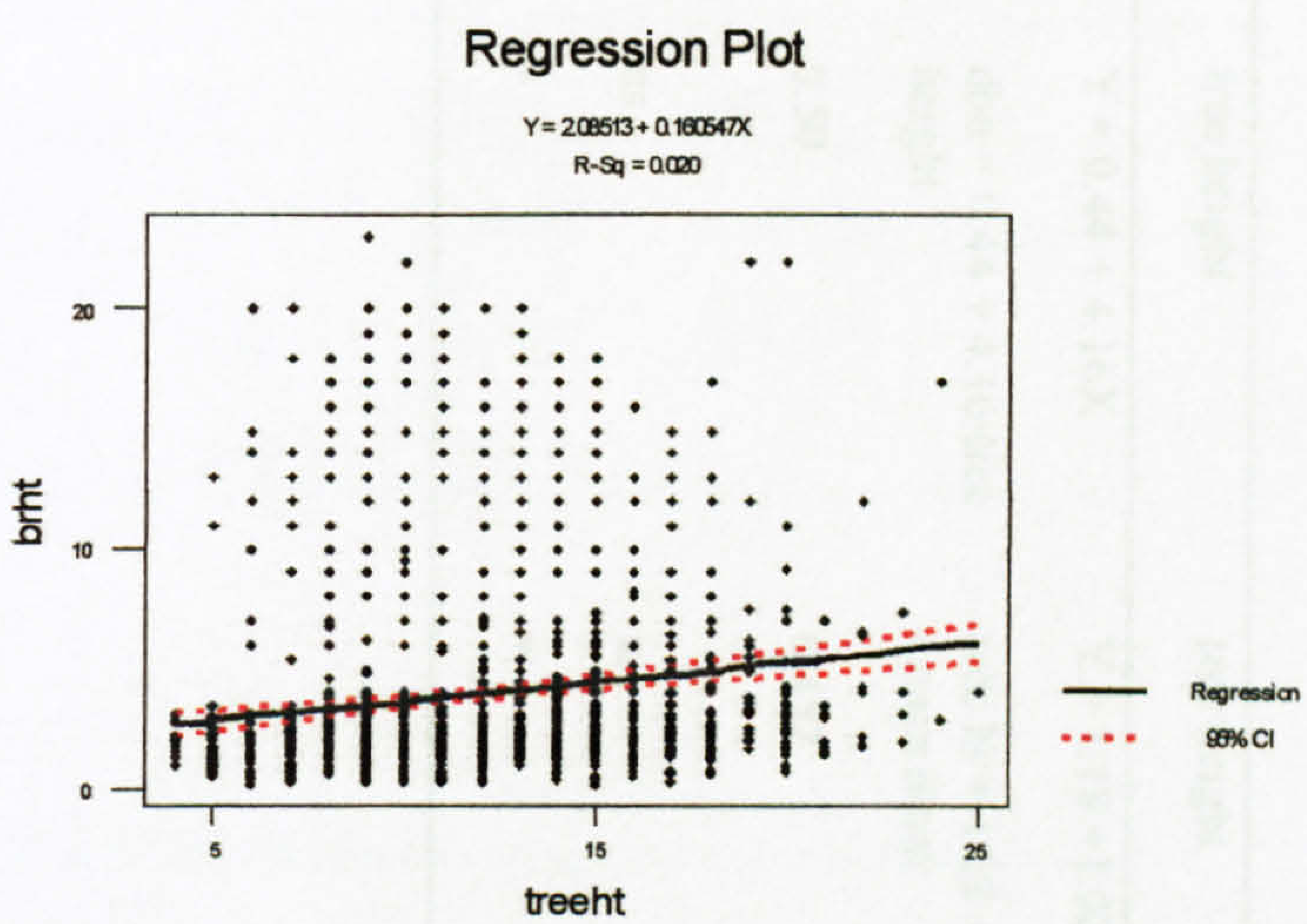


Figure 4.12e Overall regression relationship between tree crown and branch ht



. Fig.4.12f Overall regression between branching height and tree height

Table 4.19 Summary of allometric relationships between stand characters

X parameter	crown	dbh	crown	dbh	crown	branch height
Y parameter	·tree diameter	tree height	tree height	branch height	banch height	tree height
Regression	Y = 3.52 + 0.19X	Y = 0.44 + 4.16X	Y = 1.18 +1.02X	Y = 45.3 + 0.60X	Y = 12.6 + 0.094X	Y = 2.09 + 0.016X
equation	crown = 3.52 + 0.19 tree diam	dbh = 0.44 + 4.16·tree height	tree ht = 1.18 + 1.02 crown diam.	dbh=45.3+0.60 branch height	crown = 12.6 + 0.094 branch height	branch ht = 2.09 + 0.016 tree height
R^2 variation explained	0.591	0.50	0.452	0.013	0.004	0.02
regression coefficient (b)	n.s	ns	n.s	n.s	n.s	n.s
·ANOVA F ·ratio *	·*	*	*	*	*	*

Table 4.20 Regression analysis of crown on tree diameter

Source	DF	SS	MS	F
Regression	1	32711	32711	2313.61*
Error	1598	22593	14	
Total	1599	55304		

*P <0.05

Table 4.21 Regression analysis of tree diameter on tree total height

Source	DF	SS	MS	F
Regression	1	419381	419381	1595.15*
Error	1598	420130	263	
Total	1599	839511		

*P < 0.05

Table 4.22 Regression analysis of crown on tree total height

Source	DF	SS	MS	F
Regression	1	25007	25007	1318.96*
Error	1598	30297	19	
Total	1599	55304		

*P < 0.05

Table 4.23 Regression analysis of tree diameter on branching height

Source	DF	SS	MS	F
Regression	1	11521	11521	22.21*
Error	1596	827848	519	
Total	1597	839369		

*P < 0.05

Table 4.24 Regression analysis of crown on branching height

Source	DF	SS	MS	F
Regression	1	279.35	279.35	8.10*
Error	1596	55020.36	34.47	
Total	1597	55299.70		

*P < 0.05

Table 4.25 Regression analysis of branching height on tree height

Source	DF	SS	MS	F
Regression	1	624.09	624.09	32.38*
Error	1596	30757.35	19.27	
Total	1597	31381.44		

*P < 0.05

4.1.3 Morphological attributes and mean annual rainfall

Possible relationships between the various stands parameters and mean annual rainfall were investigated. Untransformed mean values for parameters were used except for the number of primary branches, where square root transformed mean values were used in the predictive relationship.

Table 4.26 Summary of regression relationships between mean annual rainfall and *Parkia biglobosa* parameters based on mean values for each of the 16 stands in Nigeria

X parameter	Rainfall	Rainfall	Rainfall	Rainfall	Rainfall	Rainfall
Y parameter	Nearest neigbour. distance	Tree height	Diameter	Crown diameter	Branching height	No of primary branches†
Equation	Y= 7.25 - 8926X	22.5 + 919.25X	Y= 13.34 1818 X	Y= 23.97 - 1490 X	Y= 2.53 + 630 X	Y= 5899 - 11033 X
Reg coeff. equation	Con dist = 7.25 - 8926 Rainfall	Tree height =22.5 + 919.25 Rainfall	Diam = 13.34 - 1818 Rainfall	Crown = 23.97 - 1490 Rainfall	Bran height= 2.53 + 630 Rainfall	No of prim. bran = 5899 - 11083 Rainfall
% (R^2 variation explained)	16	2	17	5	20	47
(b) regression co-e	n.s	n.s	n.s	n.s	n.s	*
F ratio	n.s	n.s	n.s	n.s	n.s	*

*P <0.05, n.s: not significant † Square root transformation

There was no indication that mean annual rainfall was related to any stand characters considered apart from the number of primary branches. The regression plot for number of primary branches and rainfall is indicated in Figure 4.13.

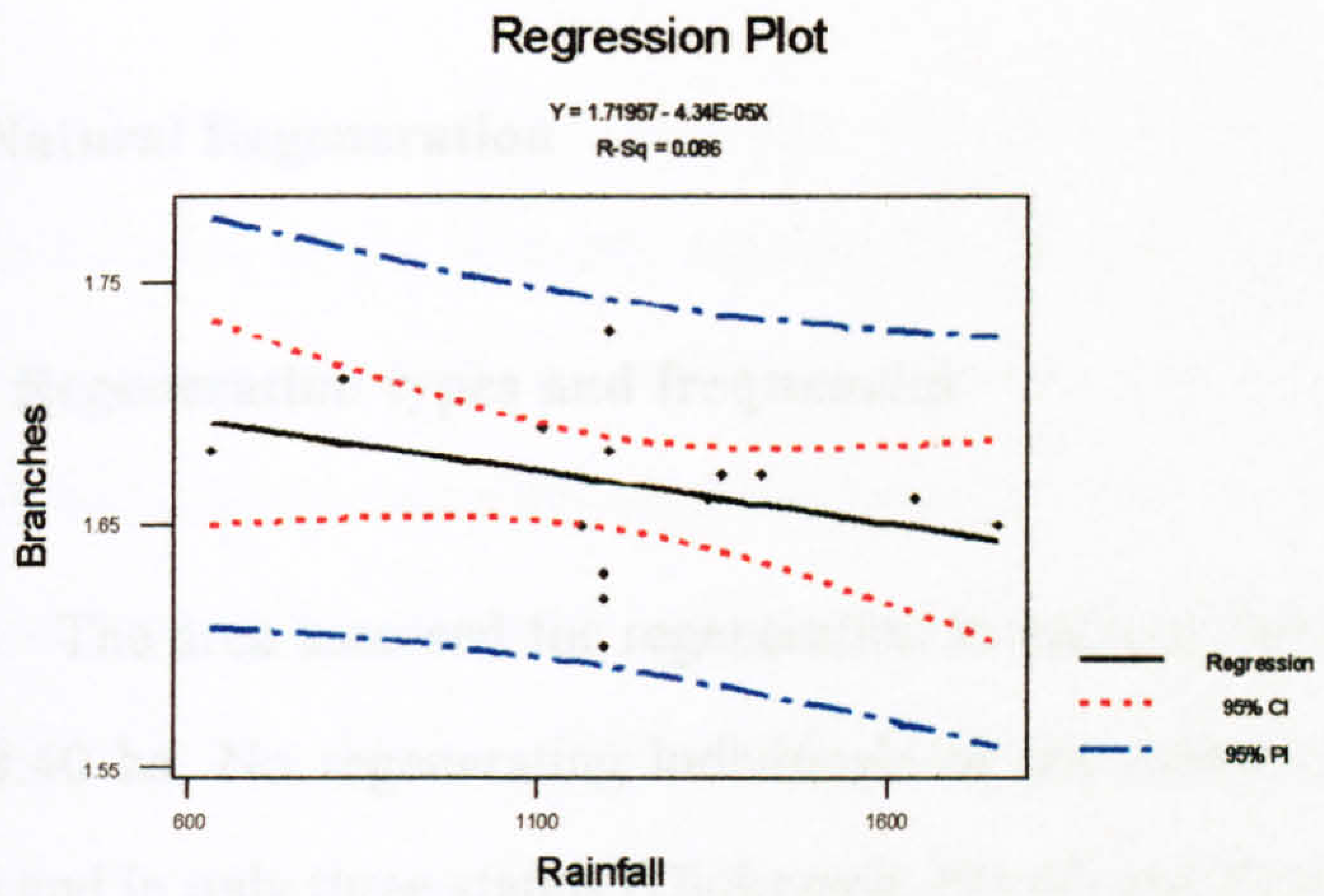


Figure 4.13 Regression relationship: mean annual rainfall in Nigeria samples stands and number of primary branches

4.2. Natural Regeneration

4.2.1 Regeneration types and frequencies

The area assessed for regeneration in each of the 16 stands varied from 0.65 ha and 8.40 ha. No regenerating individuals of any category was recorded in the Kaduna stand and in only three stands (Olokemeji, Eruwa and Kontagora I) were there more than 25 observations (Table 4.27).

Table 4.27 *Parkia biglobosa*: recorded regeneration (numbers of observations) in relation to sampled area at 16 Nigerian locations.

Location and sample area (ha)	Regeneration uninterrupted from seed			Regeneration of stump/root stock origin		
	seedling	saplings	poles	seedlings	saplings	poles
Eruwa (2.04)	8	1	0	7	1	2
Olokemeji (8.40)	19	1	0	7	1	2
Enugu (4.12)	3	3	2	4	4	7
Nsukka (1.61)	7	0	1	3	4	3
Saki (1.59)	5	2	0	10	4	1
Ilorin (0.99)	11	0	0	3	5	5
Jos. (0.94)	2	0	2	0	1	4
Makurdi (1.91)	3	2	0	0	7	3
Kaduna (0.98)	0	0	0	0	0	0
Zaria (1.45)	0	0	0	0	1	1
Kontagora I (1.22)	6	0	1	30	4	2
Kontagora II (0.94)	2	1	0	4	7	3
Kano I (0.67)	0	0	0	0	1	0
Kano II (0.65)	1	0	0	2	0	3
Kano III (0.93)	0	1	0	1	9	3
Hadejia (0.94)	0	0	2	7	8	4

Stocking per hectare of stump/root stock regeneration was generally higher than that from seed origin in every ecozone. For regeneration uninterrupted from the seed, highest stocking was of the seedling group while, in the stocking of regeneration from stumps/rootstocks, saplings were the least represented. This is possibly because with a vigorous rootstock to support shoot growth, the shoots rapidly progress through the seedling phase to the sapling phase. The ecozones comparisons showed that in stands, the Guinea-Congolian centre had optimum representation for both regeneration categories. The highest stocking per hectare was in Kontagora I of (Sudanian centre-south). Land use comparison showed that stocking was higher in the bush fallow compared with cultivated land use.

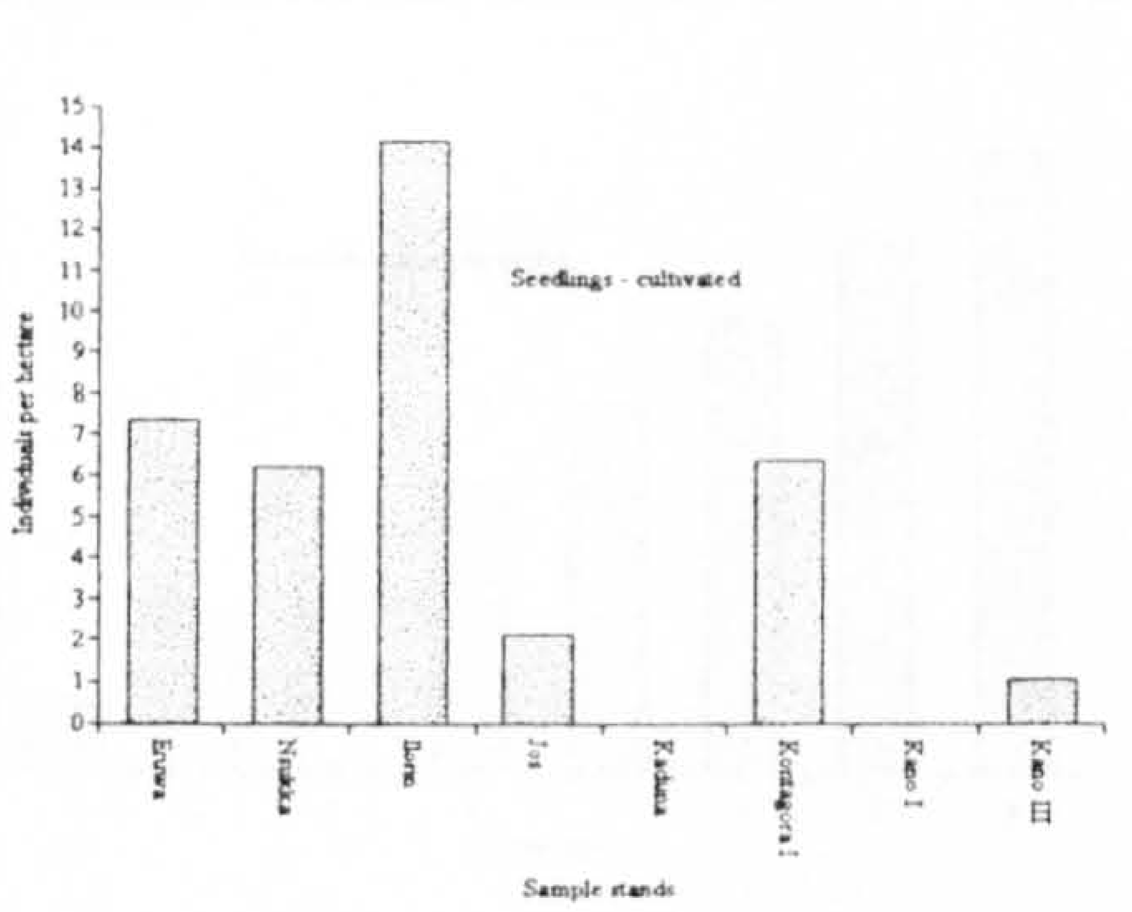
Table 4.28 *Parkia biglobosa* recorded regeneration (per hectare) by regeneration category at 16 Nigerian locations

Location	Regeneration uninterrupted from seed			Regeneration of stump/root stock origin		
Stocking (ha^{-1})	seedling	saplings	poles	seedlings	saplings	poles
Eruwa	3.92	0.49	0.00	3.43	0.49	0.98
Olokemeji	2.26	0.20	0.00	1.43	0.83	0.59
Enugu	0.73	0.72	0.49	0.97	3.4	1.69
Nsukka	0.35	0.00	0.62	1.86	2.48	1.86
Saki	3.14	1.30	0.00	6.28	2.52	0.63
Ilorin	11.11	0.00	0.00	3.03	5.05	3.03
Jos.	2.13	0.00	2.13	0.00	1.06	4.30
Makurdi	2.52	1.68	0.00	0.00	3.66	1.77
Kaduna	0.00	0.00	0.00	0.00	0.00	0.00
Zaria	0.00	0.00	0.00	0.00	0.68	0.68
Kontagora I	4.91	0.00	0.82	24.59	3.27	1.64
Kontagora II	2.12	1.06	0.00	4.26	7.44	3.19
Kano I	0.00	0.00	0.00	0.00	1.50	0.00
Kano II	1.54	0.00	0.00	3.07	0.00	4.62
Kano III	0.00	0.08	0.00	1.08	9.67	3.22
Hadejia	0.00	0.00	2.13	7.45	8.50	4.25

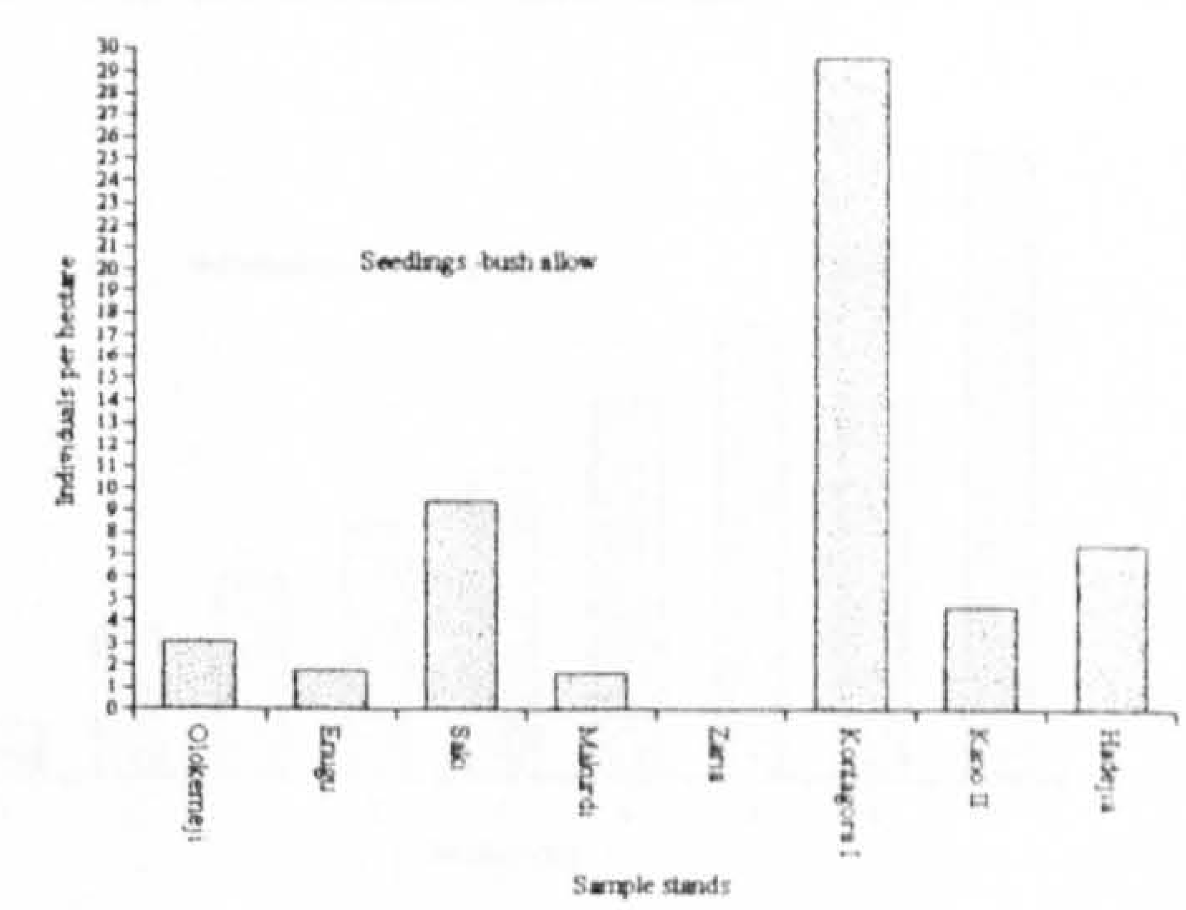
4.2.2 Abundance of regeneration in relation to ecozones and land use type

Transforming data where necessary, statistical analysis (ANOVAs) was carried out to seek evidence of differences in regeneration abundance (Figures 4.14a-f) with ecozone and land use type. No significant differences in ha^{-1} values were detected (Table 4.28). It is likely that, despite considerable sampling effort, because of the low numbers of observations made the data set were not adequate for any useful analysis. Stocking per hectare for seedlings, saplings and poles across the stands and between the two land use types indicated generally low values for cultivated compared with bush fallow (Figures 4.14a-f)

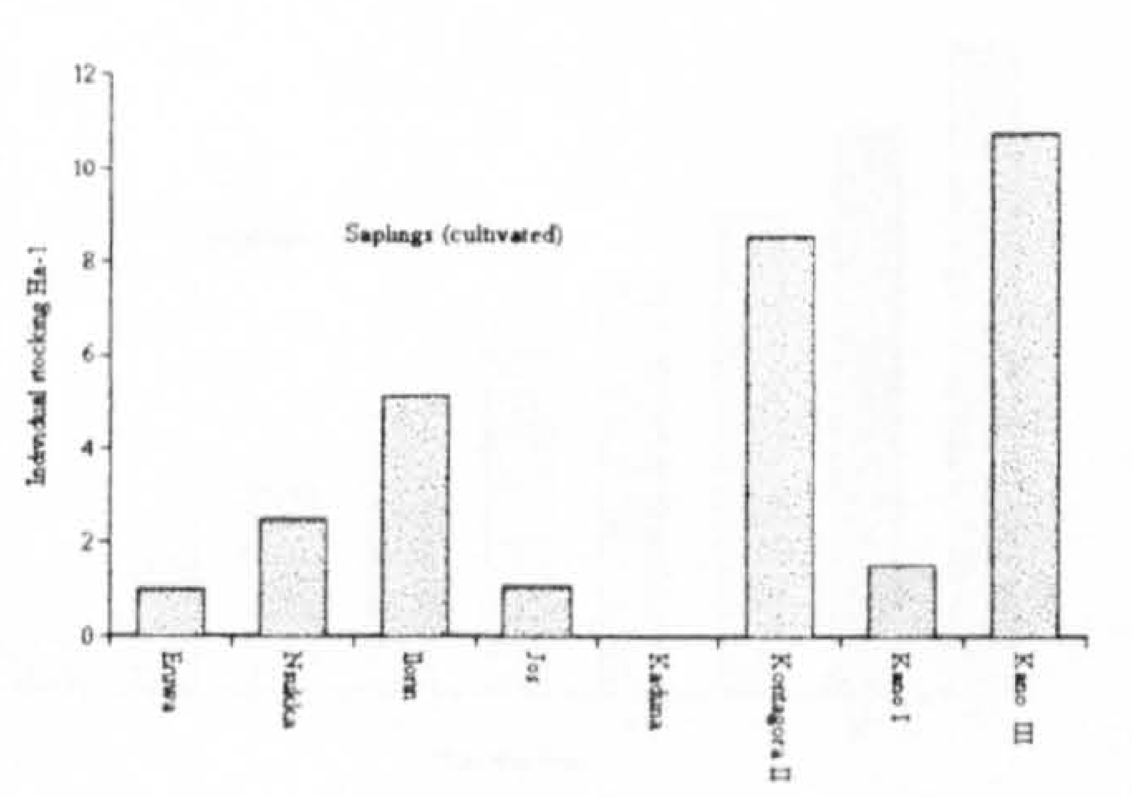
(a) Seedlings regeneration per hectare in the cultivated



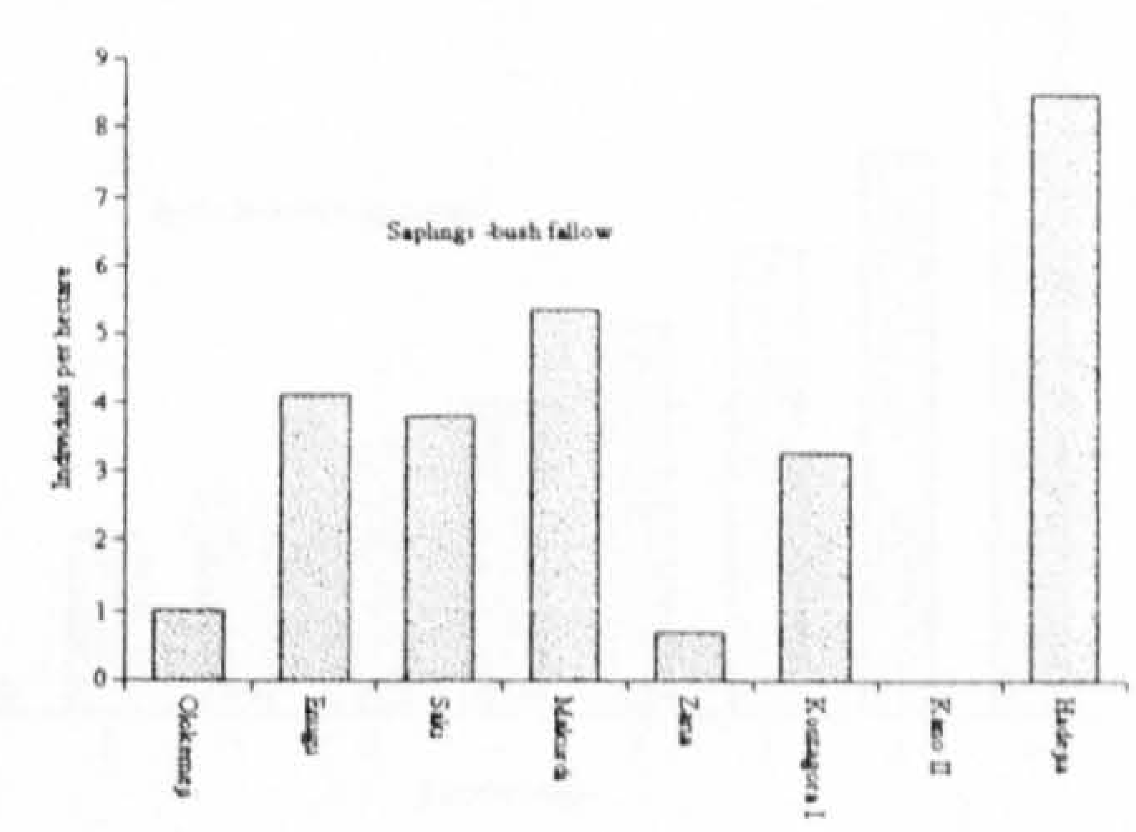
(b) Seedlings regeneration per hectare in the bush fallow



