Silva Carelica 37

LIVING ON THE LAND: CHANGE IN FOREST COVER IN NORTH-CENTRAL NAMIBIA 1943–1996

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UNIVERSITY OF JOENSUU
FACULTY OF FORESTRY

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ACADEMIC DISSERTATION

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Abstract

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The objective of the present study was to analyse the change in forest cover in the Owambo area of north-central Namibia, focusing especially on the domestic use of wood in constructions on farms. Aerial photographs from 1996, 1992, 1970 and 1943, and satellite images from 1996, 1992 and 1981, amplified by ground truth data gathered in 1996, were used to monitor and analyse expansion of the settled area and its effects on forest cover in the Ondobe and Eenhana constituencies of the Ohangwena Region. The results indicate that deforestation was caused almost entirely by clearing of land for permanent agriculture. The clay-rich sandy soils on the lower part of uplands were occupied first; whereas the slightly more elevated, but less fertile, sandy sites have been occupied later. It was estimated that a population increase of one person led to about 1 ha of deforestation. The basic layout of a farm and the architecture of a household dwelling have remained about the same throughout the period 1943–1996. The quantity of indigenous wood in constructions of a typical farm represented an over-bark removal of about 45 tons, and the annual fellings for maintenance were 0.5 tons per capita. The annual consumption of indigenous wood in the whole Owambo area was estimated to be 600 000 tons, which is lower than the sustained yield. The forest cover has changed towards on-farm tree cover, and the species composition in the agricultural fields has gradually changed towards trees producing edible fruits. The frequent change of homestead site has been an important factor in creating the characteristic agroforestry landscape of the Owambo area.

Key words agroforestry, deforestation, farming systems, human population, Owamboland, remote sensing, wood consumption

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Preface

The present study was finalised in the multidisciplinary research project 'Indigenous land use systems in Namibia' carried out in 1999–2001 by the University of Joensuu and the University of Namibia. Research on Namibia began at the University of Joensuu in the early 1980s in the Department of History, widening its range to environmental issues in 1990s, when the Faculty of Forestry became involved in the joint research projects. I first visited north-central Namibia in 1990, when I was collecting data for the study 'Forestry in Namibia 1850–1990', published in 1992. From February 1994 till January 1997 I was employed by FINNIDA (Ministry for Foreign Affairs of Finland, Department for International Development Cooperation) as a Forestry Adviser to work for the Directorate of Forestry of Namibia.

I express my gratitude to all people and institutions that have contributed to the study. In particular, I would like to thank Prof. Paavo Pelkonen, my supervisor and the director of the research project 'Indigenous land use systems in Namibia', for his constructive criticism, encouragement and support throughout. I am also much obliged to Prof. Harri Siiskonen for many inspiring discussions, valuable comments and guidance to relevant sources of information. I owe special thanks to the Namibian farmers, Mr Elia Shipandeni, Ms Martha Cornelius, Mr Jeremia Hamutenya, Mr Moses Nghikongelwa, Mr Joseph Petrus and Mr David Paulus, who kindly shared their expertise and allowed data collection on their farms. Gathering of ground truth data in Namibia was facilitated by the Directorate of Forestry, as well as by many individuals, including Ms Marjatta Elonheimo, Mr Hapheni Mtuleni, Ms Sesilia Shingo and Mr Sakeus Uusiku. Ms Satu Löfman was an excellent fieldwork assistant during data collection in Namibia, and together with Mr Perttu Anttila they provided invaluable assistance also in various stages of data processing. Mr Jukka Sepponen from MT Survey Ltd, Järvenpää, Finland, digitised from aerial photographs, with a high-quality analytic stereo plotter, the first versions of the topographic maps covering the six sample areas; the directors, Mr Kari Lindfors and Mr Vesa Rope, kindly shared their expertise on cartographic issues in general and on Namibian features in particular. I express my sincere gratitude to the evaluators, Dr Coert J. Geldenhuys and Prof. Lazarus Hangula, for their detailed and constructive comments, as well as to Dr Veli Pohjonen, Prof. Timo Pukkala, Prof. Hannu Mannerkoski, Dr Ian Hunter, Dr Ben Fuller and Mr Juha-Pekka Snäkin for their valuable contribution to the manuscript. The slide taken at the Oshigambo High School in 1969 (Figure 26) was kindly provided by Ms Sylvi Soini. The English language of this dissertation was revised by Dr Joann von Weissenberg, and the layout was finalised by Ms Leena Konttinen.

The study was financed by the University of Joensuu, the Academy of Finland and the Finnish Cultural Foundation (Regional Fund of North Karelia, Leo and Regina Wainstein Foundation, and Alma and Jussi Jalkanen Foundation).

My wife Eija deserves special thanks for her moral support and encouragement throughout this study and for constructive comments on the manuscript. I dedicate this study to my daughter, Viivi.

Joensuu, August 2001

Antti Erkkilä

Contents

Acronyms

AIDS	Acquired Immuno Deficiency Syndrome
CBD	Convention on Biological Diversity
DEM	Digital Elevation Model
ERTS	Earth Resources Technology Satellite
FAO	Food and Agriculture Organisation of the United Nations
FCCC	Framework Convention on Climate Change
GIS	Geographic Information Systems
HIV	Human Immuno Deficiency Virus
IPF	Interagency Partnership on Forests
MAI	Mean Annual Increment
MOHSS	Ministry of Health and Social Services
MSS	Multi-Spectral Scanner
NAF	National Archives of Finland
NEPRU	Namibian Economic Policy Research Unit
NFI	National Forest Inventory
NISER	Namibian Institute for Social and Economic Research
SWANU	South West Africa National Union
SWAPO	South West Africa People's Organisation
TM	Thematic Mapper
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
WCED	World Commission on Environment and Development
WRS	World Reference System

Abbreviations

a.s.l.	above sea level
dbh	diameter at breast height (circa 1.3 m)
dpi	dots per inch

Glossary

alluvial – deposited from flowing water
clay pan – small, closed basin which has an ephemerally flooded surface
efundja – major flood in the *oshana* drainage system
egumbo, see *eumbo*
epata – cooking area in the homestead
eumbo (plural *omaumbo*) – traditional household dwelling
okalupale – small reception area in the homestead
olambika – home-made brandy
olupale – large courtyard in the homestead
omahangu – pearl millet
omaongo – popular alcoholic liquor, "marula wine"
omufima (plural *omifima*) – hand-dug shallow waterhole
omuramba (plural *omiramba*) – ephemeral or fossil drainage line east of the Etosha Pan
ondombe (plural *oondombe*) – ephemerally flooded small pool
ondungu (plural *eendungu*) – hand-dug deep well
oshana – ephemeral, shallow floodwater course north of the Etosha Pan
polygynous – a husband having several wives
transhumance – seasonal transfer of cattle to different pastures

Spelling

The prefixes have been omitted when reference is made to ethnic subgroups, their territory or language, e.g. the Ndonga people instead of Omundonga (singular) or Aandonga (plural), the Kwanyama land instead of Oukwanyama or Uukwanyama, and the Kwanyama language instead of Oshikwanyama. The collective name 'Owambo' is a generally accepted term and is therefore used with the prefix instead of 'Wambo'. The generic term covering all language varieties spoken by the Owambo people is 'Oshiwambo'. The plural form 'oshanas' is commonly used in English and is therefore used instead of 'iishana' or 'oyana'.

1. INTRODUCTION

1.1 Definition of forest

Forest can be defined as an administrative or legal unit, a land cover or a land use (Lund 1999). The Global Forest Resources Assessment 2000 defines forest as land with a minimum area of 0.5 ha where the tree crown cover (or equivalent stocking level) is more than 10 %. Trees are woody perennial plants, which should be able to reach a minimum height of 5 m or more at maturity in situ. Deforestation refers to change of land cover with depletion of tree crown cover to less than 10 %. Changes within the forest class, which negatively affect the stand or site and, in particular, lower the production capacity, are defined as forest degradation (FAO 1998). In Namibia the terms desert, savanna and woodland refer to the three major vegetation regions defined by Giess (1971). Most of the land cover defined by Giess (1971) as woodlands, and a few areas defined as savannas, fall within the FAO (1998) definition of forest.

1.2 Forest cover change

Since the United Nations Conference on Human Environment in Stockholm (1972), forests in general and tropical forests in particular have been on the international agenda. In 1987, the World Commission on Environment and Development issued a report in which a new dimension for sustainable development was introduced. The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro (1992), formulated a non-legally binding Statement of Principles for the Sustainable Management of Forests as well as a chapter on deforestation in Agenda 21. Although several different definitions for sustainable development exist, there is a broad consensus that ecological, economic and social development, as well as cultural values, cannot be separated from each other. This has meant that the need for information on resource management has become more diverse and dynamic (Lund 1998). In the 1960s the emphasis in forestry was solely on timber production. In the 1970s it was realised that the majority of people in the developing countries use woody biomass for energy. The 1980s brought up topics such as bio-diversity and the role of forests in the global carbon cycle. The emerging issues of the 1990s were non-wood forest products, community-based resource management, certification of forest products, intellectual property rights and ownership of the genetic potential. Currently, the demand for reliable and location-specific information applies not only to forest resources, but also includes woody plants in agricultural fields, grazing grounds and in other land-use areas not traditionally considered to be forests (FAO 2000). The UNCED's Agenda 21 and the three follow-up conventions – the Framework Convention on Climate Change (FCCC), the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (UNCCD) – have been instrumental in broadening the focus from moist tropical forest to forests and trees in fragile ecosystems (FAO 1999). Drylands, defined as arid, semi-arid or dry sub-humid areas, are among the world's most fragile ecosystems. Besides ecological and environmental functions, dryland trees and forests are vital for local populations as the source of a wide range of wood and non-wood products (FAO 1997).

In 1995 forests are estimated to have covered 3454 million ha, 26.6 % of the total land area of the world (Greenland and Antarctica excluded). Between 1980 and 1995, the extent of the world's forests decreased by some 180 million ha, which represents an annual loss of 12 million ha. During that 15-year period, developing countries lost nearly 200 million ha of natural forests, mainly due to agricultural expansion (especially in Africa and Asia) and to development programmes (in Latin America and Asia); whereas in the developed countries, forests expanded by some 20 million ha, mainly through afforestation and reforestation. Deforestation has been greatest in the tropical zone of the developing countries, where the annual loss of forest cover between 1990 and 1995 was estimated to comprise 12.6 million ha, the annual deforestation rate being 0.7 %. Between 1980 and 1990 the annual loss of forest cover in the dry and very dry tropical zone is estimated to have been 2.2 million ha, the annual deforestation rate being 0.9 %. In tropical Africa the forest cover comprised slightly more than 523 million ha in 1990 compared with nearly 505 million ha in 1995. During that 5-year period the annual loss of forest cover in tropical Africa was 3.7 million ha, the annual deforestation rate being 0.7 % (FAO 1997). In the tropical regions, during the period 1980–1990, the annual loss of biomass due to deforestation is estimated to have been slightly over 2500 million tons, of which more than 50 % was contributed by Latin America, nearly 30 % by Asia and about 20 % by Africa (FAO 1993). If tropical deforestation and forest degradation were eliminated, global human-induced emissions of carbon would be reduced by about 23 % (FAO 1997).

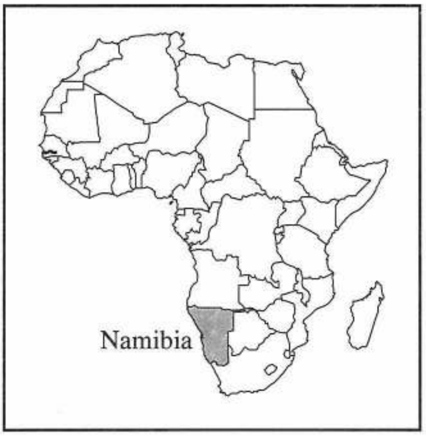


Figure 1. Map of Africa.

1.3 Degradation of wood resources in north-central Namibia

The underlying forces driving deforestation and forest degradation are complex; and even though there are global dimensions to this issue, the causes vary greatly from country to country (IPF 1996). In Namibia, which is located in tropical southern Africa (Figure 1), forest ecosystems are fragile and are affected by desertification. The international Convention to Combat Desertification (UNCCD) defines desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. The subregion of tropical southern Africa includes Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe (FAO 1997, 1999).

In Namibia, most of the forests are located in the north-central and northeastern parts, although there are also forested areas along the ephemeral rivers in the central and western parts of the country. Forests are estimated to have comprised 12.4 million ha in 1995, which is 15 % of the total land area. During the period 1990–1995, the estimated annual loss of forest cover was 42 000 ha, the annual rate of deforestation being 0.3 % (FAO 1997). The loss of woody vegetation cover and the consequent environmental and socio-economic problems are severe, especially in the Owambo area of north-central Namibia (Figure 2).

Several hundred years ago groups of Bantu-speaking cattle-herding people migrated from the north and northeast to the Cuvelai drainage basin located in the southwestern part of Africa (Williams 1991). The collective name given to these people is Owambo. When Owambos migrated to the Cuvelai drainage basin, the land was already utilised by small groups of hunting and gathering

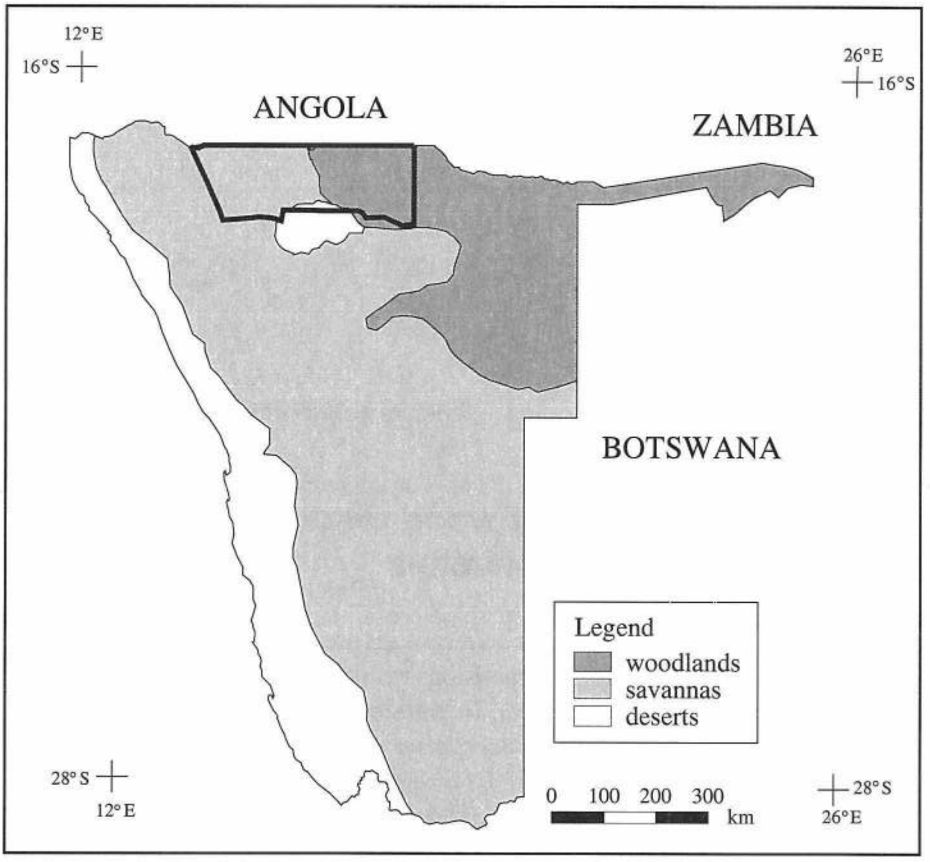


Figure 2. Location of the Owambo area of north-central Namibia in relation to the three major vegetation regions. Note: the vegetation type 'riverine woodland', which is found along all larger ephemeral and perennial rivers, is not shown on the map. Modified from: Giess (1971).

people, who apparently were loosely organised. The collective name used to define these people is the Bushmen or the San (see e.g., Lee 1979). When used in the pre-colonial context, the term 'Owamboland' refers to the area in south-central Angola and north-central Namibia inhabited by the Owambo communities, as well as the pastures and hunting grounds belonging to their sphere of interest (Siiskonen 1990). As a consequence of the scramble for colonies in Africa, Owamboland was divided into a Portuguese (northern) and a German (southern) sphere of influence. After the colonial administration was consolidated, the northern part became administratively known as Baixo Cunene, or simply Cuanhama, whereas south of the demarcation line the name 'Owamboland' was kept (Hangula 1993a, 1993b).

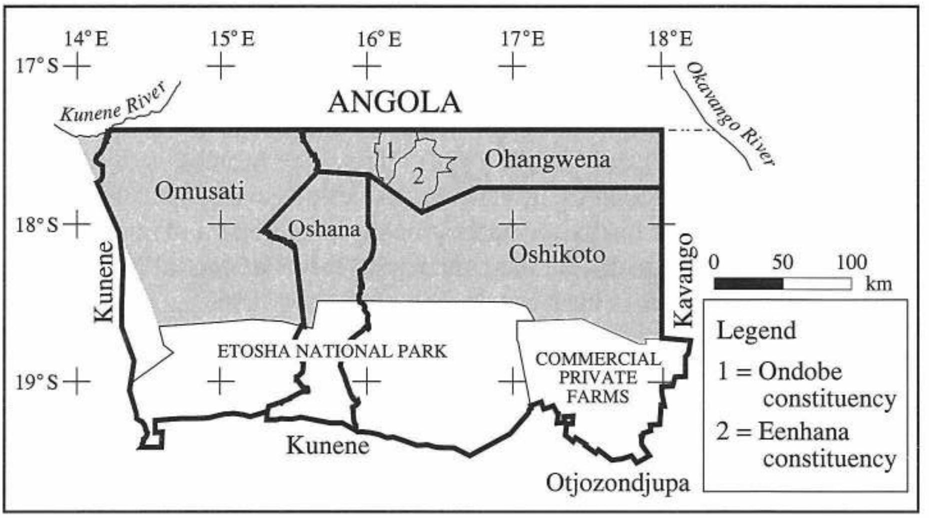


Figure 3. The former Owamboland (shaded) and the present administrative regions of north-central Namibia.

In the present study the term 'Owambo area' is used to define the former district of Owamboland. This area, comprising 5.2 million ha of semi-arid land (Merwe 1983), is outlined between the mountains of the Central Highland in the west (c. 14° E) and the Kavango Region in the east (18° E). It is bordered by Angola in the north (c. 17°23' S) and the Etosha National Park and the privately owned commercial farming area in the south (c. 18°30' S). The Owambo area completely covers the current province of Ohangwena as well as the northern parts of Omusati, Oshana and Oshikoto (Figure 3).

The earliest reports concerning degradation of wood resources in Owamboland date back to the 19th century. According to the observations of the Swiss botanist Hanz Schinz, who visited the area in 1885–1886, many of the previously well-wooded areas had been converted to agriculture; and in addition, large-scale tree felling was practised to supply wood for new domestic constructions and to maintain old ones (Schinz 1891, p. 483). A Finnish missionary, Martti Rautanen, reported in 1907 that, due to the extensive felling of trees, households in the southern Owambo communities were compelled to use millet stalks as substitutes for wooden poles in building. The representative of the mandate administration at Oshikango, next to the Namibian–Angolan border, wrote in 1931 that forest trees were being destroyed at an alarming rate. The Odendaal Commission, appointed by the South African government in 1962, considered deforestation to be one of the greatest economic and environmental problems in the area (Erkkilä and Siiskonen 1992). Deforestation in north-central Namibia was also highlighted in Namibia's Green Plan, presented for the Rio

Conference in 1992 (Brown 1992). The Directorate of Forestry within the Ministry of Environment and Tourism has recently not only acknowledged deforestation and degradation of wood resources as a national environmental issue, but has also highlighted the need for cross-sectoral cooperation to attack the problem (Kojwang and Erkkilä 1996). Thus, the Owambo area of north-central Namibia is suffering from socio-economic and environmental problems acknowledged both nationally and internationally as symptoms of unsustainable development. Paradoxically, on the commercial farms of central Namibia the main economic concern is bush encroachment (Bester 1996).

1.4 Objectives of the study

The objective of the present study was to analyse the change in forest cover in the Owambo area of north-central Namibia, focusing especially on the domestic use of wood in constructions on farms. Through cultivation, cattle herding, building homesteads, erecting fences, collecting firewood and gathering various non-wood forest products, a rural household obviously has an impact on the environment. It can be argued, however, that from a historical perspective the domestic use of wood resources by a rural Owambo household indicates a functional way of carrying out a strategy for human subsistence.