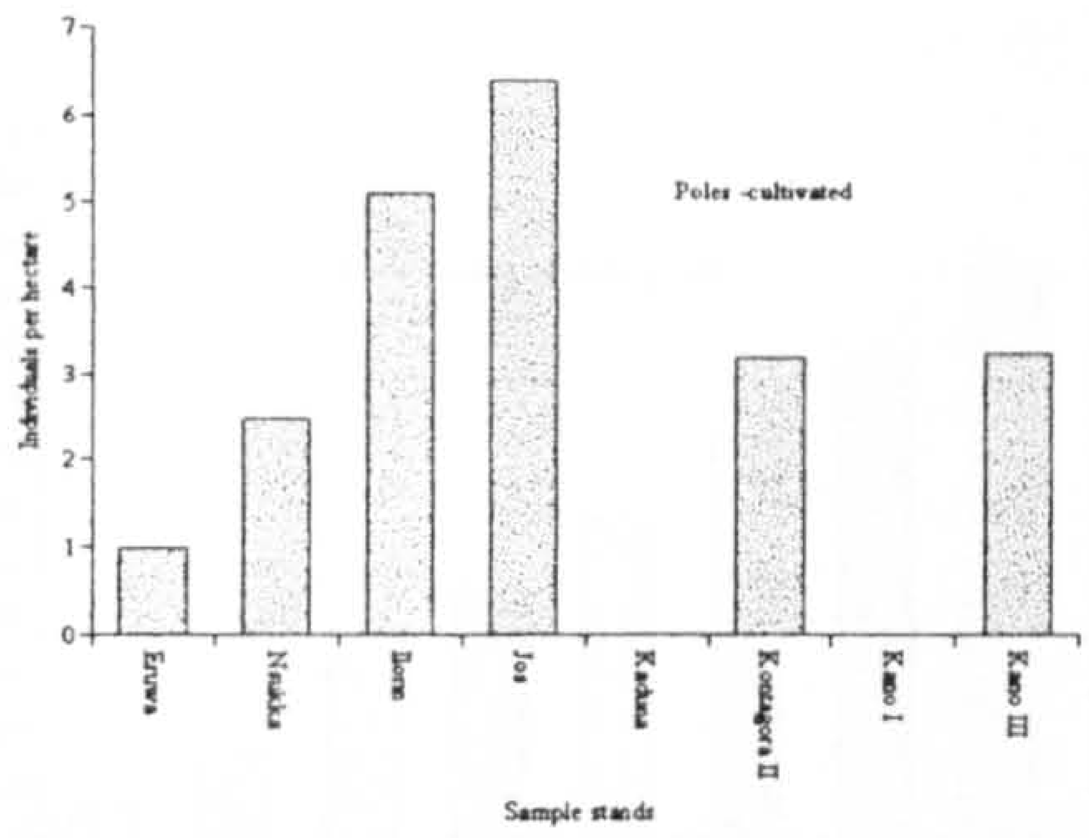
(c) Saplings regeneration per hectare in the cultivated



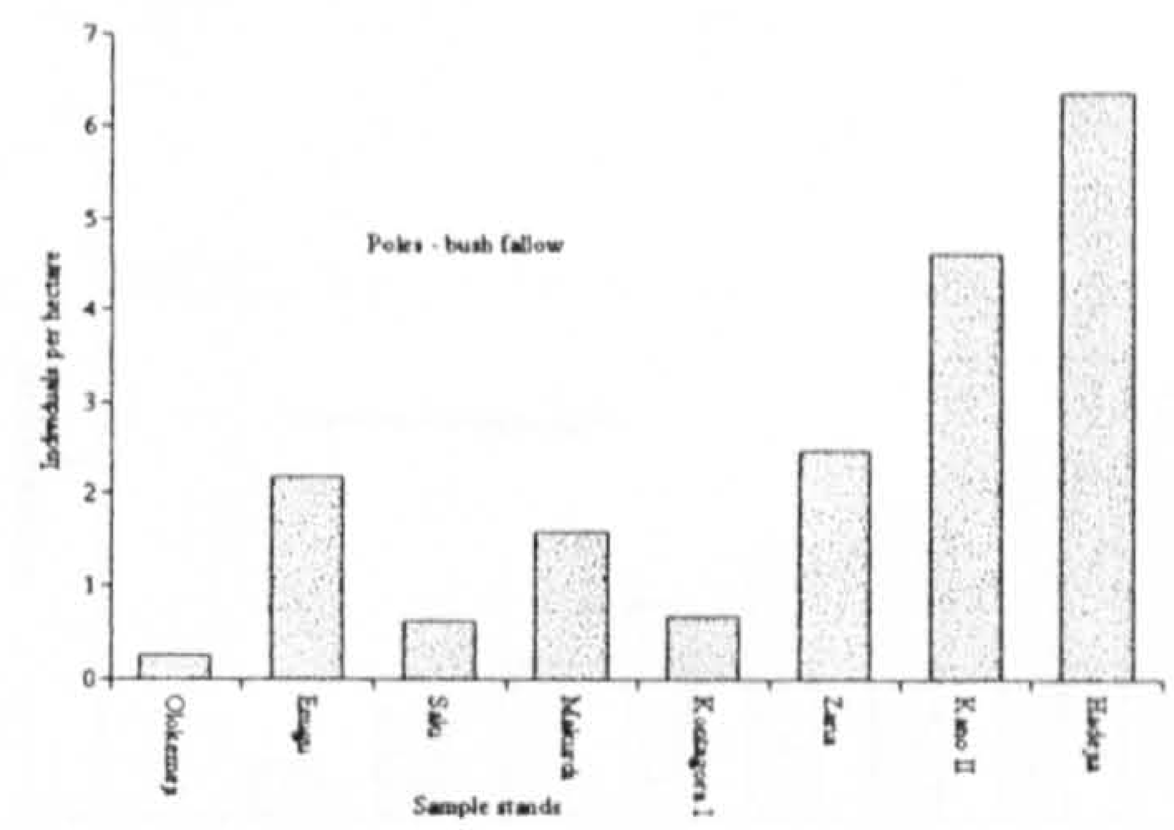
(d) Saplings regeneration per hectare in the bush fallow



(e) Poles regeneration per hectare in the cultivated



(f) Poles regeneration per hectare in the bush fallow

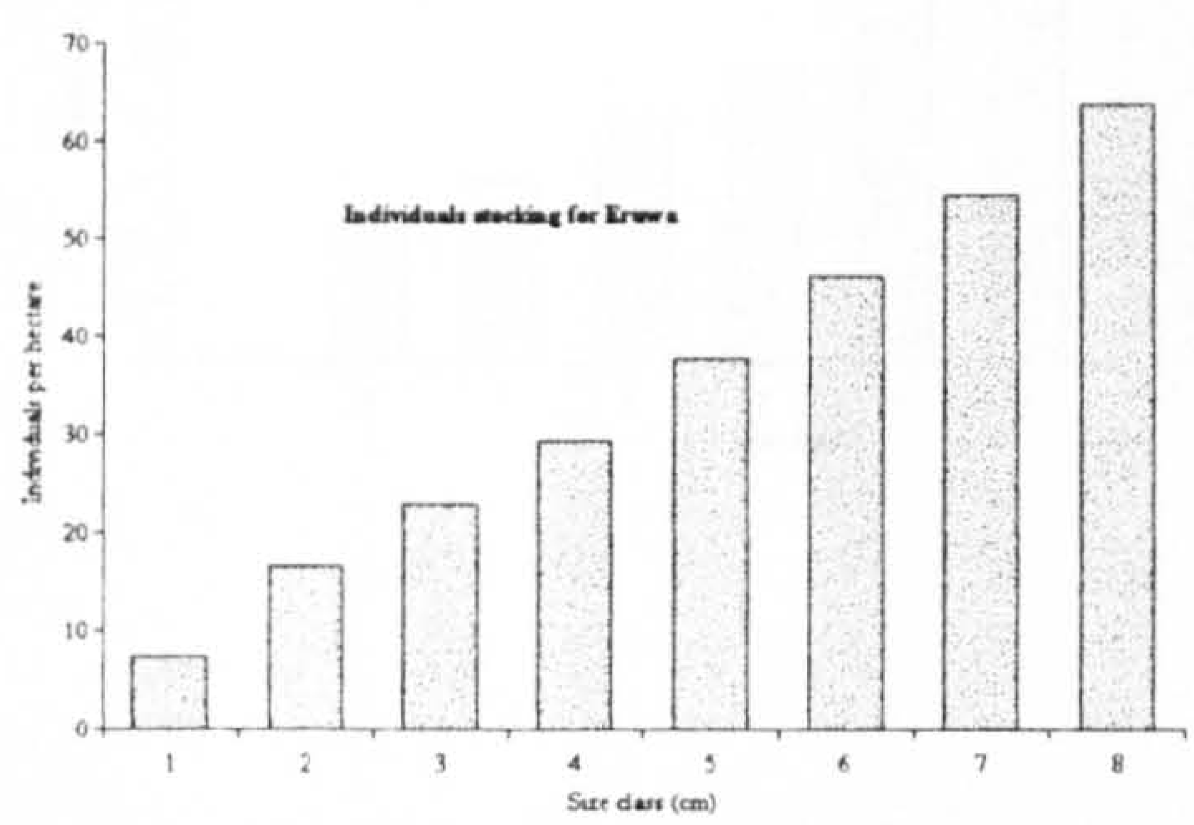


Regeneration number in relation to the whole population

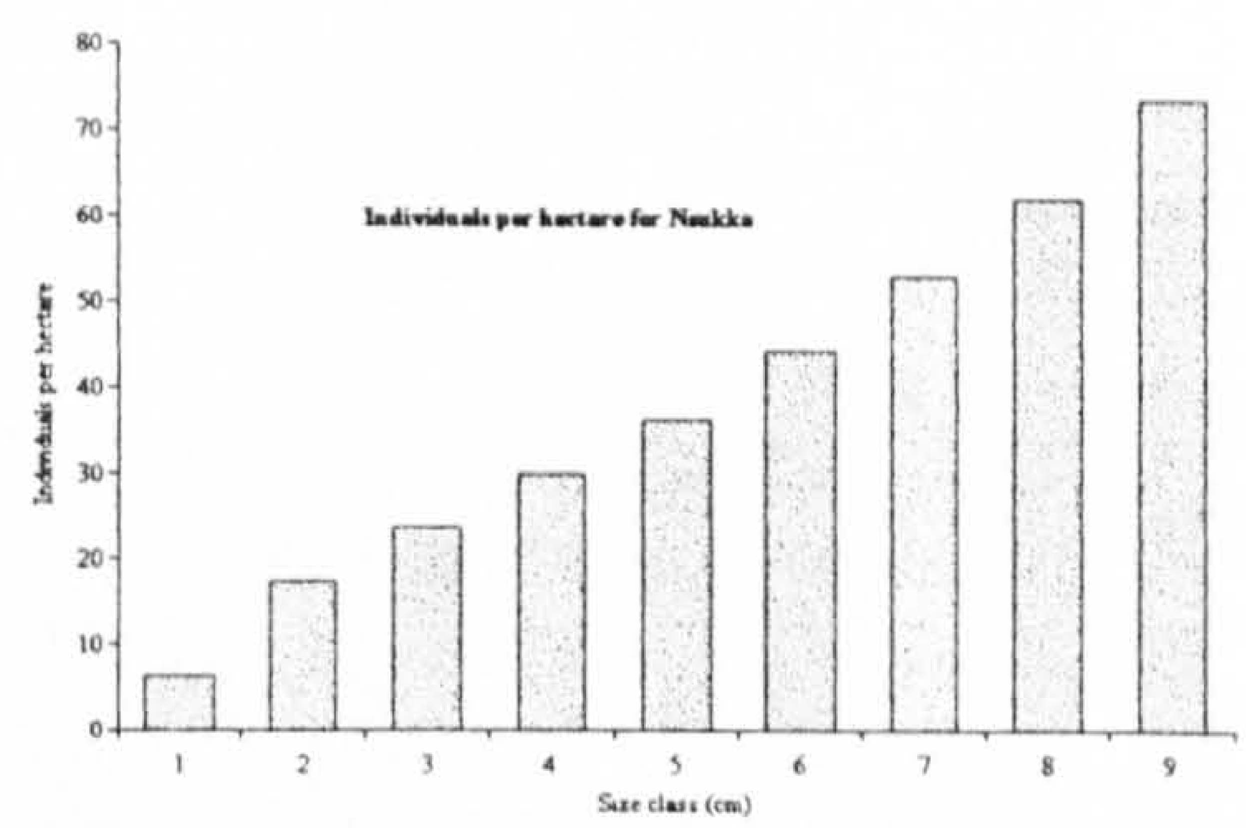
Cultivated land use

Figures 4.15a-g Accumulated stocking of all regeneration categories in the cultivated land use.

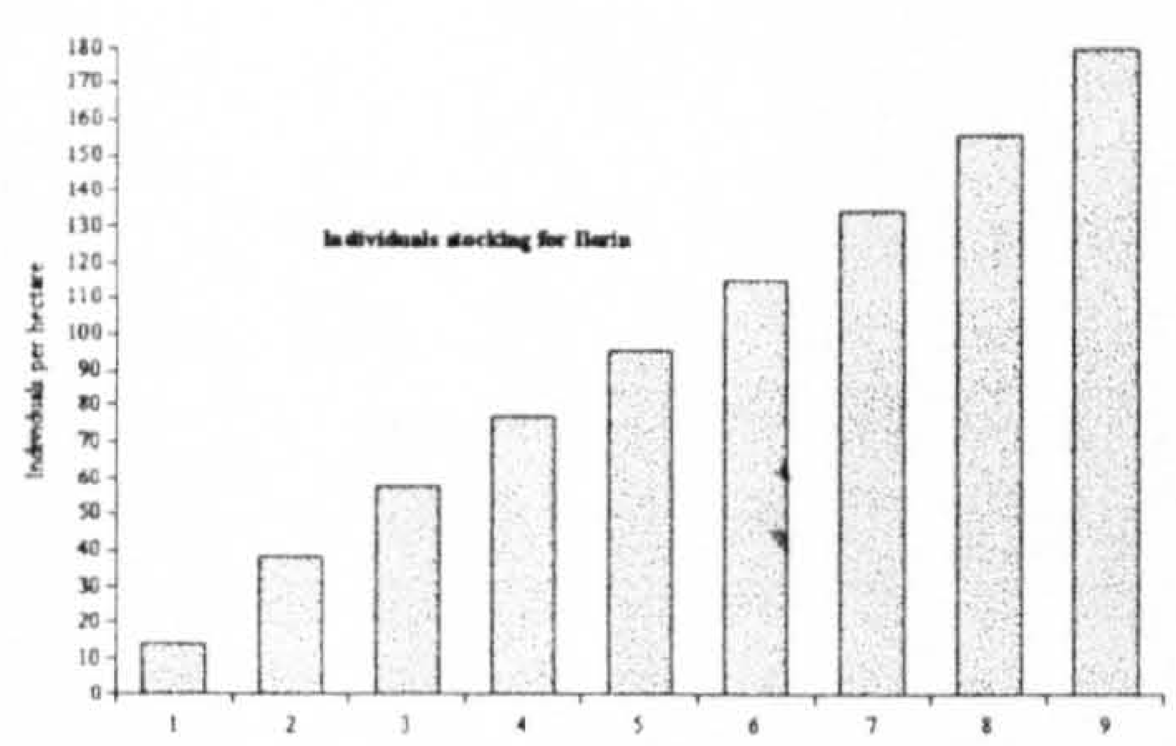
(a) Stocking of regeneration into size class in Eruwa



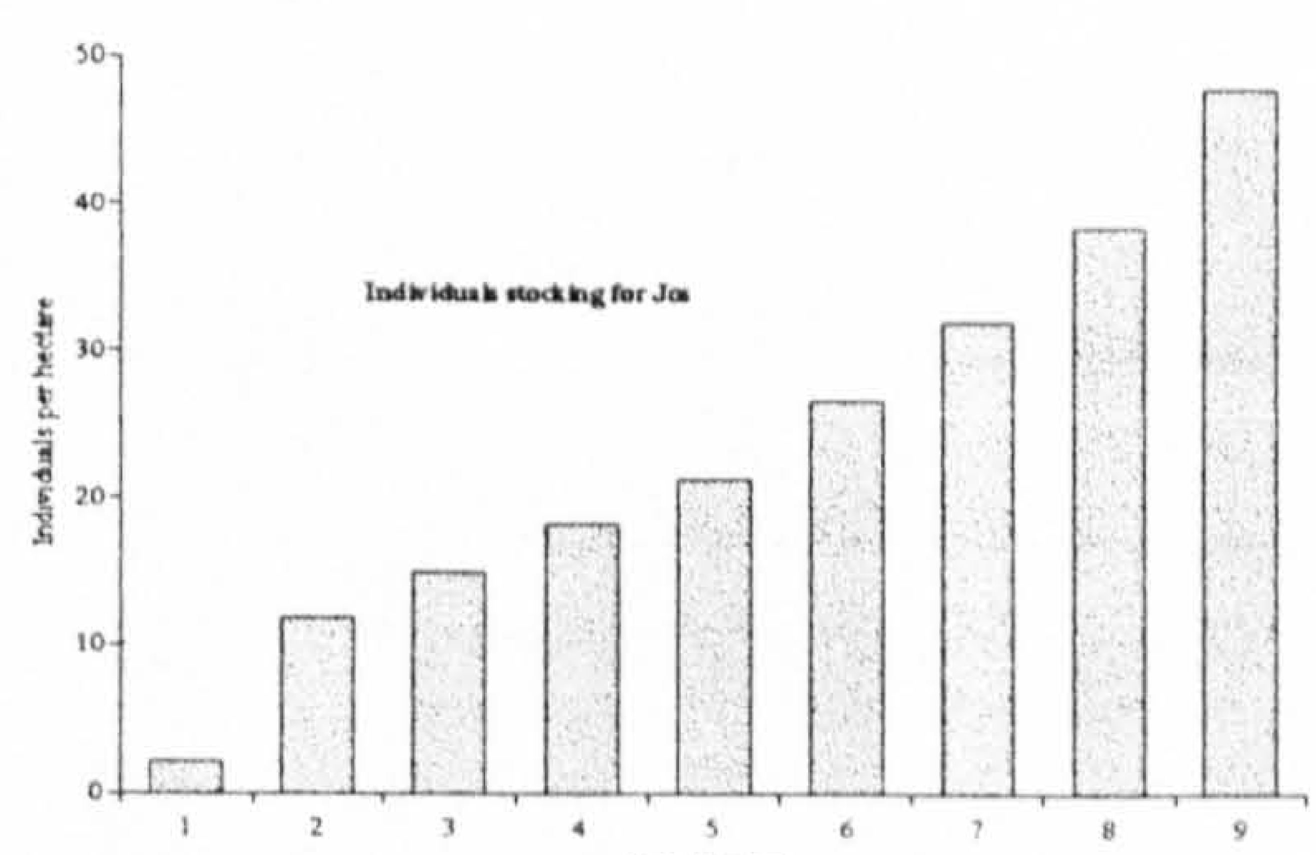
(b) Stocking of regeneration into size classes in Nsukka



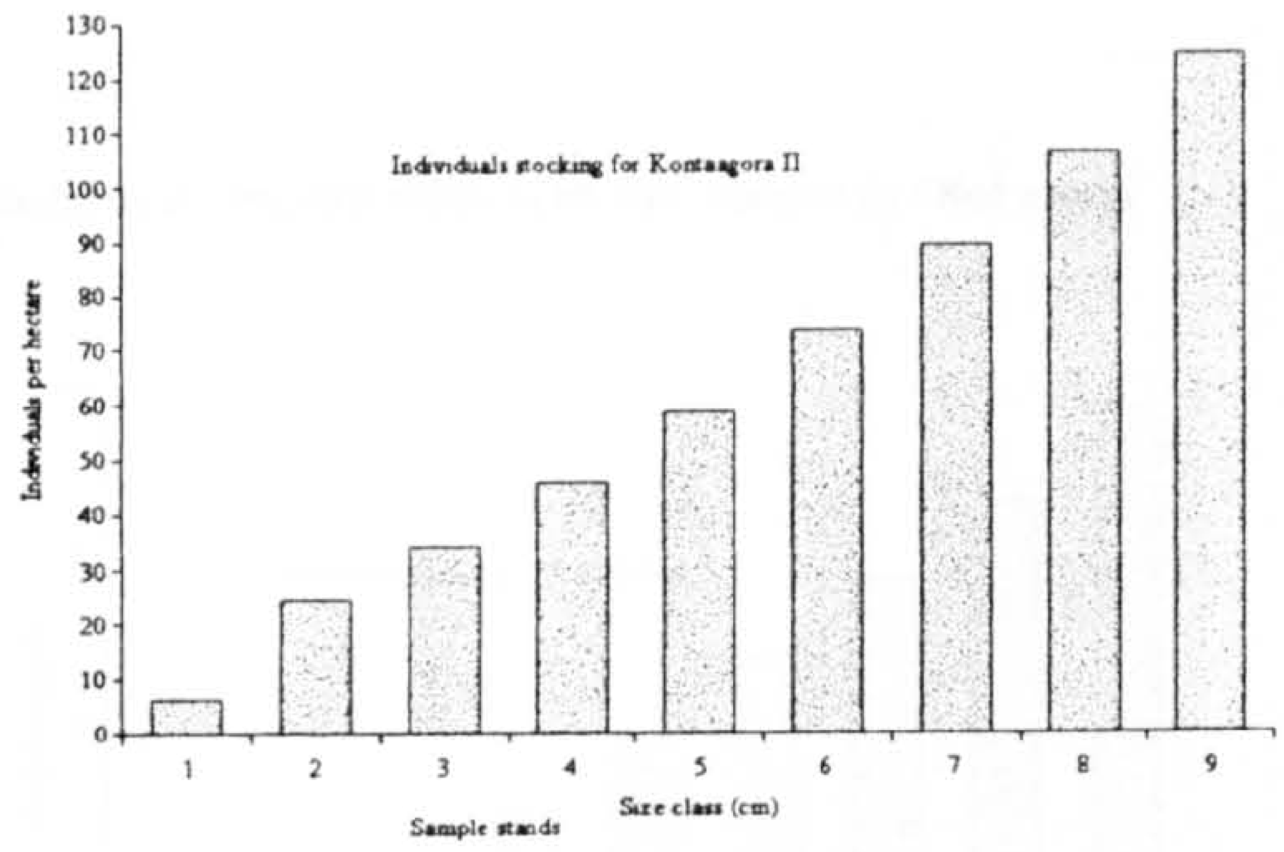
(c) Stocking of regeneration into size class in Ilorin



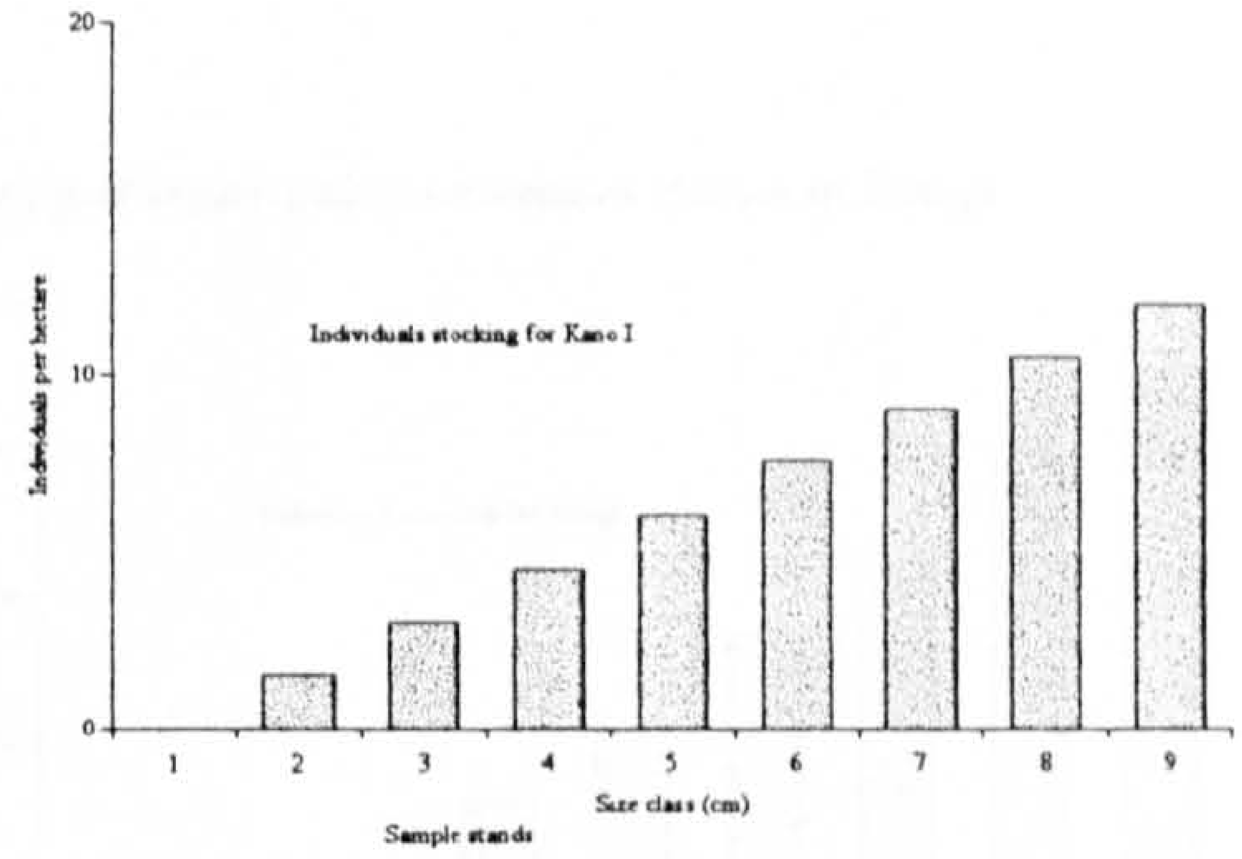
(d) Stocking of regeneration into size classes in Jos



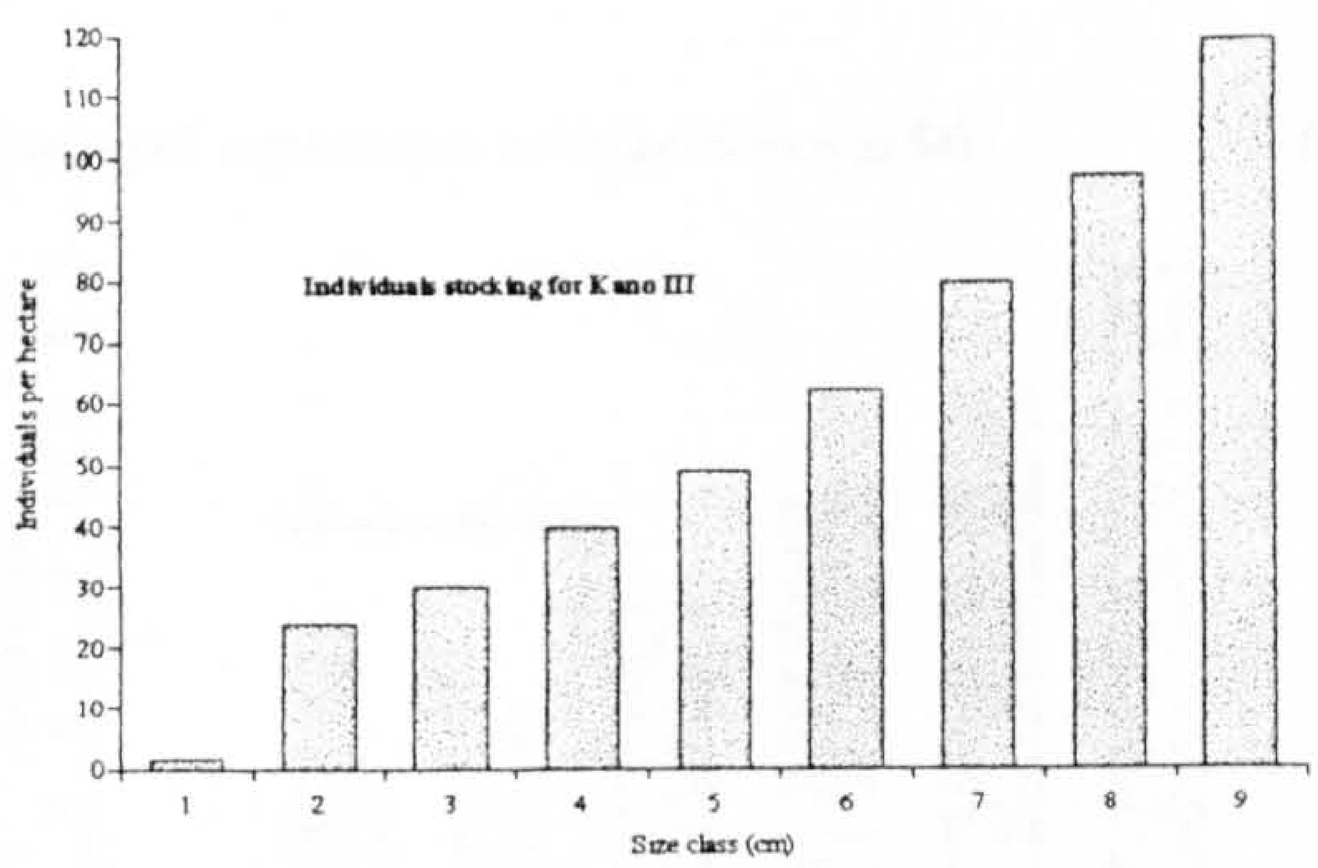
(e) Stocking of regeneration into size class in Kontagora II



(f) Stocking of regeneration into size classes in Kano I



(g) Stocking of regeneration into size classes in Kano III

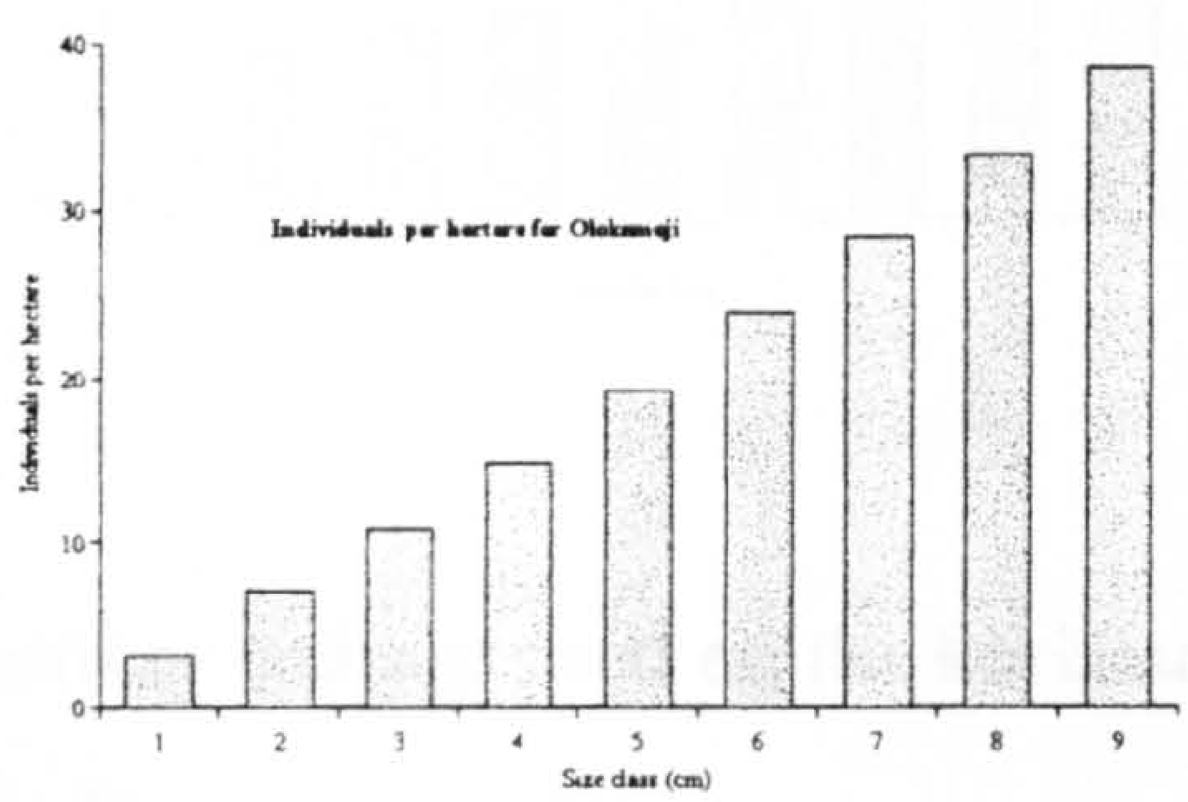


*There was no regeneration for all categoriesin Kaduna

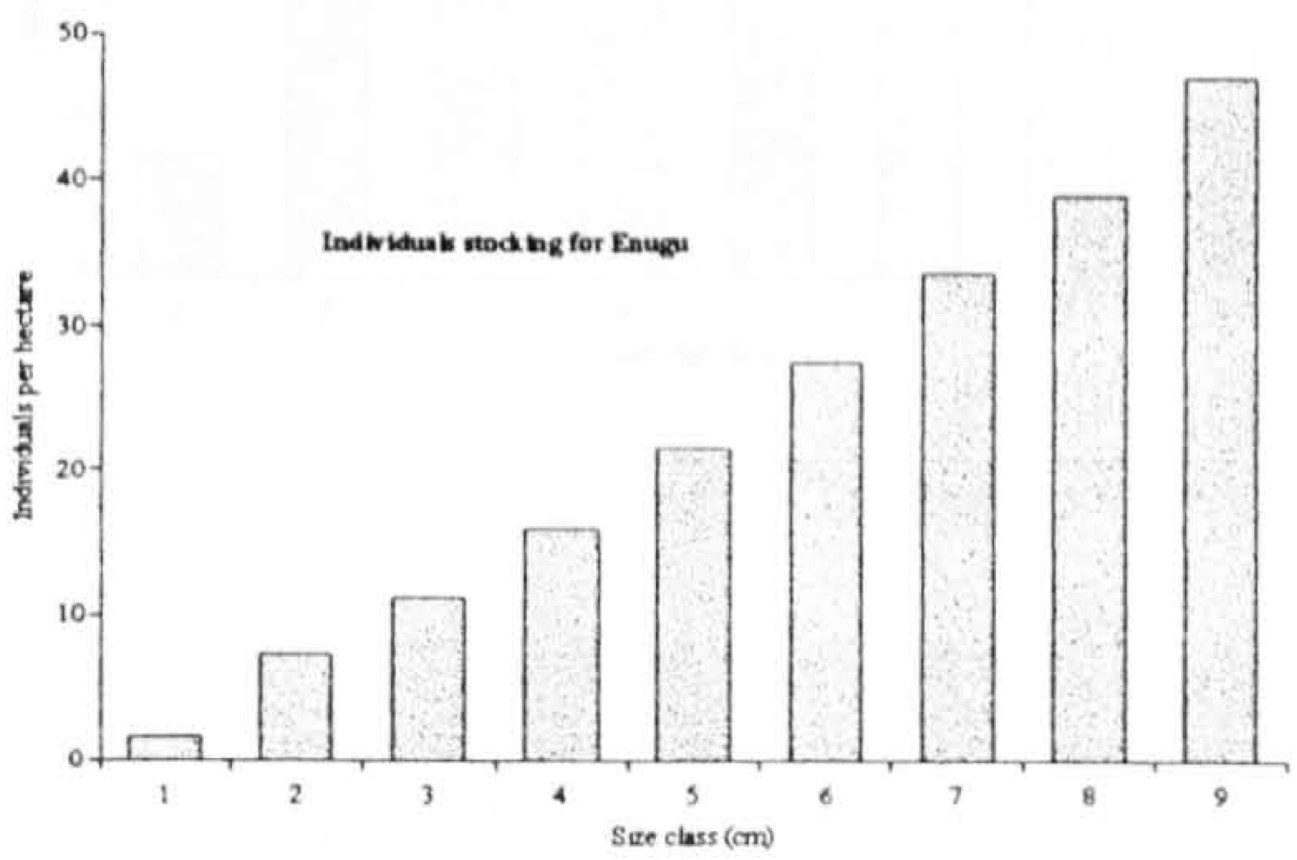
Bush fallow land use

Figures 4.16a-h Accumulated stocking for all regeneration categories in the bush fallow land use.

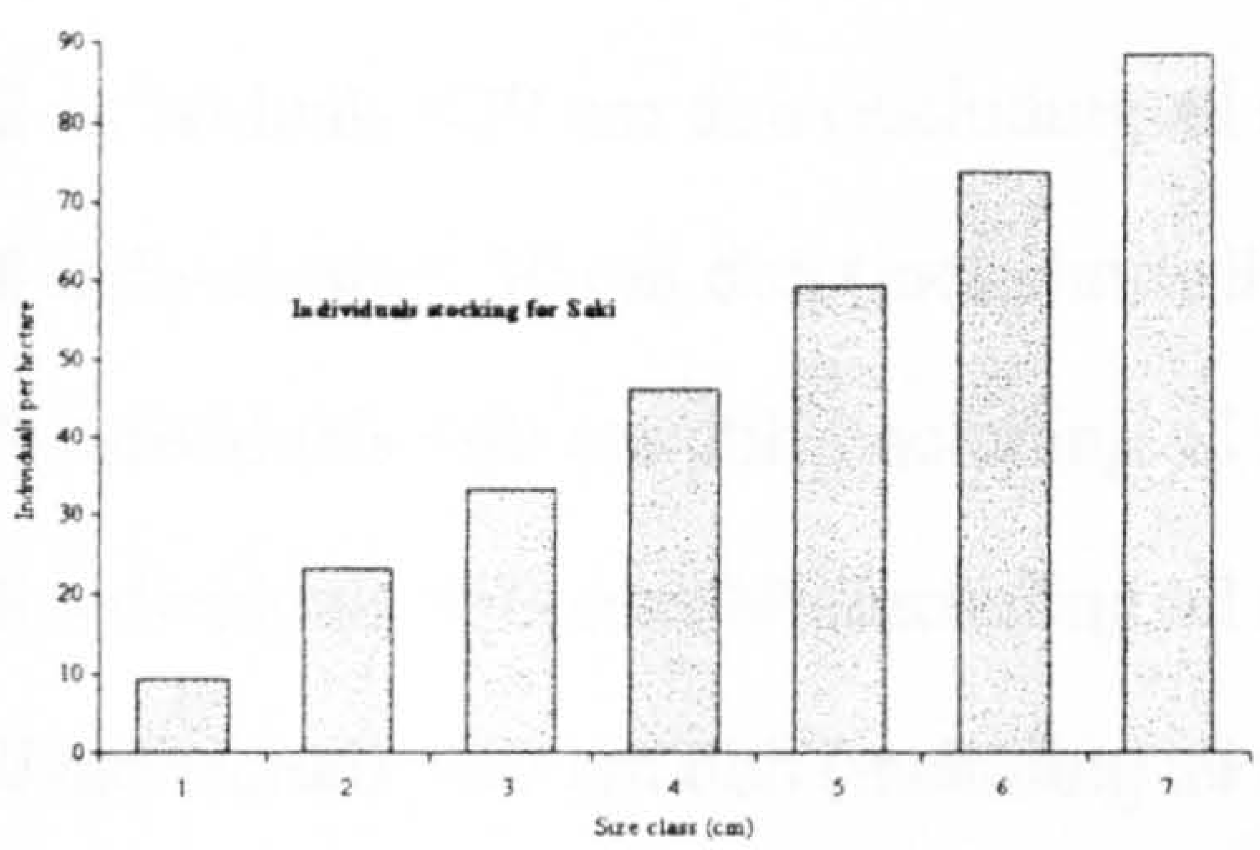
(a) Stocking of regeneration in to size classes in Olokemeji



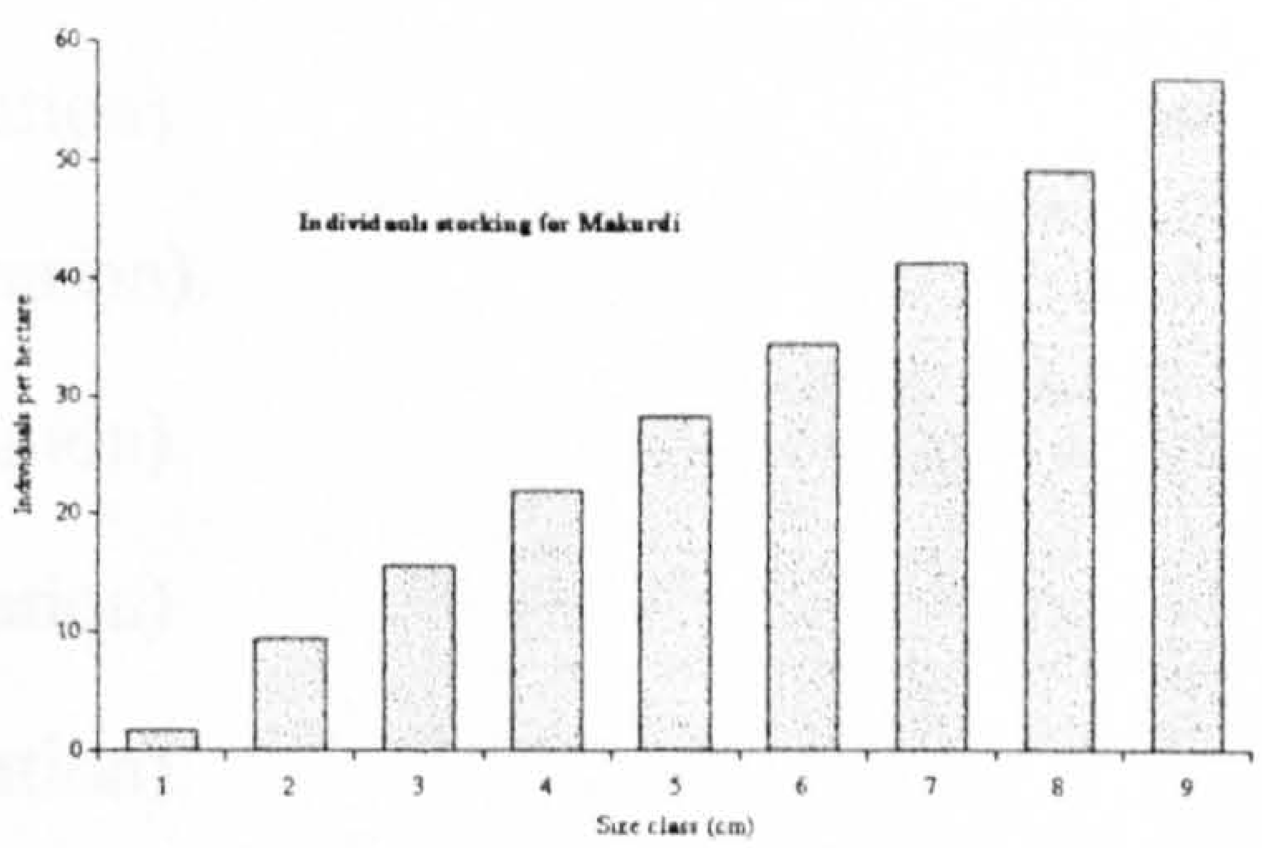
(b)Stocking of regeneration into sizees classes in Enugu



(c) Stocking of regeneration in to size classes in Saki

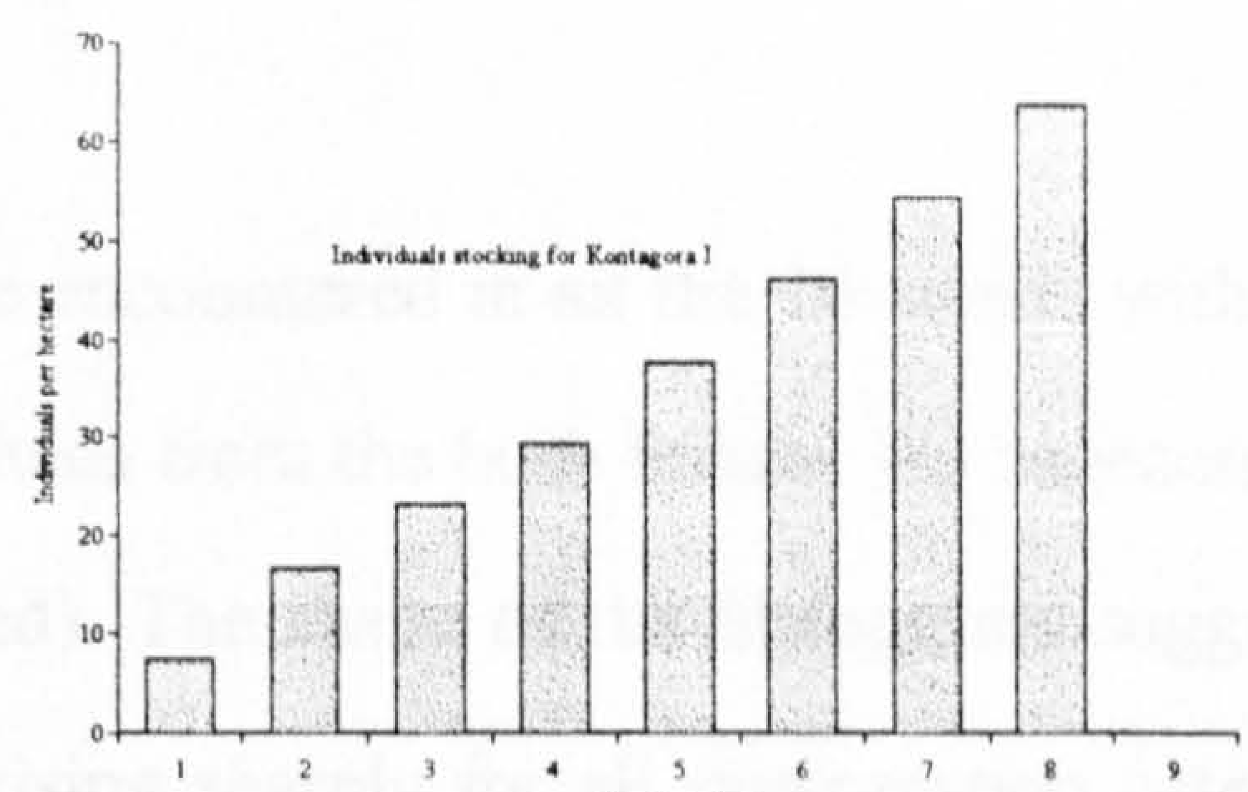


(d) Stocking of regeneration into size classes in Makurdi

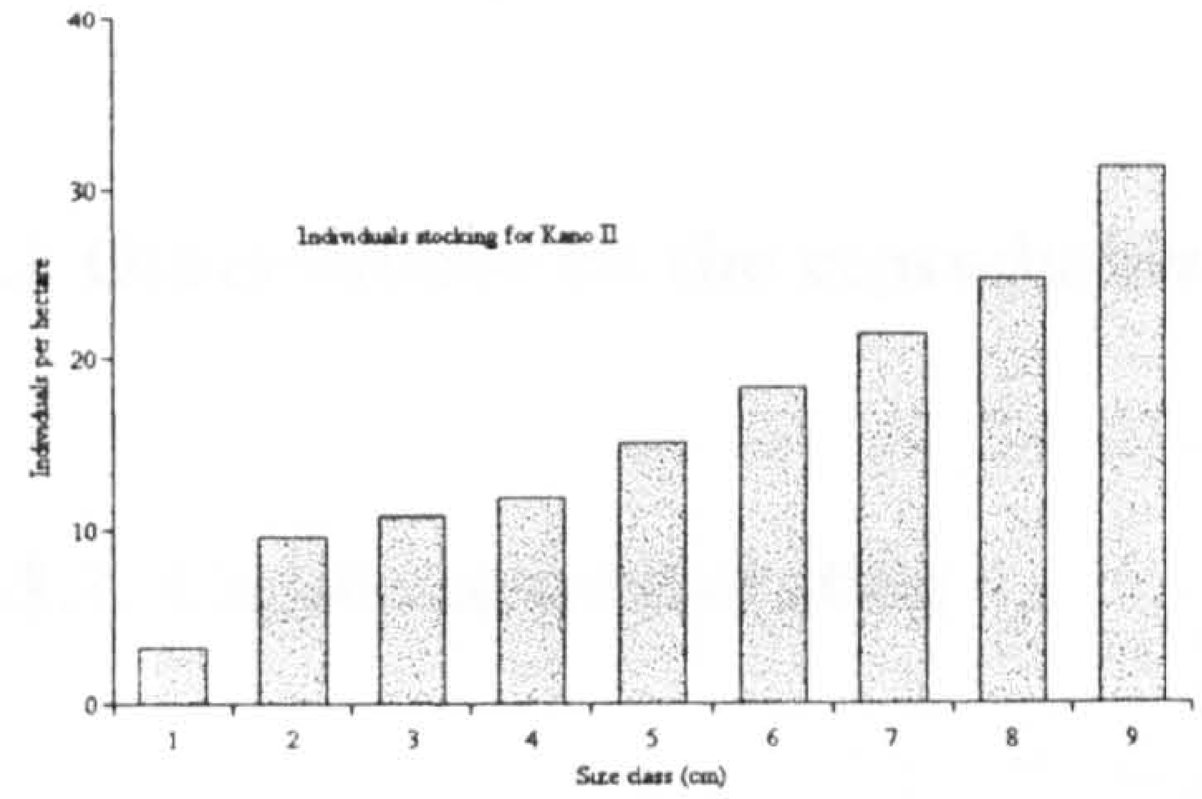


(e) Stocking of regeneration into size classes in Zaria

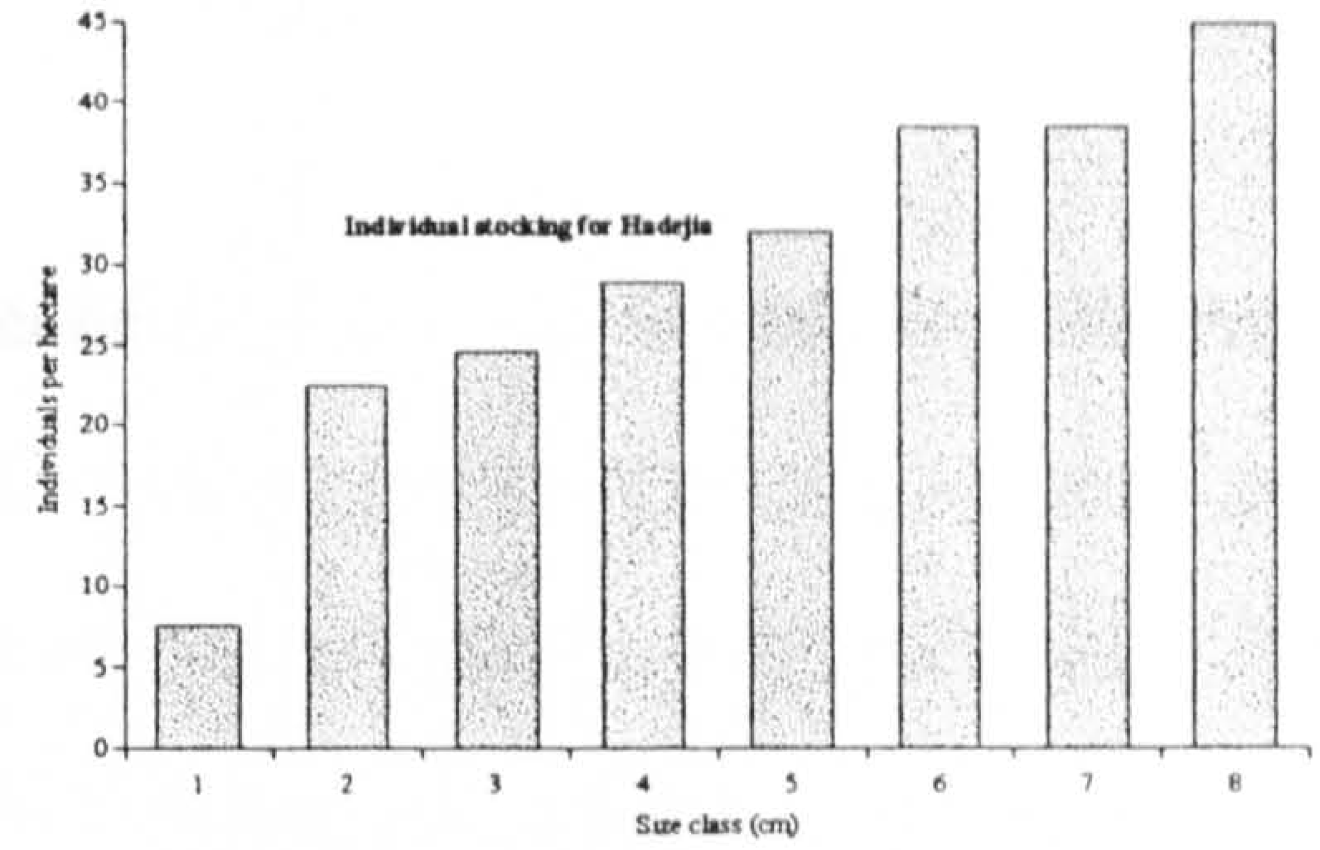
(f) Stocking of regeneration into size classes in Kontagora I



(g) Stocking of regeneration in to size classes in Kano II



(h) Stocking of regeneration into size classes in Hadejia



***Number codings used on the horizontal axis**

1 Seedling regeneration.

2 All regeneration (including seedlings).

3 All individuals <20 cm dbh (including all regeneration)

4 All individuals < 30 cm dbh (including all regeneration).

5 All individuals <40 cm dbh (including all regeneration).

6 All individuals <50 cm dbh (including all regeneration)

7 All individuals <60 cm dbh (including all regeneration).

8 All individuals <70 cm dbh (including all regeneration).

9 All individuals regardless of size.

A total of 288 regenerating individuals were encountered in all the 16 stands with 102 individuals from cultivated land use and 186 individuals from the bush fallow. No regeneration of any category was observed in Kaduna (cultivated). The shape of the histograms suggest a low value for seedling regeneration (class 1) but rising sharply for all regeneration category (size class 2) and the trend continues with increasing size class reaching the peak in category 8 or 9. Accumulated stocking comparisons between the two land use types showed an overall higher stocking in the bush fallow compared with the cultivated (Figures 4.16a-h).

4.3. Reproductive biology

4.3.1 Observations on the reproductive sequence

4.3.1.1. Capitulum maturation

In the reproductive process of *Parkia* it is convenient to differentiate several sequential phases commencing with floral bud initiation and eventually ending in pod maturity (Table 4.29). This phenological cycle from floral bud initiation to pod maturity lasts approximately 135 days in the study area (Table 4.29). Onset of flowering in *Parkia* is recognised by the appearance of tiny greenish spherical inflorescences with bracts and calyx enclosing the floral structures. Progressively the spherical capitulum, becomes enlarged and increasingly swollen until it reaches full size (2-4 cm diameter). At this stage the colour changes from green to light brown (Plates 1a and 2a).

At full development the capitulum turns from brown to maroon (Plate 2), the floral structures are revealed in sequence from proximal to distal, from the nectar secreting region to the staminoidal, ending finally at the hermaphrodite region. Blooming was not consistent or confined to a particular region of the capitulum but increased in frequency from the nectar ring to the hermaphrodite region (Plate 2a). Capitula per group ranged from 2 to 10 in most cases. Flowering in *Parkia* is such that within inflorescence groups capitula units mature in sequential order. Capitula are alternate along the main inflorescence axis with the most distal maturing first (Plate 2a).

4.3.1.2 Floral anthesis (Colour description is subjective)

Floral anthesis begins with a display of the staminate state and lasting 1.5 days to 1.75 days, characterised by bright reddish-yellow coloration and emitting a sweet scent (Table 4.29). Anthesis ends later in the pistillate state when the capitula change from dark-brown to dull brown with an outward black appearance arising from the stigmatic structures (Table 4.29, Plate 2b). If the capitulum remained beyond this stage, fertilisation was assumed to have occurred otherwise the capitula abscised. Successful pollination and fertilisation (cross/self) leads to a complete dull to dirty brown capitulum coloration after 3-4 days (Table 4.29). Without fertilisation, withering of the individual floral structures results, with the receptacle becoming highly visible (Table 4.29). Withering commences from proximal to distal region and continues until the entire receptacle is naked and later dries up. The receptacle then abscises from the peduncle and later the peduncle itself falls off the twig.

4.3.1.3 Fruit development

Podding commences 3-5 days after the pistillate phase, irrespective of capitula withering intensity or pattern (Plate 4). Instances of complete absence of withering and of partial and complete withering were observed (Plate 5). Stages in pod development involve pod elongation, seed formation, pod and seed development and ultimately pod maturity. In the Saki population, the young pod has pinkish-green coloration at the proximal end and a light green coloration at the distal end. With subsequent pod development the pinkish base disappears and a uniform green colour is apparent (Plate 5).

Pod elongation commences 4-6 days after podding (approximately 35 days after flowering). Seed initiation starts later: 7-10 days after pod emergence, as dark

Plate 4.1 Initial stage of capitulum development in *Parkia biglobosa*

spots along the entire pod length. The entire pod is green and fleshy at this stage and further development leads to a deep green appearance (Plate 6). Subsequent pod development results in a colour change from deep green to light brown or grey. Fully matured pods become ash grey to deep brown or reddish brown (Plate 7). There was no difference in the duration of whole phenological cycle with diameter class, mean deviation of 135 days in both the small and large tree sizes. A summary of the mean duration of component phases is given in Table 4.29.

Table 4.29 Duration (days) of flowering and fruiting phases in *Parkia biglobosa* at Saki population in Nigeria

	Treatments					
Reproductive phases	T1	T2	T3	T4	T5	Mean duration (days) ± s.d
Floral bud initiation and full development	11.25	11.0	11.83	11.75	11.25	11.41 ± 0.35
Swollen capitulm	3.54	3.32	3.10	2.85	3.23	3.21 ± 0.25
Expanded floral structures	2.25	2.50	1.75	2.0	2.50	2.2 ± 0.33
Staminate anthesis	1.75	1.63	1.63	1.25	1.50	1.55 ± 0.19
Pistillate anthesis	2.50	2.00	2.25	2.00	1.75	2.1 ± 0.28
Late pistillate anthesis	2.25	2.25	2.00	2.25	2.00	2.15 ± 0.14
Withering of the floral structures	3.25	3.50	3.25	3.50	3.75	3.45 ± 0.21
Pod emergence /capitulum abortion	3.63	3.50	3.62	3.38	3.62	3.55 ± 0.11
Seed formation and pod elongation	7.85	8.34	8.50	9.10	9.55	8.67 ± 0.66
Pod development and maturity	96.25	96.75	98.0	96.50	94.77	96.88 ± 0.77

4.3.2 Observations on inflorescence visitors

Most diurnal floral visitors including bees, ants and butterflies were observed during the staminate and early pistillate phases. The most commonly observed were honey bees (*Apis mellifera adansonii* Laterille; Hymenoptera, Apidae), wasps (Sphegidae) ants (Formicidae) and butterflies (*Eurema* spp). Ants

Plate 4.2a A group of fully mature capitula in different stages of the reproductive cycle

Plate 4.2b Arrow points to capitulum in stigmatic state

observed were few, crawling between the flexible peduncle and the capitulum, possibly feeding on floral gum exudates. Ants were rarely observed on the hermaphrodite region of the capitulum.