The study area, the Ondobe and Eenhana constituencies of the Ohangwena Region, can be described as a transition zone. The present study focuses on the expansion of the settled area onto forest lands in this transition zone, where relatively fertile, clay-rich savanna soils change, from west to east, to infertile, sandy woodland soils. The unique set of aerial photographs from 1996, 1992, 1970 and 1943, and the satellite images from 1996, 1992 and 1981, amplified by the ground truth data gathered in 1996, enable detailed analyses of the long-term interaction between man and the woody vegetation in the area, which remained uninhabited until the First World War.

The specific objectives of the study were:

a) to analyse the expansion of agriculture, including site selection in relation to the topographic gradient,
b) to assess changes in land cover, as well as to determine whether agriculture is rotational or permanent,
c) to examine the use of woody species, and to quantify the use of wood in constructions on farms,
d) to monitor the frequency of change in homestead site within the agricultural field area, focusing especially on agroforestry, and
e) to evaluate the role of trees and shrubs in indigenous farming systems.

2. NAMIBIA

2.1 Namibia – a country of arid land and harsh political history

The Republic of Namibia is located in southwestern Africa, between 17° S and 29° S, 11.7° E and 25.4° E (Figure 4). Namibia shares borders with Angola in the north, Zambia and Zimbabwe at the eastern end of the Caprivi Strip, Botswana in the east, and South Africa in the south and southeast. To the west the coastline of Namibia extends along the Atlantic Ocean for about 1600 km.

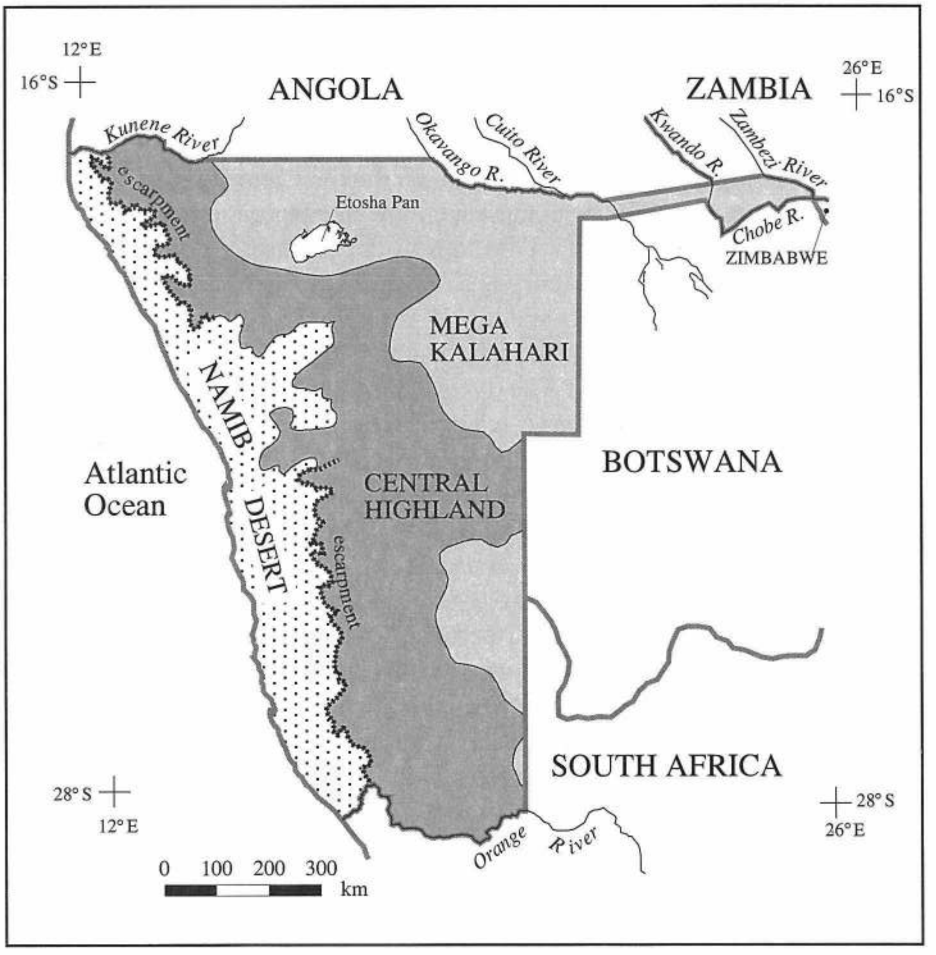


Figure 4. Geographical features of Namibia. Modified from: Wellington (1967), Mthoko et al. (1990), Thomas and Shaw (1991).

Namibia has a surface area of 82.4 million ha, which is two and a half times the size of Finland, almost three and a half times the size of the United Kingdom, and two-thirds the size of South Africa. On the African continent, Namibia is the fifteenth largest country (Brown 1992). The name 'Namib' originates from the Nama language and means "bare place" (Berry 1996).

Namibia can be divided into three distinct regions: the Namib Desert, the Central Highland and the Mega Kalahari. The Namib Desert is a 80–120 km wide coastal plain between the Atlantic Ocean in the west and the escarpment in the east. The Central Highland lies east of the Namib Desert, reaching altitudes of 1000–2000 m a.s.l. (Erkkilä and Siiskonen 1992). The Mega Kalahari, covered by sediments known as the Kalahari Group, occupies north-central, eastern and northeastern parts of the country. The most common surface unit of the Kalahari Group, the Kalahari Sand, represents an area of over 250 million ha in central southern Africa, making the largest continuous sand sea, or erg, on Earth (Thomas and Shaw 1991).

The combination of low precipitation and high evaporation makes Namibia the most arid country in Sub-Saharan Africa (Brown 1996). The annual mean precipitation ranges from less than 20 mm on the west coast to over 600 mm in the extreme northeast. The potential annual mean evaporation varies between 2600 mm in the northwest and 3700 mm in the southeast. The annual mean precipitation for the whole country is 270 mm and occurs mainly as summer rainfall, which is unpredictable and highly variable (Merwe 1983, Hutchinson 1995). Perennial rivers are limited to the southern and northern borders, and the Caprivi Region in the northeast. The rivers in the interior are ephemeral, flowing only after intensive rains in their catchment areas (Jacobson et al. 1995).

The vegetation in Namibia is defined by Giess (1971), primarily on the basis of precipitation, into the following three main regions: woodlands, savannas and deserts (Figures 5–6). Woodlands exist only in north-central and northeastern parts of the country, whereas savannas are widespread from northwest to southeast. Deserts extend along the Atlantic Ocean, but also include the Etosha Pan and surrounding flats in the northern part of the country. The Namib, with little plant cover, is "true" desert whereas the Kalahari Desert, which corresponds to the part of the Mega Kalahari between the Orange River in the south and the Etosha–Okavango–Zambezi line in the north, is in places fairly well wooded. Though the Kalahari Sand has the potential to trap and maintain moisture from bouts of rainfall, and therefore to support vegetation, the low nutrient status does not favour attempts at cultivation (Thomas and Shaw 1991).

Namibia's international boundaries were drawn as a result of historical contingency during the scramble for Africa (Hangula 1993a). In 1884 Chancellor Bismarck proclaimed the territory of South West Africa as a German protectorate. The Herero and Nama uprising (1904–1907) against German forces in the central and southern parts of the territory was met with genocide, which meant

Figure 5. Woodlands in the Owambo area of north-central Namibia. Fruit trees are growing in the cultivated fields, which have been cleared on the western side of a clay pan. Photo: Antti Erkkilä 22.2.1996.

Figure 6. Savannas in the Owambo area of north-central Namibia. Fruit trees are growing scattered in a typical agroforestry landscape.
Photo: Antti Erkkilä 22.2.1996.

extermination of three-quarters of the Herero and half of the Nama population (Drechsler 1966). By 1907 the Germans had established control in the central and southern parts of the colony, in the Police Zone, where the white settlers were guaranteed police protection. The northern parts of the territory comprised 'native reserves' which were administered indirectly without police or military presence. The northern areas were preserved to secure the long-term supply of migrant labourers required for a variety of economic projects in the Police Zone: the construction of a railway, mining and commercial farming (Tötemeyer 1978). When Britain declared war on Germany in August 1914, South African forces were used to occupy the German protectorate of South West Africa (Thompson 1990). The German troops surrendered to the South Africans on 9 July 1915 (Dierks 1999). The First World War ended on 11 November 1918.

Between 1915 and 1920 South West Africa was administered under the martial law of the Union of South Africa (Merwe 1983). The League of Nations, the multinational political body established in 1920, conferred on Britain a mandate for administering the former German South West Africa. That mandate, however, was to be exercised by the Union of South Africa, then a British dominion, on behalf of Britain. The Union of South Africa was accountable to the League's Permanent Mandates Commission. Walvis Bay, a natural deep-water Atlantic port claimed in 1878 by the British on behalf of the Cape Colony, was administratively attached to the mandate in 1922 (Kirchherr 1987). Between World Wars I and II, rebellions and uprisings against South African rule occurred among the Bondelswarts in 1922, the Basters in 1925, and the Owambo people in 1917 and 1932 (Dierks 1999).

The mandate for South West Africa continued till the end of the Second World War. After the League of Nations was dissolved in 1946, South African leaders asked the General Assembly of the United Nations to support their proposal to totally annex South West Africa. When the request was rejected, South Africa announced that it would continue to administer South West Africa in the "spirit" of the defunct League's original mandate rather than complying with the trusteeship system of the United Nations (Kirchherr 1987). Following the recommendations of the apartheid-oriented Odendaal Commission in 1964, South Africa (Union of South Africa 1910–1961) divided the territory of South West Africa into a number of ethnic 'homelands', based largely on the previously existing 'native reserves' (Figure 7). Consequently, the private farmland for whites comprised 45 % of the total area of the country, and the communal areas for the black homelands 40 %; the rest, consisting mainly of diamond mining areas and nature reserves, was owned by the state (Merwe 1983). The private farmland owned by the white settlers comprised about 4 million hectares at the end of 1903, before the Herero and Nama uprising (Wellington 1967). In 1920 the settlers owned 12 million hectares (1200 farms), and in 1925 as much as 24 million hectares (2500 farms). By the Second World War the private farmland owned by whites reached 32 million hectares (Lau 1996).

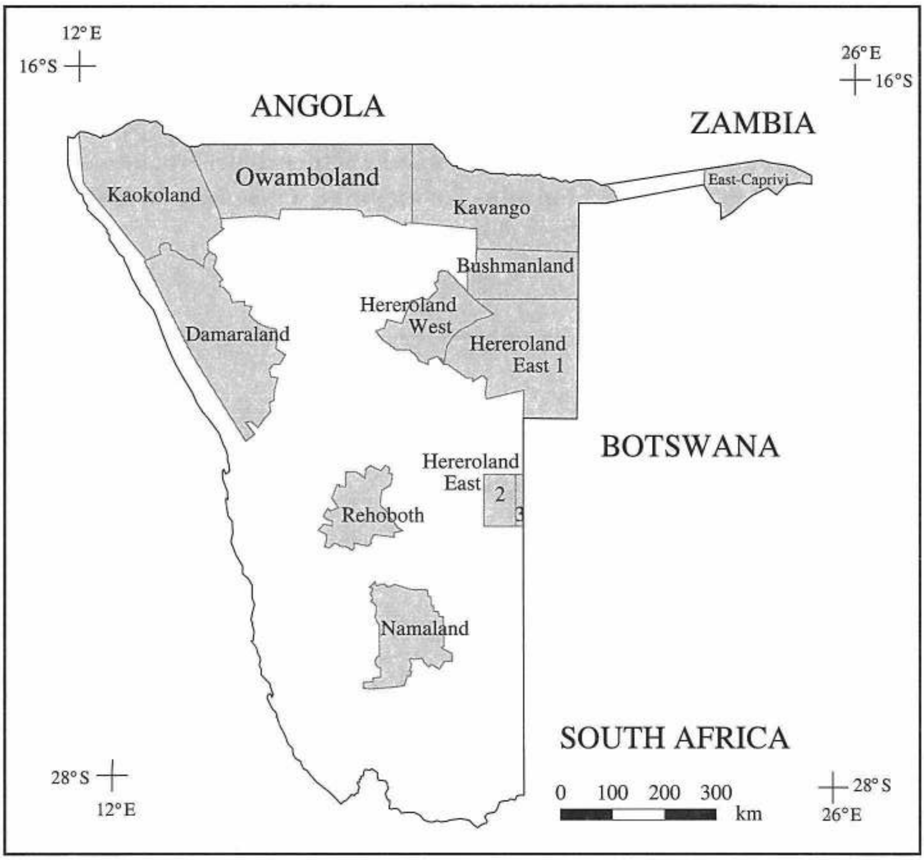


Figure 7. Land administration in 1982: homelands (shaded).
Modified from: Merwe (1983).

In 1966, after the passage of numerous resolutions and other actions, the United Nations General Assembly formally terminated the mandate and a year later established a Council for South West Africa with responsibility for administration of the territory until independence. The continuation of South African rule was presumed to constitute illegal occupation of South West Africa (Kirchherr 1987). In June 1968, the United Nations officially adopted the name 'Namibia' in place of 'South West Africa' (Dierks 1999). In 1971, the International Court of Justice gave an advisory opinion, which confirmed that South Africa's control of Namibia was illegal (Thompson 1990).

In the late 1950s, African nationalist movements, such as SWAPO (South West Africa People's Organisation) and SWANU (South West Africa National Union) were formed to resist South African rule. The armed liberation struggle against the illegal South African administration of Namibia commenced in 1966 and continued until independence. The warfare was most intense in north-central Namibia and south-central Angola (Dierks 1999). A total of 40 000–50 000 Namibians went into exile, many fleeing to camps in Tanzania, Botswana, Zambia and Angola (Hangula, pers. comm.). Namibia gained independence on 21 March 1990. The country was divided into 13 administrative regions in 1992. As a result of the Second Delimitation Commission, some of the administrative boundaries were changed in 1998 (Figure 8).

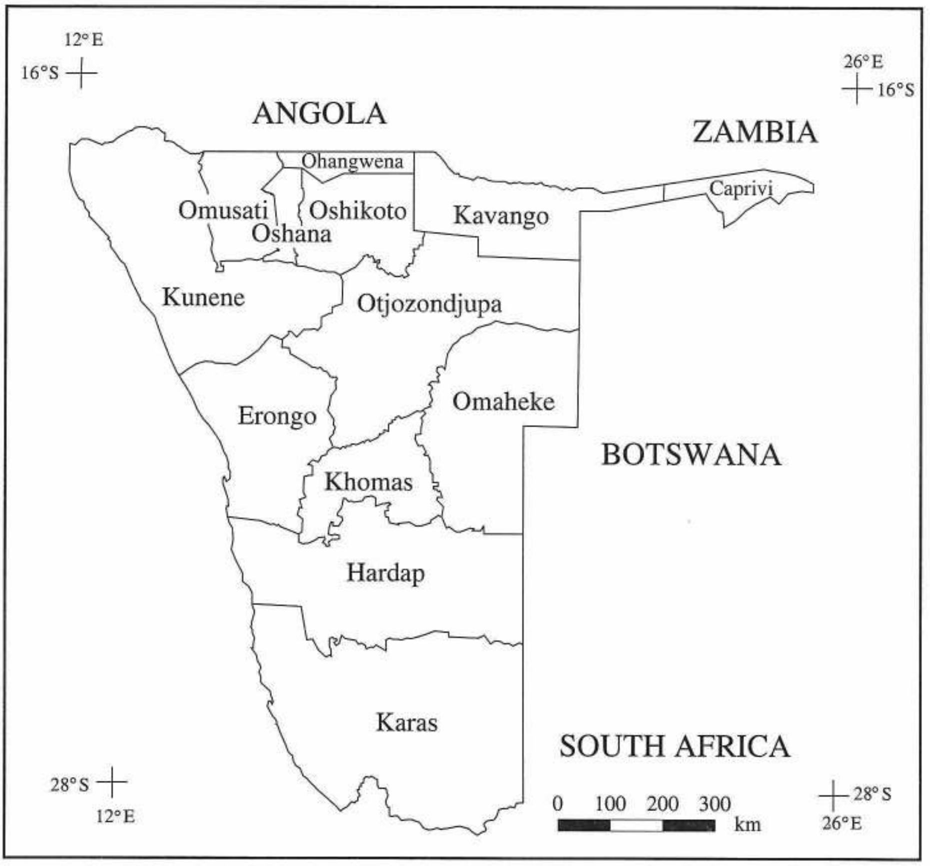


Figure 8. Present administrative regions in Namibia. Source: Ministry of Information and Broadcasting and the Electoral Commission (Namibia).

Namibia is characterised by unequal access to land and natural resources, as well as an almost bi-modal distribution of income. According to UNDP (1997), economically, Namibia is one of the most unequal societies in the world. The population density varies greatly in this vast country, most of which is arid and semi-arid land. In the 1991 population and housing census the number of inhabitants was 1.4 million, most of whom lived in the northern rural areas (Figure 9). In 2000 the Central Bureau of Statistics estimated the population of Namibia to be 1.8 million, the population density being 2.2 inhabitants km^{-2}. In 1991 the growth rate of the population was estimated at 3 %, which is projected to decline, due to the impact of HIV/AIDS, from 2 % in 2001 to 1.5 % in 2006 (MOHSS 2000). In the 1990s, migration to the towns accelerated, the annual rate of urbanisation currently being about 5 %. The fastest growing municipalities and towns are Windhoek (260 000), Walvis Bay (55 000), Rundu (35 000) and Katima Mulilo (25 000) (Melber 1996).

Despite its small population, Namibia has a rich diversity of ethnic groups. The national language of Namibia is English. The other widely spoken languages are the Owambo languages, Afrikaans, Fwe, German, Hai//om, Herero, Kwangali, Lozi, Nama/Damara, Subia, Tswana and !Kung (Grimes 1996).

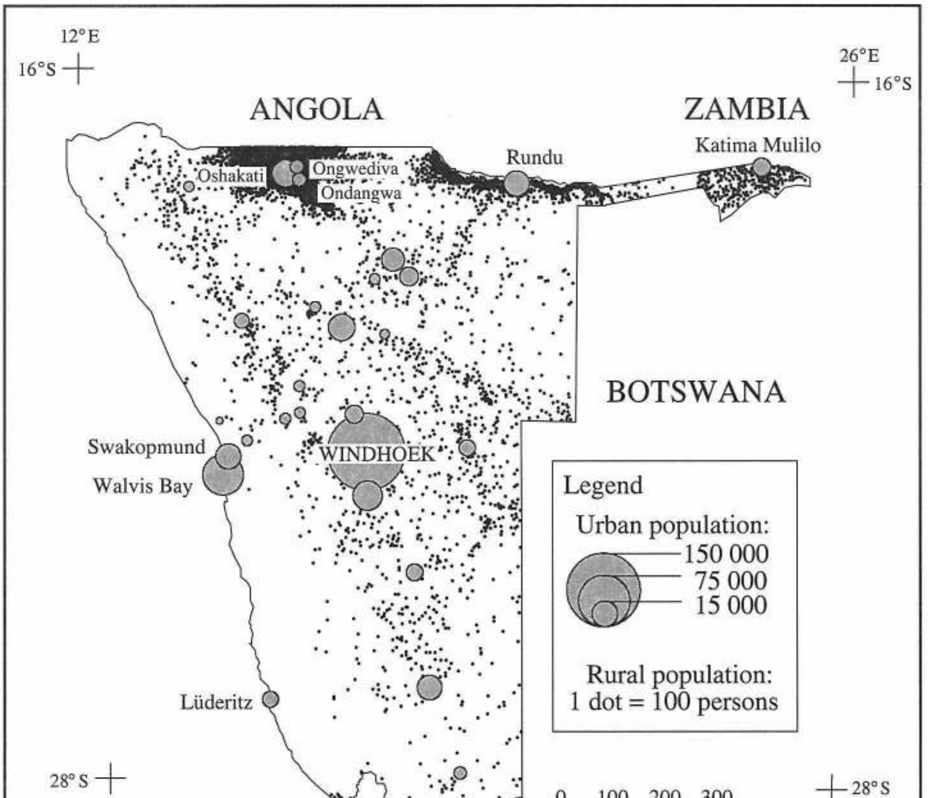


Figure 9. Distribution of Namibian urban and rural population in 1991. Modified from the 1991 population and housing census map produced by the Central Bureau of Statistics (Namibia).

2.2 Owambo area of north-central Namibia

2.2.1 Population

The Owambo languages are closely related varieties of a dialect cluster covered by the generic term 'Oshiwambo' (Legère 1998). In the mid-19th century the pre-colonial Owamboland had a population of 50 000 (Siiskonen 1990). The population consisted of 16 autonomous communities (Figure 10), which were separated by uninhabited wooded savannas (Nitsche 1913, Koivu 1925, Siiskonen 1990, Eirola 1992).

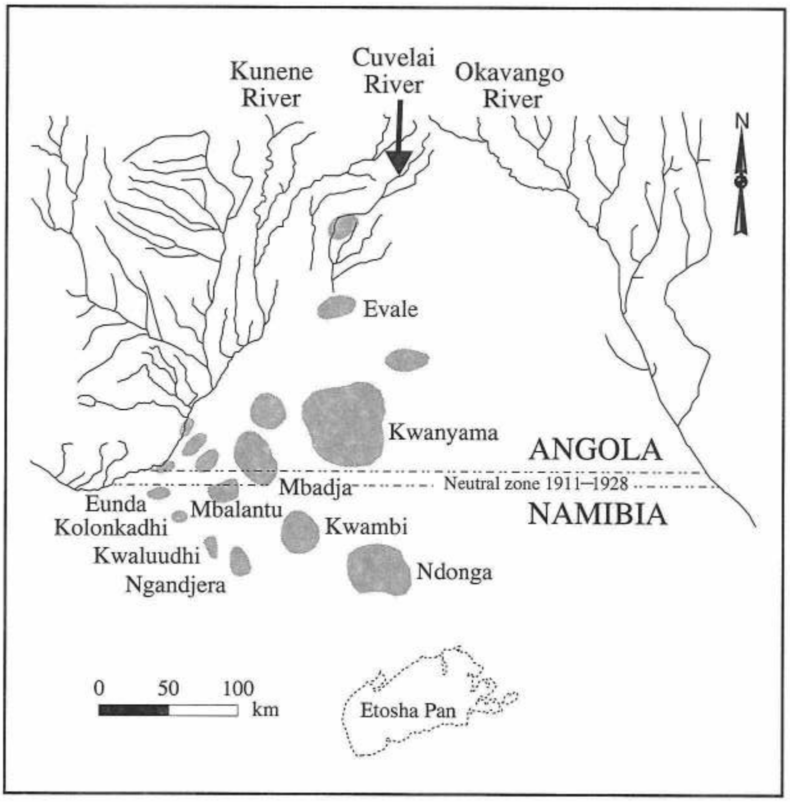


Figure 10. Approximate settled areas of the Owambo communities in the late 1800s. Modified from: Siiskonen (1990), Hangula (1993a).

In north-central Namibia, Mendelsohn et al. (2000) identified nine predominant Owambo languages and eight 'tribes or tribal authorities' (Figure 11). According to Keulder (1998), the Government of Namibia recognises the following seven traditional authorities: Kolonkadhi, Kwaluudhi, Kwambi, Kwanyama, Mbalantu, Ndonga and Ngandjera. In the past there were significant differences in the culture and customs between the ethnic sub-groups of the Owambo area, but currently these differences have diminished. The Owambo people of today can be considered to share a relatively homogenous cultural identity (Tapscott 1990).

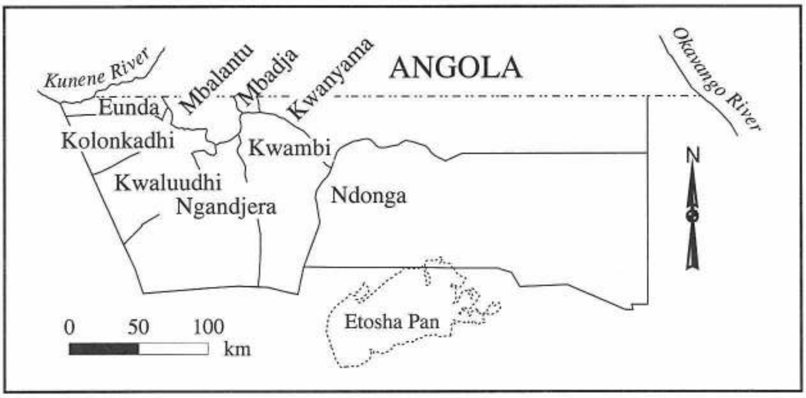


Figure 11. Approximate boundaries of predominant languages in the Owambo area of north-central Namibia. Modified from: Mendelsohn et al. (2000).

In the 1991 population and housing census the population of the Owambo area comprised 44 % of the Namibian population. In the whole country the speakers of Owambo languages constituted 51 % of the population (Central Statistics Office 1993b, 1994a). It is estimated that the Kwanyama language comprises 40 % and the Ndonga language 30 % of the Oshiwambo-speaking people in Namibia (see Legère 1998). The number of Kwanyama-speakers in Angola is assumed to be 350 000 (Ntondo 1998). Thus, the total number of Kwanyama-speakers in the two countries is about 650 000. It can be estimated that in the year 2000 the number of inhabitants in the Owambo area of north-central Namibia was 740 000, the population density being 14 inhabitants km^{-2}. The southern, western and eastern parts of the area were sparsely populated, whereas in central Owambo the population density was high.

The Owambo society is matrilineal. According to tradition, children (male children in particular) inherit from their mother's brothers, rather than from their own father. Thus, when a man dies, his cattle and other important movable possessions go to his brothers and his sisters' sons. During his lifetime a man may distribute cattle among his children, as long as his matrilineal relatives are kept informed about it. Within the households a clear distinction is made between the property of the man and that of his wives. If a wife dies, her possessions go to her own matrilineal relatives, the principal heir being the eldest grown son. Personal effects and household utensils usually go to her daughters. The practise of traditional matrilineal inheritance appears to be changing with the influence of modernisation and new legislation (Bruwer 1961, Estermann 1976, Siiskonen 1990, Tapscott 1990).

Social life in the Owambo area is characterised by the system of extended family, which provides social and economic support to its members. Children are frequently raised by grandmothers, sisters, uncles, aunts, and other family members (Tapscott 1990). In the 1992 demographic and health survey 54 % of all households had one or more foster children. Foster children were those under the age of 15, who had neither their natural mother nor their biological father living with them. Every seventh married women lived in a polygynous union, older women more often than younger. The term 'married' refers to a legal or formal marriage, as well as to informal unions (Katjiuanjo et al. 1993). In the 1991 population and housing census the mean household size was 6.0 persons, and 55 % of the households were headed by women (Central Statistics Office 1993b). Since in many cases some of the family members live elsewhere, the size of a household is often smaller than the size of a family. A typical rural family lives in a household dwelling (Figure 12), which is the economic centre of the farm (Figure 13).

2.2.2 Agro-ecological environment

The Owambo area of north-central Namibia can be subdivided into three major vegetation regions: the desert region in a small section of the Etosha plains and pan edge, savannas in the western and central parts, and woodlands in the east (Giess 1971). Desert changes to woodlands in the area east of the Etosha Pan. Savannas vary from shrubland in the west to the nearly treeless grasslands north of the Etosha Pan. Woodlands are densely wooded in the north, whereas the areas in the south are more sparsely wooded (Figure 14).

Savannas in central Owambo are characterised by a dense *oshana* network (Figure 15). *Oshanas* are shallow ephemeral floodwater courses originating in the highlands of south-central Angola, passing through the Owambo area of north-central Namibia, and terminating in the Etosha Pan. Only the central drainage lines have perennial headwaters in Angola. The Cuvelai River and its main tributaries rise as far north as the Encoco highlands in Angola, 260 km north of the Namibian–Angolan border, at an altitude of 1455 m a.s.l. in an area

Figure 12. 'Modern' house (left) and a traditional household dwelling consisting of continuous outer palisade, inner stockades, huts and other roofed shelters (right). Photo: Antti Erkkilä 22.2.1996.

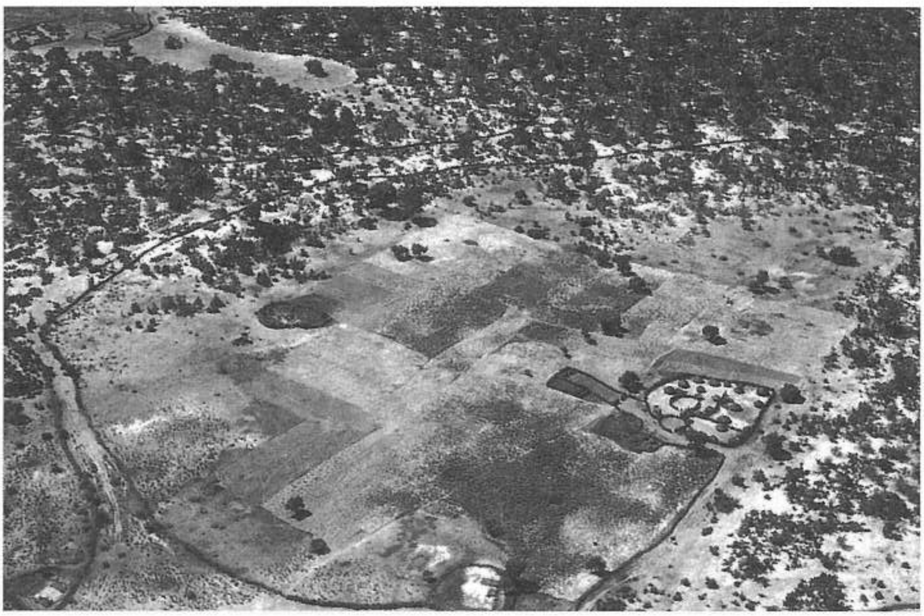


Figure 13. Farm outlined by brushwood fence. Photo: Antti Erkkilä 22.2.1996.

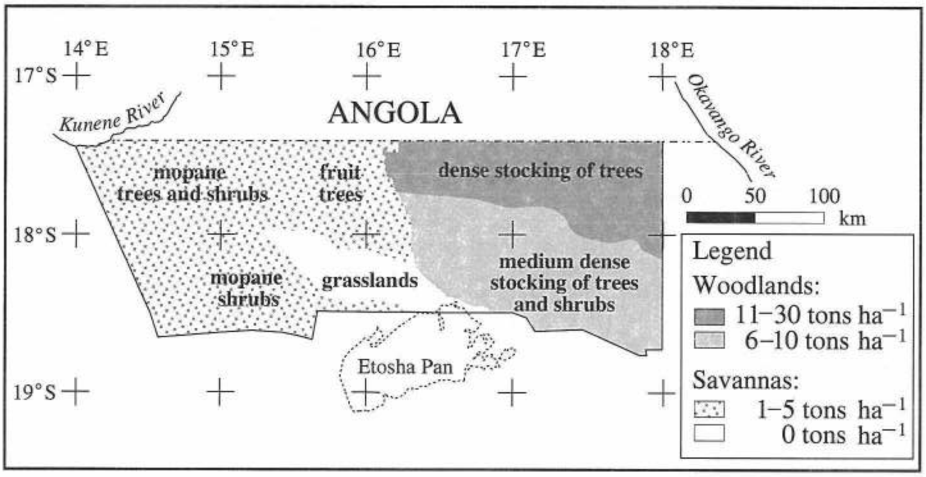


Figure 14. Aboveground woody biomass classes in the Owambo area of north-central Namibia. Cf. Geldenhuys (1992), Angombe et al. (2000), Selanniemi et al. (2000a, 2000b).

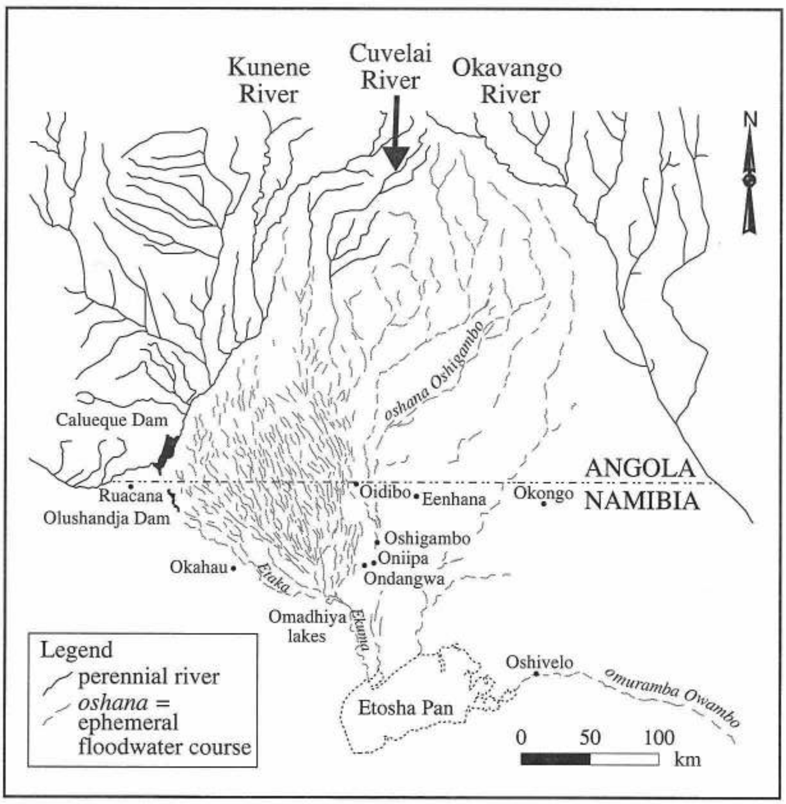


Figure 15. Cuvelai drainage basin and *oshana* network in south-central Angola and north-central Namibia. Modified from: Waal (1991), Mendelsohn et al. (2000).

with an annual mean precipitation of more than 800 mm. About 100 km north of the border the Cuvelai River reaches a very flat plain, which in good rainy seasons is flooded. At the border, at an altitude of 1105 m a.s.l., *oshanas* form a 130 km wide inland delta. About 80 km south of the border, the water courses converge into the Etaka Channel, which drains into the shallow semi-permanent Omadhiya lakes (18°08' S, 15°47' E). The well-defined Ekuma River drains the floodwater about 60 km further south to the Etosha Pan, at an altitude of 1080 m a.s.l. A major flood, *efundja*, occurs infrequently in central *oshanas*, when good and widespread rains have fallen over the Angolan catchment area. On average, an *efundja* flood occurs twice in three years. Strong local rainfall may cause water flow in the western and central *oshana* drainage systems. Drainage channels east of the Cuvelai River, such as *oshana* Oshigambo and *omuramba* Owambo, drain separately in the north and east of the Etosha Pan. *Oshana* Oshigambo is dormant and would probably only flow during a season of exceptionally high rainfall. With sufficient rain, which occurs only occasionally, water flows into the Etosha Pan from the western, central and eastern drainage systems (Stengel 1963, Carvalho 1974, Waal 1991, Marsh and Seely 1992, Mendelsohn et al. 2000).

The *oshana* delta with a surface area of 0.7 million ha represents 13 % of the Owambo area in north-central Namibia. The *oshana* complex consists of an anastomosis of wide (100–500 m) and shallow (30–100 cm) drainage channels, where the floodwater either stands or moves, depending on the amount of rainfall (Figure 16). In addition, the system includes a few shallow clay pans, and numerous small pools termed *oondombe* (singular *ondombe*). *Oshanas*, clay pans and pools usually start filling with rainwater in December, whereas floodwater from Angola reaches the Owambo area by February. *Oshanas* usually stop running by May and are completely dry by July–August. They are separated by slightly elevated terraces with lighter soils; and the banks of *oshanas*, in particular, are often lined with trees and shrubs. The deepest parts of the *oshana* channel have compact, saline soils and are usually without vegetation. *Oshana* water flow and direct rainfall both contribute to recharge of the shallow groundwater. Receding floodwater leaves behind large green pastures. Alluvial soils, especially the side slopes of the elevated terraces, support large fruit trees, and provide a relatively high potential for rain-fed agriculture. About once in three years the high floods from the upper perennial sections of the Cuvelai drainage translocate abundant supplies of fish, which provide an important supplement to the local diets (Nitsche 1913, Stengel 1963, Loxton et al. 1985, Lindeque and Archibald 1991, Waal 1991, Marsh and Seely 1992, Clarke 1998, 1999, Mendelsohn et al. 2000). The above-mentioned ecological factors are the major reasons why the *oshana* delta and nearby lands of central Owambo have become one of the most densely populated areas in Namibia. The wide barren zone in the south, west and east makes the Owambo area rather isolated. Earlier,

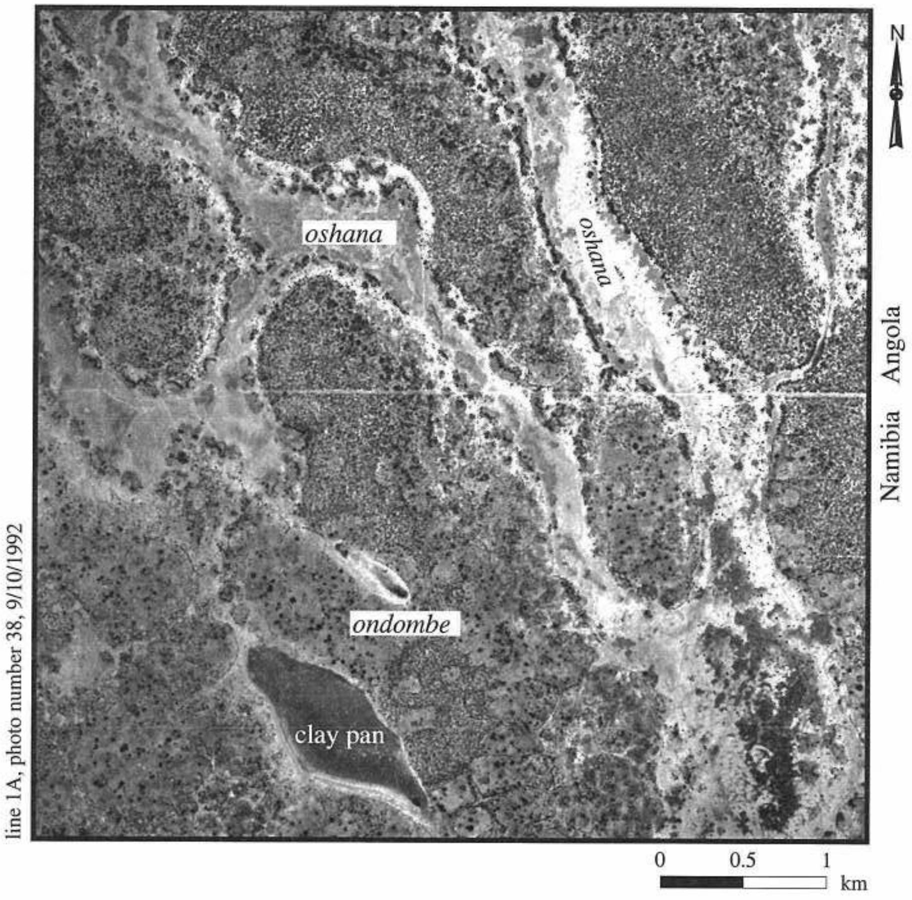


Figure 16. Ephemeral floodwater courses (*oshanas*), a small closed basin (clay pan) and a pool (*ondombe*) at the Namibian-Angolan border.
Source of data: aerial photograph from 1992;
Office of the Surveyor-General (Namibia).

the long distances with only a few reliable waterholes made it difficult to reach the area, especially from the south. The European traders first used the southern route as late as 1851 (Galton 1853, Andersson 1987). During the dry season the visitor may find the landscape in the *oshana* delta desolate, and during the prolonged droughts even terrifying; but after good rains the floodwater converts the sand plains into an attractive lake district.

There are two seasons in the Owambo area of north-central Namibia: the dry season lasts from May to October; the other season, from November to April, is characterised by occasional rainfall. The annual mean precipitation increases from 350 mm in the southwest to 550 mm in the northeast. The monthly mean precipitation is highest in February. The precipitation is not only low but is also characterised by disparity in the annual, seasonal and spatial distribution; and even floodwater cannot bridge the long dry season (Merwe 1983, Loxton et al. 1985). According to Lempp (1963), severe drought and/or famine has recurred over the course of time as follows:

1872–1875 dry years,
1878–1879 drought and bad harvest, famine,
1880 drought and serious famine,
1897 great famine and epidemics,
1900–1903 famine around Oniipa,
1904–1905 famine in Olukonda, Ondangwa and Oniipa,
1907–1908 drought in the Ngandjera land, killing famine,
1913 famine,
1915 killing famine,
1920 drought in the Kwambi land,
1924 drought,
1927–1930 dry years, severe drought and famine,
1933 minor famine,
1940–1944 no exact records,
1940–1941 serious drought at Oshigambo,
1946 drought and famine,
1948 drought in the Kwanyama land, insufficient harvest,
1952/53 drought,
1955 bad harvest,
1957–1960 drought.

Namibian Weather Bureau records annual precipitation data in periods from May 1st to April 30th. The long-term weather data show that at the Namibian–Angolan border, in the Ohangwena Region, the annual mean precipitation is about 100 mm higher than in the areas 40–60 km further south (Figures 17–18). This is an important benefit for the rain-fed agricultural production.