The floral visitors' foraging behaviour suggests some crown height preferences. Bees and butterflies were actively observed at the lower and middle crown heights while wasps were more frequently evident in the upper crowns. The sun rose above the horizon at about 07.30 hours while bee visitation started at about 06.30 hours, increasing rapidly to a peak at about 08.30 hours. Between 09.00 hours and 13.00 hours a general decline in the diurnal visitor population was apparent. At about 18.00-19.00 hours activity revived but at a lower level and lasted for only short period. Wasps and butterflies were conspicuous from about 07.00 hours to 08.30 hours. Their visits were of short duration and sporadic in nature with frequent flights from one tree to another.

Honey bees had the longest foraging period and visits were mainly to the nectar secreting region of each capitulum. About 1-3 minutes was spent on each capitulum before moving (within or between trees). Wasps and butterflies moved rapidly within crowns and between trees without showing any defined foraging behaviour. Duration of contact with the capitulum was short.

The main nocturnal visitors observed at *Parkia* capitula between 17.45 hours and 20.30 hours were bats. Foraging activities were restricted to the middle and upper tree crowns and rarely extended below 5 metres. Light conditions prevented detailed observation of foraging behaviour on different capitula. It is, however, likely that activities will be similar to those reported by Baker & Harris (1957,1959) and Hopkins (1983). Bat foraging sometimes resulted in capitulum abscission from the twigs. The duration of the visit to each capitulum was short. Inter-tree flight was rapid.

4.3.3 The effects of restricted accessibility to pollinators

Seven parameters were assessed in this study:

- number of aborted capitula.
- percentage abortion in relation to total number of screened capitula.
- number of podded capitula.
- pod yield.
- seed per pod.
- pod length.
- pod diameter.

All parameters were examined for apparent normality and transformation applied where necessary (Table 4.30)

Table 4.30 Parameters assessed in *Parkia biglobosa* reproductive study and transformation applied

Parameters	Abortion number	Percentage abortion	Podded capitula	Pod yield	Seed yield	Pod length	Pod diameter
Appearance of frequency of distribution.	Positive skew	Positive skew	symmetrical	symmetrical	symmetrical	symmetrical	symmetrical
Transformation used	Square root	Arcsine	not applicable	not applicable	not applicable	not applicable	not applicable
Recorded variable	percentage	qualitative	integer	integer	integer	continuous	continuous

The number of aborted capitula represents a percentage variable and deviates from a normality and was square root transformed. Abortion percentage is qualitative variable which deviates from normal distribution and was back transformed (arcsine). Frequency distribution for other parameters were symmetrical. All parameters were subjected to statistical analysis (ANOVAs) to check if there were first and second order interactions but there was none (Table 4.31).

Plate 4.3 One month old developing pod in *Parkia biglobosa*

Plate 4.4 *Parkia biglobosa* pod nearing maturity

Plate 4.5 Fully mature pod of *Parkia biglobosa* at harvesting

Table 4.31 Summary of analysis of variance of all the parameters investigated

Parameters	Aborted capitula (transformed value)	Percentage abortion (transformed value)	Podded capitula	Pod yield	Seeds per pod	Pod length	Pod diameter
Main factors :							
Tree size (S)	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Crown level (L)	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Treatment (T)	*	*	*	*	*	*	n.s
Interactions:							
S x L	n.s	n.s	n.s	n.s	n.s	n.s	n.s
S x T	n.s	n.s	n.s	n.s	n.s	n.s	n.s
L x T	n.s	n.s	n.s	n.s	n.s	n.s	n.s
S x L x T	n.s	n.s	n.s	n.s	n.s	n.s	n.s
ANOVA F							
ratio* n.s							

*P < 0.05, n.s. not significant

Closer examination of treatments effects through Tukey's pairwise test indicated that capitula accessibility either overnight (T_3) or during the day (T_4) influenced the number of aborted capitula when compared with open pollination (Table 4.32). Both completely inaccessible capitula (T_2) and capitula inaccessibility overnight (T_3) significantly increased the percentage abortion when compared with the assisted pollinated (T_5). All the other treatments differed significantly from the assisted pollinated capitula for number of podded capitula except inaccessible capitula during the day (T_4). Treatments had the most significant effects on pod production. The control (T_1) had the highest number of pods and differed significantly from all the other treatments ($P < 0.05$) while the other treatments also differed significantly from the assisted pollinated. Treatments had no significant effect on number of seed set per pod except between treatments (T_3) and (T_5) and (T_4) and (T_5). All the other treatments differed significantly from the assisted pollinated capitula in pod length except the control (Table 4.32)

Table 4.32 Summary of Tukey's pairwise treatments comparisons for all the parameters

Parameters	Aborted capitula	Percentage abortion	No of podded capitula	No of pods	Seeds per pod	Pod length
Treatments comparisons						
I and II	n.s	n.s	n.s	*	n.s	n.s
I and III	*	n.s	n.s	*	n.s	n.s
I and IV	*	n.s	n.s	*	n.s	n.s
I and V	n.s	n.s	*	*	n.s	n.s
II and III	n.s	n.s	n.s	n.s	n.s	n.s
II and IV	n.s	n.s	n.s	n.s	n.s	n.s
II and V	n.s	*	*	*	n.s	*
III and IV	n.s	n.s	n.s	n.s	n.s	n.s
III and V	*	*	*	*	*	*
IV and V	n.s	n.s	n.s	*	*	*

*$P < 0.05$, n.s = not significant.

Treatments

T_1 - control, capitula open to all pollinators.

T_2 - capitula completely inaccessible to pollinators.

T_3 - capitula inaccessible overnight to pollinators (18.00 - 07.00 hours).

T_4 - capitula inaccessible during the day to pollinators (06.00 hours -19.00 hours).

T_5 - assisted pollination (self/cross).

4.3.3.2 Abortion levels

From the 142 capitula monitored, 46 individuals (32.40%) aborted. The number of aborted capitula per treatment ranged from 12 out of (35) in the control (T_1), 7 out of 28 in the completely inaccessible capitula (T_2), 4 out of (26) in the capitula inaccessible overnight (T_3) 11 out of 30 in the capitula inaccessible during the day (T_4) and 12 out of (23) in the assisted treatment (T_5). The number of aborted capitula comparisons between the crown heights showed that the upper crown (>5 m crown height) had more aborted capitula compared with the lower crown level (3-5 m crown height) while, between tree sizes similar number were observed for number of aborted capitula.

4.3.3.3 Pods production and character

Out of the 142 capitula monitored 96 (67%.) developed to the fruiting stage. Comparison between the two crown levels indicated more podded capitula from the (>5 m) crown height compared with (3-5 m) crown height. Comparisons between the two tree size classes showed higher number of pods in the (>40 cm) tree diameter class compared with the (10-39 cm) tree diameter class. Regression relationship between observed number of podded capitula and the total number of pods obtained for all treatments was significant ($n = 96$, $r^2 = 0.492$, $P < 0.05$). The regression relationship is indicated as: Podded capitula = 0.914 + 0.954 Pods.

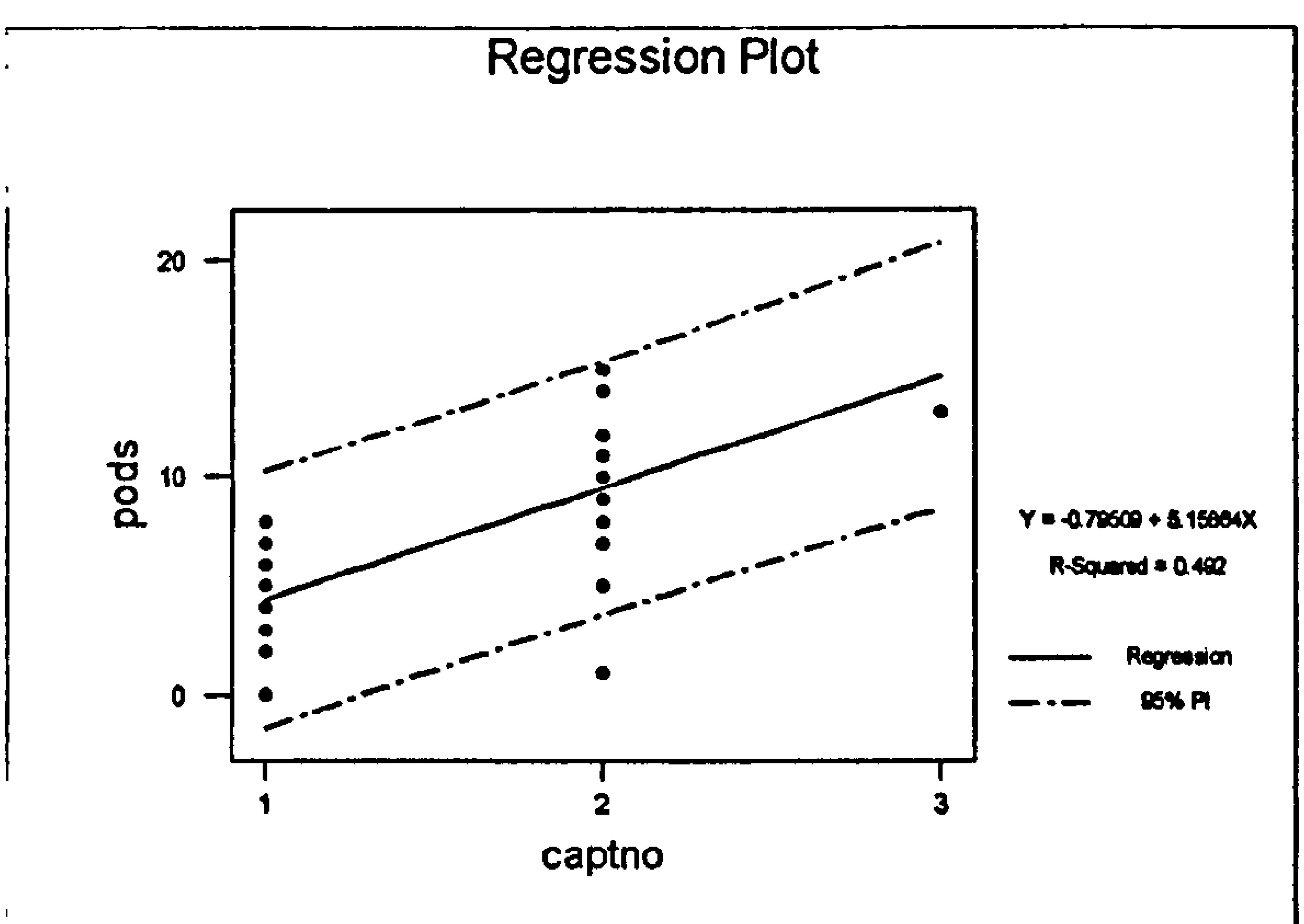


Figure 4.17 Regression relationship between podded capitula and number of pods

*captno = (number of podded capitula)

A total of 473 pods were obtained from the 96 podded capitula (4.93 pods per capitulum). Calculated fruiting efficiency was 20.30% i.e. (number of podded capitula/total of pods). The control treatment (T_1) had the highest (capitulum/pod) ratio with 141 pods from 23 capitula (6.13 pods capitulum^{-1}) (Table 4.33). while, the lowest was from the assisted pollinated treatment with 26 pods from 11 capitula (2.36 pods per capitulum). Pod yield in relation to crown heights showed that the (> 5 m crown height) had more number of pods compared with the lower crown. Comparisons between the tree sizes indicated more pods from the (10-39 cm) tree size class compared with the (> 40 cm) size class (Table 4.33).

Table 4.33 Numbers of pod set in relation to tree size classes, crown heights and pollination methods in *Parkia biglobosa* at Saki, Nigeria 1995.

		Treatments				
Tree size class (cm)	Crown heights (m)	T_1	T_2	T_3	T_4	T_5
S_1 (10-39)	C_1 (3-5)	36	27	29	32	5
	C_2 (> 5)	42	24	30	31	5
S_2 (>40)	C_1 (3-5)	34	21	17	19	7
	C_2 (> 5)	29	23	21	32	9
Cumulative pod yield		141	95	97	114	26

Treatments

T_1 - control, capitula open to all pollinators.

T_2 - completely inaccessible capitula.

T_3 - capitula inaccessible overnight to pollinators 18.00 - 07.00 hours).

T_4 - capitula inaccessible during the to pollinators (06.00 hours -19.00 hours)

T_5 - assisted pollinated (cross/self)

The mean pod set per treatment ranged from 2.17 in the assisted pollinated capitula (T_5) to 11.92 individuals in the control (T_1). The 141 pods from 23 podded capitula in the control treatment (6.13 pods capitulum^{-1}) accounted for .(29.94%) of the total pod production. The completely inaccessible capitula (T_2) had a total number of 95 pods (20.08%) from 21 capitula (4.52 pods capitulum^{-1}). The inaccessible capitula overnight (T_3) had 97 pods (20.51%) from 22 capitula (4.41 pods capitulum^{-1}). Capitula inaccessible during the day (T_4) produced 114 pods (24.10%) from 19 capitula (6.0 pods capitulum^{-1}). The assisted pollinated capitula (T_5) produced 26 pods (5.50%) from 11 capitula (2.36 pods capitulum^{-1}) (Table 4.34).

The breakdown for the assisted pollinated treatment on the basis of pollen sources indicated that selfing of capitula from the same tree had a total of 5 pods (1.66 ± 0.67 pods). Crossing with neighbouring capitula gave 7 pods (2.33 ± 0.33 pods) while distant outcrossing between capitula produced 14 pods (2.33 ± 0.37 pods). Index of Self-incompatibility (ISI) (the pod set ratio of selfing divided by pod set of outcrossing (near and far crosses) : (Zapata & Arroyo, 1978; Tybirk, 1993) calculated for assisted pollinated only in this experiment was 0.24. The breakdown for the assisted pollinated treatment by pollen sources is presented below (Table 4.35). The more closer the capitula the more likely the incompatibility.

Table 4.34 *Parkia biglobosa:* mean number of pods set treatment at Saki, Nigeria in 1995

Treatments	Number of pod set (mean ± se)
Control (T_1)	11.92 ± 0.77
Completely inaccessible capitula (T_2)	7.83 ± 0.78
Capitula inaccessible overnight (T_3)	8.08 ± 0.65
Capitula inaccessible during the day (T_4)	8.58 ± 1.01
Assisted pollination (T_5)	2.17 ± 0.34

Table 4.35 Breakdown of assisted pollinated treatment by source of pollen

Breakdown by source of pollen	Mean pod by pollen source
Within same tree	1.66 ± 0.67
Neighbouring tree (within population)	2.33 ± 0.33
Distant tree (outcrossing)	2.33 ± 0.37

4.3.3.4 Seed production

A total of 7667 seeds were obtained from the 473 pods (16.21 seeds pod^{-1}). However number of seeds per pod ranged from 6 to 25 for individuals. The frequency distribution of seeds per pod indicated that pod with 18 seeds had the highest frequency of occurrence while pods with less than 6 seeds or more than 25 seeds were least encountered (Figure 4.18). The unimodal distribution of number of seeds per treatment was between 11.67 and 17.65 seeds. The highest number of seeds per treatment was obtained in the capitula inaccessible during the day (T_4) while, the lowest number was from the assisted pollinated (T_5). The distribution of number of seeds per pod is indicated below (Figure 4.18).

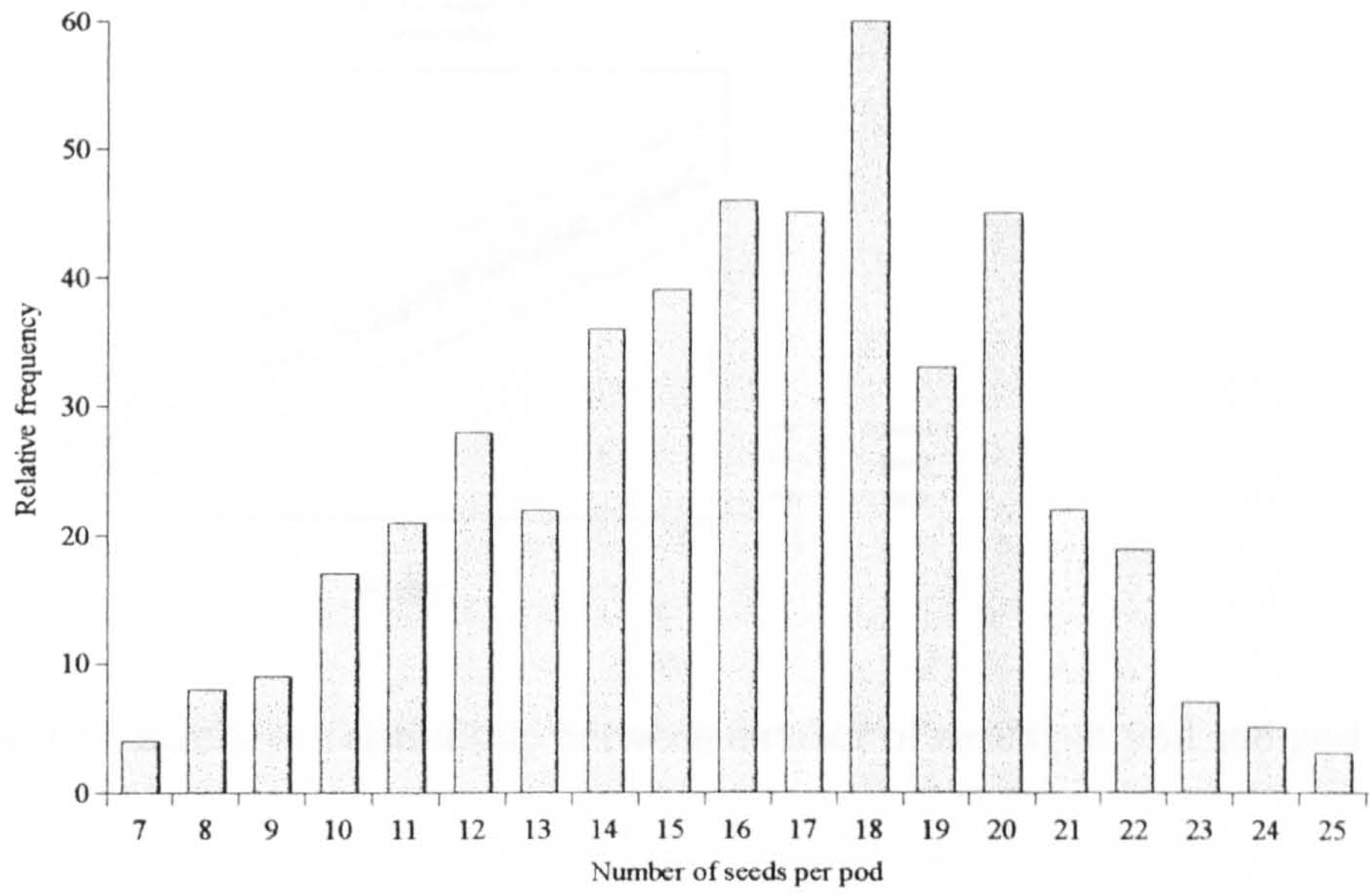


Figure 4.18 Frequency distribution of number of seeds per pod in *Parkia biglobosa* at Saki, Nigeria.

Pod length and diameter

The mean pod length per treatment ranged from 15.33 ± 0.21 cm to 23.26 ± 1.17 cm in assisted pollinated (T_5) capitula and capitula inaccessible during the (T_4) respectively. However the individual pod length ranged from 14.90 cm to 26.06 centimetres. Unit space per seed in the pod showed that each seed occupies approximately 1.3 cm. Pod length and number of seed set per pod were positively correlated and significant (n= 473, r^2 = 0.739, $P < 0.05$) (Figure 4.19). The regression relationship indicates: Seeds no = 2.03 + 0.662 Pod length.

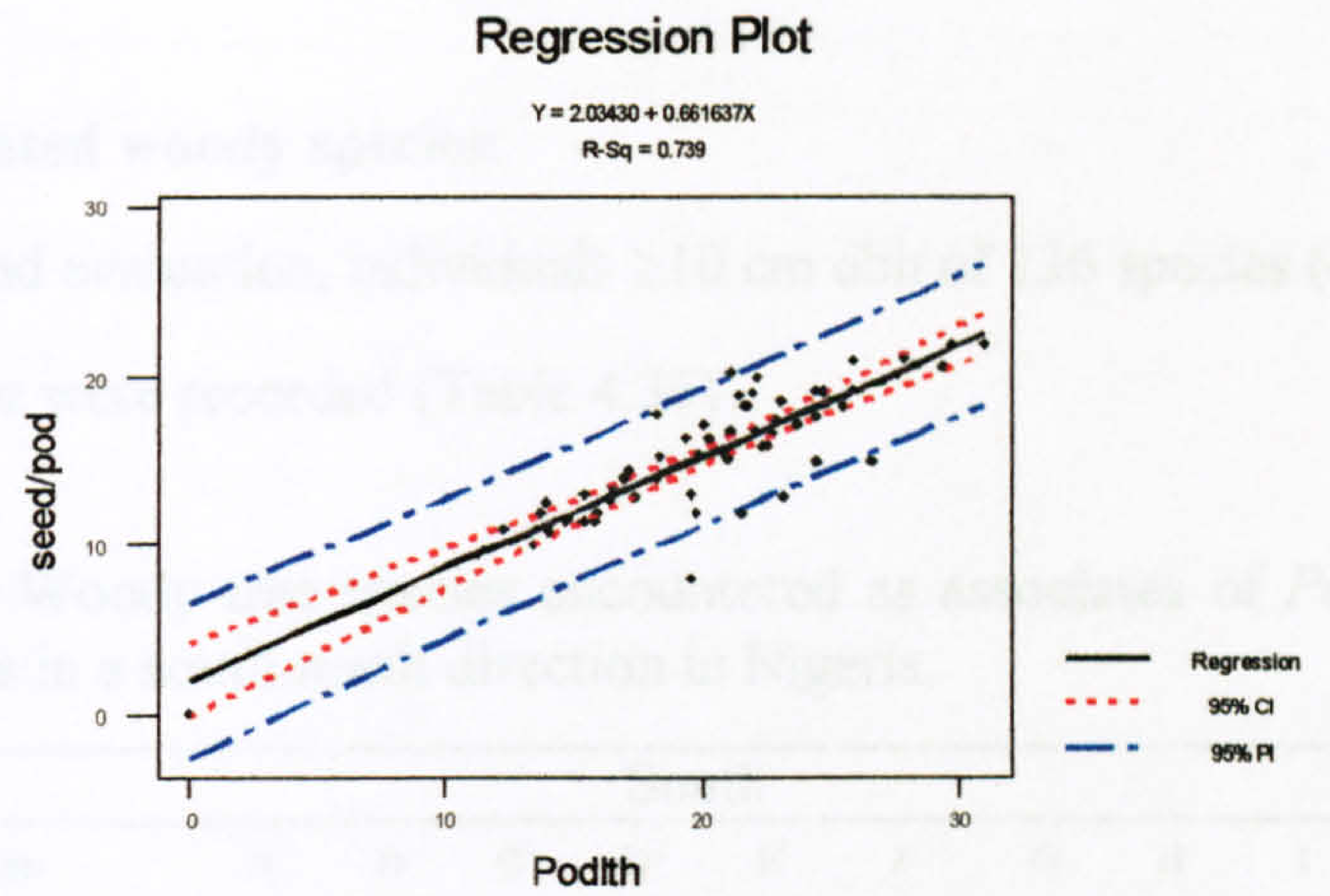


Figure 4.19 Regression relationship between number of seeds per pod and pod length

The mean pod diameter was (1.81± 0.03 cm) however, it ranged from 1.77 ± 0.08 cm to 1.90 ± 0.95 cm per treatment. Regression relationship between pod length and pod diameter was positive and significant (n= 473, $r^2 = 0.525$, $P < 0.05$)

Pod diameter = 0.889 + 0.0429 Pod length (Figure 4.20).

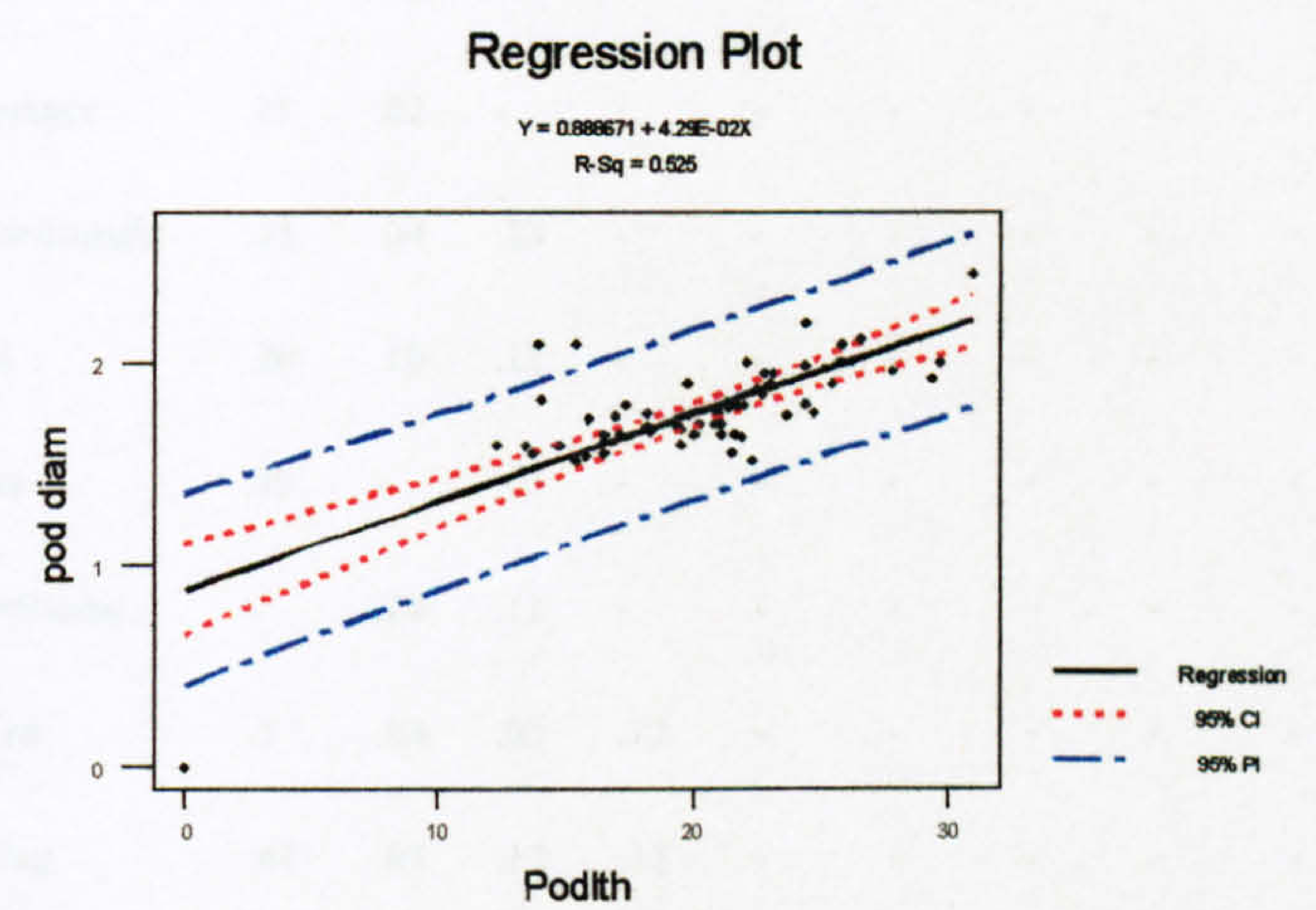


Figure 4.20 Regression relationship between pod diameter and pod length

4.4 Associated woody species

During stand evaluation, individuals ≥10 cm dbh of 136 species (41 families) in addition to *P biglobosa* were recorded (Table 4.36)

Table 4.36 Woody tree species encountered as associates of *Parkia biglobosa* in sixteen sample sites in a south-north direction in Nigeria.

	South										North					
Species distribution Stocking (ha^{-1})	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Gliricidia sepium	.15	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harungana madagascariensis	.05	.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samanea saman	0.1	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Margaritaria discoidea	.1	.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manihot glaziovii	.15	.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leucaena leucocephala	.20	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tectona grandis	.15	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mitragyna inermis	.11	.02	-	-	-	-	-	-	-	-		-	-	-	-	-
Holarrhena floribunda	.15	.04	.13	-	-	-	-	-	-	-	-	-	-	-	-	-
Cocos nucifera	.20	.10.	.11	-	-	-	-	-	-	-	-	-	-	-	-	-
Grewia venusta	.10	-	.03	-	-	-	-	-	-	-	-	-	-	-	-	-
Ziziphus mauritiana	-	.20	.11	-	-	-	-	-	-	-	-	-	-	-	-	-
Milicia excelsa	.1	.04	.05	.12	-	-	-	-	-	-	-	-	-	-	-	-
Parinari excelsa	.44	.05	.12	.13	-	-	-	-	-	-	-	-	-	-	-	-
Lannea kerstingii	.05	.10	.02	.10	-	-	-	-	-	-	-	-	-	-	-	-
Manilkara mochisia	.05	-	-	.19	-	-	-	-	-	-	-	-	-	-	-	-
Parkia bicolor	-	-	.05	-	-	-	-	-	-	-	-	-	-	-	-	-
Morus mesozygia	-	-	.05	-	-	-	-	-	-	-	-	-	-	-	-	-
Cola gigantea	-	-	-	.06	-	-	-	-	-	-	-	-	-	-	-	-
Parinari curatellifolia	.10	.07	-	.13	.06	-	-	-	-	-	-	-	-	-	-	-
Lannea humilis	.1	.05	-	.06	.06	-	-	-	-	-	-	-	-	-	-	-

	South						North									
Species distribution Stocking (ha^{-1})	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P.
Cussonia arborea	.25	.04	-	-	.75	-	-	-	-	-	-	-	-	-	-	-
Stereospermum kunthianum	.20	-	-	-	.31	-	-	-	-	-	-	-	-	-	-	-
Ceiba pentandra	.05	-	-	-	.13	-	-	-	-	-	-	-	-	-	-	-
Lecaniodiscus cupanioides	-	.10	-	-	.06	-	-	-	-	-	-	-	-	-	-	-
Afzelia africana	.05	.04	.10	.31	.25	.10	-	-	-	-	-	-	-	-	-	-
Erythrina senegalensis	.05	.03	-	.06	.31	.80	-	-	-	-	-	-	-	-	-	-
Carica papaya	.21	.05	.30	-	.25	.10	-	-	-	-	-	-	-	-	-	-
Cola nitida	.10	.03	-	-	.06	.20	-	-	-	-	-	-	-	-	-	-
Hyphaene thebaica	.05	.02	-	-	.44	.10	-	-	-	-	-	-	-	-	-	-
Spondias mombin	.34	.01	-	-	-	.20	-	-	-	-	-	-	-	-	-	-
Phoenix dactylifera	-	.01	.02	-	-	.20	-	-	-	-	-	-	-	-	-	-
Celtis integrifolia	-	-	.03	-	.06	-	-	-	-	-	-	-	-	-	-	-
Lannea microcarpa	-	-	.02	-	.06		-	-	-	-	-	-	-	-	-	-
Sterculia setigera	-	-	-	06	.13	-	-	-	-	-	-	-	-	-	-	-
Terminalia laxiflora	-	-	-	.06	.06	-	-	-	-	-	-	-	-	-	-	-
Pseudocedrela kotschyi	-	-	.05	-	-	.20	-	-	-	-	-	-	-	-	-	-
Zanha golungensis	-	-	.03	-	-	.10	-	-	-	-	-	-	-	-	-	-
Allophylus africanus	-	-	.07	-	.06	.41	-	-	-	-	-	-	-	-	-	-
Securidaca longepedunculata	-	-	.02	-	.19	.20	-	-	-	-	-	-	-	-	-	-
Salvadora persica	-	-	.02	.06	-	.10	-	-	-	-	-	-	-	-	-	-
Sorindeia grandifolia	-	-	-	.06	-	.10	-	-	-	-	-	-	-	-	-	-
Millettia thonningii	-	-	-	-	.06	-	-	-	-	-	-	-	-	-	-	-
Oxyanthus racemosus	-	-	-	-	.25	.30	-		-	-	-	-	-	-	-	-
Haematostaphis barteri	-	-	-	-	.31	.20	-	-	-	-	-	-	-	-	-	-
Flacourtia indica	-	-	-	-	-	.20	-	-	-	-	-	-	-	-	-	-
Combretum fragrans	-	-	-	-	-	.10	-	-	-	-	-	-	-	-	-	-
Zanthoxylum zanthoxyloides	-	-	-	-	-	.10	-	-	-	-	-	-	-	-	-	-

	South								North							
Species distribution Stocking (ha^{-1})	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Pachystela brevipes	-	-	-.	-	-	1.15	-	-	-	-	-	-	-	-	-	-
Olax subscorpioidea	.30	.05	.05	.06	.06	.80	.11	-	-	-	-	-	-	-	-	-
Ekebergia senegalensis	.20	.01	.05	-	.19	.41	.43	-	-	-	-	-	-	-	-	-
Phyllanthus physocarpus	.05	.02	-	.13	-	.30	.17	-	-	-	-	-	-	-	-	-
Lophira lanceolata	.41	.08	.44	.06	.06	.40	-	.16	-	-	-	-	-	-	-	-
Dalbergia sissoo	.10	.11	.10	-	.12	10	.23	.10	-	-	-	-	-	-	-	-
Crossopteryx febrifuga	.20	.05	.07	.5	.06	.10	-	.15	-	-	-	-	-	-	-	-
Anogeissus leiocarpa	.54	.03	.05	-	.06	.2	.11	.15	-	-	-	-	-	-	-	-
Citrus sinensis	.05	.04	.02	.12	-	-	-	.05	-	-	-	-	-	-	-	-
Combretum molle	.05	.02	.02	-	-	-	-	.15	-	-	-	-	-	-	-	-
Maranthes polyandra	.05	.07	-	-	-	.30	-	.05	-	-	-	-	-	-	-	-
Senna siamea	.10	.02	-	-	-	-	-	.12	-	-	-	-	-	-	-	-
Delonix elata	.20	.02	-	-	-	-	-	.32	-	-	-	-	-	-	-	-
Erythrophleum suaveolens	-	-	.02	-	-	-	.11	-	-	-	-	-	-	-	-	-
Irvingia gabonensis	-	-	.30	.19	-	-	.17	-	-	-	-	-	-	-	-	-
Pentaclethra macrophylla	-	-	-	.13	-	-	.22	-	-	-	-	-	-	-	-	-
Anthocleista vogelii	-	-	.17	.13	-	.71	-	.15	-	-	-	-	-	-	-	-
Trichilia emetica	-	-	.10	-	.06	-	-	.16	-	-	-	-	-	-	-	-
Pericopsis elata	-	-	.07	-	-	.41	-	.16	-	-	-	-	-	-	-	-
Strychnos innocua	-	-	-	-	.10	-	.11	-	-	-	-	-	-	-	-	-
Uapaca togoensis	-	-	-	-	-	.20	.21	-	-	-	-	-	-	-	-	-
Maerua parvifolia	-	-	-	-	.0	-	-	.05	-	-	-	-	-	-	-	-
Morinda lucida	-	-	-	-	.19	-	-	.05	-	-	-	-	-	-	-	-
Ziziphus abyssinica	-	-	-	-	-	-	.21	-	-	-	-	-	-	-	-	-
Ficus vogelii	-	-	-	-	-	-	.11	-	-	-	-	-	-	-	-	-
Euphorbia poissonii	-	-	-	-	-	-	-	.05	-	-	-	-	-	-	-	-

				South								North				
Species distribution Stocking (ha^{-1})	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Diospyros ferrea	-	-	-	-	-	-	-	.15	-	-	-	-	-	-	-	-
Bauhinia rufescens	-	-	-	-	-	-	-	.05	-	-	-	-	-	-	-	-
Alchornea cordifolia	.10	.01	.07	-	-	.70	-	-	.11	-	-	-	-	-	-	-
Lannea barteri	.2	-	.07	.06	.20	-	-	-	.10	-	-	-	-	-	-	-
Pericopsis laxiflora	.15	.02	.10	.19	.38	.40	-	-	-	.06	-	-	-	-	-	-
Ficus sycomorus	.10	.01	-	.06	.38	-	.2	-	-	.50	-	-	-	-	-	-
Vernonia amygdalina	.15	-	.17	-	-	.54	.42	-	-	.06	-	-	-	-	-	-
Combretum nigricans	-	-	-	-	-	-	.11	-	-	.07	-	-	-	-	-	-
Euphorbia kamerunica	-	-	-	-	-	-	-	-	.10	-	-	-	-	-	-	-
Syzygium guineense	.05	-	.05	-	-	-	-	.05	-	-	.11	-	-	-	-	-
Boswellia dalzielii	.05	.03	-	-	-	-	-	-	-	-	.21	-	-	-	-	-
Hexalobus monopetalus	.05	-	-	-	-	-		-	-	-	.11	-	-	-	-	-
Combretum glutinosum	.05	-	-	-	-	-	-	-	-	-	.11	-	-	-	-	-
Daniellia oliveri	2.5	.51	.27	.81	1.40	1.91	2.1	1.2	-	.14	9.44	.82	-	-	-	-
Nauclea latifolia	.64	.08	.53	.25	.19	.10	.22	.21	-	.06	.11	.08	-	-	-	-
Detarium macrocarpum	.10	.04	.23	.50	-	.50	-	-	-	-	1.91	2.78	-	-	-	-
Gmelina arborea	.20	.04	.10	.19	-	.3	-	.42	-	-	.21	.08	-	-	-	-
Bauhinia monandra	.19	.04	09	-	.06	-	.32	-	-	-	-	.16	-	-	-	-
Entada africana	.49	.11	.1	-	.13	.10	-	-	-	-	-	.16	-	-	-	-
Terminalia avicennioides	.05	.01	.07	-	.06	-	-	-	-	-	3.9	1.3	-	-	-	-
Psidium guajava	.09	.02	.12	-	-	2.03	-	-	-	.10	-	.35	-	-	-	-
Terminalia glaucescens	.04	.01	.07	-	.06	-	-	-	-	-	4.0	.30	-	-	-	-
Hymenocardia acida	.20	-	.10	.06	.10	.11	.11	-	-	-	-	.08	-	-	-	-
Anacardium occidentale	.3	.06	-	.13	.88	.71	-	.31	-	-	-	.33	-	-	-	-
Bridelia scleroneura	.25	.08	-	.19	.75	.20	-	.05	-	-	.21	-	-	-	-	-
Antiaris toxicaria	.10	.02	-	.12	.50	-	-	-	-	-	-	.06	-	-	-	-
Piliostigma reticulatum	.29	.02	-	-	.06	.10	.32	-	-	.06	.11	.16	-	-	-	-

	South									North						
Species distribution Stocking (ha^{-1})	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Dalbergia melanoxylon	.15	.05	-	-	.13	.20	.21	.10	-	-	.11	.08	-	-	-	-
Blighia sapida	.15	.02	-	-	1.10	.30	-	-	-	-	-	.08	-	-	-	-
Boscia senegalensis	.20	-	-	-	.13	.10	-	-	-	-	.10	.08	-	-	-	-
Dialium guineense	.10	-	.04	-	-	.20	-	-	-	-	-	.06	-	-	-	-
Detarium senegalense	.15	-	-	.13	-	-	-	-	-	-	-	.07	-	-	-	-
Eucalyptus camaldulensis	-	.06	.02	.19	.06	-	.32	.05	.71	-	-	.16	-	-	-	-
Ficus capensis	-	.05	.05	.44	-	.30	.43	.21	1.20	.07	-	.08	-	-	-	-
Ficus glumosa	-	.05	.05	.44	-	.30	.43	.15	.20	.06	-	.08	-	-	-	-
Prosopis africana	-	-	.34	1.74	-	.10	-	.89	-	-	.53	.49	-	-	-	-
Sclerocarya birrea	-	-	.05	-	-	.20	-	-	-	-	-	.06	-	-	-	-
Moringa oleifera	-	-	-	.06	-	-	-	-	-	-	.11	.16	-	-	-	-
Dichrostachys cinerea	-	-	-	-	-	-	-	-	-	-	.11	-	-	-	-	-
Combretum collinum	-	-	-	-	-	-	-	-	-	-	-	.08	-	-	-	-
Albizia chevalieri	.15	.02	.34	.12	.06	.30	.21	.11	-	.06	.43	-	-	.31	-	-
Acacia macrothyrsa	-	-	.13	-	-	-	.11	-	.10	.06	.11	.08	-	.31	-	-
Isoberlinia doka	-	-	-	-	-	-	.21	-	.30	.28	.21	.25	.30	.61	-	-
Annona senegalensis	.44	.07	-	.13	.38	.20	.21	.16	-	-	1.70	1.50	.50	.62	.11	-
Burkea africana	.30	.02	-	.13	.31	-	-	.11	-	-	.64	.16	-	1.84	.11	-
Piliostigma thonningii	.20	.02	.07	.25	.06	.30	1.5	-	-	-	.96	.97	4.10	4.29	.22	-
Vitex doniana	.54	.15	.07	.40	.94	.10	.75	-	-	.30	1.0	.50	-	.31	.65	.75
Mangifera indica	.54	.11	.22	.37	.94	1.41	.21	1.0	.31	.89	.64	1.10	-	.31	-	.32
Vitellaria paradoxa	1.92	.33	.19	.12	1.70	2.1	.10	.05	1.62	1.17	1.38	3.52	.60	2.91	1.2	.32
Elaeis guineensis	.30	.12	.15	1.92	.40	.40	.32	.42	-	-	-	-	-	-	-	.32
Pterocarpus erinaceus	.88	.07	.10	.50	.06	-	-	-	.10	-	.11	-	.15	-	.11	.33
Pterocarpus lucens	.34	.21	.16	.01	-	-	-	.28	-	-	.81	1.00	-	-	.25	.78
Azadirachta indica	.29	.06	.17	-	.69	1.11	-	.47	-	-	3.72	.57	-	.76	.32	.96

				South									North			
Species distribution Stocking (ha^{-1})	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Tamarindus indica	.20	.01	-	-	-	-	.11	-	.10	1.31	-	-	.15	1.10	.97	.75
Adansonia digitata	.05	-	-	-	.25	1.41	.21	-	-	-	-	-	.89	3.52	1.7	3.74
Ficus thonningii	05	-	-	-	-	-	.02	-	-	.14	-	-	-	-	.11	.11
Bombax costatum	.15	-	-	-	-	-	-	-	.10	.07	-	.16	-	.31	.32	.53
Borassus aethiopum	-	.05	-	-	-	.10	-	-	-	6	.11	.08	.30	.31	.11	-
Diospyros mespiliformis	-	-	.05	-	.44	.30	.32	-	.16	.34	.32	.16	1.04	2.76	.96	.75
Faidherbia albida	-	-	-	-	-	.10	.11	-	-	-	-	-	-	1.10	.43	.54
Balanites aegyptiaca	-	-	-	-	-	-	-	.05	-	-	.32	-	.19	.15	-	.32
Acacia nilotica	-	-	-	-	-	-	-	-	-	.07	.32	.16	2.52	1.23	.54	.86
Number of species in each stand	81	72	64	48	65	67	50	36	11	22	39	35	12	19	17	15
Associated species in each ecozone				267				218				107				63

(-) indicates no stocking of a particular associated woody tree species in the sample stand.

Legend

Names of sample stands in Nigeria in relation to the ecozones where associated species were recorded with *P biglobosa* .

Ecozones	Sample stand names			
	A	Eruwa	C	Enugu
Guinea-Congolian centre	B	Olokemeji	D	Nsukka
Guineo-Congolian/Sudanian centre	E	Saki	F	Ilorin
	G	Jos	H	Makurdi
Sudanian centre- south	I	Kaduna	J	Zaria
	K	Kontangora I	L	Kontangora II
Sudanian centre- north	M	Kano I	N	Kano II
	O	Kano III	P	Hadejia

An ordered table of associated species with *Parkia* indicated nineteen species were confined to the extreme south of the range (Guinea-Congolian centre). Fifteen species however showed consistency in all the sites, i.e. (being found in at least one of the site in each ecozone (Table 4.36). *Vitellaria paradoxa* was the only species with 100% consitency with *P biglobosa* (Table 4.36). *P. biglobosa* was dominant in all the sample stands investigated with an overall stocking per hectare > than any other single species. Twenty one species were particularly well represented having i.e. (≥1 tree per hectare) in at least one of the sample stands. Thirty nine other species were poorly represented being found in one sample stand in at least one of the four ecozones (Table 4.36)

The first two ecozones (sites A-H) accounted for 76 species (59%) of the total number of associated species recorded, while the Sudanian centre- south (ecozone III) accounted for 48 species (35%) and the Sudanian centre-north (ecozone IV) less than 6%. The vegetation of ecozone I can be described as *Parinari-Lannea-Milicia-Holarrhena* while, *Cocos-Tectona-Leucaena* dominated the lower stratum. In ecozone II the vegetation can be described as *Lophira-Anogeissus-Afezelia-Erythrina-Cussonia* while, *Cola-Carica-Phoenix* formed the lower stratum. Ecozone III is principally of *Vitellaria-Diospyros Daniellia-Nauclea-Detarium-Ficus with Isoberlina-Mangifera-Azadirachta* forming the next stratum. The vegetation of ecozone can best be described as *Piliostigma-Adansonia-Vitellaria-Diospyros-Acacia-Burkea* species while, *Balanites-Faidherbia-Tamarindus-Azadirachta-Vitex* dominated the under-storey (Table4.36).

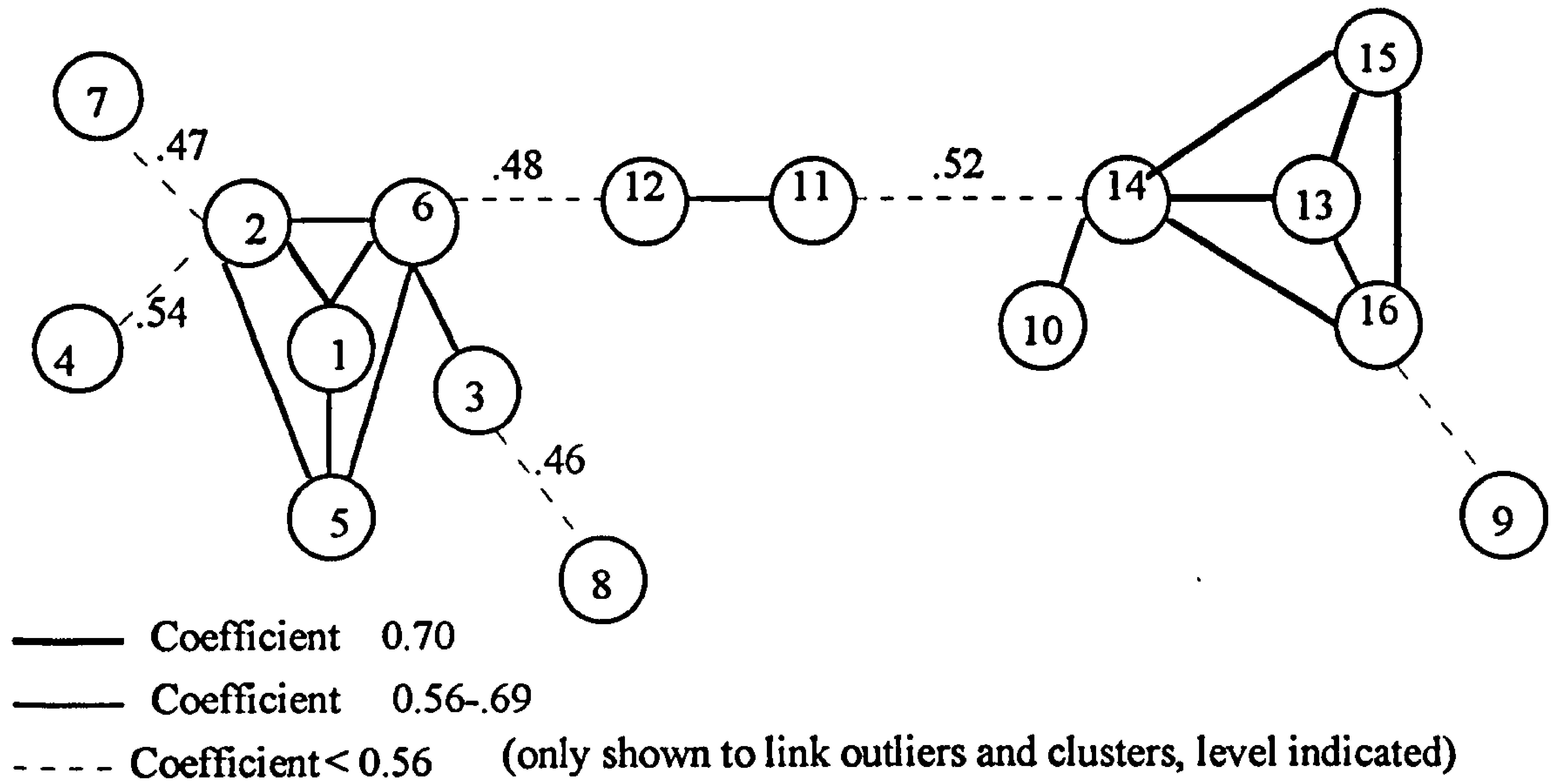
Similarity between sample stands

Based on floristic composition the degree of association expressed as Sørenson similarity coefficient between between pairs of samples is shown with stands arranged in (top, left) in a south-north (base, right) sequence (Table 4.37).

Table 4.37 Sørenson (Ss) similarity coefficient for pairings of 16 sample stands in Nigeria based on presence of species represented by individual ≥10cm diameter at breast height.

Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Eruwa	-	.82	.53	.52	.59	.58	.45	.40	.13	.28	.38	.42	.14	.23	.24	.20
2 Olokemeji		-	.53	.54	.60	.57	.47	.42	.15	.31	.35	.42	.17	.25	.25	.16
3 Enugu			-	.51	.53	.56	.44	.46	.19	.28	.36	.45	.13	.24	.20	.17
4 Nsukka				-	.52	.48	.40	.44	.20	.27	.35	.40	.09	.20	.18	.15
5 Saki					-	.59	.40	.42	.16	.23	.38	.36	.13	.21	.22	.20
6 Ilorin						-	.46	.39	.13	.25	.39	.49	.17	.30	.24	.20
7 Jos							-	.37	.23	.44	.33	.40	.26	.40	.36	.31
8 Makurdi								-	.17	.24	.39	.37	.16	.25	.15	.19
9 Kaduna									-	.42	.21	.28	.43	.33	.35	.54
10 Zaria										-	.42	.46	.41	.58	.51	.54
11 Kontagora I											-	.62	.42	.52	.42	.40
12 Kontagora II												-	.31	.48	.43	.30
13 Kano I													-	.70	.76	.59
14 Kano II														-	.83	.70
15 Kano III															-	.75
16 Hadejia																-

The Sørenson coefficients of similarity between pairs of sample stands ranged from 0.09 to 0.83 (Table 4.37). Every sample was related to at least one other sample by a coefficient of at least 0.46. Most had at least one value ≥ 0.55. A constellation diagram (Figure 4.21) based on Table 4.37 reveals two major clusters of samples. The larger cluster contains samples from the south, but the Enugu (site3) , Makurdi (site 8) and Jos samples (site 7) are only loosely linked to the cluster. The Jos and Makurdi samples are also isolated geographically, partly explaining their generally low similarity coefficients. The second cluster is the northern group of samples. The Kaduna sample (site 9) is loosely linked with this group. The two clusters are not strongly linked with each other- the connection is via the Kontagora samples.



Foot note

The number in circles identify sample sites. The lines linking the circles represent the strength of the relationship existing between the sample at the ends. The closer the linkage between circles the higher the similarity coefficient.

Figure 4.21 Constellation diagram showing relationship of 16 sample stands with *Parkia biglobosa* dominant based on Søreson similarity coefficients for presence of species represented by individuals ≥10 cm diameter at breast height.

CHAPTER FIVE

DISCUSSION

Parkia biglobosa has been widely recognised as an important indigenous fruit tree throughout its range, and it has acquired protective status from Senegal to Sudan. Recent ethnobotanical surveys (Soladoye *et al.*, 1989) and socio-economic studies indicate that *Parkia biglobosa* is still ranked highest among the list of edible forest products locally sold in the markets (Awodola, 1993; Gakou *et al.*, 1995). Further, despite the slow growth rate compared with many exotic species, interest continues to grow, among the farmers, in the silvicultural and integration of *Parkia* in afforestation projects and farms (Douglas & Hart, 1985; Popoola & Maisanu, 1995).

Currently, in Nigeria, and several other parts of the range, various action programmes are being put in place to conserve and preserve the remaining genepool. There are increasing threats to the existing populations from demographic pressure on land, illegal felling, deforestation for large scale mechanised farming, and prevalent annual bush fire (Kio *et al.*, 1987; Ladipo *et al.*, 1990). In Nigeria, the Federal Government initiated action with the Third National Development Plan (1975-1980), which included a special programme to appraise the indigenous fruit trees, including *Parkia biglobosa.* The level of awareness has steadily increased in both research institutions and in the forestry arms of the government. Unfortunately, however, the global recession and the drastic economic reforms introduced in recent times have had a significant effect on the level of in-situ conservation of many indigenous fruit trees including *Parkia biglobosa.* Local people have eliminated several stands of *Parkia* because of un-affordable cost of other sources of fuel energy sources (Kerosene and domestic gas).

The long history of association with the rural population range-wide in the provision of food, medicinal services, and an alternative income source means that, in many areas, *Parkia biglobosa* has formed an integral part of the regional economic systems (Agbahungba & Depommier, 1993). Restricted to the Sudanian Centre of Endemism, *Parkia biglobosa* is at some risk throughout the entire area of occurrence because mean rainfall and drought are becoming evident on an annual basis (Rocheleau *et al.*, 1988; Baumer, 1990). Rocheleau *et al.* (1988) report the disappearance of *Parkia biglobosa* within the past 40-60 years from many locations in Niger as a result of drought.

The distribution map for of *P biglobosa* (Figure 2.4) prepared in the present study is more comprehensive than that of Hopkins (1983) and Hopkins & White (1984) because it has not been limited to herbaria voucher specimens. Use has been made of ecological literature which has the advantage of giving better indications of areas where the tree is most frequent and those where it occurs only sporadically. It remains the case that the map is not finally definitive - there are parts of the range, especially in Tchad, the Central Africa Republic, Zaria and Sudan for which little information seems to have been reported.

The distribution pattern and ecological amplitude of *Parkia biglobosa* reported in this thesis broadly matches those of *Vitellaria paradoxa* subsp. *paradoxa* (Hall *et al.*, 1996), another highly valued Sudanian woodland species. The *Parkia biglobosa* distribution reported in this work extends outside the West Africa mainland, but does not penetrate so far into Uganda, barely reaching that countries northern border (Figure 2.4). Despite this, however, there is enough similarity in the distribution pattern to suggest a role for management action to favour both *Parkia* and *Vitellaria* at the same time.

Linking the distribution map pattern in this study with physical and environmental factors, especially climate, reveals that fairly similar conditions prevail wherever *Parkia* *biglobosa* has been reported as a vegetation component. The broad range of rainfall requirement lies principally with a mean annual rainfall of 400-1400 mm, associated with 2-7 months of dry months (months with <50 mm) and mean annual temperature of 20-30°C. The rarity of *Parkia biglobosa* where mean annual rainfall is below 400 mm is noteworthy which further confirms the Sudano-sahelian range limit (Hopkins & White, 1983; Rocheleau *et al.*, 1988). The species-site preferences offer guidance in the development of appropriate management protocols for future provenance collections and selection for plantation establishment. The distribution range to the Guinea-Congolian centre, associated with higher soil moisture, proves very encouraging for in-situ conservation work, as the current population is not threatened by drought and intensive grazing limiting regeneration in these areas.

Parkia is most frequent in the landscape of crystalline basement complex rocks, weathered to deep loamy-sand to loamy-clay. On redistributed sands, such as the aeolian sands of north-east Nigeria, *Parkia* is not widespread - perhaps because these are less fertile than sands developed in-situ weathering. The typical toposequence position of the species correspond to site conditions favourable for crop growing, explaining the prominence in farmed areas, despite any strong planting tradition. Recognition of the value has enabled what Keay (1951) suggests is a species absent or less represented in natural Sudanian woodland, to persist, since the farmers eliminate regeneration of species that might displace it (such as *Isoberlinia doka*).

The absence of any enumeration study covering the four different different ecozones was a gap in the knowledge concerning management. For resource management, in an in-situ context, targeting well-developed stands is necessary in order to focus on populations which are relatively dense, and hence likely to prove more productive per unit land area. Comparing sample populations in different ecozones exposes possible productivity gradients, paralleling the climatic gradient of which the various West African ecozones are sections. The findings from this study are of interest in their indication of contrasts between zones and the higher stocking where the mean annual rainfall was only around 1000 mm. Even at higher concentration found in this study (ca 15 individuals ≥ 10 cm dbh per hectare), the distribution is sparse. However, this underlines the need for caution in interpreting almost all previous records of numbers of *Parkia biglobosa* from ecological samples. These have usually sampled too small an area for such a thinly dispersed species and too few observations have been made. The approach followed here, ensuring 100 individuals were recorded, overcomes this problem.

The variation in stocking with ecological zones is likely to arise from different influences in the different zones. This study's intention was essentially to characterise the population and establish their status. Future work to explain the differences would be appropriate, but some observations can be made here. The differences in size and status indicate that, in the driest conditions investigated, individual trees were smaller than in the moister ecozones. Site potential limitations covered explain this. This would be compatible with the higher stocking rates in the north, on the basis that more individuals could be supported by the available resources.

However, it is also possible that the northernmost population were of younger, as well as smaller, individuals. This, in turn, can arise if there were differences in longevity, or if local practise dictated elimination or destructive use of older individuals to a greater extent in that area - to favour crops or because tree yields were past their peak. In the moister ecozones, where *Parkia biglobosa* belongs to a younger savanna formation that has replaced forest cleared to secure cropland, severe competition from luxuriant grass swards active for all or nearly all the year, may restrict the success of *Parkia* regeneration. When dry season effects in this moist zone are severe enough, the abundant grass is a high fuel load- fires in this case, even if at full intensity only at intervals of a few years, may kill a high population of any regeneration. As well as these factors, there is also the possibility of variation in the populations arising from genetic differences from area to area.