The monthly mean temperature at Ondangwa ranges from 26 °C in November to 16 °C in July. During the coolest period, June–August, the night temperatures drop to 7 °C while day temperatures rise to 27 °C or higher. Although frosts are rare, the risk increases towards the southwest. The hottest period is from October to December, when the maximum day temperature may reach 40 °C. Evaporation is very high throughout the year but is extremely high in spring, during the months of the first rains. It is estimated that the annual potential evaporation exceeds the annual precipitation by a factor of about five (Merwe 1983, Loxton et al. 1985).

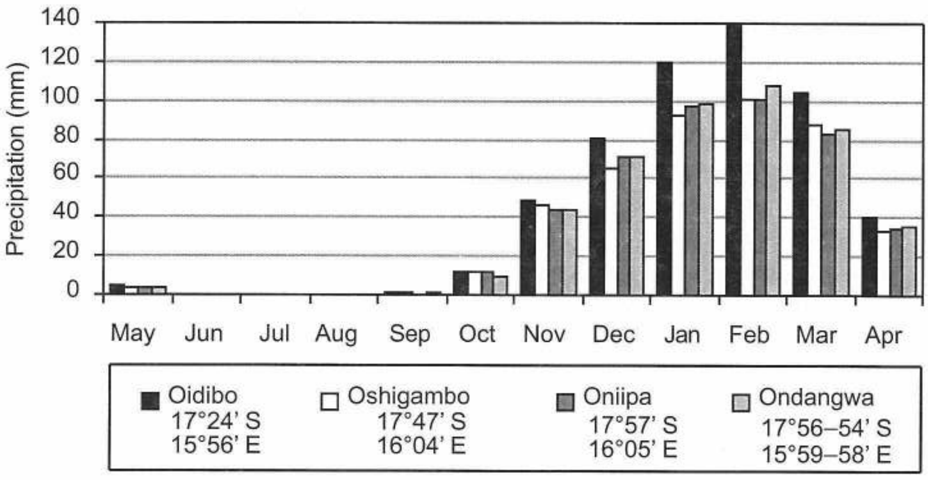


Figure 17. Monthly mean precipitation between 1927/8 and 1971/2 at four weather stations located in the Owambo area of north-central Namibia. Seasons with incomplete data are excluded. n=4 x 37 years.
Source of data: Namibian Weather Bureau.

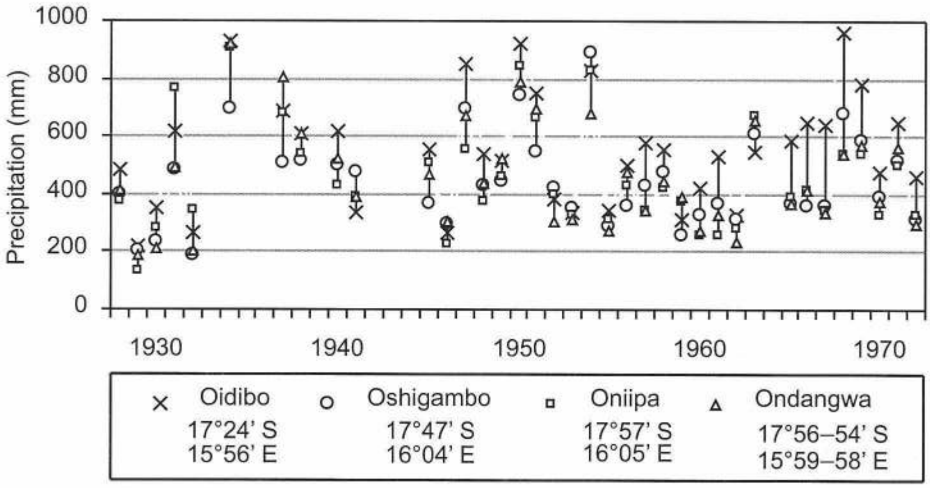


Figure 18. Annual precipitation between 1927/8 and 1971/2 at four weather stations located in the Owambo area of north-central Namibia. The gauging season begins on May 1st and ends on April 30th. Seasons with no or incomplete data are left blank. n=4 x 37 years.
Source of data: Namibian Weather Bureau.

Geologically, the Owambo area belongs to the Mega Kalahari, which is covered by unconsolidated Kalahari sand (Thomas and Shaw 1991). Apart from sites near the Kunene River in the northwest, no original rocks or even stones are exposed. Precipitated calcareous concretes, "white stones" are found on some sites. The terrain is characterised by slightly elevated dunes (uplands) and depressions (valleys). In some areas the elevations and valleys are more definite, whereas in many others the difference in altitude is less noticeable. The highest tops of the dunes or uplands usually have loose or slightly cemented, infertile sands (Soini 1981). The valleys, especially the floodwater courses and basins, have clay soils, which are usually water-logged and too saline for crop production. The cultivated fields and household dwellings are commonly found in the uplands, especially in the lower part, near the compact valley soils. At the valley margins the soils have more moisture, more organic matter and slightly higher levels of nutrients than the soils in the higher part of the topographic gradient. In addition, in the lower part of the landscape profile there is a better chance of finding shallow potable groundwater. In the eastern woodlands, dominated by deep Kalahari sands, the soils in the scattered clay pans, interdune valleys and fossil drainage channels are clayey sands and are therefore favoured for crop production (Nitsche 1913, Urguhart 1963, Williams 1991, Marsh and Seely 1992, Mendelsohn et al. 2000).

Groundwater in the Owambo area occurs in three relatively discrete compartments: the discontinuous perched aquifer, the main shallow aquifer and the deep aquifer. Potable groundwater reserves are formed by shallow aquifers in central Owambo and by deep aquifers in the eastern areas. The discontinuous perched aquifer is an ephemeral water source, located, in particular, in the floodwater courses of the *oshana* area at depths less than 15 m. This groundwater resource is accessed by conical, unlined hand-dug wells and pits, called *omifima*. To prevent contamination from the underlying highly saline aquifer, the wells penetrate only the top of the thin body of potable water. During the dry season the water level drops considerably, and the wells in the discontinuing perched aquifer often dry out completely for several months. The main shallow aquifer can be considered a permanent source of water, unreliable only during dry periods. The water quality varies from potable to highly saline. This fresh water resource is accessed by hand-dug wells, called *eendungu*, which are often covered and sometimes lined with logs. The depth of hand-dug wells commonly ranges from 10 m to 30 m. The deep aquifer occurs below a depth of 50 m. It is saline and becomes more saline with increasing depth. Geographically, in the Ohangwena Region, the deep aquifer appears to be related to the 1130 m topographic contour. Above this contour the quality of groundwater from the deep aquifer increases progressively. Although groundwater resources are present in considerable amounts throughout the Owambo area, they are frequently unusable because of their high salinity and because their yields are often highly unpredictable. Saline groundwater comes close to the surface, especially in the south towards the northern margins of the Etosha Pan (Loxton et al. 1985, Marsh and Seely 1992, Department of Water Affairs 1996, Vainio-Mattila 1996, Mendelsohn et al. 2000).

Since the 1920s the expansion of the settled area has been facilitated by dam-building programmes, primarily in the *oshana* delta and surrounding area, and by drilling boreholes, especially in the eastern woodlands. The first boreholes were apparently drilled in 1926 (Loxton et al. 1985). The most important water-supply infrastructure was initiated in the *oshana* delta, when the building of an earth-lined canal between Outapi and Oshakati was started in 1959. The aim of the canal was to channel floodwater towards the population centres around Oshakati and Ondangwa. In 1970, the canal was extended westwards to transport water pumped from the perennial Kunene River (Lempp 1963, Marsh and Seely 1992). In the mid-1990s the piped water-supply system consisted of 950 km of pipelines, 92 km of open channels, 29 pumping stations and nine purification plants, located mostly in the densely populated savannas (Department of Water Affairs 1996). The water infrastructure in the remote areas of sparsely populated eastern woodlands and western savannas is based primarily on boreholes. In the mid-1990s, despite the extensive piped system and numerous boreholes, 85 % of the households in Omusati, 80 % in Ohangwena and 62 % in Oshana regions had no water pipe or well within a 5-minute walking distance from the house (Central Statistics Office 1996). In recent years, the development and construction of a pipeline system for supplying safe water within 2.5 km for each household in the central Owambo has been recognised as a priority (Mendelsohn et al. 2000).

According to Marsh and Seely (1992), development of a large-scale infrastructure, especially canals and roads perpendicular to the direction of potential floodwater flow, threatens the integrity of the *oshana* system. It is assumed that the flow of water in the *oshana* system has been altered, and consequently in some areas there has been less water available for groundwater recharge and vegetation growth. Recent monitoring by Clarke (1999) indicates that the infrastructure is not consistently altering *oshana* vegetation, and the design of large culverts for roads and inverted siphons for the canal seem to allow adequate flow of water. Nevertheless, introduction of a safe and reliable water supply has induced people to settle permanently in the vicinity of the water infrastructure. Obviously, without the development of a water-supply infrastructure, large areas in the Owambo area would be unsuitable, both for permanent settlement and sedentary livestock farming, not to mention development of urban centres.

2.2.3 Farming and land tenure

The traditional subsistence strategy in the Owambo area of north-central Namibia is based on rain-fed agriculture and on livestock farming supported by migratory seasonal grazing. Currently, the welfare of many rural households is highly dependent on pensions, as well as on the wages of family members in nearby urban centres, the remittances of migrant workers and small-scale business activities in the informal sector (Tapscott 1990, Central Statistics Office 1996, Central Bureau of Statistics 1999).

In the traditional agriculture of this region, the fertility and the texture of cultivated soils are improved primarily by manuring. Apparently, the benefits are greater when manure is applied to sandy rather than clayey soils (see Bradley and Dewees 1993). The role of livestock management has been essential in soil improvement. Stock animals are penned in the field area for the night and put out to pasture in the morning (Figure 19). A substantial part of the nitrogen available in livestock manure is derived from woody-vegetation browse (Figure 20). After the harvest the herd is allowed to graze the weeds and remaining stalks. When the fodder and grazing near the household dwelling become scarcer, many herds of cattle are driven to the distant cattle posts, where grass and water are abundant throughout the dry period. Goats remain on the farms. In the past, cattle were sent to seasonal pastures (especially to the Oshimolo grazing area in southern Angola) in the beginning of the dry season and were only brought back home after the first rainfall. A few cows were kept on the farm to satisfy the need for fresh dairy products. The main restriction on cattle raising was access to water, rather than fodder or grazing. The highly complicated system of cattle-lending contracts enabled people who did not own cattle to have access to cattle products, including manure (Koivu 1925, Loeb 1951, Bruwer 1961, Elonheimo 1967, Carvalho and Silva 1973, Carvalho 1974, Soini 1981, Siiskonen 1990, Tapscott 1990, Williams 1991, Kreike 1996).

Currently, seasonal migration of cattle has become less common, as an increasing number of herds are kept permanently in the areas where water is available in canals, dams and watering points. Transhumance has also been disrupted by the regulations at the Namibian–Angolan border, and by fencing off the communal land. Large-scale fencing was first seen in the 1970s in the Mangetti block, east of Oshivelo and north of *omuramba* Owambo, where farms were leased for cattle raising through a parastatal organisation for business development (Tapscott and Hangula 1994). In the 1980s and 1990s an increasing number of affluent farmers started spontaneously fencing off communal land for private pastures, especially around the Mangetti farms block in the present Oshikoto Region (Fuller et al. 1996). The leased ranches in the Mangetti farms block comprise 137 000 ha, while another 500 000 ha of nearby areas have been fenced off for private use with or without permits provided by the Ndonga Traditional Authority (Holme and Kooiman 1994).

Figure 19. Livestock pen made of densely stacked wooden poles.
Photo: Antti Erkkilä 25.2.1996.

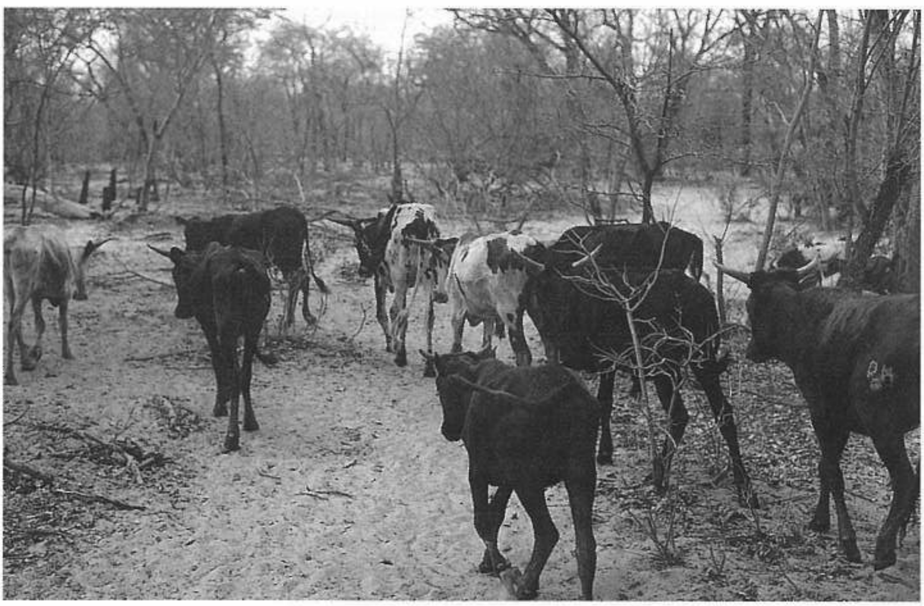


Figure 20. Browsing in the late dry season in the vegetation region defined as woodlands. Photo: Antti Erkkilä 16.10.1996.

It is assumed that currently only 30 % of the cattle are moved between grazing and settled areas. Cattle are brought to densely populated areas at the end of summer, usually between March and May, and sent back to cattle posts between August and November. The main motive for moving cattle is to take advantage of new pastures that have grown during the summer rains and also to allow them to feed on *Pennisetum glaucum* (L.) R.Br. (pearl millet, *omahangu*) stubble after the harvest. The second move, back to the cattle posts, occurs when grazing has been depleted in the settled area (the *oshana* delta and surrounding areas). The movements of cattle occur mainly within the boundaries of the Owambo area in Namibia, but also to a certain extent across the Namibian–Angolan border. In some instances, cattle are moved into the northern Kunene Region (former Kaokoland) as well as into the western parts of the Kavango Region (Tapscottt 1990, Pendleton et al. 1992, Tapscott and Hangula 1994, Fuller et al. 1996, Mendelsohn et al. 2000).

In 1998 the estimated numbers of livestock in the Owambo area included 1 100 000 goats, 550 000 cattle and 107 000 donkeys. About 80 % of the cattle are owned by some 20 % of the households; over 50 % of the households own no cattle. It seems that livestock in general and cattle in particular are increasingly owned by a few prosperous businessmen, politicians, teachers, mine-workers, civil servants, and other employees with regular income rather than by full-time small-scale farmers. Many poorer farmers do not own nor even have access to cattle and/or goats. Consequently, without cattle, manuring is difficult, if not impossible (Central Statistics Office 1996, Fuller et al. 1996, Mendelsohn et al. 2000).

At the homestead, which includes several huts and a surrounding palisade, the soil becomes gradually more fertile due to household litter and other debris. In the past, the position of the homestead was changed frequently, e.g. in the Kwambi land every 2nd or 3rd year (Koivu 1925), and in the Kwanyama land at an interval of 3–4 years (Tönjes 1996). The old household dwelling site, especially the area of livestock pens, became the most productive section of the cultivated field. The process of change in homestead site is discussed in more detail in section 4.4.

The fertility and texture of cultivated soils are also enhanced by applying earth from scattered termitaria (Kreike 1996), in which the levels of soil organic matter, nitrogen, phosphorus and exchangeable cations are concentrated (Campbell et al. 1993, Frost 1996). In addition, leaf litter from trees and shrubs growing in the field are important sources of organic matter and plant nutrients. The soils are enriched by nitrogen through the leguminous species, often intercropped with *Pennisetum glaucum*, the staple crop, and *Sorghum bicolor* (L.) Moench. Cultivated legumes include *Vigna subterranea* (L.) Verdc. (bambara groundnut) and *V. unguiculata* (L.) Walp. (cowpea) (Rodin 1985, Central Statistics Office 1997, Matanyaire 1998, Central Bureau of Statistics 1999).

In the past, the cultivation of land was extremely laborious. Koivu (1925) mentions that 1–2 workers were needed to hoe a quarter of a hectare of land to prepare it for sowing and, above all, to keep the parcel free of weeds. Due to the intensive and manual care of the crops, the term 'garden' rather than 'field', is often used to describe this kind of production unit (see e.g., Koivu 1925, Loeb 1951, Tönjes 1996).

Since the 1940s, with the adaptation of the plough and the use of draught animals, soil cultivation has gradually become easier, although still in the 1990s weeding remained a major bottleneck in agricultural production. Ploughing has helped to increase the cultivated area, especially tilling of the heavier soils near the valley bottoms. However, this does not mean that the yields would have become any higher (Kreike 1995). In the 1990s most of the fields were 2–5 ha. The main facility used for field preparation was a hand hoe followed by cattle in Ohangwena and Oshikoto, donkey in Omusati and tractor in Oshana (Central Statistics Office 1997). The number of donkeys has increased dramatically since the 1920s (Bruwer 1961, Hahn 1966, Elonheimo 1967), and the first tractors appeared in the 1960s (Rodin 1985, Siiskonen 1996). Currently the majority of the fields are ploughed using oxen, donkeys and tractors. Reverse development in cultivation practises (from plough back to hand hoe), however, also coexists, as an increasing number of households are no longer able to maintain the livestock needed for draught power (and manure), nor are they able to borrow or rent the facilities. While over the short term donkeys provide the draught power needed for production of pearl millet, they are much less useful in the farming system than cattle are, due to the fact that donkey manure is inferior (Matanyaire 1998, Central Bureau of Statistics 1999, Mendelsohn et al. 2000).

The documentation on fallow systems is scanty and even controversial. Siiskonen (1990, 1996) argues that during the mid-nineteenth century the land was kept fertile through slash and burning and that periodically it was allowed to lie fallow, whereas Koivu (1925) states that the only fallow period was the dry period of about 6 months. Bruwer (1961) describes a case where permanent agriculture had been practised since 1897. Nevertheless, in the mid-1990s the estimated fallow area in the Owambo area of north-central Namibia was only 2 % (Central Statistics Office 1997).

Land tenure in the Owambo area has been based on land allocations through a hierarchy of traditional leaders (Werner 1998). Traditionally, the farmer owned his cattle and other movable property, but not the land (Bruwer 1961, Williams 1991). In the Kwanyama areas, after the death of King Mandume ya Ndemufayo in 1917, the territory was run by the Council of Senior Headmen, consisting of eight, and later nine, persons representing the districts into which the Kwanyama land was divided (Bruwer 1961, Hinz 1998). Each district was divided into wards, which consisted of a certain number of homesteads. Each ward was controlled by a headman. After Mandume, the Kwanyama people were without a king for more than 80 years until recently the Kwanyama King was reinstated in Namibia. Under the Ndonga King there are 9 senior-headmen, who in turn may have 70 to 100 headmen each (Hinz and Joas 2000). In 1993 the system of regional government was introduced. In 1998 the boundaries of the three administrative regions (Omusati, Oshana and Oshikoto) and some of the constituencies were changed. Currently, the administrative regions of Ohangwena, Omusati, Oshana and Oshikoto are each governed by a governor together with a number of councillors, each representing a constituency (Mendelsohn et al. 2000). The traditional leaders enjoy a high level of autonomy, and they continue to allocate land independently of government officials (Cox 1998a).

Traditionally, the land has been allocated for residential and agricultural purposes, whereas the remaining land has been in communal use, including grazing, seasonal fishing, hunting and gathering, and providing water supplies. In the past the use of an allocated plot was personal, usually lifelong. When a person who had obtained the land died, the plot was returned for reallocation. Widows together with their children were often forced to leave the farm. In inhabited areas a fee was generally paid to the chief or the headman upon the allocation of land. In uninhabited areas the establishment of a farm required permission, but no fee was charged. Since the Second World War land has increasingly begun to be inherited by the descendants of the deceased landowner (Bruwer 1961, Siiskonen 1990, NEPRU 1991, Williams 1991, Kreike 1995, Notkola and Siiskonen 2000). In recent years the Owambo traditional authorities have changed their customary laws and now allow a widow to take over her husband's land rights without extra payment (Becker 1997).