There is already evidence of genetic variation in *Parkia biglobosa* with longitude - in leaflet length and pod sizes for example (Hopkins, 1983), although not with latitude as has been tentatively suggested above. Direct evidence of variation is, however, accumulating from recent isoenzyme work (Sibidou *et al.*, 1995), although so far restricted to populations from Cameroun westward. Hopkins & White (1984) note uniformity in typical Sudanian species (compared with Zambezian) and consider *Parkia biglobosa* unusual in its clinal variation; but their view can be challenged. Earlier views have regarded their clinal pattern as a discontinuous one with two distinct taxa separated longitudinally, like *Vitellaria paradoxa*, with eastern and western subspecies (Hall *et al.*, 1996). Until more of the typical widespread Sudanian species are investigated in detail, it is perhaps premature to stress any uniformity. It is likely that understanding of infraspecific taxa in *Parkia biglobosa* will be of value in the development and improvement programmes for the species, and allow variants differing in economic value to be identified as a basis for multiplication, breeding and conservation.

Almost all *Parkia biglobosa* is still in a wild state in unselected populations that can be presumed to exhibit wide natural variability. By selective retention of trees with the most valued characteristics, some influence will have been executed on the farmland populations, of course, but this has been an essentially opportunistic process and further positive selection and breeding should be manifested in great increases in yield and adaptability to sites and farming systems. *Parkia* performance in trials plots (Awodola, 1993; Fagbemi, 1994) has demonstrated improved positive height increment and better overall growth compared with wild stands. The observed higher stocking density in this study in farmed lands and partly protected lands is indicative of *Parkia* being managed and preserved, using an integrated management approach that actively involves farmers. Practical conservation of *Parkia* on a local scale can be undertaken with action in existing farmlands, and other populations supplemented with planting.

Interventions in the present population are now urgently needed. There are indications that, presently, the farmed parklands of Sudanian Africa are degrading, in terms of both woody plants diversity generally, and specifically through reduced seedling regeneration (Kessler & Boni, 1991; Kessler, 1992). Apart from diminishing mean annual rainfall in the parklands, land disturbance and increasing grazing intensity are having modifying effects and are major obstacles to regeneration (Rocheleau *et al.*, 1988; Sene, 1985). This study illustrates this graphically for Nigeria where, from 30 hectares examined within *Parkia biglobosa* stands, only 288 regenerating individuals were encountered (9.8 trees ha^{-1}).

These were individuals referred to a very broad category (<10 cm dbh) and predominantly restricted to small sizes within this. The implication is that very few survive to sizes which are able to reproduce sexually. Without knowledge of growth rates and age size relationship in the different ecozones, interpretation can only be speculative. Even so, it would be unwise to assume that, as old individuals die or are removed, that there are enough replacements to sustain the integrity of the populations. Values reported by Gijsbers *et al.* (1994) were still lower than those of this study - 0.9 ha^{-1} for saplings, indicating that regeneration problems are not limited to the Nigerian part of the range.

Several factors make it probable that the situation could worsen. Range-wide, the mean annual rainfall has been decreasing, while, simply with rising demographic pressures, an increased total land area is cultivated with fallow periods shortened. Diminishing crop yields are compelling farmers to farm more land and clear fallow sooner, even when household size stays constant. In savanna woodland, management practices do not at present include any actions to favour the regeneration of indigenous woody species. Forms of intervention are needed which local people will be able to adopt, even in these difficult circumstances. Renewable resources professionals, linked to farmers through extension staff, will help in this drive. Both enhanced protection of naturally established seedlings and planting actions could have significant positive effects.

Parkia biglobosa exhibits seed coat dormancy. Under natural conditions it takes about 21 days for the natural dormancy to be broken - through exposure herbivores, (passage through the gut) and seed coat changes with time, when exposed to the prevailing biotic and microclimatic environment. Farmers have little interest in naturally dispersed seed and even of young seedling stock. Lack of regulation of range-lands suggests that more control of seedling positions and vigour are needed. This effectively means that seedlings should be specially raised and planted at appropriate points where they are adequately protected.

Managing the woodlands to favour existing naturally regenerated seedlings need to aim at supplemental seedlings to supply existing natural parklands of *Parkia*. This will require an initial understanding of the mechanisms of dispersal; the specific agents playing active roles and the fate of disperse seeds. In the lowland range of *Parkia biglobosa* in Nigeria, climatic conditions favour regeneration of seedlings due to higher soil moisture and reduced livestock grazing. However, the zone also has large quantities of highly combustible materials in terms of fuel load, a single fire in a given season may wipe out all the stands. Monitoring of naturally regenerated seedlings is difficult. The survival of the seedlings to reproductive age will involve both deliberate fire control and promotion of all early burning, where strict fire control is impracticable. Extension staff will have significant roles to play in bush fire control and in training farmers.

In the Guinea-Conglian/Sudanian transition zone, the land degradation is less severe while available soil moisture is higher, but the problem of deforestation, particularly for large scale mechanised farming, is noteworthy. Therefore, the need to identify areas of dense *Parkia* population, which can be modified to restricted natural reserves, will be desirable. Fire plays significant roles in depleting the current genepool of *Parkia* in the range, while at the same time it promotes seed germination (Menaut, 1983; Fatubarin, 1987). However, early burning is less destructive, while late burning has serious, devastating effects on woody species. Management policies, therefore, require some level of direct government protection of wild species, while at the same time increasing awareness on the implications of late burning to the maintenance of existing *Parkia* populations.

Flowering and fruiting in *Parkia* are dry season events, while in many parts of the range, fruit matures at the beginning of the rains. Coincidence of fruit maturation with the onset of rains maximises the prospect that moisture will be available for germination. Under natural conditions, high regeneration is not favoured by *Parkia biglobosa* seeds, due to seed coat dormancy and the low population of red brown seeds which readily germinate compared with the dark brown seeds (Etejere *et al.*, 1982). The hard seed coat often inhibits immediate germination (Etejere *et al.*, 1982), but also protects the seed from destruction while it passes through the gut of predators and potential animal dispersal agents (Hopkins, 1983). Animal dispersal makes it difficult to estimate overall regeneration of this species in nature.

Casual observations during field studies, however, revealed very low seedling-mother tree distances, implying an uneven (clumped) seedling dispersion. Clumping of seedlings around the parent tree increases the chance that the entire regeneration of a season may be eliminated by seasonal fires. This study suggests moderate re-sprouting through coppice shoots, as observed by Gijsbers *et al.* (1994), but the slow growth rate of the species leaves the young plants vulnerable, even if they escape death by fire in any year. Enrichment planting is an option available where there is doubt as to the ability of natural seedling to sustain the population. Local community action that will promote and encourage rehabilitation of depleted sites through natural regeneration could be achieved with strict fire, especially where there are relict living rootstocks. In reality, such action will often be impracticable and there is need to aim at management that will promote and maintain natural conditions where fuel accumulation is minimal. Success with direct seeding on the field has not been encouraging and establishment rates have been poor (Bonkoungou, 1987). Until nursery raising of *Parkia biglobosa* becomes wide-spread, the obvious option will be to use wildings from better stock for enriching and rejuvenating deteriorating stands.

Vigorous stock of known origin are needed for supplying to farmers as a better alternatives than wildings, and development of efficient and in-expensive silvicultural methods for breaking seed dormancy and raising vigorous seedlings in village conditions are needed. The availability of improved seedlings with more vigour and selected desirable characters will encourage farmers involvement in the development of this resource, and ensure the preservation of existing seedlings under in-situ conservation. Species multiplication through cuttings, layering, budding and suckers have proved very promising in the current research on *Parkia biglobosa*. What is now required is perfection of the techniques and production.

The majority of existing *Parkia biglobosa* populations are in the wild, and are tended as a secondary crop by farmers, with little or no time devoted to organised management. Silvicultural findings have, however, shown that when *Parkia* is treated as a component of an organised agroforestry system with adequate nutritional requirements, the species responds to a more vigorous performance than is usual with natural regeneration

(Okafor, 1978; Awodola, 1993). Farmer's perceptions of stock quality indicates a preference for stock which matures early and fruits heavily. Selection of these traits within existing populations on farmers' fields will involve farmers directly in seed raising and transplanting for improvement of the species.

On the national and regional scale, genetic evaluation and improvement of *Parkia biglobosa* requires adequate information on variation between and within populations from different ecozone and different levels of land use intensity. The present study has shown variation in morphological characters and size in *Parkia biglobosa* in a south-north direction, within Nigeria, which is relevant to future provenance studies. The southern range showed taller tree height, but with smaller tree diameter classes while, the northern counterpart are shorter but with more trees belonging to larger diameter classes.

There has been a gap in the knowledge of *Parkia biglobosa* performance under different land use intensities, but this study indicates that *Parkia biglobosa* is well adapted as a tree of actively cultivated land, and this is consistent with the observation of néré performance near villages in Burkina Faso indicated by Timmer *et al.* (1996). Studies of natural populations of *Parkia biglobosa* in Burkina Faso indicate that *Parkia* trees near village fields (near the farm) benefit from protection against fires and uncontrolled bush fires and from regular soil manuring (Kater *et al.*, 1992; Timmer *et al.*, 1996). An in-situ conservation approach for *Parkia,* that aims at establishing plots close to settlement rather than in isolated/more distant fields, should be viable.

In the Sudanian region, farmers tend to keep about two trees per hectare (Kater *et al.*, 1992) in their fields, but where taller trees can be bred and are available to farmers the depressive shade effect of *Parkia* on associated food crops may be minimised to some extent. Pruning of trees is not a usual practice among farmers. However, a conscious pruning management that aims at obtaining a tree structure which allows either morning or afternoon sunshine to reach the crops under the canopy, offers a stable agroforestry system with *Parkia biglobosa*. Exploitation of shorter tree heights, as found in the northern zone population in this study, could be exploited in pastoral-based systems where shorter tree heights and more branches are often desired by livestock farmers in the provision of shade (Bayer, 1990). This, and other implications of variation in the form of *Parkia biglobosa* are indicated in Table 5.1.

Table 5.1 Implications of variation in form of *Parkia biglobosa* along south-north gradient in Nigeria

	Southern part	Northern part
Tree morphology	Longer bole fewer major branches	Shorter bole, more major branches
Prevalent agriculture	Arable cropping	intense arable cropping close to towns, much pastoral agriculture elsewhere
Possible positive role of *P biglobosa*	boundary marking; fruit harvesting	fruit harvest; shade; major source of food.
Acceptable locations for trees	plot boundaries	disperse through pasture

Many more significant technical advances in the management of *Parkia biglobosa* will be possible, as more is learnt of its reproductive biology. An understanding of the breeding system is needed for developing successful crossing, so that the attractive traits of different populations can be combined. At present, there is still negligible knowledge of spatial and temporal barriers to populations, either separately or operating together. The timing of flowering can serve as an isolating mechanism in plant speciation. In *Parkia biglobosa*, flowering is a dry season event occurring at the time of maximum evapotranspiration. Fruiting coincides with the onset of the rainy season, which, prior to this, low soil moisture limits nutrient supply to the developing fruits. Nutritional studies already indicate higher vigour in *Parkia* when additional nutrients are provided (Awodola, 1993).

The number of flowers and fruits, and the way they are clustered in time and space, influence pollinator attraction, pollen flow, resource allocation and seed dispersal. The effectiveness of any visitor as a pollen vector will depend on many factors, but especially on its feeding behaviour and the timing of its visits (Hopkins, 1983; Baker, 1986). A range of flower visitors including bats, attracted to *Parkia biglobosa*, were observed in this study, but they were mainly pollen thieves and nectar lapping visitors. The timing of pollen release, which occurs overnight, probably excludes birds from playing active roles in *Parkia biglobosa* pollination (Pettet, 1977). Pollination success was, however, apparently low, both at the level of the capitulum and the level of the flower. Although an individual *Parkia biglobosa* may produce many inflorescences, not all progress to fruiting state. The capitulum abortion rate observed in this study was over 30% - slightly lower than that reported by Tybirk (1991) in African acacias. Flowering in *Parkia* is such that, within inflorescence groups, capitula units mature in sequential order with the most distal maturing first. This acropetal arrangement favours selective abortion (Stephenson, 1981). In *Parkia biglobosa,* resource allocation appears to favour capitula at a higher (>5 m) crown level, compared with those at lower crown (3-5) level. It is, however, not clear whether the observed foraging behaviour of bats is responsible, or resource allocation within the tree.

In the pollination experiment, the open pollinated treatment produced the highest number of pods, suggesting that visiting pollinators (thought to be bats at Saki) play a significant part in the fruit production process, despite the measure of self-compatibility indicated by Hopkins (1983) and also noted here, with two pods obtained from the assisted pollination treatment. Stephenson (1981) reports that, in general terms, the ultimate number of flowers that set fruit largely depends on the resources of the maternal parent. While the proportion of flowers that set fruit decreases as the number of pollinated flowers increases. When buds or newly opened flowers are artificially thinned from many orchard species, the percentage of pollinated flowers that initiate fruit increases in proportion to the intensity of thinning.

Within the pods, *Parkia biglobosa* invests heavily in the fruit pulp at the expense of the seed, which accounts for less than 20% of overall pod weight. This makes the fruit attractive to frugivores at the expense of the much desired seeds required for natural regeneration and food. In the case of this species, where it is the seed that has particular economic value, improvement of *Parkia biglobosa* fruit quality would entail channelling more resource to the seed and less to other parts of the fruit.

Within the context of attaining effective in-situ conservation of *Parkia biglobosa* as resource for the future, the need to adopt a joint forest management programme, in which local communities participate effectively with the Forestry Department and share responsibilities and benefits from the forest, would be desirable. Nevertheless, unless access and the current existing land user rights decree in Nigeria is modified, there is little incentive to manage woodlands sustainably. Success depends upon the clarity and practicality of policies, and positive action from institutions assigned the responsibility for implementation. Management efforts will require assessment of the cropping systems and crops desired most frequently by farmers on *Parkia biglobosa* farmlands. These cropping systems are the framework in which an appropriate spatial organisation must be put in place for *Parkia* trees. Where *Parkia* trees are planted in a defined spatial arrangement, the effect on competition with associated food crops could be reduced, while at the same time effective gene flow within the population could be enhanced and high fruit production favoured.

Extension activities will require strengthening. Effective co-operation with local people would, more than any other step, increase awareness of the value of *Parkia biglobosa* as a resource, and secure its involvement in rational utilisation. Achieving this would involve a systematic and comprehensive inventory of the existing populations of *Parkia biglobosa* in the natural woodlands, farmlands, near settlement and in forest communities. Inventories will need to be followed by implementation of a monitoring scheme on the rate of population depletion and the extraction rates for fruits under different ecozone and land use intensity situations.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following six conclusions are drawn from this study:

1 Suitable sites for *Parkia biglobosa* have moderately to well-drained deep fertile loam or sandy loam soil previously under cultivation and these sites are in relatively low toposequence positions over a wide range of altitudes (0-1300 m).

2 Occurrence of the species is generally where there is a mean annual rainfall from >400 mm to 1400 mm combined with a succession of 2-7 month with >50 mm mean rainfall.

3 In populations in the southern part of the range individuals ≥10 cm dbh are more widely spaced than in northern populations, where adjacent individuals are, on average, 25 m apart.

4 There is morphological variation among natural populations of *Parkia biglobosa* in a south-north direction in the overall size of the larger individuals (taller in the south but more slender) and the architecture (more primary branches in the north).

5 At the present time regeneration is not abundant and generally is in the form of coppice shoots rather than from seed.

6 Flowering and fruiting are mainly dry season events. Allocation of resources to inflorescence production is very high in the species but not fully translated to economic yield in form of pods. Self-compatibility is indicated. A range of insects visit *Parkia* but it is questionable whether they play significant pollination roles.

Recommendations

Based on the current findings from review of literature's and the field survey, the following eight recommendations are made relating to in-situ and ex-situ conservation and promotion of the *Parkia biglobosa* resource.

1 The mother trees supplying today's harvest are ageing but natural regeneration is apparently insufficient to ensure their replacement. There is a need to embark on deliberate planting programmes to enrich and rejuvenate the populations of the main production areas.

2 To minimise the losses of young plants to fire, enrichment needs to be in areas where cultivation is sufficiently intense to make burning unnecessary in land preparation or otherwise in areas where an early burning policy can be applied effectively.

3 Farmers protection of existing stands or isolated trees invoking local and traditional regulation should be encouraged by the government, both to consolidate and enhance the productivity of the populations throughout Nigeria. This would constitute an in-situ conservation measure.

4 An option for ex-situ conservation of *Parkia* is to introduce it as a component species of urban open spaces and Biological Gardens although it may result in intra-specific crossing.

5 Methods of species multiplication through seeds, cuttings, layering and genetic improvements which are vital for the future improvement of the species, need to be developed and adapted for application at village level.

6 Extension efforts should be further geared towards encouraging the farmers to do more direct planting.

7 More field germplasm banks are required for ex-situ conservation, along with continuous provenance collections for screening desirable traits. This should be tied to on-going improvement efforts.

8 The need to promote the current social status will renew planting interest in the species as a viable resource through improved market outlets and research effort in the bi-products utilisation of *Parkia biglobosa*.

REFERENCES

ABBIW, D. 1990. *The useful plants of Ghana.* Intermediate Technology Publications/Royal Botanic Gardens, London/Kew. 337 pp.

ABE, J.O. 1995. Community participation in foresty development in Nigeria - Osun State experience. In: *Forestry and the Small Scale Farmer.* Proceedings of the 24th Annual Conference of the Forestry Association of Nigeria held in Kaduna, Kaduna State, 30th October - 4th November 1995. (Ed. by E.A. Oduwaiye) pp. 19-27. Hedimo Litho Press, Ibadan. 331 pp.

ADAM, J.G. 1968. Sénégal. In: *Conservation of Vegetation in Africa South of the Sahara.* (Ed. by I. Hedberg & O. Hedberg). *Acta Phytogeographica Suecica,* **54**: 65-69.

ADEJUWON, J.O. 1971 The ecological status os savanna associated with inselbergs in the forest areas of Nigeria.*Tropical Ecology* **12** : 51-65

ADELODUN, M. 1944. Firewood supply from Kano farms. *Farm and Forest,* **5**: 30.

ADELOYE, A.A., AWOSANYA, B., JOSEPH, K. & OLAWOYE, S. 1993. The feeding value of cured *Parkia filicoidea* Welw. leaves with cassava peels to the goat. *Bioresource Technology,* **45**: 85-87.

ADEMILUYI, E.O. & OKEKE, R.E. 1977. Wood quality of fourteen savanna timber species in relation to pulp-making. *Obeche,* **13**: 39-47.

ADESINA, F. A. 1994 A prelimanary investigation into agroforestry pracices in the savanna belt of Western Nigeria Agroforestry systems **27**: 197-206

ADERIBIGBE, E.Y. & ODUNFA, S.A. 1988 Growth and extracellular enzymes production by strains of *Bacillus* species isolated from fermenting African locust bean, iru. *Journal of Applied Bacteriology* **69**: 662-671

ADEWOYE, R.O. & AJAYI, O.O. 1988. Flavonols, flavones and tannins *of Parkia clappertoniana. Journal of the American Leather Chemists Association,* **83**: 153-156.

ADEWOYE, R.O. & AJAYI, O.O. 1988. Phenolic constituents of *Parkia clappertoniana* fruit husk. *Journal of the Society of Leather Technologists and Chemists,* **72**: 27-29.

ADEWOYE, R.O. & AJAYI, O.O. 1989. Anthocyanids of *Parkia clappertoniana. Journal of the Society of Leather Technologists and Chemists,* **73**: 120-121.

ADEWOYE, R.O., SHOK, M. & LEMU, S. 1986. *Parkia clappertoniana* fruit husk - a promising tanning material of Nigeria. Part 1. *Journal of Leather Research,* **4**: 17-22.

ADEWUMI, B.A. & IGBEKA, J.C. 1993. The effect of steaming on the physical and dehulling characteristics of locust bean (*Parkia biglobosa*). *Tropical Agriculture,* **70**: 380-382.

AGBAHUNGBA, G. & DEPOMMIER, D. 1989. Aspects du parc à karités-nérés (*Vitellaria paradoxa* Gaertn. f. *Parkia biglobosa* Jacq. Benth.) dans le sud du Borgou (Bénin). *Bois et Forêts des Tropiques*, **222:** 41-54.

AGBOOLA S. A. 1979 An Agricultural Atlas of Nigeria Oxford University 248 pp

GYEMAN V.K. 1994. *Land, Tree and Forest Tenure sytems: implications for forestry development in Ghana.* African Development Foundation, Washington. 36 pp.

AIYANIA, O.A.J., OKAFO, C.C., YAKASSAI, B.A. & OSENI, T.O. 1995. Preferred trees by farmers: a case study in Bauchi state In: *Forestry and the Small Scale Farmer.* Proceedings of the 24th Annual Conference of the Forestry Association of Nigeria held in Kaduna, Kaduna State, 30th October - 4th November 1995. (Ed. by E.A. Oduwaiye) pp. 230-234. Hedimo Litho Press, Ibadan. 331 pp.

AKINOLA, B.A. 1995. Policy issues in foresty and small scale farming in the southern part of Nigeria with particular reference to Oyo State. In: *Forestry and the Small Scale Farmer.* Proceedings of the 24th Annual Conference of the Forestry Association of Nigeria held in Kaduna, Kaduna State, 30th October - 4th November 1995. (Ed. by E.A. Oduwaiye) pp. 127-133. Hedimo Litho Press, Ibadan. 331 pp.

ALABI, D.A. 1993 *Parkia biglobosa*: an endangered species. 265-283.Workshop on conservation of threathened species in Nigeria. Nigerian Forestry Preoceedings 1993

ALLEN, O.N. & ALLEN, E.K. 1981. *The Leguminosae: a source book of characteristics, uses and nodulation.* Macmillan, London. 812 pp.

AMUBODE, F.O & FETUGA, B.L. 1983. Proximate composition and chemical assay of the methionine, lysine and tryptophan concentrations of some forest tree seeds. *Food Chemistry*, **12**: 67-72.

AMUBODE, F.O & FETUGA, B.L. 1984. Amino acid composition of some lesser known tree crops. *Food Chemistry*, **13**: 299-307.

ANDERSON, D.M.W. & PINTO, G.L. DE 1985. Gum polysaccharides from three *Parkia* species. *Phytochemistry*, **24**: 77-79.

ANDREWS, F.W. 1952. *The flowering plants of the Anglo-Egyptian Sudan.* Vol. **II** (*Sterculiaceae-Dipsaceae*). Buncle, Arbroath. 485 pp.

ANON. 1975. *Annual Report of the Federal Department of Forest Research, Nigeria,* 1974/75. Federal Department of Forest Research, Ibadan. 117 pp.

ANON. 1981. A 'new' protein food from a traditional process. *Nutrition Reviews*, **39**: 9-11.

ANON. 1992. *Fiches de Projet de Recherche du Centre National de recherche Forestière*. CNRF-ISAR, Butare.

AUBRÉVILLE, A. 1950. *Flore Forestière Soudano-Guinéenne*. Société d'Editions Géographiques, Maritimes et Coloniales, Paris. 523 pp.

AYENSU, E.S. 1974. Plant and bat interactions in West Africa. *Annals of the Missouri Botanical Garden*, **61**: 702-724.

AWODOLA, A. M. 1991 Indices of macro-nutrient deficiences in Parkia biglobosa seedlings. Faculty of Agriculture, Usamn Danfodio University Sokoto 6th May

AWODOLA, A. M. 1993 Effect of sources and rates of NPK suply on growth of Parkia biglobosa (R.Br. ex G. Don) seedlings in tghe semi-arid zone. Proceedings of the 20th Annual Conference of the Forestry Association of Nigeria . 138-144

AWODOLA, A. M. & OKORO, S.P.A 1993 A study on establishment techniques for *Balanites eagyptiaca* , Parkia biglobosa and Prosopis cineria in Zamfara Forest Reserve. Report presented at the EEC linkage seminar series for commissioned studies. Faculty of Agriculture, Usman Danfodio University Sokoto, 25 th February.

BABAJIDE, L. & FUWAPE, A. 1984. Burning and related characteristics of forty two Nigerian fuelwood tree species. *Nigerian Journal of Forestry*, **14**:35 pp

BARBOUR, K. M. OGUNTOYINBO, J. S. ONYEMELUKWE, J. O. S & NWAFOR, J. 1984 Nigeria in Maps 148 pp Hodder and Stoughton Educational Hong Kong

BAKER H.G. 1986. Breeding systems of plants. In: *Plant Ecology in West Africa*. (Ed. by G.W. Lawson) pp. ?-?. John Wiley & Sons, Chichester. 357 pp.

BAKER, H.G. & HARRIS, B.J. 1957. The pollination of *Parkia* by bats and its attendant evolutionary problems. *Evolution* **11**: 449-460.

BAKER, H.G. 1983. Evolutionary relationships between flowering plants and animals in American and African tropical forests. In: *Tropical forest ecosystems in Africa and South America: a comparative review*. (Ed. by B.J. Meggers, E.S. Ayensu, & W.D. Duckworth) pp. 145-149. Smithsonian Institution Press, Washington. 34 pp

BALOGUN, A.M. & FETUGA, B.L. 1985. Fatty acid composition of seed oils of some members of the leguminosae family. *Food Chemistry*, **17**: 175-182.

BALOGUN, A.M. & FETUGA, B.L. 1989. Anti-nutritional components in some lesser-known leguminous crop seeds in Nigeria. *Biological Wastes*, **28**: 303-308.

BALOGUN, A.M. & FETUGA, B.L. Chemical composition of some underexploited leguminous crop seeds in Nigeria. *Journal of Agricultural and Food Chemistry*, **34**: 189-192.

BALOGUN, O.O. & ODUTUGA, A.A. 1977. Chemical composition and nutritive value of lipid-protein concentrate from West African locust bean (*Parkia filicoidea* Welw.) *Nutrition Reports International*, **25**: 867-878.

BALOGUN , O.O. & ODUTUGA, A.A. 1981. The extraction of nitrogen from the West African locust bean seed (*Parkia filicoidea* Welw.). *Journal of the Science of Food and Agriculture*, **32**: 868-872.

BAUMER, M. 1990. *The potential role of agroforestry in combating desertification and environmental degradation: with special reference to Africa.* Technical Centre for Agriculture and Rural Cooperation. Wageningen. 250 pp.

BAYER, W. 1990. Use of native browse by Fulani in central Nigeria. *Agroforestry Systems*, **12**: 217-228.

BENE, J.G. BEALL, H.W. & COTE, A. 1977. *Trees, food and people: land management in the tropics*. International Development Research Centres, Ottawa. 52 pp.

BENTHAM, G. 1842. Notes on Mimoseae with a short synopsis of species. *Journal of Botany*, **4**: 323-418.

BENTHAM, G. 1865. Parkia. In: *Genera plantarum. Vol.* **1**, *Part* **2**. (Ed. by G. Bentham & J.D. Hooker) pp. 558-559. Lovell Reeve & Co., London.

BENTHAM, G. 1875. Revision of the Suborder *Mimoseae*. *The Transactions of the Linnean Society of London*, **30**: 335-364.

BERHAUT, J. 1967. *Flore du Sénégal.* Second edition. Editions Clairafrique, Daka. 487 pp.

BERNARD, C., OUALBADET, M., NKLO, O. & PELTIER, R. 1995. Parcs agroforestiers dans un terroir Soudanien: cas du village Dolékaha au nord de la Côte d'Ivoire. *Bois et Forets des Tropiques*, **244**: 25-42.

BERRY, S. 1988. Property rights and rural resource management: the case of tree crops in West Africa. *Cahiers des Sciences Humaines* ORSTOM, **24**: 3-16.

BLAIR, A.R.; LAWTON, M. & ROSE, R.I. 1977 Land resources of Central Nigeria. Environmental aspects of the Kaduna Plains. Vol.1 and 2.Ministry of Overseas Development .

BONKOUNGOU, E.G. 1987. *Monographie de Néré,* Parkia biglobosa *(Jacq.) Benth.; espèce agroforestière à usages multiples.* IRBET/CNRST, Ouagadougou. 47 pp.

BOOTH, F.E.M. & WICKENS, G.E. 1988. Non-timber uses of selected arid zone trees and shrubs in Africa. *FAO Conservation Guide* **19**. FAO, Rome. 176 pp.

BOSSUT, P. 1986. Quelques essais de culture in vitro de jeunes plantes d'*Azadirachta indica* et de *Parkia biglobosa* élevés en conditions artificielles. *Thèse de DEA*, Université de Nancy-ENGREF. 58 pp.

BOULVERT, Y. 1980. Végétation forestière des savanes centrafricaines. *Bois et Forêts des Tropiques*, **191**: 21-45.

BOURLIÈRE, F. & HADLEY, M. 1983. Present day savannas: an overview. In: *Tropical savannas, Ecosystems of the world*, **13**. (Ed. by F. Bourlière) pp. Elsevier, Amsterdam. 730 pp.

BREMAN, H. & KESSLER, J.J. 1995. Woody plants in agro-ecosystems of semi-arid regions: with an emphasis on the Sahelian countries. *Advanced Series in Agriculture* **23**. Springer Verlag, Berlin. 342 pp.

]BROWN, R. 1826. *Narrative of travels and discoveries in northern and central Africa.* (Ed. by D. Denham & H. Clapperton).

BURKHILL, H.M. 1985. *The Useful Plants of West Tropical Africa. Vol.* **3**. Second edition. Royal Botanic Gardens, Kew, London.34-67 pp

BUSSON, F. 1965. *Plantes alimentaires de l'Ouest Africain; etude botanique, biologique et chimique*. Leconte, Marseilles. 568 pp.