In the beginning of 2001 the land tenure system in the communal areas remained unclear, since the Communal Land Bill was not yet gazetted, despite several years of public consultation (see Hangula 2000). In fact, the term 'communal' poorly describes the current tenure and production system in the Owambo area of north-central Namibia. Mendelsohn et al. (2000) define the following three major land-use categories in the Owambo area: small-scale farming in the central part (50 %), large-scale farming in the southeastern part (20 %) and communal grazing in the southwestern part (30 %). Recent forest inventories show that 28 % of the Omusati and 22 % of the Oshana regions (north of the Etosha National Park) have been fenced off to private, primarily small-scale, farms (Selanniemi et al. 2000a, 2000b). The eastern part of the Oshikoto Region is nearly completely fenced off to private, large-scale farms (Holme and Kooiman 1994, Cox 1998b).

2.2.4 Constructions on farms

In the Owambo area of north-central Namibia a farm occupied by a family is composed of the household dwelling, the cultivated field, and the area of private pasture land (cf. Carvalho 1974). In the densely populated areas, however, the small size of a farm may not allow any private pasture land. Farms in the densely populated areas are either evenly distributed or clustered, depending on the ecological formations. In the sparsely populated areas, isolated farms are also found. The family either has a private waterhole within the farm area, or it is dependent on a communal waterhole in the neighbourhood. A hand-dug shallow waterhole, *omufima*, is protected by an enclosure, usually built of thorny bushes and branches, sometimes strengthened with fencing poles. A deeper hand-dug well, *ondungu*, is often covered and lined with logs (Vainio-Mattila 1996). The boundary of a farm, as well as the crop fields, may be fenced. There are two main methods of building farm fences (Figure 21). Earlier fences were piles of brushwood, but nowadays fences are increasingly built by erecting wooden poles and connecting strands of wire between the poles (Erkkilä, pers. obs.).

The household dwelling is placed within the farm area, either in the middle or on the periphery of the cultivated field. The household dwelling is called *eumbo* in the Kwanyama language and *egumbo* in Ndonga. The *eumbo* is the economic centre for a small or an extended family. The dwelling unit varies from a simple to an extremely complex structure, but the basic layout and pattern is always about the same. In the terminology of the present study a 'household dwelling' or *eumbo* consists of the homestead and the attached livestock pen(s), if there are any. The traditional homestead has a continuous outer palisade, usually 2–3 metres in height, consisting of tightly packed vertical wooden poles or laths, which are partly buried in the ground (Figure 22). The outer palisade is often strengthened by lateral beams and strong bark twine. The inner stockades separate the homestead into different sections and enclosures – for social life, sleeping, cooking and storage facilities. The urinals are concealed behind huts and stockaded walls along the outer palisade; otherwise, the surrounding field or bush is used as a toilet. In the densely populated but sparsely wooded areas the outer palisade and the inner stockades may be replaced by millet or sorghum stalks, or by bundles of brushwood (Erkkilä and Siiskonen 1992).

Enclosed by the outer palisade there are round huts and shelters, which have conical roofs with a wooden frame covered by grass or millet stalks (Urquhart 1963). The walls of the huts are commonly built of tightly packed vertical poles or air-dried mudblocks (Figure 23). Sometimes the walls are made of bundles of millet stalks, which are lashed together between a mud wall plinth and the underside of the roof (Mills 1984). Open shelters, which have no walls, have either a conical or a flat roof structure supported by a few vertical poles. In some huts the gaps between the tightly packed vertical poles are sealed by clay-

Figure 21. Two types of farm fences: pole fence (left) and brushwood fence (right). Photo: Antti Erkkilä 12.10.1996.

Figure 22. An outer palisade defines the perimeter of a traditional homestead. Photo: Antti Erkkilä 15.10.1996.

Figure 23. Two types of hut walls: wooden poles (left) and mudblocks (right). Photo: Antti Erkkilä 15.10.1996.

rich earth removed from termitaria. The floor of a hut may be daubed with clay; otherwise the interior floor surface of the *eumbo* is sand. Large, traditional granary baskets are used to store the pearl millet grain. Granary baskets are lifted from the soil by a wooden frame and protected from rain by a conical thatched roof. A large granary basket is placed under an individual open shelter, but 2–3 slightly smaller containers may be grouped together under one roof. The granary baskets are made of saplings, which are woven together with bark twine. The inner part of the basket is plastered with clay. In most cases the granary is within the outer palisade, but it may also form a separate entity a few metres away (Erkkilä, pers. obs.).

In the Ohangwena Region a very large household dwelling is often a maze of stockaded passages and enclosures. Socially, the most important enclosure is a large courtyard called the *olupale*. This circular area, edged by a stockade, is a meeting place where guests are received. On the western side of the *olupale* there is a fireplace around which sitting logs form an angular U-shape. The householder's place is in the middle, facing the fire and the direction east; on the opposite wall there may be an ox skull rack symbolising the wealth of the owner. In former times the sacred fire was kept burning in the *olupale* (Hahn 1966, Rodin 1985). In the cooking area, *epata*, there is a fire-place (protected by an open shelter during the rains), a pantry and often also a few large granary baskets. The wife's sleeping hut is located centrally, near the *epata* and *olupale*, whereas the husband's sleeping hut and enclosure are further away, far from the main entrance. On the periphery of the *olupale* there is often a thatched hut where visitors are received in the comfort of shade or, depending on the season, out of the rain. Usually the *eumbo* has separate compartments for boys and girls, near the entrance and close to the cooking area, respectively. There may also be a small reception area for less formal meetings, the enclosure called *okalupale*. The size and complexity of the *eumbo*, the number of huts and the granary baskets indicate the status of the householder (Erkkilä, pers. obs.).

The original function of the elaborated household fortification was to protect the inhabitants against enemies on the one hand and against dangerous wild animals on the other. The fortification was made so strong that the enemy's arrows could not penetrate the palisade walls, and the labyrinthine passages easily confused a stranger. Since the ground is rockless and level, wood was the obvious choice for residential and defensive constructions. The most elaborate fortifications were built by the Owambo people living in Evale, in southern Angola. There the outer palisade consisted of a double row of tightly packed vertical poles; the hollow between the two rows was filled with clay. Elaborate *omaumbo* (singular *eumbo*) were also built in the Kwanyama land (south of Evale), where there was no problem to obtain poles for domestic constructions. In the Ndonga land to the south there was a shortage of wood, not only for construction, but also for fuel. Therefore, in the beginning of the 20th century, the poorest Ndonga households were compelled to use millet stalks in building, as a substitute for poles (Loeb 1962, Erkkilä and Siiskonen 1992, Tönjes 1996).

In the *eumbo* architecture there have been a few minor changes in the last hundred years. In general, the trend has been from a complex pattern to a more simple layout. One of the reasons is the change from a polygamous to a monogamous family. In the polygamous system each wife has her own sleeping hut, and often also an individual enclosure, *epata* (Estermann 1976, Tönjes 1996). The change from polygamy to monogamy has been influenced by the Christian missions. In the Owambo area of north-central Namibia the percentage of Christian population increased from about 27 % in 1933 to 43 % in 1953 (Notkola and Siiskonen 2000) and to 78 % in 1973 (Tötemeyer 1978). At the end of the 1940s, most of the Kwanyama families were polygamous, with a poor man having perhaps two wives, a wealthier man six, and a senior-headman a dozen or more (Rodin 1985).

In former times a Kwanyama *eumbo* was protected by an additional circular barrier, which sometimes was another stockade, but often was a fence made of thorny bushes and branches. A visitor entering the *eumbo* was always supposed to use the main entrance, which faced east. He was first led to the right, via a semicircle gateway, and finally, if summoned by the householder, through the stocked passage to the meeting place, *olupale* (Schinz 1891, Bruwer 1961, Loeb 1962, Urquhart 1963, Elonheimo 1967). In the present study it was discovered that in the 1990s the above-mentioned extra barrier or passage was very rare in the Ondobe and Eenhana constituencies, and consequently the main entrance faced west. In addition, in the past it was common that enclosures for livestock pens formed an integral part of *omaumbo*. Nowadays the livestock pen, if there is one, is either attached as an extension to the outer palisade of the homestead, or a livestock pen forms an enclosure separate from the household dwelling. The livestock pens attached to the outer palisade usually have a stockaded wall, whereas many of the livestock pens that are separate from the household dwelling are built of thorny branches. A funnel-shaped brushwood fence is often built to drive the cattle into the enclosure.

In the Owambo area of north-central Namibia the first missionary buildings had about 50 cm-thick walls made of air-dried clay bricks. The supporting structure of a house, including the roof framing, was built of tree trunks. Millet stalks were used for covering the roof. The saddle roof had long eaves, which provided much-appreciated shade and, most of all, protected the soft clay-brick walls on all sides. The local soil was not suitable for manufacturing burnt bricks. Air-dried clay bricks have been used in walls since the arrival of the first missionaries in 1870, and the first metal-sheeted roof was built in 1908 (Koivu 1925, Peltola 1958, Tönjes 1996).

Since the beginning of the 1960s, new construction materials and building designs have become increasingly common also in the indigenous architecture. The new components in buildings include sheet iron and sawn timber, as well as steel frames for doors and windows (Bruwer 1961, Mills 1984). The upright walls of traditional round huts are more commonly made of bricks or blocks – based on clay, cement and sand, or a mixture of clay and cement (Elonheimo 1967, Rodin 1985, Kreike 1995, Conroy 1999). Clay for mudblock constructions is often obtained from scattered termitaria (Cunningham 1993). According to Rodin (1985), in the beginning of the 1970s the layout of an *eumbo* was rather rectangular or square, not circular like at the end of the 1940s. The new rectilinear style is best manifested in 'modern' houses (typically of brick-wall construction with corrugated iron roofing), which are commonly built not only in urban centres but also in the densely populated rural areas.

In the urban and peri-urban areas many people live in iron shacks, where the walls and roof are made of scrap metal or a mixture of available materials (Pendleton et al. 1992). In the beginning of the 1990s the only urban centres in the Owambo area were Ondangwa, Ongwediva and Oshakati. A 1992 survey (NISER 1992), comprising 200 households within a 100 km radius of Oshakati, defines dwellings as traditional (67.5 %), modern (5.0 %), shanty (3.5 %) or mixed (24.0 %) accommodation. In the 1991 population and housing census, in the Ohangwena, Omusati, Oshana and Oshikoto regions 87 % of all households lived in traditional (wooden) houses, 9 % in modern (brick) houses and 3 % in improvised (waste material) houses (Table 1).

Table 1. Households by type of house in north-central Namibia, according to the 1991 population and housing census.

Region	Traditional house		Modern house		Improvised housing		Other housing		Total[(1)]	
	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
Ohangwena	27 892	98	409	1	56	0	70	0	28 427	100
Omusati	30 136	98	563	2	20	0	163	1	30 882	100
Oshana	15 581	70	4 476	20	1 821	8	312	1	22 190	100
Oshikoto	16 297	76	4 008	19	863	4	258	1	21 426	100
Total	89 906	87	9 456	9	2 760	3	803	1	102 925	100

[(1)] Totals may not tally due to rounding.
Modern house includes detached house, semi-detached house, and flat.
Other housing includes mobile home and single quarters.
Source: Central Statistics Office (1994a).

2.2.5 Migration from savannas to woodlands

At the end of the 19th century the Cuvelai drainage basin supported a population of 100 000 (Siiskonen 1990). Although the Owambo people were settled on the major flood plain, they used the surrounding areas for hunting and for seasonal pastures. The eastern woodlands were occupied by the San communities, which temporarily abandoned their settlements in order to follow migrating wildlife (Kreike 1996).

In the beginning of the 20th century the relationship between population growth and expansion of the settled area was noted by the Finnish missionaries, who had been working in the Owambo areas since 1870. When Albin Savola arrived in Oniipa in 1893, the uninhabited frontier northeast of the Oniipa Mission was about 2 km; in 1915 it was already 40 km (Savola 1916, 1924). In 1908 the Finnish Mission decided to build a new station 15 km north of Oniipa, on the bank of a well-defined floodwater course, *oshana* Oshigambo. At that time the designated Oshigambo parish centre and the surrounding areas comprised 40 % of the Oniipa parishioners. The travelling time from the Oniipa Mission to Oshigambo was 6–7 hours (Peltola 1958). By 1915 the inhabited area ruled by the Ndonga King had spread out far from the *oshana* delta, extending from the savannas to the eastern woodlands. The Kwanyama settlements south of the present Namibian–Angolan border reached *oshana* Oshigambo, but not yet the woodland frontier further east (Nitsche 1913, Eirola 1992).

Until the First World War the Portuguese troops were unable to fully control the Owambo areas in southern Angola. Similarly, on the southern side of the border, the Owambo communities were virtually independent and ruled by their own leaders. The German colonial power had the main focus in the central and southern parts of South West Africa. Owamboland, for which the Germans used the term 'Amboland', had no exploitable natural resources, but the area was regarded as an important labour reserve. The exact borderline between the German and Portuguese possessions remained unresolved, despite the 1886 agreement on boundaries. The Germans claimed that the border in the north ran along the latitude of the Kazombue waterfall in the Kunene River, whereas the Portuguese argued that the border was 10 km further south, at the Ruacana Falls. Nevertheless, the border had no meaning for the African population (Nitsche 1913, Hangula 1993a, Vigne 1998).

The Germans surrendered to the South Africans on 9 July 1915. The South Africans and the Portuguese agreed on the joint administration of the disputed border area, the so-called neutral zone (Pritchard 1915, Hangula 1993a, Vigne 1998). According to the strict border regulations, the territory and subjects of the Kwanyama King, Mandume son of Ndemufayo, were divided between the two colonial empires (Silvester 1995, The Power Stone 1999). Mandume was forced to leave his residence in southern Angola and decided to move to the neutral zone, where he died two years later during a battle against the joint South African–British troops, strengthened by some Owambo forces (Williams 1991). The harassment practised by the Portuguese troops, taxation and the forced labour policy drove a large number of the Owambo people, especially the Kwanyama, from their cultivated lands in southern Angola to the uninhabited savannas further south, where land was less fertile and rains unreliable (Helenius 1944, Kreike 1996). Due to drought and the war, there was a devastating famine, which killed 20 000 people (Siiskonen 1996).

The artificial borderline established in 1926 by the Union of South Africa and Portugal incorporated the disputed neutral zone into Angola and split the Owambo communities of Mbalantu, Mbadja and Kwanyama (Hangula 1993a). Consequently, the movement of people and cattle from southern Angola to northern Namibia increased tremendously. According to Loeb (1962), 40 000 Kwanyamas moved south joining the 20 000 Kwanyama people already living on the southern side of the border, while another 20 000 remained in Angola.

One of the Kwanyama migrants was Haufiku (since 31.8.1919 Paulus) Hamûtenja, an important man related to the royal clans. In 1915 King Mandume allocated Haufiku a land in Edundja, a few kilometres south of the neutral zone, about 11 km southeast of Oshikango. The allocated area was already settled by a few Ndonga people, who had to give way to the important Kwanyama headman. Paulus (Haufiku) Hamûtenja helped the Kwanyama migrants from Angola to settle either in savannas or in the eastern woodlands of the present Ohangwena Region. By 1927 Edundja could support no more migrants. As a Kwanyama headman and a newly consecrated pastor, he felt that it was his duty to lead the people from the overcrowded areas to the new frontier. He left his old home and established a new settlement in Eenhana, in woodlands, 35 km east of Edundja. Occasionally, fresh water had to be transported to the new settlement from Okangudi, about 25 km west of Eenhana – a detail that indicates how critical the water problem is during the dry season (Helenius 1944). The water crisis in Eenhana and in many other new settlements was solved by deepening natural depressions and building dams, later also by drilling boreholes. Currently, Eenhana is one of the three declared urban centres in the Ohangwena Region with the head office of the regional government, a church, a hospital, schools, shops and an open-air market (Mendelsohn et al. 2000).

In the mid-1920s the settlement frontier in the present Ohangwena Region was 35 km east of Eenhana (NAF 1928) and about twenty years later reached Kavango (NAF 1945, 1948). Between 1929 and 1930 migration to the eastern woodlands decreased, since the severe drought compelled the inhabitants to move further west (Siiskonen 1998) and even north, back to Angola (NAF 1931). The migration from southern Angola to the Owambo area of north-central Namibia continued throughout the 1930s, 1940s and 1950s (NAF 1933, 1935, 1938, 1952, 1959). The increase in population led to a serious shortage of arable land, and agricultural production barely met the demand for food (Bruwer 1961).

Since the mid-1940s, migrant work in the central and southern parts of Namibia has been the most important source of income for many Owambo households, including the Kwanyama. In 1960 the number of recruited migrant workers from the former Owamboland was almost 15 000 and in 1974 about 36 000. Until the 1970s the working contracts were made for 12 to 24 months, after which labourers had to return to their 'native reserve', north of the veterinary cordon fence, known also as the 'red line'. Only male migrant labourers were allowed to leave the native reserves and enter the so-called Police Zone, the area reserved for the white population. Like all native reserves (homelands), the former Owamboland was a restricted area for non-Owambos, and only white administrative officials had unimpeded access to it. When the male recruits were away, the farming and the other household activities in the native reserves were increasingly the burden of women (Bruwer 1961, Hangula 1993b, Notkola and Siiskonen 2000).

In 1960–1961 a veterinary fence was built along the Namibian–Angolan border to prevent movements of cattle across the border (Kreike 1996). However, fencing did not prevent cross-border mobility; and seasonal, peaceful movement of people and cattle was frequent until intensification of the struggle for liberation in the 1970s (Barnard 1985, Notkola and Siiskonen 2000). According to missionary reports, migration from Angola to the Owambo area of north-central Namibia continued throughout the 1960s (NAF 1966, 1969).

The armed liberation struggle concentrated first on eastern Caprivi, but in the mid-1970s the whole of northern Namibia became a war zone. A large number of the Owambo people, including more than 10 000 Angolan refugees, migrated from the insecure border areas, mainly to the Oshakati–Ongwediva–Ondangwa nexus region. More than 3000 people were forced to move away from the 1-km wide zone along the Namibian–Angolan borderline between the Kunene and Okavango rivers. Many young Owambo people crossed the northern frontier and joined the other Namibian refugees in Angola (Tötemeyer 1978, Barnard 1985, Merwe 1989, Brown 1995, Namhila 1997). Due to the South African invasion, many Owambo people in the Cunene province of southern Angola were forced to leave their home area and flee to Namibe and south of Huila province (Ntondo 1998). The war ended in 1989 and by the end of 1991 nearly 50 000 exiles repatriated to Namibia. Nearly 80 % of the returnees were resettled in the Owambo area of north-central Namibia, many of them in the vicinity of Oshakati and Ondangwa (Pendleton et al. 1992).

According to the 1990 survey, people moved to the Oshakati–Ongwediva–Ondangwa nexus region, where the population was estimated to be 80 000, from all over the Owambo area, the major reason for migration being employment (Pendleton et al. 1992). In this particular survey it was found that over 50 % of the population had settled in the nexus region in the 1980s, and about 25 % during 1986–1990. Thus, the war, which continued for 23 years, promoted the process of urbanisation. In 1974–1988 the Oshakati settlement, which was established in 1966, was a major centre of South African military operations (Hangula 1993b). Exile, war and drought have been reasons for the extensive migration in the Owambo area of north-central Namibia. Pendleton and Frayne (1998) discovered another important motive for migration: family reasons.

The expansion of small-scale farms to the eastern woodlands has been a gradual process. Between the 1920s and the 1970s the suitable sites along the Namibian–Angolan border, the present Ohangwena Region, were settled. Since the late 1970s the Kwanyama herders have moved further south to the woodlands of the present Oshikoto Region, establishing cattle posts and permanent settlements. In the mid-1980s a new type of farming began: large-scale farmers started fencing off communal land for private pastures in the northeastern Oshikoto Region (Fuller et al. 1996). Due to the civil strife in southern Angola, the cross-border mobility in the Ohangwena and Omusati regions has continued. Since 1990, when Namibia gained independence, the most important part of population movements has been urbanisation. It has been estimated that in the past 10 years the population of Windhoek has increased by 100 000 (Melber 1996). The major population movements are illustrated in Figure 24 and present land-use in Figure 25.

Currently, the highest human population density is on the savannas of the central Owambo area, primarily in the *oshana* delta and surrounding areas, as well as along the road between Ondangwa and Oshivelo. The major urban centres of the Owambo area are Oshakati, Ongwediva and Ondangwa (Oshana Region), and the growth centres Outapi, Oshikuku and Okahau (Omusati Region), Oshikango and Eenhana (Ohangwena Region). In the Ohangwena Region the population density is 60–70 inhabitants km^{-2} in the west, and 20–40 inhabitants km^{-2} in the transition zone (see section 4.1). In the eastern woodlands of the Ohangwena and Oshikoto regions, the settlements are scattered over a few suitable sites on clay pans, interdune valleys and other depressions. The mean population density in this area is about 5 inhabitants km^{-2} (Mendelsohn et al. 2000).