CAILLIÉ, R. 1830. *Travels through Central Africa to Timbuctoo: and across the Great Desert to Morroco, performed in the years 1824-28. Vol.* **1**. Henry Colburn and Richard Bentley, London. New Impression 1992, DARF Publishers, London. 475 pp.

CAMPBELL-PLATT, G. 1980. African locust bean (*Parkia* species) and its West African fermented food product, dawadawa. *Ecology of Food and Nutrition*, **9**: 123-132.

CANDOLLE, A.P. DE 1825. Leguminosae. In: *Prodromus Systematis Naturalis Regni Vegetabilis, Part* **2**. Treuttel & Würtz, Paris. 644 pp.

CARLOWITZ, P. VON 1991. *Multipurpose trees and shrubs: sources of seeds and inoculants.* ICRAF, Nairobi. 328 pp.

CHAMBERS, R. & LEACH, M. 1989. Trees as savings and security for the rural poor. *World Development*, **17**: 329-342.

CHAMBERS. R. & LONGHURST, R. 1986. Trees, seasons and the poor. *IDS Bulletin*, **17**: 44-50.

CHAPMAN, G.P. 1970. *Patterns of change in tropical plants*. University of London Press, London. 112 pp.

CHATTERTON, J.M. 1990. *Parkia biglobosa*: a literature review. *M.Sc. thesis*, SAFS, University of North Wales, Bangor. 42 pp.

CHEVALIER, A. 1910. Mission scientifique de l'Afrique occidentale française. Dahomey. Les *Parkia* de l'Afrique occidentale. *Bulletin du Museum National d'Histoire Naturelle, Paris*, **16**: 169-174.

CHOWDHURY, A.R., BANERJI, R., HISRA, G. & NIGAM, S.K. 1984. Studies on leguminous seeds. *Journal of the American Oil Chemists Society*, **61**: 1023-1024.

CLAYTON, W.D. 1958. Secondary vegetation and the transition to savanna near Ibadan, Nigeria. *Journal of Ecology*, **46**: 217-238.

CLAYTON, W.D. 1961. Derived savanna in Kabba Province, Nigeria. *Journal of Ecology*, **49**: 595-604.

CLAYTON, W.D. 1963. The vegetation of Katsina Province, Nigeria. *Journal of Ecology*, **51**: 345-351.

CLINE-COLE, R.A., FALOLA, J.A., MAIN, H.A.C., MORTIMORE, M.J., NICHOL, J.E. & O'REILLY, F.D. 1988. Wood fuel in Kano, Nigeria: the urban-rural conflict. *Social Forestry Network Paper* **7b**. ODI, London. ?? pp.

COSSALTER, C., IYANABO, D.E. & FUGALLI, O. 1988. *Tree improvement and silvo-pastoral management in Sahelian and north sudanian Africa: problems, needs, and research proposals*. International Union of Forestry Research Organisations, Nairobi. ?? pp.

COVI, L. 1971. Etude des plantes africaines d'intérêt thérapeutique ou alimentaire. Le *Parkia biglobosa*, Benth. (Ouelle). Néfétou, Soumbala, Afiti. *Medecine d'Afrique Noire*, **18**: 883-892.

CTFT, 1979. *Fiche monographique sur Parkia biglobosa*. 14 pp.

DALZIEL, J.M. 1937. *The Useful Plants of West Tropical Africa*. pp. 217-220. Appendix to the *Flora of West Tropical Africa* by J. Hutchinson & J.M. Dalziel. Crown Agents, London. 612 pp.

DAFNI, A. 1992 Pollination ecology, a practical approach. Oxford University Press, Oxford 250 pp

DEARDEN, P.J. & CASSIDY, E.M. 1990. Food Security: an ODA view. *IDS Bulletin*, **21**: 81-83.

DELWAULLE, J.C. 1979. Plantations forestières en Afrique tropicale sèche. Techniques et espèces à utiliser. *Bois et Forêt des Tropiques*, **187**: 3-30.

DEREK, B. WEBB, P .W. HENMAN, J. P. S. 1984 A guide to species selection for Tropical and sub Tropical Plantations. Tropical Forfest Papers No 15 2nd edition Revsed 200pp

DEPARTMENT OF FOREST RESOURCES MANAGEMENT, 1986. *Feasibility study on indigenous forest fruit trees in Nigeria - Irvingia gabonensis and Parkia clappertoniana*. University of Ibadan, Nigeria. 198 pp.

DEPOMMIER, D. & FERNADES, E. 1985. Aspects du parc à karités-nérés (*Butyrospermum parkii, Parkia biglobosa*) dans la région de l'Ouham (République Centraficaine). *ICRAF, Provisional Report*. 27 pp.

DESVAUX, N. A. 1826 Observations sur la famillie des Legumineuses. Ann. Sci. Nat.(Paris) 9: 404-431

DOUGLAS, J.S. & HART R. DE 1985. *Forest farming: towards a solution to problems of world hunger and conservation*. Intermediate Technology Publications, London. 207 pp.

DUNDAS, J. 1938. Vegetaion types of the Colonie du Niger. *Imperial Forestry Institute Paper*, **15**: 1-10.

EKA, K. 1980. Effect of fermentation on the nutrient status of locust bean. *Food Chemistry*, **5**: 303-308.

EKPENYONG, T.E., FETUGA, B.L. & OYENUGA, V.A. 1977. Fortification of maize flour-based diets with blends of cashewnut meal, African locust bean meal and sesame oil meal. *Journal of the Science of Food and Agriculture*, **28**: 710-716.

ELIAS, T.S. 1981. Mimosoideae. In: *Advances in legume systematics, Part* **1**. (Ed. by R.M. Pohill & P.H. Raven). Royal Botanic Gardens, Kew. 425 pp.

EL-AMIN, M.H. 1990. *Trees and Shrubs of the Sudan*. Ithaca Press, Exeter. 484 pp.

EL-HADJI, S. 1985 Trees, food production and the struggle against desertification. *Unasylva* 37 (150): 19-25.

ETEJERE, E.O., FAWOLE, M.O. & SANI, A. 1982. Studies on the seed germination of *Parkia clappertoniana*. *Turrialba*, **32**: 181-185.

EXELL, A.W. 1944. *Catalogue of the vascular plants of S. Tomé*. British Museum (Natural History) London, 428 pp.

EXELL, A.W. 1973. Angiosperms of the Islands of the Gulf of Guinea (Fernando Po, Príncipe, S. Tomé, and Annobon). *Bulletin of the British Museum (National History) Botany*, 4: 325-411.

EZENWA, I.V. & ALASIRI, K.O. 1991. Use of leguminous tree leaves as a source for maize in a lateritic soil. *Nitrogen Fixing Tree Research Reports*, 9: 21-24.

FAGBEMI, T. 1989. Agroforestry potentials of *Parkia biglobosa* R. Br. ex G. Don. in the savanna zone of Nigeria. In: *Trees for development in sub Saharan Africa.* Proceedings of a regional seminar held by the IFS, 20th-25th February 1989, pp. 71-76. ICRAF, Nairobi. 15 pp

FAGBEMI, T. 1994. Performance of *Parkia biglobosa* and *Leucaena leucephala* in mixed silviculture with *Gmelina arborea* in the savanna zone of Nigeria. *African Crop Science Journal*, 2: 279-284.

FAIRBARN, W.A. 1939. *Ecological succession due to biotic factors in Northern Kano and Katsina provinces of northern Nigeria.* Imperial Forestry Institute, University of Oxford.68 pp

FAY, M. J. 1984 Plants of Bambari region (*Parkia*) Central Africa Rebuplic (Kew Gardens).

FANDOHAN, S. 1983. An economic survey of some indigenous food trees (*Parkia biglobosa* Benth. and *Irvingia gabonensis* Baill.) in the People's Repubic of Benin. *Thèse de Dilpome d'Ingeneur Agronom*, Universités de Benin et Ibadan. IITA, Ibadan. 151 pp.

FAO. 1967. *Lists of foods used in Africa.* Rome: FAO. ?? pp.

FAO. 1977. Appendix 8, Forest genetic resource priorities. 8. Africa. *Report of the Fourth Session of the FAO Panel of Experts on Forest Gene Resources,* held in Canberra, Australia 9-11 March 1977, pp. 62-64. FAO, Rome. 75 pp.

FAO-UNESCO 1977 Soil maps of the World: 1:50,000000, Vol VI Africa Unesco-Paris

FAO. 1984. Appendix 8, Forest genetic resource priorities. 8. Africa. *Report of the Fifth Session of the FAO Panel of Experts on Forest Gene Resources* held in Rome, Italy 8-11 December 1981, pp. 52-100. FAO, Rome. 101 pp.

FAO, 1984 Agroclimatic data for Africa. Volume 2 FAO, Rome.

FAO. 1987. *Manual of traditional food plants.* Food and Nutrition Paper, 42. FAO, Rome.88 pp.

FAO. 1988a. Appendix 5, Forest genetic resource priorities. 8. Africa. *Report of the Sixth Session of the FAO Panel of Experts on Forest Gene Resources,* held in Rome, Italy 10-12 December 1985, pp. 12-79. FAO, Rome. 79 pp.

FAO. 1988b. Traditional food plants. *Food and Nutrition Paper,* **42**: 1-593.

FAO. 1989b. Utilisation of tropical foods: tropical beans. *Food and Nutrition Paper* **47**: 1-74.

FAO/WHO. 1970. *Report of the joint FAO/WHO committee on requirements for protein and energy.* FAO, Rome..

FAPULOWO, O.O. & AFOLABI, O. 1986. Nature of lipids in African locust beans (*Parkia filicoidea* Welw.), and changes occuring during storage and processing. *Journal of Agricultural and Food Chemistry,* **34**: 246-248.

FARIA, S.M. DE, LEWIS, G.P., SPRENT, J.I. & SUTHERLAND, J.M. 1989. Occurrence of nodulation in the Leguminosae. *New Phytologist,* **111**: 607-619.

FATUBARIN, A. 1987. Observations on the natural regeneration of the woody plants in a savanna ecosystem in Nigeria. *Tropical Ecology,* **28**: 1-8.

FELKER, P. & BANDURSKI, R.S. 1977. Protein and amino acid composition of tree legume seeds. *Journal of the Science of Food and Agriculture,* **28**: 791-797.

FELKER, P. & BANDURSKI, R.S. 1979. Uses and potential uses of leguminous trees for minimal energy input in agriculture. *Economic Botany,* **33**: 172-184.

FELKER, P. 1981. Uses of tree legumes in semi arid regions. *Economic Botany,* **35**: 174-186.

FERGUSON, E.L., GIBSON, R.S., OPARE-OBISAW, C., OSEI-OPARE, F., STEPHEN, A.M., LEHRFELD, J. & THOMPSON, L.U. 1993. The zinc, calcium, copper, manganese, nonstarch polysaccharide and phytate content of seventy eight locally grown and prepared African foods. *Journal of Food Composition and Analysis,* **6**: 87-99.

FETUGA, B.L., BABATUNDE, G.M. & OYENUGA, V.A. 1973. Protein quality of some Nigerian feedstuffs. II. Biological evaluation of protein quality. *Journal of the Science of Food and Agriculture,* **24**: 1515-1523.

FETUGA, B.L., BABATUNDE, G.M. & OYENUGA, V.A. 1973. Protein quality of some Nigerian feedstuffs. I. Chemical assay of nutrients and amino acid composition. *Journal of the Science of Food and Agriculture,* **24**: 1505-1514.

FETUGA, B.L., BABATUNDE, G.M. & OYENUGA, V.A. 1974. Protein quality of some unusual protein foodstuffs: studies on the African locust-bean seed (*Parkia filicoidea*). *British Journal of Nutrition,* **32**: 27-36.

FETUGA, B.L., BABATUNDE, G.M., EKPENYONG, T.E. & OYENUGA, V.A. 1973. Chemical composition and amino-acid profiles of some lesser used tropical protein meals. *Alimentation Animal*, **17**: 53-58.

FISHWICK T. S 1964 Selected savanna species and germination period in Nigeria. Savanna series No 5

FORD, R.E. 1991. Ethnobotany, desertification and food security in Northern Yatenga, Burkina Faso: the case of the Kumba, Dogon, Fulbe/Rimmaaybe and Mossi. Paper presented to the Association of American Geographers Conference, April 1991, Miami, Florida. 14 pp.

FORSTER, H. 1983. *Tree species plantation trials and silvicultural studies in the Gambia, 1981-1983*. Gambian-German Forestry Project. DFS GmbH for GTZ GmbH, Report No. 9.

FORSYTH, J. 1966. *Agricultrual Insects of Ghana*. Ghana Univerisities Press, Accra. 163 pp.

FORESTRY RESEARCH INSITITUTE OF NIGERIA 1983 *Parkia biglobosa* provenance collection notes and map.

FORESTRY RESEARCH INSITITUTE OF NIGERIA 1986 Seminar papers

GAKOU, M., FORCE, J.E. & MCLAUGHLIN, W.J. Non-timber forest products in rural Mali: a study of villager use. *Agroforestry Systems*, **28**: 213-226.

GBILE, Z.O. 1980. *Vernacular names of Nigerian Plants (Hausa)*. Federal Department of Forestry, Lagos. 63 pp.

GEERLING, C. 1982. *Guide de terrain des ligneux Sahéliens et Soudano-Guinéens*. Pudoc, Wageningen. 340 pp.

GHAZANFAR, S.A. 1989. *Savanna plants of Africa: an illustrated guide*. Macmillan, London. 227 pp.

GIFFARD, P.L. 1974. *L'arbre dans le paysage Sénégalais: sylviculture en zone tropicale sèche*. Centre Technique Forestier Tropical, Dakar. 431 pp.

GIJSBERS, H.J.M., KESSLER, J.J. & KNEVEL, M.K. 1994. Dynamics and natural regeneration of woody species in farmed parklands in the Sahel region (Province of Passoré, Burkina Faso). *Forest Ecology and Management*, **64**: 1-12.

GILL, L.S. & BAMIDELE, J.F. 1981. Seed morphology, germination and cytology of three savanna trees. *Nigerian Journal of Forestry*, **11**: 16-20.

GIRGIS, P. & TURNER T.D. 1972. Lesser known Nigerian Edible Oils and Fats. III. Fatty acid compositions as determined by Gas-Liquid chromatography. *Journal of the Science of Food and Agriculture*, 23: 259-262.

GOLDBLATT, P. 1979. Cytology and the phenology of Leguminosae. In: *Advances in Legume systematics. Vol* 1, *Part* 2. (Ed. by R.M. Polhill & P.H. Raven) pp 427-463. Royal Botanic Gardens, Kew. 1049 pp.

GOMES E SOUSA, A.F. DE 1929. Notas sôbre a flora da Guiné Portuguesa. *Boletin da Agência General das Colônias*, 5: 99-139.

GOOR, A.Y. & BARNEY, C.W. 1976. *Forest Tree Planting in Arid Zones*. Ronald Press Company, New York. 504 pp.

GOTZ, E. 1983. *Timber Trees of the Gambia*. Bundersforschungsanstalt für Forst und Holzwirtschaft, Hamburg; Stiftung Walderhaltung in Afrika. 105 pp.

GOUDET, J.P. 1985. The balance of the natural environment in dry tropical Africa ligneous vegetation and desertification. *Bois et Forêts des Tropiques*, 207: 3-15.

GOUDET, J.P. 1991. Les productions arborées ligneuse et non-ligneuses. *Savanes d'Afrique, terres fertiles* (Ed. by C. Pieri) pp. 195-214. Ministère de la Coopération et du Developpement, Paris. 587 pp.

GRÜNMEIER, R. 1990. Pollination by bats and non-flying mammals of the African tree *Parkia bicolor*, Mimosaceae. *Memoirs of the New York Botanical Garden*, 55: 83-104.

GUILLOTEAU, J. 1954. Scheme for the improvement of the agricultural economy of Senegal. *Sols Africains*, 3: 182-235.

GUINET, P. 1981. Mimosoideae: the characters of their pollen grains. In: *Advances in legume systematics. Vol* 1, *Part* 2. (Ed. by R.M. Polhill & P.H. Raven) pp. 835-857. Royal Botanic Gardens, Kew. 1049 pp.

GUINKO, S. & PASGO, L.J. 1992. Harvesting and marketing of edible products from local woody species in Zitenga, Burkina Faso. *Unasylva*, 43: 16-19.

HAGOS, T.H. 1962. A revision of the genus *Parkia* R. Br. (Mim.) in Africa. *Acta Botanica Neerlandica*, 11: 231-265.

HALLÉ, F., OLDEMAN, R.A.A. & TOMLINSON, P.B. 1978. *Tropical trees and forests: an architectural analysis*. Springer Verlag, New York. 441 pp.

HALLIDAY, J. 1984. Register of nodulation reports for leguminous trees and other arboreal genera with nitrogen fixing members. *Nitrogen Fixing Tree Research Reports*, 2: 38-45.

HARRIS, B.J. & BAKER, H.G. 1959. Pollination of flowers by bats. *Nigerian Field*, **24**: 151-159.

HAMILTON, W. 1825 Circular desirous of West Indian plants. Plymouth, England

HALL. J. B. AEBISCHER, D. P TOMLINSON, H. OSEI-AMANING, E & HINDLE, J. R. 1996 *Vitellaria paradoxa*. A Monograph. SAFS University of Wales

HILL, A.F. 1937. *Economic botany: a textbook of useful plants and plant products.* McGraw-Hill, London. 592 pp.

HOGG, T. 1994. *Parkia biglobosa*: a review of phenology and ecology in mainland Africa. *B.Sc. Honours Dissertation*, School of Agricultural and Forest Sciences, University of Wales, Bangor. 51 pp.

HOLLAND, J.H. 1922. The Useful Plants of Nigeria. *Bulletin of Miscellaneous Information. Additional Series*, IX. HMSO, London. 963 pp.

HOWARD, W. J. 1976 Land resources of Central Nigeria Landforms, soils and vegetation of the Benue valley Vol. 1 & 2 Land Resource Report 7 Ministry of Overseas Development

HOOKER, W.J., 1849. *Niger Flora, or an Enumeration of the Plants of Western Tropical Africa.* Hippolyte Bailliere, London. 587 pp.

HOPKINS, B. 1962. Vegetation of the Olokemeji Forest Reserve, Nigeria. 1. General features of the reserve and the research sites. *Journal of Ecology*, **50**: 559-598.

HOPKINS, B. 1965. *Forest and Savanna: an introduction to tropical plant ecology with special reference to West Africa.* Heinemann, Ibadan & London. 100 pp.

HOPKINS, H.C. & WHITE, F. 1984a. *Parkia biglobosa* (Jacq.) R. Br. Ex. G. Don. (1830). Distributiones Plantarum Africanarum, **27**. *Bulletin Botanique National de Belgique*, **54**: 245.

HOPKINS, H.C. & WHITE, F. 1984b. The ecology and chorology of *Parkia* in Africa. *Bulletin du Jardin Botanique National de Belgique Bulletin National Plantentuin Belgique*, **54**: 235-266,

HOPKINS, H.C. 1983. The taxonomy, reproductive biology and economic potential of *Parkia* (Leguminosae: Mimosoideae) in Africa and Madagascar. *Botanical Journal of the Linnean Society*, **87**: 135-167

HOPKINS, H.C. 1984. Floral biology and pollination ecology of the neotropical species of *Parkia. Journal of Ecology*, **72**: 1-23.

HOPKINS, H.C. 1986. Parkia (Leguminosae: Mimosoideae). *Flora Neotropica, Monograph,* **43**. 117 pp.

HOPKINS, H.C. 1989. Patterns of diversity, distribution and speciation in *Parkia*. Bul. I.G.S.M.:**17**: 61-77

HOUÉROU, H.N. LE 1980a. The role of browse in the Sahelian and Sudanian zones. In: *Browse in Africa: the current state of knowledge.* (Ed. by H.N. le Houérou) pp. 83-100. ILCA, Addis Abba. 491 pp.

HOUÉROU, H.N. LE 1980b. Chemical composition and nutritive value of browse in tropical west Africa. In: *Browse in Africa: the current state of knowledge.* (Ed. by H.N. le Houérou) pp. 261-288. ILCA, Addis Abba. 491 pp.

HUTCHINSON, J. & DALZIEL, J.M. 1954. *Flora of West Tropical Africa. Vol.* **1**. Second Edition. Crown Agents, London. 828 pp.

HUTCHINSON, J. 1969. *Evolution and phylogeny of flowering plants: Dicotyledons; facts and theory.* Academic Press, London. 717 pp.

IBIYEMI, S.A., ABIODUN, A. & AKANJI, S.A. 1988. *Adansonia digitata* Bombax and *Parkia filicoidea* Welw.: fruit pulp for the soft drink industry. *Food Chemistry,* **28**: 111-116.

IBIYEMI, S.A., EHUSANI, R.O., AMAORGU, F.B. & ATTEH, J.A. 1989. Studies of the Thermal Effect on *Parkia* seeds. *Food Chemistry,* **33**: 165-171.

IBRAHIM, M.H. & ANTAI, S.P. 1986. Chemical changes during fermentation of Africa locust bean (*Parkia filicoidea*) seeds for production of 'dawadawa'. *Plant Foods for Human Nutrition,* **36**: 179-184.

ICHIRE, O. 1992. Trees for food and fodder production in dryland Nigeria. *Agroforestry Today,* **5**: 12-13.

IKENOBOMEH, M.J., KOK, R. & INGRAM, J.M. 1986. Processing and fermentation of the African locust bean to produce dawadawa. *Journal of the Science of Food and Agriculture,* **37**: 273-282.

IRVINE, F.R. 1961. *Woody plants of Ghana: with special reference to their uses.* Revised edition. Oxford University Press, London. 868 pp.

JACKSON, J.A.D. 1973. *Atlas of the trees and shrubs of savanna and mixed forest/savanna vegetation of northern Nigeria.* Federal Department of Forestry, Ibadan. 294 pp.

JACQUES-FELIX, F. 1963. Contribution de Réné Caillié à l'ethnobotanique africaine au cours de ses voyages en Mauritanie et à Tombouctou (1819-1828). *Journal d'Agriculture Traditionelle et Botanique Appliquée,* **10**: 551-582.

JACQUIN, N.J. 1763 Selectrum stirpium amercanarium histroria Wein.

JAEGER, P. & ADAM, J.G. 1967. Sur la présence en piedmont ouest des monts Loma (Sierra Leone) d'un groupement forestier rélictuel à *Tarrieta utilis* Sprague (Sterculiacées). *Comptes Rendus hebdomadaires des Séances. Acadamie des Sciences, Paris,* série D, **265**: 1627-1629.

JAEGER, P. 1956. Contribution à l'étude des forêts reliques du Soudan occidental. *Bulletin de l'Institut Française d'Afrique Noire,* **18**: 993-1053.

JAEGER, P. 1968. Mali. In: *Conservation of vegetation of Africa south of the Sahara.* (Ed. by I. Hedberg & O. Hedberg). *Acta Phytogeographica Suecica,* **54**: 51-53.

JENÍK, J. & HALL, J.B. 1966. The ecological effects of the harmattan wind in the Djebobo Massif (Togo Mountains, Ghana). *Journal of Ecology,* **54**: 767-779.

JONES, E.W. 1963a. The forest outliers in the Guinea zone of Northern Nigeria. *Journal of Ecology,* **51**: 415-434.

JONES, E.W. 1963b. The Cece Forest Reserve, Northern Nigeria. *Journal of Ecology,* **51**: 461-466.

JOSENS, G. 1983. The soil fauna of tropical savannas. III The termites. In: *Tropical savannas.* Ecosystems of the world, **13**. (Ed. by F. Bourlière) pp. ?-?. Elsevier, Amsterdam. 730 pp.

KALIN ARROYO, M. A. & ZAPATTA, M. K. 1981. Breeding systems and pollination biology in the Leguminosae. In: *Advances in Legume systematics. Vol.* **1**, *Part* **2**. (Ed. by R.M. Polhill & P.H. Raven) pp. 723-769. Royal Botanic Gardens, Kew. 1049 pp. *Lebensmittel, Wissenschaft und Technologie,* **23**: 260-261.

KATER, L.J.M., KANTE, S. & BUDELMAN, A. 1992. Karité (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*) associated with crops in South Mali. *Agroforestry Systems,* **18**: 89-105.

KEAY, R.W.J. 1949. An example of Sudan zone vegetation in Nigeria. *Journal of Ecology,* **37**: 335-364.

KEAY, R.W.J. 1955. A new species of *Parkia* R. Br. (Leguminosae-Mimosaceae). *Bulletin du Jardin Botanique de l'Etat à Bruxelles,* **25**: 209-212.

KEAY, R.W.J. 1959a. *An outline of Nigerian vegetation.* Third edition. Federal Government Printer, Lagos. 46 pp.

KEAY, R.W.J. 1959b. Derived savanna - derived from what? *Bulletin de l'Institut Française d'Afrique Noire*, **21**: 427-438.

KEAY, R.W.J. 1989. *Trees of Nigeria*. Oxford: Clarendon Press. 476 pp.

KEAY, R.W.J., ONOCHIE, C.F.A. & STANFIELD, D.P. 1964. *Nigerian trees. Vol.* 2. Nigerian National Press, Apapa.

KENNEDY, J.D. 1932. *Forest Flora of Southern Nigeria*. Government Printer Press, Lagos. 107 pp.

KERSHAW, K.A. 1968. A survey of the vegetation in Zaria Province, N. Nigeria. *Vegetatio*, **15**: 244-268.

KESSLER, J.J. & BONI, J. 1991. L'agroforestrerie au Burkina Faso. Bilan et analyse de la situation actuelle. *Tropical Resource Management Papers, No.* **1**. 144 pp.

KESSLER, J.J. 1992. The influence of karité (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*) trees on sorghum production in Burkina Faso. *Agroforestry Systems*, **17**: 97-118.

KESSLER, J.J. 1994. Agroforestry in Burkina Faso: a careful balance. *Ag. Siev*, **6**: 4-5.

KIO, P.R.O & ABU, M. 1988 High Forest Management in Nigeria. Workshop paper

KIO, P.R.O. , GBILE, Z.O , BAMIGBALA, E.O & LADIPO, D.O 1985 Stategies for the conservation of natural forests and grazing lands in Nigeria. Technical Report. Forestry Research Institute of Nigeria (Savanna series) No 52, 30pp.

LADIPO, D.O., SOLADOYE, M.O. & KAPOOR, P. 1990. Conservation of the genetic resources of *Parkia biglobosa* (Jacq) Benth.: a multipurpose forest tree species in Nigeria. *Paper presented at the International Symposium on the Conservation of Biodiversity, IITA, Ibadan, Nigeria. 2nd-5th September 1990*. 9 pp.

LAWSON, G.W. 1986. *Plant Ecology in West Africa: systems and processes.* John Wiley & Sons, Chichester. 357 pp.

LAWSON, G.W., JENÍK, J. & ARMSTRONG-MENSAH, K.O. 1968. A study of a vegetation catena in Guinea Savanna at Mole Game Reserve (Ghana). *Journal of Ecology*, **56**: 505-522.

LE-HOUEROU, H. N. 1980 Browse in Africa:The current state of knowledge. Papers present at the International Symposium on Browse in Africa. Addis abba April 8-12

LEEUW, P.N. DE 1979. Species preferences of domestic ruminants grazing Nigerian savannah. In: *Wildlife Management in Savanna Woodland.* (Ed. by S.S. Ajayi & L.B. Halsted), pp. 110-122. Taylor & Francis, London. 237 pp.

LETOUZEY, R. 1968. *Étude phytogéographique du Cameroun.* Lechevalier, Paris. 511 pp.

LOBREAU-CALLEN, D., DARCHEN, R. & THOMAS, A. LE, 1986. Apport de la palynologie à ola connaissance des relations abeilles/plantes en savanes arborées du Togo et Bénin. *Apidologie*, **17**: 279-306.

LOUDON J. C 1832 A Catalogue of the plants (indigenous, cultivated in or introduced to Britain. Part 1 The Linnean arrangement 277pp

LENGKEEK, A. G. 1992 A biosystematical analysis of *Parkia biglobosa* in West Africa Agricultural Univerisity Wageningen

LOCK, J.M. 1989. *Legumes of Africa: a check list.* Royal Botanic Gardens, Kew. 619 pp.

MARCHAL, J.-Y. 1980. Arbres et brousses du paysage soudana-sahelien: dynamiques des formations végétales au nord de la Haute Volta. *Cahiers de l'Office de la Recherche Scientifique et Technique Outre-Mer*, **167**: 1-873.

MARSHALL, A.G. 1985. Old world phytophagous bats (Megachirptera) and their food plants: a survey. *Biological Journal of the Linnaean Society*, **83**: 35-369.

MACMILLIAN, H.F. & BARLOW, I. 1991 Tropical planting and gardenig. Malayan Nature Society 250-327. Kuala Lampur

MAYDELL, H.J. VON 1990. *Trees and shrubs of the Sahel: their characteristics and uses.* Deutsche Gesellschaft fur Technische Zusammenarbeit, Eschorn. 525 pp.

MAGENOT, S. & MANGENOT, G. 1957 Nombres chromosoniques nouveax chez diveses dictolyledones et monocotyledones d' Afrique ocidentale *.Bull. Jard. Bot Etat* **27**: 637-654

MENAUT, J-C. 1983. The vegetation of African savannas. In: *Tropical savannas. Ecosystems of the world*, **13**. (Ed. by F. Bourlière) Elsevier, Amsterdam. 730 pp.