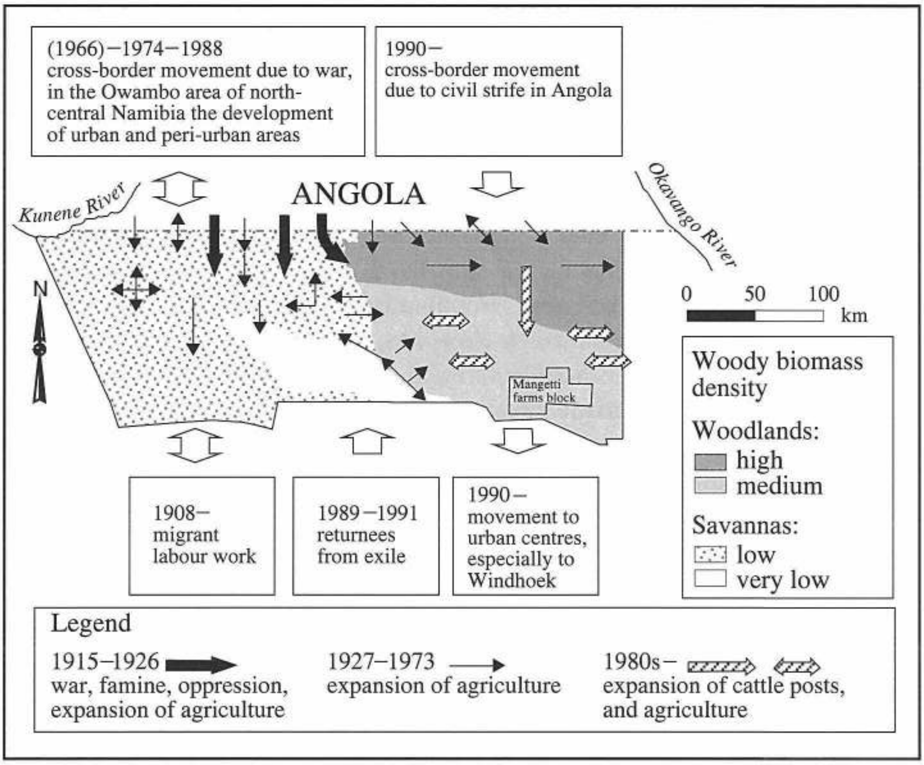


Figure 24. Major population movements in the Owambo area of north-central Namibia.

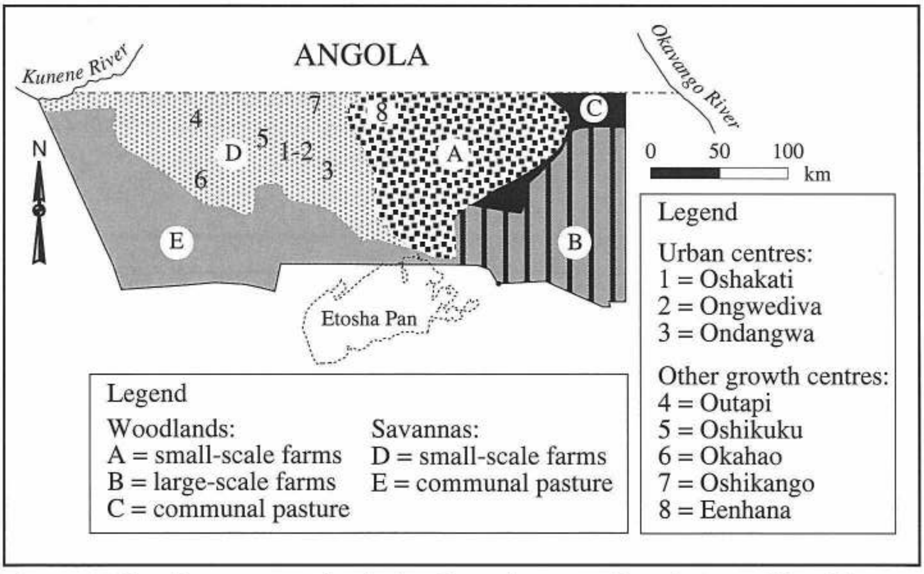


Figure 25. Land-use categories in the Owambo area of north-central Namibia. Modified from: Mendelsohn et al. (2000).

2.2.6 Change from forest to on-farm tree cover

The Owambo area of north-central Namibia is dominated by two vegetation regions defined by Giess (1971) as savannas and woodlands; the respective vegetation types in the two regions are *mopane savanna*, and *tree savanna and woodland*. Since Giess, several other descriptions have been introduced (Table 2). Savannas are characterised by grasslands in the area north of the Etosha Pan, treeless *oshanas* and scattered fruit trees in the Cuvelai delta, and low shrubland in the areas further west. Woodlands in the east are characterised by forest cover, which is fragmented by clay pans, drainage lines, cultivated fields and patches of shrubland. *Colophospermum mopane* (J.Kirk ex Benth.) J.Kirk ex J.Léonard is the characteristic woody species on savannas and *Burkea africana* Hook. on woodlands. *C. mopane* occurs either as a shrub, or a tree, usually 5–9 m in height, although it may reach 13 m (Erkkilä, pers. obs.). The species favours clay-rich soils and in western and central Owambo area forms homogenous, almost pure stands (Timberlake 1995, 1999). It is deciduous, but may retain its leaves throughout the dry season (Palgrave 1990).

Table 2. Vegetation types covering the Owambo area of north-central Namibia as proposed since 1971.

A. WOODLANDS

Year	Author	Description
1971	Giess	Tree savanna and woodland
1978	Werger and Coetzee	*Baikiaea plurijuga* vegetation
1982	Huntley	Moist/dystrophic savannas
1982	Rutherford	*Burkea africana* savanna
1983	White	Zambezian dry deciduous forest and scrub forest
1985	Loxton et al.	Mixed woodland on deep aeolian sands
1993	Scholes and Walker	Broad-leafed savanna (high-rainfall, nutrient-poor)
1994	Millington et al.	Open woodland
1992	Marsh and Seely	2 different types
2000	Mendelsohn et al.	8 different types

B. SAVANNAS

Year	Author	Description
1971	Giess	Mopane savanna
1978	Werger and Coetzee	*Colophospermum mopane* vegetation
1982	Huntley	Arid/eutrophic savannas
1983	White	Zambezian mopane woodland and scrub woodland
1985	Loxton et al.	4 different types
1993	Scholes and Walker	Fine-leafed savanna (low-rainfall, nutrient-rich)
1994	Millington et al.	Transitional wooded grassland
1992	Marsh and Seely	9 different types
2000	Mendelsohn et al.	15 different types

Until the 20th century the Owambo communities were separated by forested land (see e.g., Nitsche 1913). In 1866, the missionary Hugo Hahn travelled 15 hours through uninhabited, forested areas on his way from the territory of the Ndonga people to the territory of the Kwanyama people. Since the travelling speed with ox-wagons was 4 km per hour, the forested zone between the Ndonga in the south and the Kwanyama in the north can be estimated to have been about 60 km (Hahn 1867, p. 291). In the beginning of the 20th century the width of the forested belt between the two communities was perhaps 40 km (Siiskonen 1990), and in the 1950s about 10 km (Erkkilä and Siiskonen 1992). According to recent inventories, 4.5 % of the Omusati Region (north of the Etosha National Park) is forested, but there are no forested areas in the Oshana Region (Selanniemi et al. 2000a, 2000b). In the beginning of 2001 the National Forest Inventory (NFI) was not yet completed in the eastern parts of the Owambo area, the Ohangwena and Oshikoto regions (Chakanga, pers. comm.).

More than 60 indigenous woody species occur on the savannas of the Owambo area (Clarke 1999, Craven 1999, Selanniemi et al. 2000a, 2000b). A large proportion of woody biomass, especially in the densely populated *oshana* delta, consists of indigenous trees that produce edible fruits, such as *Adansonia digitata* L., *Berchemia discolor* (Klotzsch) Hemsl., *Diospyros mespiliformis* (Hochst. ex A.DC.), *Ficus sycomorus* L., *Hyphaene petersiana* Klotzsch and *Sclerocarya birrea* (A.Rich.) Hochst. The aboveground woody biomass is, however, rather small and scattered. Recent forest inventories indicate a mean woody biomass of 0.6 tons ha^{-1} (dbh $\geq$ 5 cm) in the Oshana Region and 2.2 tons ha^{-1} in the Omusati Region (Selanniemi et al. 2000a, 2000b), assuming a basic density of 0.7 tons m^{-3} (ERL... 1985). Basic density is defined as oven-dry weight (ton) divided by green volume (m^3).

A fenced trial in the Oniipa constituency of the Oshikoto Region gives a fairly good indication of the natural regeneration potential in degraded savannas. The trial was established in 1967 (Figure 26) next to the Oshigambo High School (17°47' S, 16°04' E) in order to study the impact of fertilisation on an overgrazed sandy site (Soini 1981). Previously the trial site had been heavily trampled by passing cattle, goats and donkeys and had no woody vegetation cover (Väisälä 1967, photo taken 1965, p. 12.). The trial was abandoned in the early 1970s, but over the years the livestock-proof fence was maintained. In 1993 (Figure 27) trees and shrubs in the fenced area, covering a rectangle of about 4.5 x 68.0 m, were enumerated by the author of the present study. The oven-dried, above-ground biomass was estimated to be 22 tons ha^{-1}, when volume equations produced by the National Forest Inventory Project (1997) were used and a basic density of 0.7 tons m^{-3} was assumed. The estimated annual increment during 26 years – the period of total protection – was 0.8 tons ha^{-1}.

The tree species in the woodlands include *Acacia erioloba* E.Meyer, *Baikiaea plurijuga* Harms, *Boscia albitrunca* (Burch.) Gilg & Benedict, *Burkea*

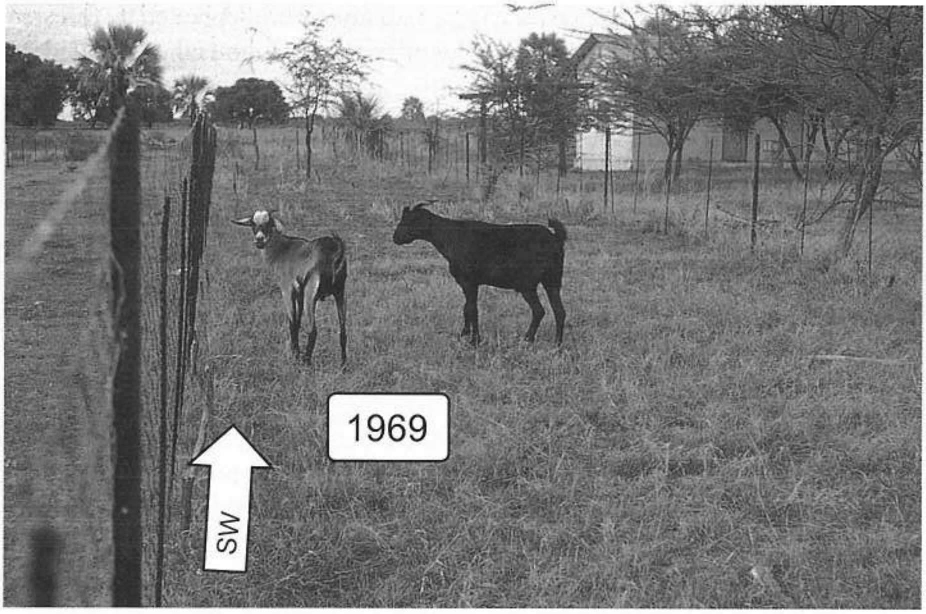


Figure 26. Newly fenced trial site in 1969 at the Oshigambo High School. The two goats were penned in temporarily and are not part of any scientific experiment. Photo: Sylvi Soini.

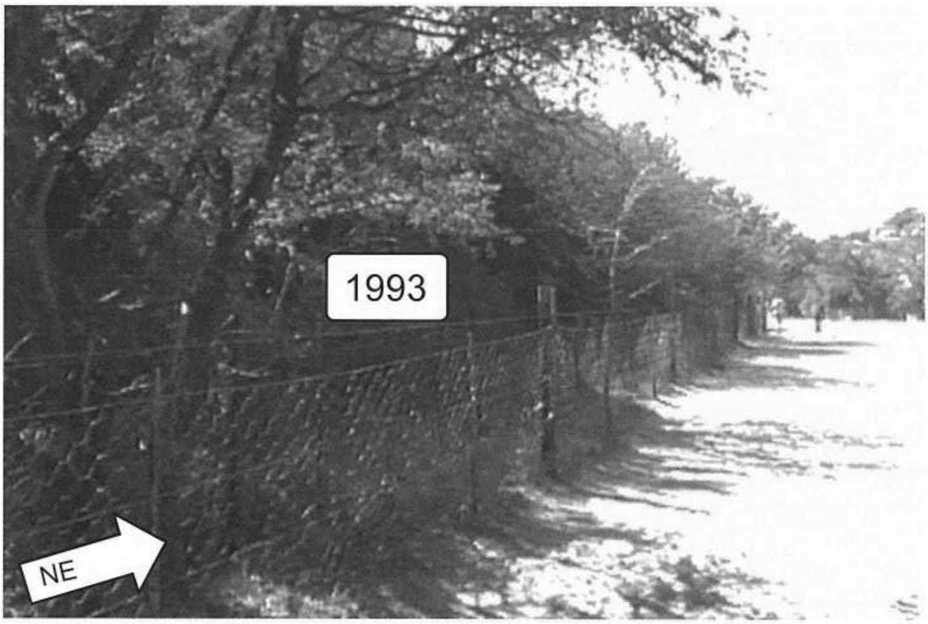


Figure 27. Fenced trial site on 3 June 1993 at the Oshigambo High School. The site is an example of natural regeneration potential in the degraded savannas. Photo: Antti Erkkilä.

africana, *Combretum* spp., *Erythrophleum africanum* (Welw. ex Benth.) Harms, *Guibourtia coleosperma* (Benth.) J.Léonard, *Lonchocarpus nelsii* (Schinz) Heering & Grimme, *Pterocarpus angolensis* DC., *Schinziophyton rautanenii* (Schinz) Radcl.-Sm., *Strychnos* spp., *Terminalia sericea* Burch. ex DC. and *Ziziphus mucronata* Willd., and the shrub species *Croton gratissimus* Burch., *Euclea* spp., *Grewia* spp. and *Ximenia* spp. The height of the dominant trees is usually 7–14 m, occasionally up to 16 m (Erkkilä, pers. obs.). The following species produce highly valued, edible fruits: *Euclea* spp., *G. coleosperma*, *Grewia* spp., *S. rautanenii*, *Strychnos* spp., *Ximenia* spp. and *Z. mucronata* (Rodin 1985).

Based on the forest inventory of 1973, in the present Eenhana constituency, assuming a basic density of 0.7 tons m^{-3}, the mean density of woody biomass can be estimated at 12 tons ha^{-1} (dbh $\geq$ 10 cm) on the northern sample plots and 26 tons ha^{-1} on the southern sample plots (Figure 28). In the areas further east, towards the Kavango Region, the density of woody biomass was even higher (Geldenhuys 1992). In the forest inventory of 1999, assessment of the Okongo Proposed Community Forest (55 918 ha) in the eastern Ohangwena Region next to the Kavango Region, indicates 30 tons ha^{-1} for living trees (dbh $\geq$ 5 cm) and 4 tons ha^{-1} for deadwood (Angombe et al. 2000c).

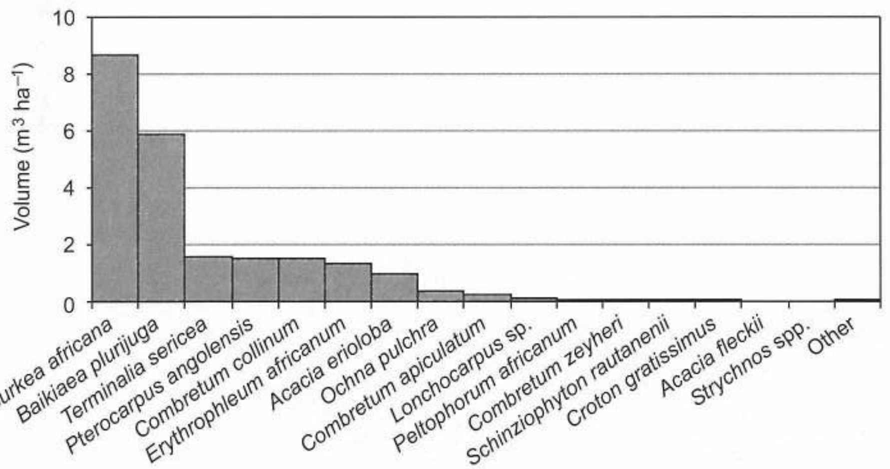


Figure 28. Mean volume of the growing stock (dbh $\geq$ 10 cm) by species in forested areas in the Eenhana constituency of the Ohangwena Region, based on the forest inventory of 1973. The data comprise 859 trees enumerated from 68 sample plots covering a total of 10.7 ha at 17 different sample points. Source of inventory data: CSIR (South Africa), see Geldenhuys (1992). Source of volume equations: National Forest Inventory Project (1997).

When a new farm is established on a wooded area, the felled trees and shrubs are utilised for construction and for fuel (Mills 1984, Flower 1999). In general, locally available wood resources and tree species are utilised, if possible. In the densely populated *oshana* delta and surrounding areas there is a shortage of wood; therefore many households acquire poles and even firewood from far away, either from the sparsely populated western and southwestern savannas or from more wooded eastern areas (Figure 29) and to a certain extent also from Angola. Transport is usually arranged by pick-up trucks (NISER 1992, Cunningham 1993).

In woodlands, the predominant method of harvesting is selection felling. In a survey conducted by the author in 1993 in western parts of the Eenhana constituency, it was estimated that 20 % of the *Colophospermum mopane* and 40 % of the *Terminalia sericea* trees remained standing after several selection fellings. The other utilised but less desired tree species included *Burkea africana*, *Baikiaea plurijuga* and *Combretum collinum* Fresen. The trees utilised were mostly small- and medium-diameter trees, whereas large trees (dbh > 15 cm) were left standing. The trees were cut by axe at various heights. The trees on the sample plots had been felled over an unknown period, and some of the stumps were coppicing. All stems with dbh ≥ 5 cm were counted. The data include 218 stumps.

Figure 29. Firewood (left) and construction poles (right) on sale along the road from Oshigambo to Eenhana. Photo: Antti Erkkilä 18.10.1996.

In their daily routines, rural households in the Owambo area of north-central Namibia are highly dependent on wood resources. It has been estimated that 96 % of the households use firewood as their main cooking fuel. Due to the prevailing climatic conditions, only a very limited amount of firewood is used for heating houses. The principal lighting fuel is paraffin oil, followed by candles and crop residues. Crop residues are also commonly used for cooking. Animal dung is used mainly for cooking, especially during the dry season and in areas where firewood supplies are scarce. The use of charcoal is practically non-existent (NISER 1992, Central Statistics Office 1993b). The mean consumption of firewood has been estimated at 1.0 kg per day per inhabitant (Klaeboe and Omwami 1997).

In the Owambo area of north-central Namibia, *Colophospermum mopane* has been used extensively for constructions on farms, and for firewood. Consequently, numerous, previously densely wooded stands of C. *mopane* have been clear-cut and converted either to 1–2 m high shrubland, or cultivated fields (Erkkilä and Siiskonen 1992). In the beginning of the 20th century, *Spirostachys africana* Sond., a medium-sized tree, provided a substantial timber resource on the savannas (Koivu 1925, Tönjes 1996). Since this species produces very hard and durable building logs, it was used extensively in early missionary houses and schools (Savola 1916, Erkkilä and Siiskonen 1993). It was also utilised among the indigenous population for poles (Koivu 1925, Bruwer 1961). Currently, in addition to *C. mopane*, the tree species commonly utilised for poles include *Terminalia prunioides* M.A.Lawson and *T. sericea* (Erkkilä, pers. obs.). Thorny branches of *Acacia erioloba*, *Combretum imberbe* Wawra and *Ziziphus mucronata* (Rodin 1985), as well as shrubs of *C. mopane* (Marsh and Seely 1992, Marsh 1994), are used for brushwood fences.

Many of the woody species occurring in the Owambo area have multiple uses (Le Roux 1971, Rodin 1985, Erkkilä and Siiskonen 1992, Marsh 1994; Hangula et al. 1998). *Colophospermum mopane* is used not only for poles and for fuel, but the straight stems of medium-sized trees are suitable for making mortars and pestles (Figure 30). Flexible saplings are used for roof frames, as well as for making granary baskets. The tough, stringy bark is commonly used in various twines needed in buildings and basket making. The leaves host larvae (mopane "worms") of the Saturniidae moth *Imbrasia belina* Westwood, which are used for food. The leaves and young twigs are important sources of browse for cattle, goats and wildlife, especially during the dry season, when very little other forage is available (Gelens 1996, 1999, Timberlake 1999). Excellent fodder species, both in times of drought and during the wet season, include *Acacia erioloba*, *Baphia massaiensis* Taub., *Bauhinia petersiana* Bolle, *Boscia albitrunca* and *Lonchocarpus nelsii* (Rodin 1985). The crushed roots of *B. albitrunca* are used for curdling milk (Erkkilä, pers. obs.).

Figure 30.Wooden pestles, made of mopane trees (*Colophospermum mopane*), are on sale at the Ondangwa market. Photo: Antti Erkkilä.

One of the most important multi-purpose species is *Hyphaene petersiana*, the only indigenous palm species occurring in north-central Namibia. It usually is solitary, but may also occur in clusters. While a full-sized palm has a branchless stem up to 13 m in height, the appearance in the early stages of growth is bushy (Erkkilä, pers. obs.). The pliable, unopened leaf of a juvenile palm is cut and broken into strips to be used for weaving all kinds of coiled baskets and trays (Figure 31). The mature female plants produce apple-sized fruits, which have an edible spongy layer. The fleshy, fibrous outer layer of the seed can be removed and fermented to make palm "wine", which may be further distilled to make an intoxicating beverage known as *olambika* (Rodin 1985, Sullivan et al. 1995). Sometimes palm wine is made from sap obtained by tapping the tree near the growing tip; in the process the tree eventually dies (Hahn 1966, Rodin 1985, Palgrave 1990). In 1915, it was reported from the Kwanyama areas that, due to the serious famine, people cut down palm trees to eat the soft core wood in the upper part of the trunk – thus almost all mature palm trees were destroyed (Urquhart 1963, Estermann 1976, Tönjes 1996). Trunks of dead trees are hollowed out and used as drinking troughs for cattle. Stems and long petioles are occasionally used to build farm fences (Erkkilä, pers. obs.). In the absence of alternative sources of fodder, small, unstemmed juvenile plants are browsed by domestic cattle, goats and donkeys, despite the fibrous texture and unpalatability of the palm leaves (Konstant et al. 1995).

Sclerocarya birrea – a large, single-stemmed, wide-spreading and branchy, deciduous tree that grows up to 15 m in height (Erkkilä, pers. obs.) – is of great importance, not only in the Owambo area of north-central Namibia (Figure 32), but also in many other parts of southern Africa (Shone 1979, Fox and Norwood Young 1982). The female tree produces fleshly fruits the size of a plum. The fruit pulp, which is rich in vitamin C, is eaten fresh, squeezed for juice or fermented into a highly appreciated alcoholic liquor called *omaongo* (Hangula et al. 1998). Each fruit has a single stone, inside which there are two or three seeds containing protein-rich oil (Palgrave 1990). The kernel and kernel oil are important ingredients in cooking. The season of ripe fruits, which is also the time when large amounts of *omaongo* are consumed, is celebrated as the "Month of Marula" (Rodin 1985), a period that may last from two to six weeks (Nitsche 1913, Loeb 1962). In former times householders were expected to bring some of the newly ripened fruits, as well as one or two pots of *omaongo* to the king (Savola 1916, Koivu 1925, Loeb 1962).

Edible fruits of indigenous woody species provide a supplement to the diet, which may be crucial during years of crop failures. Fruit trees are well recognised in the customary law (Hinz and Joas 2000). According to Kaulinge (1997), the first order of Mandume ya Ndemufayo, the Kwanyama King in 1911–1917, dealt with the utilisation of fruit trees. Mandume forbade the cutting of any fruit tree, banned the picking of unripe fruits, and ordered that ripe fruits were to be reached while standing on the ground or by climbing the tree, instead of using a throwing-club to get them down (Loeb 1962). The Kwanyama traditional authority has recently ordered that unauthorised felling of a fruit tree is an offence and liable to conviction and payment of a fine not to exceed the price of two head of cattle (Hinz 1998). During the marula festivities, nobody is allowed to carry arms and there are no traditional court sessions (Nitsche 1913, Rodin 1985). The author attended the meeting of 24 February 1996, where Elia Shipandeni, the deputy headman of Oidimba, announced the beginning of the "Month of Marula" (see The Forest... 1996).

Fruit trees also play an important role in traditional farming systems. When new lands were opened for cultivation, the bulk of the woody vegetation was removed. However, desirable fruit trees were left standing, even if they were growing in the middle of cultivated fields (Nitsche 1913, Koivu 1925, Bruwer 1961, Siiskonen 1990, Marsh 1994). Koivu (1925) emphasised that *Diospyros mespiliformis* and *Ficus sycomorus* were common in the uninhabited savannas, whereas *Berchemia discolor*, *Hyphaene petersiana* and *Sclerocarya birrea* spread only along the settlement frontier. He argued that man has intentionally promoted certain tree species and thus changed the original environment (forest) to his liking (on-farm tree cover). Therefore, according to Koivu (1925), the new landscape in the settled area is not *natural*, but rather a man-made *park*.

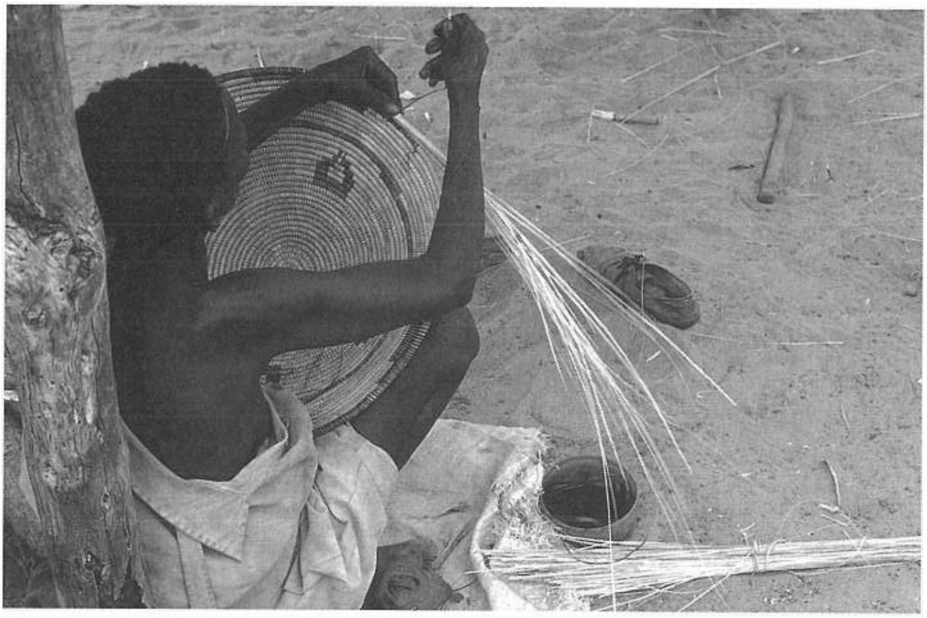


Figure 31. Basket-making using strips of palm leaves (*Hyphaene petersiana*). Photo: Antti Erkkilä 15.10.1996.

Figure 32. The large fruit tree (*Sclerocarya birrea*) near Oshikango provides a popular market site. Photo: Antti Erkkilä 12.4.1996.

3. MATERIAL AND METHODS

3.1 Study area

The Ohangwena Region lies between 15°30' E and 18°00' E (Figure 33). It is a narrow, 260 km long and 30–60 km wide strip covering an area of 10 582 km^2, which is 20 % of the Owambo area of north-central Namibia. The Ohangwena Region shares borders with Angola in the north (17°23'23.73" S), the Omusati Region in the west, the Oshana and Oshikoto regions in the south and the Kavango Region in the east. The study area, the Ondobe and Eenhana constituencies of the Ohangwena Region, is located in the transition zone, where relatively fertile savanna changes to infertile woodland, an area that remained uninhabited until the First World War. A major reason for selecting that particular study area was the availability of a unique set of aerial photographs from 1996, 1992, 1970 and 1943 (see section 3.2). The long-term interaction between man and the woody vegetation was analysed in the test area of 28 x 15 km, and in the six sample areas. The aerial photographs covering the six sample areas were examined in detail using a high-quality analytic stereo plotter, whereas in the test area the method used was less intensive (see section 3.2).

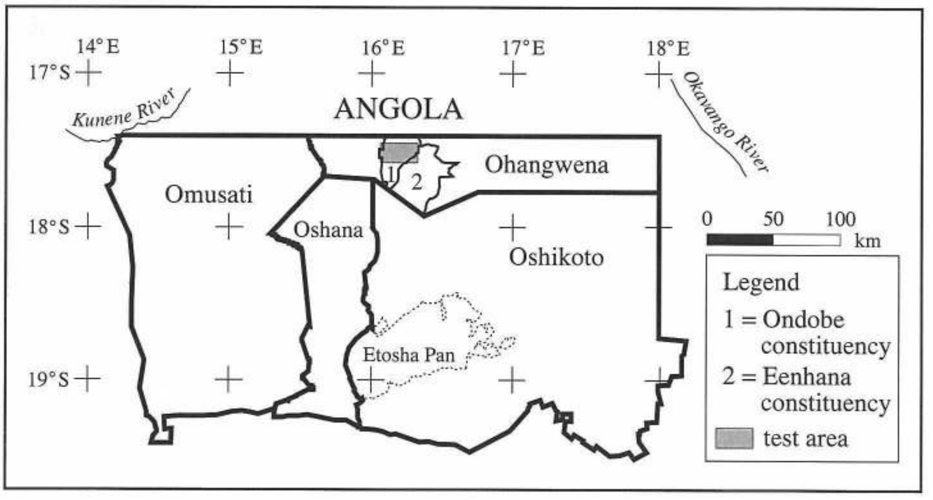


Figure 33. The Ondobe and Eenhana constituencies, and the administrative regions of north-central Namibia.

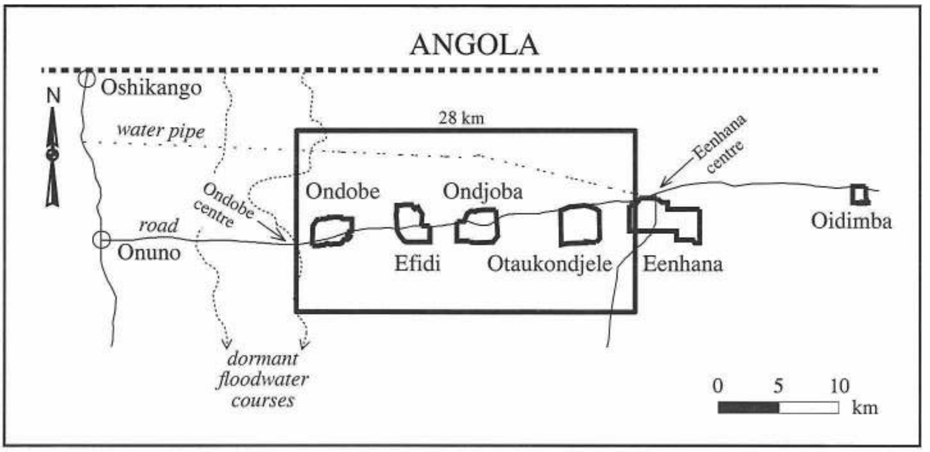


Figure 34. Test area and the six sample areas.

The test area (Figure 33) is located 5 km south of the Namibian–Angolan border between 17°26' S and 17°34' S, 16°03' E and 16°19' E. It lies east of Ondobe, a proposed settlement centre, and west of Eenhana, the regional capital of Ohangwena (Figure 34). The Omafo–Eenhana water pipe passes through the northern part of the test area. The Onuno–Ondobe–Eenhana–Okongo road traverses the test area from west to east, and the Oniipa–Oshigambo–Eenhana road a short distance in the southeastern corner. The road from west to east, to Eenhana, was pushed through around 1930 (Helenius 1944). In the early 1980s the roads were upgraded and gravelled, primarily for military purposes. The Onuno–Ondobe–Eenhana road was tarred in the late 1990s (Mendelsohn et al. 2000). The main water pipe from Omafo to Eenhana was built in the early 1980s and reconstructed in 1994–1996 (Karsten, pers. comm.). The clay pans and other water-logged, ephemerally flooded depressions are estimated to cover 3 % of the test area (see section 3.2). The topography varies from 1101 m a.s.l. in the southwest to 1118 m a.s.l. in the northeast. Fresh groundwater is found in the shallow aquifers, which are accessed by hand-dug wells and pits (Vainio-Mattila 1996).

The six sample areas (Figure 34) represent the rural farming communities of the study area; the centre of Eenhana is excluded. The sample area of Ondobe is located partly within the flood plain of *oshana* Oshigambo, a dormant drainage line, and entirely within savannas, whereas the other five sample areas are located in the vegetation region defined as woodlands. The sample area of Oidimba represents the easternmost area covered by the aerial photography of 1992. Homesteads and farms in Oidimba are located on the western side of an ephemerally flooded clay pan. The shape of the six sample areas is a result of four different stereo restitutions: the sample boundaries were determined by an intersection of geo-referenced map layers of 1996, 1992, 1970 and 1943. The six sample areas cover a total of 4618 ha.

The woody vegetation cover on agricultural fields was analysed by studying 35 agricultural field unit samples, covering a total of 225 ha, that were selected from various parts of the six sample areas. Tree and shrub species were identified during the collection of ground truth data, whereas the crown coverage and the boundaries of the samples were determined from the aerial photographs of 1996. In the terminology of the present study 'agricultural fields' consist of the area in cultivation and the "fallow" area occupied by homesteads and livestock pens.

3.2 Aerial photography

In the Ohangwena Region there have been six major projects in which aerial photography has been used for a systematic land survey. The first aerial photography, conducted in 1943, consisted of seven latitudinal flight strips starting at the Namibian–Angolan border and extending about 20 km southwards. The flight plan of the aerial photography indicates a scale of 1 : 25 000, but the aerial photographs used in the present study proved to have a photo scale of 1 : 30 000. The date of the aerial photography is unknown, but it is assumed that photos were taken during the dry season, the traditional period for aerial photography in Namibia (Pienaar, pers. comm.).

The next aerial photography, taken in July–August 1964 and having a photo scale of 1 : 75 000, was used for mapping vegetation in a forest inventory project (Geldenhuys 1992). The third aerial photography, taken in August 1970 and having a photo scale of 1 : 50 000, was used for topographic mapping. This photography covers the western part of the Ohangwena Region to 16°30' E. The overlapping flight of June 1972 covers the area eastwards, starting from 16°00' E. The following topographic mapping was carried out in 1992, using a photo scale of 1 : 30 000. This mapping project covers the western part of the Ohangwena Region to 16°30' E. During the project the aerial photos were taken twice, first in April and again in October. The reason for this repetition was a technical failure during the earlier photography, which prevented reliable stereoscopic restitution. Topographic maps were produced from the October 1992 aerial photographs in two phases: Part A comprises the northwestern part of the Ohangwena Region to 16°20' E, and Part B an extension southwards and eastwards to 16°30' E. The map database was produced by MT Survey Ltd in Finland (an enterprise that specialises in high quality cartography) by order of the Water Supply and Sanitation Project in the Ohangwena Region. In 1996 most of northern Namibia was photographed during a national mapping programme using a photo scale of 1 : 80 000. The test area and the six sample areas of the present study were photographed on 31 August 1996 using a photo scale of 1 : 30 000.

In all these projects panchromatic film was used to produce black-and-white aerial photographs. The spectral sensitivity of panchromatic film extends over the ultraviolet (UV) and visible wavelengths, but not the near-infrared (IR) portions of the spectrum (see e.g., Lillesand and Kiefer 1994). The aerial photographs from August 1996, October 1992, April 1992, August 1970 and 1943 were selected for the present study (Table 3 and Appendix 2). The reason for not using the aerial photography of 1964 was the poor visual quality of the photos. The aerial photography of April 1992 was used only to assess the frequency of changes in homestead sites visually. The source material includes panchromatic diapositives, contact prints, enlargements, scanned raster images, and a digital topographic-map database. Diapositives comprise the aerial photography of 1996, October 1992, 1970 and 1943. Enlargements 1 : 30 000 were produced from the aerial photography of 1970 and contact prints from the aerial photography of 1996, October 1992, April 1992, and 1943. Raster images were produced from the aerial photography of 1996, 1970 and 1943 by scanning diapositives using a 400-dpi resolution. Raster images were resampled using the nearest-neighbour method and an output resolution of 1 x 1 m. The nearest-neighbour method uses the intensity value of the closest pixel to assign a value to the output pixel (see e.g., Lillesand and Kiefer 1994). Digital topographic-map database comprises Part A of the above-mentioned topographic mapping project based on the aerial photography of October 1992, and includes elevation points, 2-m vertical contour lines, clay pans and locations of homesteads.

Table 3. Aerial photography used in the present study.

Year	Month	Dates	Season	Photo scale	Job/Project
1943	?	?	Dry (?)	1 : 30 000	27
1970	August	2	Dry	1 : 50 000	678
1992	April	19	Late rainy	1 : 30 000	'Engela project'
1992	October	9–10	Dry	1 : 30 000	'Engela project'
1996	August	31	Dry	1 : 30 000	'Eenhana'

The aerial photographs from October 1992, covering the six sample areas, were rectified using the same ground control points as were used in the 1992 topographic mapping project. The aerial photographs from 1996, 1970 and 1943 were oriented by transferring common points from the aerial photographs of 1992. Mapping features for the six sample areas were recorded with an analytic stereoplotter from diapositives of the aerial photography (Table 4). The result of the stereo restitution was, however, incomplete; some of the relevant line and point features were missing, there were double recordings and the data layers needed reorganisation. The database was revised by viewing the map layers and scanned raster images on the computer screen. The map features were also verified from the contact prints and enlargements of the aerial photographs using a 10x scale lens or a mirror stereoscope. Stereo restitution for the 35 agricultural field unit samples was revised and supplemented by digitising crown projections from the scanned raster images. In the process a mirror stereoscope was used to verify the crowns visually from the contact prints. Trees and shrubs were identified during the 1996 field survey.

All map layers and photo images were geo-referenced with the Namibian National Coordinate System. The data were analysed using a commercial Geographic Information Systems (GIS). The method is discussed in more detail in sections 4.1–4.5.

Table 4. Digital map layers produced for the six sample areas.

Feature	Type	Aerial photography			
		1943	1970	1992	1996
Boundary of the sample area (constant)	Polygon	x	x	x	x
Forest	Polygon	x	x		x
Non-forest 1: agricultural fields	Polygon	x	x		x
Non-forest 2: clay pans (constant)	Polygon	x	x	x	x
Non-forest 3: other open land	Polygon	x	x		x
Homestead: 'modern' houses	Polygon				x
Homestead: outer palisade	Polygon/Line	x	x	x	x
Homestead: inner stockades	Line				x
Brushwood fences	Line	x	x		x
Poles fences	Line				x
Fences in livestock pens	Line	x	x		x
Fence around the well	Line				x
Gravel road (constant)	Line			x	x
Homestead: huts, and other roofed shelters	Point				x

Non-forest farmland = agricultural fields + other open land.

3.3 Landsat satellite imagery

The Landsat programme started when the ERTS-1 (Earth Resources Technology Satellite) was launched on 23 July 1972. The spacecraft was later renamed Landsat-1, and it was followed into orbit by Landsat-2 on 22 January 1975 and Landsat-3 on 5 March 1978. The sensor used in the satellites was the Multi-Spectral Scanner (MSS). The scene size was 185 x 185 km. Spatial resolution of the MSS was 80 m with spectral coverage in four bands from visible green to near-infrared (IR) wavelengths. Only the MSS sensor on Landsat-3 had a fifth band in the thermal-IR. The opportunities for environmental monitoring were significantly improved on 16 July 1982 when Landsat-4, carrying a Thematic Mapper (TM), was launched. This instrument scanned the earth in seven spectral bands, with the scene size remaining at 185 x 185 km. The TM sensor has a spatial resolution of 30 m for visible, near-IR, and mid-IR wavelengths and 120 m for the thermal-IR band. Landsat-5 followed on 1 March 1984 with an identical sensor. The World Reference System I (WRS I) is used to identify the scene locations (orbit path/scene row) for Landsats-1, -2 and -3 and the WRS II the scene locations for Landsats-4 and -5. The theoretical repetitive coverage of Landsat-1, -2, and -3 was 18 days, which with Landsat-4 and -5 was reduced to 16 days. The availability of satellite data is, however, much less, due to the fact that clouds disturb data acquisition. In addition, many images from the earlier years have been lost because of technical problems with satellites, the data-receiving process and storage capacities. Thus, the availability of cloud-free Landsat images, especially from the 1970s, is limited (Lauer et al. 1997).