MORISON, C.G.T., HOYLE, A.C. & HOPE-SIMPSON, J.F. 1948. Tropical soil-vegetation catenas and mosaics. *Journal of Ecology*, **36**: 1-84.

MORTIMORE, M.J. & WILSON, J. 1965. Land and People in the Kano Close-settled zone. Ahmadu Bello University, *Department of Geography Occasional Paper, No.* **1**. 120 pp.

MULLER, J. 1970. Palynological evidence on early differentiation of angiosperms Biol. Rev. 43:417-450

MULLER-DOMBOIS, S. & ELLENBERG, W. 1974 *Aims and Methods Vegetation Ecology*. Muller-Dombois, Wley N.Y.

MURDOCH, G. OJO-ATERE, J COLBORNE, G. OLOMU, E.I. & ODUGBESESAN 1976 Soils of the Western Statge of Nigeria. The Enviroment

NATIONAL ACADEMY PRESS, 1984. *Agroforestry in the West African Sahel.* National Academy Press, Washington D.C. 86 pp.

NICHOL, J.E. 1989. Ecology of fuelwood production in Kano Region, Northern Nigeria. *Journal of Arid Environments*, **16**: 347-360.

NIGERIA THREATENED ENVIRONMENT 1991:A national profile (NEST) Nigeria Environment Study/Action Team Intec Printers Limited. Ibadan.

NIKIÉAMA A. 1993. Regeneration *of Parkia biglobosa* (Jacq.) R. Br. ex G. Don. in an agroforestry system: a pilot study in Burkina Faso. *M.Sc. thesis*, Wageningen Agricultural University. 65 pp.

NORMAND, D. 1950. *Atlas des Bois de la Côte d'Ivoire. Tome* **1**. CTFT, Nogent sur Marne.12 pp.

NORTON, A. 1988. *The socio-economic background to community forestry in Northern Ghana.* Overseas Development Administration. 89 pp.

ODUNFA, S.A. & ADESOMOJU, A. 1986. Fatty acid composition of African locust bean (*Parkia biglobosa*). *Chemie Mikrobiologie Technologie der Lebensmittel*, **10**: 125-127.

ODUNFA, S.A. & ADESOMOJU, A.A. 1985. Effects of fermentation on the fatty acids of African Locust bean during iru production. *Journal of Plant Foods*, **6**: 111-115.

ODUNFA, S.A. & ADEWUYI, E.Y. 1985. Optimization of process conditions for the fermentation of African locust bean (*Parkia biglobosa*). **1**. Effect of time, temperature and humidity. *Chemie Mikrobiologie Technolgie der Lebensmittel*, **9**: 6-10.

ODUNFA, S.A. & OYEWOLE, O.B. 1986. Identification of *Bacillus* species from 'Iru', a fermented African locust bean product. *Journal of Basic Microbiology*, **26**: 101-108.

ODUNFA, S.A. 1982. Carbohydrate changes in fermenting locust bean during iru preparation. *Journal of Plant Foods*, **4**: 105-110.

ODUNFA, S.A. 1985. Biochemical changes in fermenting African locust bean (*Parkia biglobosa*), during 'iru' fermentation. *Journal of Food Technology*, **20**: 295-303.

Odutuga, A. & Oyelola, B. 1980. Digestibility of neutral lipids and phospholipids from raw and cooked locust bean seeds (*Parkia filicoidea* Welw.) by rats. *Nutrition Reports International,* **26**: 429-438.

Ogbadu, L.J. & Okagbue, R.N. 1988. Fermentation of African locust bean (*Parkia biglobosa*) seeds: involvement of different species of *Bacillus*. *Food Microbiology,* **5**: 195-199.

Ogigigiri, M.A. & Igboanugo, A.B.I. 1985. Root growth characteristics of some exotic and indigenous tree species in the Nigerian savanna. *Pakistan Journal of Forestry,* **35**: 97-103.

Ogunbunmi, E.M. & Olumbe, B. 1982. Proteins and amino acid contents of some Nigerian food condiments. *Nutrition Reports International,* **22**: 497-502.

OGUNTALA, B. A 1979 Natural and artificial regeneration of forests in Nigeria An Ecological analysis . The Nigeria Journal of Forestry Vol 9 Nos 1&2

Oje, K. 1993. Locust bean pods and seeds: some physical properties of relevance to dehulling and processing. *Journal of Food Science and Technology,* **30**: 253-255.

Okafor, J.C. 1978. Development of forest tree crops for food supplies in Nigeria. *Forest Ecology and Management,* **1**: 235-247.

Okafor, J.C. 1980. Edible indigenous woody plants in the rural economy of the Nigerian high forest zone. *Forest Ecology and Management,* **3**: 45-55.

Okafor, J.C. 1980. Trees for food and fodder in the savanna areas of Nigeria. *International Tree Crops Journal,* **1**: 131-142.

Okpala, J.O. 1989. *Nigerian tree crops: Parkia* in the economy of the savannah rural population. *Savanna,* **10**: 92-96.

Okpala, J.O. 1990. Analyses of some macronutrients and food substances in the mature fruit parts of *Parkia biglobosa* (Jacq.) R. Br. *Nigerian Journal of Botany,* **3**: 209-214.

OLAPADE, E.O. 1995 Foods and Herbs fo diabetes mellitus and Hypertension. NARL Specialist Clinic. Centre for Research and Development of Phytomedcines. Nigeria

Oladele, F.A., Fawole, M.O. & Bhat, R.B. 1985. Leaf anatomy of *Parkia clappertoniana* Keay (Mimosaceae). *Korean Journal of Botany,* **28**: 21-28.

Oliver, D. 1871. *Flora of Tropical Africa. Vol.* **II.** *Leguminosae to Ficoideae*. Reeve & Co., London. 613 pp.

ONI, O. & LADIPO, D.O. 1989. Growth variations in some progenies of *Parkia biglobosa* (syn. *Parkia clappertoniana*) Keay. *Paper presented at the 16th annual conference of the Genetics Society of Nigeria, 9-13th April, 1989. Anambra State University of Technology, Enugu*. 9 pp.

ONUOHA, P. N. 1995 Comparative effects of organic and inorganic fertilizers on the growth of Parkia biglobosa (Jacq.) Benth seedl,ings

OSONUBI, O. & FASEHUN, F.E. 1987. Adaptations to soil drying in woody seedlings of African locust bean (*Parkia biglobosa* (Jacq) Benth). *Tree Physiology*, 3: 321-329.

OTEGBEYE, G.O. 1995. Agroforestry: impact of community participation in forestry development in the sudano-sahelian region of Nigeria. In: *Forestry and the Small Scale Farmer*. Proceedings of the 24th Annual Conference of the Forestry Association of Nigeria held in Kaduna, Kaduna State, 30th October - 4th November 1995. (Ed. by E.A. Oduwaiye) pp. 59-64. Hedimo Litho Press, Ibadan. 331 pp.

OUEDRAOGO, A.S. 1992. *Parkia biglobosa* (Leguminosae) en Afrique de l'Ouest: Biosystematique et Amélioration. *Ph.D. Thesis*. Institute for Forestry and Nature Research, Wageningen. 205 pp.

PARK, M. 1799 Travels in the interior districts of Africa in 1795, 1796, and 1799 (Reprinted) by J. Dent and sons)

PALLIOT DE BEAUVOIS, A.M. F. J. 1816 Flore d' Oware et Benin en Afrique, Vol. 2 (15): 53

PETTET, A. 1977. Seasonal changes in nectar feeding by birds at Zaria, Nigeria. *The Ibis*, 119: 291-308.

POBÉGUIN, H. 1906. *Essai sur la Flore de la Guinée Française*. Challamel, Paris. 392 pp.

POLHILL, R.M., RAVEN, P.H. & STIRTON, C.H. 1981. Evolution and systematics of the Leguminosae. In: *Advances in legume systematics*. (Ed. by R.M. Polhill & P.H. Raven) pp. 1-26. Royal Botanic Gardens, Kew. 425 pp.

POPOOLA, L. & MAISANU, H. 1995. Socio-economic values of some potential farm forestry species in Sokoto state. In: *Forestry and the Small Scale Farmer*. Proceedings of the 24th Annual Conference of the Forestry Association of Nigeria held in Kaduna, Kaduna State, 30th October - 4th November 1995. (Ed. by E.A. Oduwaiye) pp. 109-119. Hedimo Litho Press, Ibadan. 331 pp.

PULLAN, R.A. 1974. Farmed parkland in West Africa. *Savanna*, 3: 119-151.

RAINTREE, J.B. 1983. Bio-economic considerations in the design of agroforestry cropping systems. In: *Plant Research and Agroforestry.* (Ed. by P.A. Huxley) pp. ?-?. ICRAF, Nairobi. 617 pp.

RAISON, J.P. 1988. *Parkia* in Africa: state of knowledge and future research.

RAMSAY, D.M. & LEEUW, P.N. DE 1964a. An analysis of Nigerian savanna. I. The survey area and the vegetation developed over Brima sandstone. *Journal of Ecology*, **52**: 233-254.

RAMSAY, D.M. & LEEUW, P.N. DE 1964b. An analysis of Nigerian savanna. III. The vegetation of the middle Gongola region by soil parent materials. *Journal of Ecology*, **52**: 643-660.

RAMSAY, D.M. 1964. An analysis of Nigerian savanna. II. An alternative method of analysis and its application to the Gombe sandstone formation. *Journal of Ecology*, **52**: 457-466.

RAVEN, P.H. & AXELROD, D.I. 1974. Angiosperm biogeography and past continental movements. *Annals of the Missouri Botanical Garden*, **61**: 539-673.

RAVEN, P.H. & POLHILL, R.M. 1981. Biogeography of the Leguminosae. In: *Advances in legume systematics, Part* 1. (Ed. by R.M. Pohill & P.H. Raven) pp. 27-34. Royal Botanic Gardens, Kew. 425 pp.

REIJNTJES, C., HAVERKORT, B. & WATERS-BAYER, A. 1992. *Farming for the future: an introduction to low-external-input and sustainable agriculture.* Macmillan, London. 250 pp.

RENDU, F., SALEUN, S. & AUGER, J. 1993. *Parkia biglobosa* seeds possess anti platelet activity. *Thrombosis Research*, **71**: 505-508.

ROBERTS, H. 1969. Forest insects of Nigeria with notes on their biology and distribution. *Commonwealth Forestry Institute*, **44**: 15 pp

ROCHELEAU, D WEBBER, F. FIELD-JUMA, A 1988 Agroforestry in Dryland Africa ICRAF Nairobi 307 pp

SABIITI, E.N. & COBBINA, J. 1992a. Initial agronomic evaluation of *Parkia biglobosa* in the humid zone of Nigeria. *Agroforestry Systems*, **17**: 271-279.

SABIITI, E.N. & COBBINA, J. 1992b. *Parkia biglobosa*: a potential multipurpose fodder tree legume in West Africa. *International Tree Crops Journal*, **7**: 113-139.

SALARD-CHEBOLDAEFF, M. 1978 Sur la palynoflore Maestrichtienne et Tertiare du bassin sedimentaire littoral du Cameroun. *Pollen et Spores* **20**: 215-260

SANFORD, W.W. 1982. Leguminosae of the Nigerian savanna: incidence and nodulation. In: *Nigerian Savanna*. Selected papers from the man and biosphere state of knowledge workshop. (Ed. by W.W. Sanford, H.M. Yesufu & J.S.O. Ayeni) pp. 225-232. Kainji Lake Research Institute, New Bussa. 440 pp.

SAVILL, P.S. & FOX, J.E.D. 1967. *Trees of Sierra Leone*. ?? pp.

SAVENJA, H. J . F 1993 Silvicultural management pracices in the Sudan AND Sahel zone with an emphasis on the sylvopastorial vegetations. Acompliation of literature. Forestry Dept Agricultural Unversity The Netherlands 12 pp

SAYERS, J.A., HARCOURT, C.S. & COLLINS, N.M. 1992. *The conservation atlas of tropical forests: Africa*. Macmillan, London. ?? pp.

SCHERY, R.W. 1952. *Plants for man*. Prentice Hall, New York. 564 pp.

SEIF, A.G. EL DIN 1980. Agroforestry practices in the dry regions. *Proceedings of the Kenya National Seminar on Agroforestry*. ?? pp.

SENE, H. EL 1985. Trees, food production and the struggle against desertification. *Unasylva*, **37**: 19-25.

SIBIDOU, S. VAN DER MAESEN, L. J. G. & JOLY, H. 1995 Genetic diversity and reproductive biology of *Parkia biglobosa* Second Annual Report Commision of the European Communities Directorate General for Science. Contract CT92-0072 SAFS .University of Wales.

SHARLAND, R.W. 1991. Trees in the garden: interaction between the wild and agricultural domains in practice among the Moru of the southern Sudan. *Unasylva* **42**: 55-61.

SNEDECOR, G. W & COCHRAN, W. G 1967 Statistical methods 6th ed. Iowa State Univ. Press Ames Iowa 583 pp

SMITH, N.J.H., WILLIAMS, J.T., PLUCKNETT, D.L. & TALBOT, J.P. 1992. *Tropical forests and their crops*. Ithaca, New York.124pp

SOLADOYE, M.O., OHIERE, S.S. & IBIMODE, B.M. 1989. Ethino-botanical study of two indigenous multipurpose plants in the Guinea savanna zone of Kwara state - *Vitelleria paradoxa* and *Parkia biglobosa*. *Paper presented at the biennial conference of the Ecology Society of Nigeria, 14th August 1989*. FRIN, Ibadan. 13 pp.

SOME, L.M., SARY, H. & BELLEFONTAINE, R., 1990. Cold chamber storage of seeds of six Sahelo-Sudanese tree species. *Bois et Forêts des Tropiques*, **225**: 42-46.

SOME, L.M., VERWEY, H. & SACANDE, M. 1990. Methodology and costs for treatment of *Parkia biglobosa* fruits. In: *Tropical Seed Research. ACIAR Proceedings No.* 28 (Ed. by J.W. Turnbull) pp. 82-85. ACIAR, Canberra. 156 pp.

SØRENSON, T. 1948 A Method of establishing groups of equal amplitude in plant sociology based on similarity in species content *Biol. Skr. K danske Vidensk Selsch* 5(4): 1-34

SOWUNMI, M.A. 1973. Pollen grains of Nigerian plants. 1. Woody species. *Grana* 13: 145-186.

STAFFORD, W. & OKE, O.L. 1977. Protein isolate from lesser known oilseeds from Nigeria. *Nutrition Reports International,* 16: 813-820.

STEPHENSON, A.G. 1981 Flowering and Fruit Abortion: proximate causes and ultimate functions. *Annual Rev. Ecology Systematics* 12: 253-279

STEWART, G.R. & OREBAMJO, T.O. 1983. Studies of nitrate utilization by the dominant species of regrowth vegetation of tropical West Africa. *Symposium of the British Ecological Society,* 22: 167-88.

SIMMONS, E. B 1976 Calorie and protein intakes in three villages of Zaria province. Samaru Miscellanenous Paper 55 A. B. U

SZOLNOKI, T.W. 1985. *Food and Fruit Trees of The Gambia.* Bundersforschungsanstalt für Forst und Holzwirtschaft, Hamburg, Stiftung Walderhaltung in Afrika. 132 pp.

TAYLOR, C.J. 1960. *Synecology and Silviculture in Ghana.* Nelson, Edinburgh. 418 pp.

TEKLEHAIMANOT, Z., TOMLINSON, H., LEMMA, T. & REEVES, K. 1996. Vegetative propagation of *Parkia biglobosa* (Jacq.) Benth., an undomesticated fruit tree from West Africa. *Journal of Horticultural Science,* 71: 205-215.

TERRIBLE, M.P.B. 1975. Essai d'évaluation de la végétation ligneuese. In: *Atlas de Haute-Volta.* CVRS, Ougadougou. 67pp

TIMMER, L.A., KESSLER, J.J. & SLINGERLAND, M. 1996. Pruning of néré trees (*Parkia biglobosa* (Jacq. Benth.) on the farmlands of Burkina Faso, West Africa. *Agroforestry Systems,* 33: 87-98.

TOMLINSON, H., TEKLEHAIMANOT, Z., TRAORÉ, A. & OLAPADE, E. 1995. Soil amelioration and root symbioses of *Parkia biglobosa* (Jacq.) Benth. in West Africa. *Agroforestry Systems,* 30: 145-159.

TOTHILL, J.D. 1948. *Agriculture in the Sudan.* Oxford University Press, London. 974 pp.

TULEY, P. 1972. *The land resources of north east Nigeria I-III.* Land Resources Division, ODA, London.134pp

TYBIRK, K. 1991. Regeneration of woody legumes in Sahel. *AAU Reports,* **27.** Botanical Institute, Aarhus University. 81 pp.

UMOH, I.B. & OKE, O.L. 1974. Nutritive value of some lesser known oilseeds in rats. *Nutrition Reports International,* **9**: 453-460.
UNWIN, A.H. 1920. *West African Forests and Forestry.* T. F. Unwin Ltd., London. 527 pp.

VALETTE, J. 1973 The reconnaissance soil survey of the Mokwa-Kontagora-Kainji area, North Western and Kwara State, Nigeria Soil Survey Bulletin 44 Institute of Agicultural Research A.B.U. Nigeria.

VARAIGNE, L. & LABEYRIE, V. 1981. First data on Bruchidae which attack the pods of legumes in Upper Volta, of which eight species are man consumed. In: *The Ecology of Bruchids attacking legumes.* (Ed. by?) pp. 83-93.? ?? pp.

VIGNE, C. 1936. Forests of the northern territories of the Gold Coast. *Empire Forestry Journal,* 15: 210-213.

VIVIEN, J. 1990. Fruitiers sauvages du Cameroun. *Fruits Paris,* **45**: 149-160.

VOORHOEVE, A.G. 1964. Some notes on the tropical rain forest of the Yoma-Gola National Forest near Bomi Hills, Liberia. *Commonwealth Forestry Review,* **43**: 17-24.

WAGNER, M.R., ATUAHENE, S. K. N. & COBBINA, J. R. Forest entomology in West Tropica Africa : forest insects of Ghana. Kluwer, Dordrecht. 210 pp

WALTER, H. LIETH, H. 1960-7 Klinadimgram- wetaltals Jena Fisher.

WEBER, F.R. 1986. *Reforestation in Arid Lands.* Volunteers in Technical Assistance. Arlington, Virginia. 335 pp.

WILDENOW, K. 1806 Caroli á Linné species plantarum, ed 4 Vol.4 (2) .

WIGHT, R. & ARANOTT, G. A. W. 1834 Prodomus florae pennisulae Indiae orientalis .London

WHITE, F. 1965. The savanna woodlands of the Zambezian and Sudanian Domains. An ecological and phytogeographical comparison. *Webbia,* **19**: 651-681.

WHITE, F. 1979. The Guineo-Congolian Region and its relationships to other phytochoria. *Bulletin du Jardin Botanique National de Belgique*, **49**:11-55.

WHITE, F. 1983a. Vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. *UNESCO Natural Resources Research* **20**. UNESCO, Paris. 356 pp.

WORKMAN, S.W. 1986. Nodulation trials with selected arboreal legumes of Burkina Faso, West Africa. *Nitrogen-fixing Tree Research Reports*, **4**: 7-8.

ZECH, W. & WEINSTABEL, P.E. 1983. Location, state of nutrition and feed value of tree species important in forestry in Upper Volta. *Plant Research & Development*, **17**: 42-60.

MISSING PAGES REMOVED ON INSTRUCTION FROM THE UNIVERSITY

Appendix 2

List of woody tree species observed as associates of *P. biglobosa* and their families: subfamilies

Species	Family: subfamily
Adansonia digitata L.	Bombacaceae
Acacia macrothyrsa HARMS	Leguminosae: Mimosoideae
Acacia nilotica (L.) WILLD.	Leguminosae : Mimosoideae
Acacia seyal (L.) DELILE.	Leguminosae : Mimosoideae
Afzelia africana PERS.	Leguminosae: Caesalpinioideae
Albizia chevalieri HARMS	Leguminosae: Mimosoideae
Allophylus africanus P. BEAUV.	Sapindaceae
Alchornea cordiflora (SCHUM & THONN.) MUELL. ARG.	Euphorbiaceae
Anacardium occidentale L.	Anacardiaceae
Annona senegalensis PERS.	Annonaceae
Anogeissus leiocarpa (DC.) GUILL.& PERR.	Combretaceae
Anthocleista vogelii PLANCH.	Loganiaceae
Antiaris toxicaria LESCH.	Moraceae
Azadirachta indica A. JUSS.	Meliaceae
Balanites aegyptiaca (L.) DELILE	Balanitaceae
Bauhinia monandra KURZ	Leguminosae :Caesalpinioideae
Bauhinia rufescens LAM.	Leguminosae :Caesalpinioideae
Blighia sapida KONIG.	Sapindaceae
Bombax costatum PELLEGR. & VUILLET	Bombacaceae
Borassus aethiopum MART.	Arecaceae
Boscia senegalensis (PERS.) POIRET	Cappraceae
Boswellia dalzielii HUTCH.	Burseraceae
Bridelia scleroneura MULL. ARG.	Euphorbiaceae
Burkea africana HOOK.	Leguminosae:Caesalpinioideae
Carica papaya LINN.	Caricaceae
Ceiba pentandra (LINN.) GAERNT.	Bombacaceae
Celtis integrifolia LAM	Ulmaceae
Citrus sinensis OSBECK	Rutaceae
Cocos nucifera LINN.	Arecaceae
Cola gigantea A. CHEV.	Sterculiaceae
Cola nitida (VENT.) SCHOTT & ENDL.	Sterculiaceae
Combretum collinum FRESEN	Combretaceae
Combretum fragrans F. HOFFM.	Combretaceae
Combretum glutinosum DC.	Combretaceae
Combretum molle R.BR. EX G. DON	Combretaceae
Combretum micranthum G. DON	Combretaceae
Combretum nigricans GUILL.& PERR.	Combretaceae
Crossopteryx febrifuga (G. DON) BENTH.	Rubiaceae
Cussonia arborea A. RICH..	Araliaceae
Dalbergia melanoxylon GUILL. & PERR..	Leguminosae: Papilionoideae
Dalbergia sissoo ROXB.	Leguminosae: Papilionoideae
Daniellia oliveri (ROLFE) HUTCH. & DALZ.	Leguminosae: Caesalpinioideae

Species	Family: Subfamily
Delonix elata (L.) GAMBLE	Leguminosae:Caesalpinioideae
Detarium macrocarpum GUILL. & PERR.	Leguminosae: Caesalpinioideae
Dialium guineense (WILLD.)	Leguminosae: Caesalpinioideae
Detarium senegalense GUILL. & PERR.	Leguminosae: Caesalpinioideae
Dichrostachys cinerea (L.) WIGHT & ARN.	Leguminosae: Mimosoideae
Diospyros ferrea (WILLD.) BAKH.	Ebenaceae
Diospyros mespiliformis DC.	Ebenaceae
Ekebergia senegalensis A. JUSS.	Meliaceae
Elaeis guineensis JACQ.	Arecaceae
Entada africana GUILL. & PERR.	Leguminosae: Mimosoideae
Erythrina senegalensis DC.	Leguminosae: Papilionoideae
Erythrophloeum suaveolens (GUILL & PERR.) BRENAN	Leguminosae: Caesalpinioideae
Eucalyptus camaldulensis DEHN.	Lecythidaceae
Euphorbia kamerunica PAX,	Euphorbiaceae
Euphorbia poissonii PAX.	Euphorbiaceae
Faidherbia albida (DELILE) A. CHEV.	Leguminosae: Mimosoideae
Ficus sycomorus LINN.	Moraceae
Ficus sur FORSSK.	Moraceae
Ficus glumosa DEL.	Moraceae
Ficus thonningii BLUME	Moraceae
Ficus vogelii HOOK. F.	Moraceae
Flacourtia indica (BURM.F) MERR.,	Flacourtiaceae
Gliricidia sepium (JACQ) WALP.	Leguminosae: Papilionoideae
Gmelina arborea ROXB.	Verbenaceae
Grewia venusta FRESEN.	Tiliaceae
Haematostaphis barteri HOOK. F.	Verbenaceae
Harungana madagascariensis LAM.	Clusiaceae
Hexalobus monopetalus A.RICH.) ENGL. & DIELS	Verbenaceae
Hippocretea indica (WILLD.) ENGL.	Celastraceae
Holarrhena floribunda (G. DON) DUR. & SCHINZ	Apocynaceae
Hymenocardia acida TUL.	Euphorbiaceae
Hyphaene thebaica (L.) MARTIUS	Arecaceae
Indigofera spinosa FORSSKÅL	Leguminosae: Papilionoideae
Irvingia gabonensis (AUBRY-LACMTE) BAILL.	Irvingiaceae
Isoberlinia doka CRAIB & STAPF.	Leguminosae: Caesalpinioideae
Khaya senegalensis (DESR.) A. JUSS.	Meliaceae
Lannea barteri (OLIV.) ENGL.	Anacardiaceae
Lannae humilis (OLIV.) ENGL.	Anacardiaceae
Lannea microcarpa ENGL.& K. KRAUSE	Anacardiaceae
Lannae kerstingii ENGL. & K. KRAUSE	Anacardiaceae
Lecaniodiscus cupanioides BENTH.	Sapindaceae
Leucaena leucocephyala (LAM.) DE WIT	Leguminosae: Mimosoideae
Lonchocarpus laxiflorus GUILL.& PERR.	Leguminosae: Papilionoideae
Lophira lanceolata KEAY	Ochnaceae
Maerua parvifolia PAX	Capparaceae
Mangifera indica LINN.	Anacardiaceae
Manihot glaziovii MULL. & ARG.	Euphorbiaceae
Manilkara mochisia (BAKER) DUBARD	Sapotaceae

Species	Family: Subfamily
Maranthes polyandra (BENTH.) PRANCE	Chrysobalanaceae
Milicia excelsa (WELW.) C.C BERG	Moraceae
Millettia thonningii SCHUM & THONN.	Leguminosae: Papilionoideae
Margaritaria discoideae (BAILL.)	Euphorbiaceae
Mitragyna inermis (WILLD.) KUNTZE	Rubiaceae
Morinda lucida BENTH.	Rubiaceae
Moringa oleifera LAM	Moringaceae
Morus mesozygia STAPF.	Moraceae
Nauclea latifolia SMITH	Rubiaceae
Olax subscorpioidea OLIV.	Olacaceae
Oxyanthus racemosus SCHUM. & THONN.) KEAY.	Rubiaceae
Pachystela brevipes (BAK.) BAILL	Sapotaceae
Parinari curatellifolia PLANCH	Chrysobalanaceae
Parinari excelsa SABINE	Chrysobalanaceae
Parkia bicolor (A.) CHEV.	Leguminosae: Mimosoideae
Pentaclethra macrophylla BENTH	Leguminosae: Mimosoideae
Pericopsis elata (HARMS) VAN. MEEUWEN	Leguminosae: Papilionoideae
Phoenix dactylifera LINN.	Arecaceae
Phyllanthus physocapus MUELL .ARG.	Euphorbiaceae
Piliostigma reticulatum (DC.) HOCHST.	Leguminosae: Caesalpinoideae
Piliostigma thonningii (SCHUM.) MILNE-REDH.	Leguminosae: Caesalpinoideae
Prosopis africana TAUB.	Leguminosae: Mimosoideae
Pseudocedrela kotschyi (SCHWEINF.) HARMS	Meliaceae
Psidium guajava LINN.	Myrtaceae
Pterocarpus lucens GUILL. & PERR.	Leguminosae: Papilionoideae
Pterocarpus erinaceous POIRET	Leguminosae: Papilionoideae
Salvadora persica LINN.	Salvadoraceae
Samanea saman (JACQ) MERRILL.	Leguminosae: Mimosoideae
Senna siamea (LAM.) IRWIN & BARNEBY	Leguminosae: Mimosoideae
Sclerocarya birrea (A. RICH) HOCHST	Annonacaceae
Securidaca longepedunculata FRESEN.	Polyalaceae
Sorindeia grandifolia ENGL.	Anacardiaceae
Spondias mombin LINN.	Anacardiaceae
Sterculia setigera DELILE	Sterculiaceae
Stereospermum kunthianum CHAM.	Bignoniaceae
Strychnos innocua DEL.	Loganiaceae
Syzygium guineense(WILLD.) DC	Myrtaceae
Tamarindus indica L.	Leguminosae: Caesalpinioideae
Tectona grandis LINN. F	Verbenaceae
Terminalia avicennioides GUILL. & PERR.	Combretaceae
Terminalia mollis LAWS.	Combretaceae
Terminalia laxiflora ENGL.	Combretaceae
Trema orientalis (LINN.)	Ulmaceae
Trichilia emetica VAHL	Meliaceae
Uapaca togoensis PAX	Euphorbiaceae
Vernonia amygdalina DEL.	Asteraceae
Vitellaria paradoxa C. F. GAERTN.	Sapotaceae
Vitex doniana SWEET	Verbenaceae

Species	Family:Subfamily
Zanha golungensis HEIR.	Sapindaceae
Zanthoxylum zanthoxyloides (LAM.) ZEP. & TIMLER.	Rutaceae
Ziziphus abyssinica A. RICH.	Rhamnaceae
Ziziphus mauritiana LAM.	Rhamnaceae