Obviously, most of the Landsat data are acquired during the dry season. The optimum period for distinguishing woody vegetation classes in the satellite data is usually the beginning of the dry season (Heist and Kooiman 1992, FAO 1996). Then the spectral signature of the tree and shrub cover and that of the non-woody undergrowth (grasses and forbs) present the highest contrast. In northern Namibia the satellite data received in May are perhaps most suitable for monitoring wood resources because at that time the woody species are still in full leaf, but the herbaceous layer is dry. Thus the possibility to confuse the herbaceous layer with trees and shrubs in the satellite data is minimised. The following images were used in the present study: Landsat TM 1996, Landsat TM 1992 and Landsat MSS 1981 (Figure 35, Table 5). The images were acquired in May within 11 calendar days.

The Landsat TM 1992 was rectified and geocoded with the nearest-neighbour method to the Namibian National Coordinate System. The Landsat TM 1996 and the Landsat MSS 1981 were rectified to match the Landsat TM 1992. All images were resampled with the nearest-neighbour method to a ground resolution of 50 x 50 m. In order to study the change in land cover in the test area, the Landsat images were classified into forest and non-forest land-cover classes. Each of the images was classified separately using all four bands of the MSS image and seven bands of the TM images. A supervised maximum-likelihood method, which is a decision rule based on the probability that a pixel belongs to a particular class, was used in the classification (see e.g., Lillesand and Kiefer 1994). The sample pixels in the training data were determined visually on the computer screen utilising both raster and vector data derived from the aerial photography of 1996, 1992 and 1970. All pixels used in the training data were selected from the areas that had remained unchanged. Since the test area covers a range from savannas to woodlands, it was decided to classify the area separately in four quadrats of 7 x 15 km. Each quadrat was classified using training data derived from a total of 500 pixels representing forested and non-forested areas. The analysis is resumed in section 4.2.1.

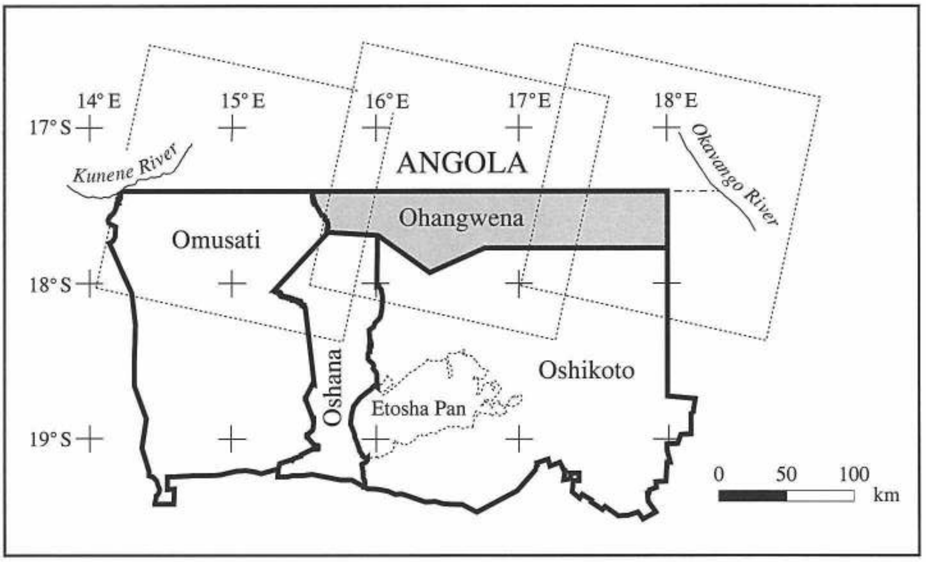


Figure 35. The Ohangwena Region and Landsat coverage. The square in the middle indicates the approximate locations for the images used in the present study.

Table 5. Landsat satellite images used in the present study.

Year	Month	Date	Season	Sensor/ satellite	Frame ID (path/row)	Sun elevation (°)	Sun azimuth (°)
1981	May	15	Early dry	MSS-2	192/72		
1992	May	10	Early dry	TM-5	179/72	39.0	48.0
1996	May	21	Early dry	TM-5	179/72	36.0	48.0

Frame ID= orbit path, scene row.

3.4 Ground truth data

A transect survey for assessing different fencing methods was conducted between 15°54' E and 16°20' E. The survey was carried out in the area along the road from Onuno via Eenhana to Oshigambo and along the water pipe from Onambutu to Omakango, covering a travelling distance of 150 km (Figure 36). The type of farm fence was recorded from a total of 483 farms.

Eight pole fences without droppers were examined along the Omakango–Onambutu water pipe, between 16°05' E and 16°12' E. A pole fence consists of upright poles and strands of wires tightened between the poles. Droppers are sticks or laths hanging in the wires, whereas the thicker bearing poles are partly buried in the ground. A pole fence without droppers consists of bearing poles

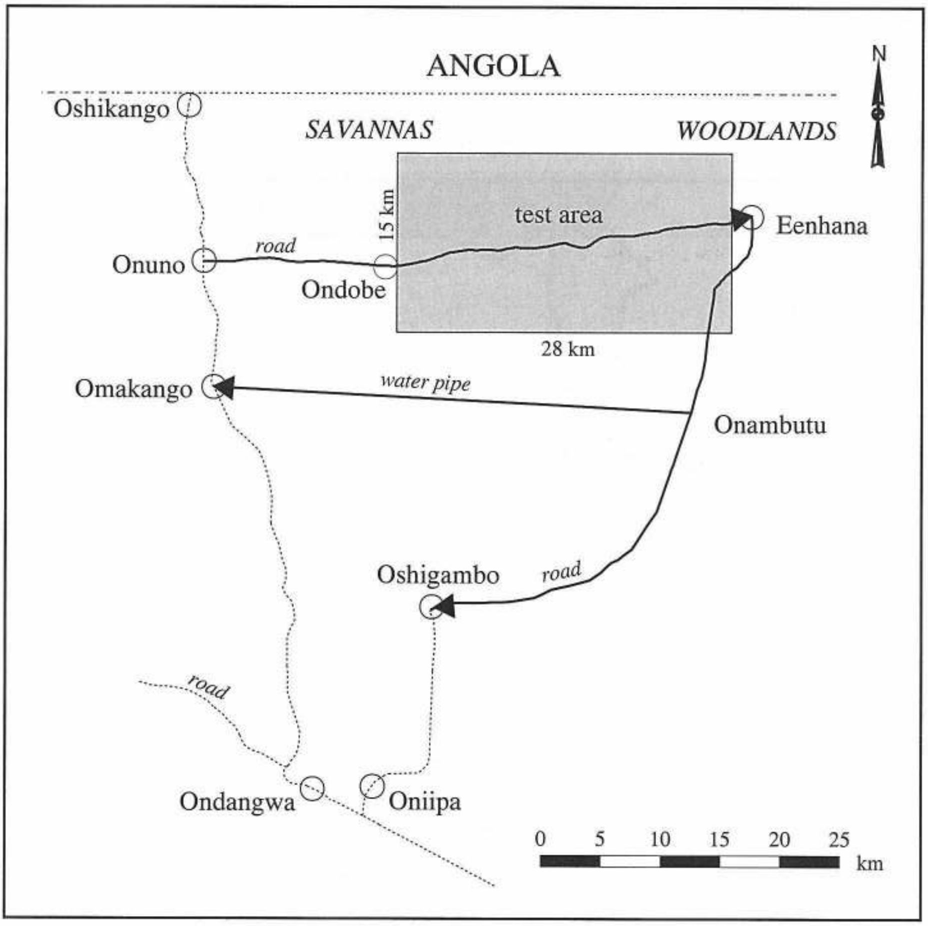


Figure 36. Survey route (lines ending with an arrowhead) in the assessment of farm fences.

only. From each pole fence without droppers a sample of 50 m was examined. The samples represent newly erected pole fences, which are built especially to demarcate farm boundaries rather than to protect crop fields. The data comprise a total of 90 poles. The species of wood in each pole was identified. The distance between poles and the aboveground height of the poles were recorded in 10 cm classes, and diameter at the middle of the pole in 1 mm classes. The underground length of the pole was estimated to be 50 cm. The pole volume was estimated as a cylinder from the mid-diameter and the total length.

Three pole fences with droppers were investigated in the sample area of Oidimba. The samples comprise a total length of 26 m, and include 130 poles and droppers. The poles were measured and their volumes estimated as in the case of pole fences without droppers. The samples represent densely stacked livestock-proof fences, which are common around crop fields, especially in the densely populated savannas.

Outer palisades and inner stockades were examined in five homesteads located in the four sample areas. The householders are Moses Nghikongelwa (Ondobe), Joseph Petrus (Ondjoba), Martha Cornelius (Eenhana), David Paulus and Elia Shipandeni (Oidimba). The samples comprise a total length of 85 m. The species of wood in each pole was identified. The aboveground height of the vertical poles and the lengths of lateral poles falling within the limits of each sample were recorded in 10 cm classes, and diameter at the middle of the pole in 1 mm classes. The underground length of the pole was estimated to be 40 cm. The pole volume was estimated as a cylinder using the mid-diameter and the total length. The data include 1281 vertical and 47 lateral poles.

The field survey on agroforestry relied on topographical map sheets with a scale of 1 : 5000, where agricultural field boundaries, farm fences, homesteads and trees were demarcated. To produce these maps, aerial photographs from 1992 were first rectified and the topographic features then digitised with an analytic stereoplotter. During the field survey the species were identified and their names were indicated next to the corresponding symbol on the topographical maps. Trees and shrubs, which were found in the field but which were not represented on the printed map sheets, were added. Field identification was related to the crown projections digitised from the aerial photographs of 1996. The data comprise 782 crown projections.

The ground truth data were gathered on 7–18 October 1996. The on-farm sites were selected according to their accessibility; no farms were entered without the householder's permission. The gathering of ground truth data was assisted by the local inhabitants. Whenever possible, farmers met during the field survey were interviewed. The inquiries were focused on trees and shrubs in the cultivated fields, land clearing, change in homestead site and durability of poles, among other issues related to the local farming systems. Recorded interviews and observations provided essential background information for the study.

4. RESULTS AND DISCUSSION

4.1 Population and housing

4.1.1 Household size

In the terminology of the present study a 'homestead' includes huts and other roofed shelters, granary baskets, outer palisade and inner stockades, but it excludes enclosures for livestock. A 'household dwelling' or *eumbo* includes those livestock pens that are attached to the outer palisade. It is assumed that each homestead is occupied by a household, and that each homestead/ household dwelling represents a farm. Estimation of household size was based on the 1991 population and housing census and on aerial photographs from 1992, the selected area comprising the northwestern part of the Ohangwena Region (Figure 37).

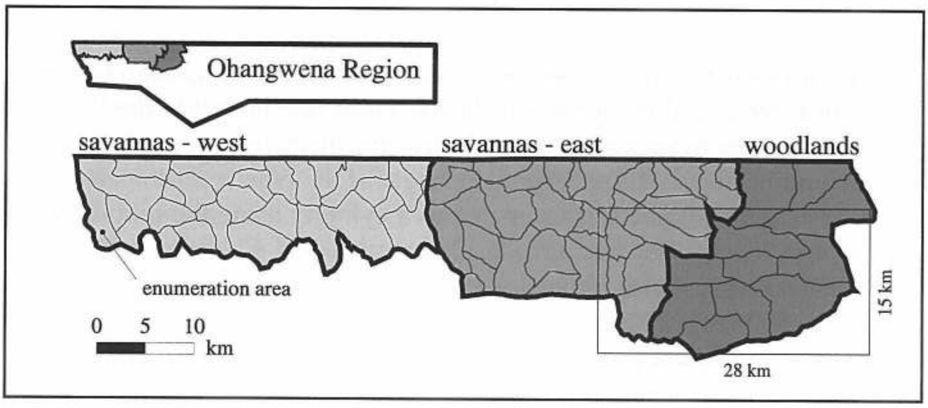


Figure 37. Selected 1991 census enumeration areas (shaded) and the test area.

The homestead data of the 1992 digital topographic-map database were revised by overlaying transparent 1 : 30 000 homestead map sheets on the aerial-photograph contact prints. The homesteads on the map sheets were compared with homesteads on contact prints by examining the locations with a 10x scale lens. The homesteads that were not represented in the map sheets, i.e. that were omitted during the stereo restitution, were added to the database and a few double recordings were corrected. Double recording was caused by the custom of moving a homestead after a few years to a new site within the agricultural field. For this reason, in the middle of the transfer process a homestead may have buildings at two sites, and therefore double registration is possible.

Household size was first estimated by dividing the human population (1991) in each enumeration area by the number of homesteads (1992). The result showed very high variation between the enumeration areas, which is an indication of the unreliability of the spatial information. This can be explained by the fact that the enumeration boundaries in the 1991 population and housing census were drawn on outdated topographic maps, based on the aerial photography of 1970 and 1972. Therefore, in the present study the geographical scope of the enumeration areas was widened. Two of the aggregated units are located in savannas, west (27 enumeration areas) and east (32 enumeration areas) of the Ondangwa–Oshikango road, and the third in woodlands (11 enumeration areas).

The mean population size per homestead in savannas was 6.7–6.8 persons and in woodlands 6.2 persons (Table 6). This result can be compared with the 1991 population and housing census, where the mean household size in north-central Namibia ranged from 5.7 persons in the Oshana Region to 6.2 persons in the Ohangwena Region. In the 1933 Owamboland census the mean household size varied from 5.0 persons on the Ngandjera land to 6.2 persons on the Kwanyama land. This indicates that in the Owambo area the mean household size has remained fairly stable over the decades. It can, therefore, be assumed that the enumeration of homesteads from the aerial photographs from 1996, 1992, 1970 and 1943 provides a fairly accurate estimate of the human population. Thus, in the present study the mean household size in the test area was estimated to be 6.2 persons.

4.1.2 Homestead density

Estimation of the homestead density in the test area was based on the aerial photographs from 1996, 1992, 1970 and 1943. The aerial photographs from 1943 and 1970 were examined using a 10x scale lens. Homesteads were located and marked with a circle on the contact prints from 1943 and on enlargements from 1970. Circles representing homesteads were then transferred to transparent templates. In order to ensure as accurate spatial registration as possible, transparent 1 : 30 000 topographic map sheets with clay pans, vertical contour lines and homesteads were used in the orientation. These map sheets were printed from the October 1992 digital topographic-map database, in which the photographs had been rectified using ground control points in order to ensure high cartographic accuracy. Finally, the homestead sites of 1943 and 1970 were digitised as point features from the transparent templates. The procedure used for the homestead map layer of 1992 is described in section 4.1.1 above. The homestead map layer of 1996 was produced by editing the map layer of 1992.

Table 6. Household size and population density in north-central Namibia.

A. 1991 POPULATION AND HOUSING CENSUS & 1992 AERIAL PHOTOGRAPHY

Selected area in the western part of the Ohangwena Region	Total population[1]	Number of homesteads[2]	Persons per homestead	Population density (inhabitants km^{-2})
savannas - west	21 838	3 220	6.8	64
savannas - east	29 454	4 395	6.7	72
woodlands	6 388	1 027	6.2	22
Total	57 680	8 642	6.8	56

Source: [1] Central Statistics Office (1994b), [2] interpretation of aerial photographs.

B. 1991 POPULATION AND HOUSING CENSUS

Region	Household population	Number of households	Persons per household	Population density (inhabitants km^{-2})
Ohangwena	175 139	28 427	6.2	17
Omusati	183 492	30 882	5.9	14
Oshikoto	123 560	21 426	5.8	5
Oshana	126 677	22 190	5.7	25
Owambo area of north-central Namibia	595 413	99 952	6.0	12

Source: Central Statistics Office (1993b, 1994a), Tötemeyer et al. (1997).

C. 1933 OWAMBOLAND CENSUS

Community	Total population	Number of households	Persons per household
Kwanyama	41 215	6 689	6.2
Mbalantu	6 349	1 023	6.2
Kolonkadhi & Eunda	2 532	422	6.0
Ndonga	34 195	5 850	5.8
Kwambi	11 405	2 039	5.6
Kwaluudhi	6 169	1 174	5.3
Ngandjera	5 996	1 189	5.0
Total	107 861	18 386	5.9

Source: Siiskonen (1996).

D. POPULATION DENSITY IN THE OWAMBO AREA OF NORTH-CENTRAL NAMIBIA

Year	1933[3]	1970[4]	1981[4]	1991[4]	2000[5]
Population density (inhabitants km^{-2})	2	6	9	12	14

Source: [3] Siiskonen (1996), [4] Central Statistics Office (1993a),
[5] Central Bureau of Statistics (Namibia).

The test area was subdivided into a 1 x 1 km grid. The cell was regarded as inhabited if it contained one or more homesteads. The mean homestead density was calculated for the whole test area and for 1-km wide longitudinal sectors.

The results show that in the whole test area the mean homestead density increased from 1.9 homesteads km^{-2} in 1943 to 5.5 homesteads km^{-2} in 1996. In 1943 the mean homestead density in longitudinal sectors ranged from 5.3 homesteads km^{-2} in the western part of the test area (savannas) to 0.3 homesteads km^{-2} in the eastern part of the test area (woodlands), and in 1996 from 11.8 (west) to 2.4 (east) homesteads km^{-2}. The proportion of inhabited area increased from 62 % in 1943 to 92 % in 1996.

4.1.3 Population density

Human population density in the test area was derived from the enumeration of homesteads, assuming a mean household size of 6.2 persons. The mean population density was estimated for the whole test area and for 1-km wide longitudinal sectors. In the whole test area the mean population density increased from 12 inhabitants km^{-2} in 1943 to 34 inhabitants km^{-2} in 1996. In 1943 the mean population density in the longitudinal sectors ranged from 33 inhabitants km^{-2} in the western part of the test area (savannas) to 2 inhabitants km^{-2} in the eastern part of the test area (woodlands), and in 1996 from 73 (west) to 15 (east) inhabitants km^{-2} (Figure 38).

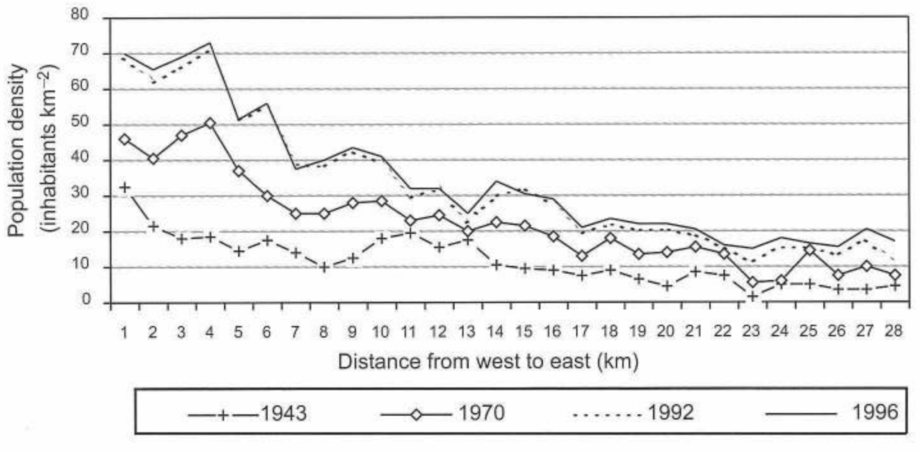


Figure 38. Mean population density in the 1-km wide longitudinal sectors in the test area. Source of data: aerial photographs from 1996, 1992, 1970 and 1943.

4.1.4 Population growth

The number of homesteads in the test area was 787 in 1943 and 2315 in 1996. The annual rate of change was calculated using the following formula:

$$p = 100 \cdot [((X_t/X_{t-n})^{1/n}) - 1]$$

where
p = annual compound rate of change,
X_t = number of homesteads at the end of the period,
X_{t-n} = number of homesteads in the beginning of the period,
n = length of the period.

During the period 1943–1970, the annual rate of change was 2.5 %. During the period 1970–1992, the annual rate of change declined to 1.7 %, and from 1992 to 1996 to 1.2 %. Assuming that a homestead represents a constant number of persons, the growth rate of population would be the rate of increase in the number of homesteads.

4.1.5 Priority in site selection

The locations of homesteads in the test area were registered from the aerial photographs from 1996, 1992, 1970 and 1943. A grey-shaded contour map was generated from the 1992 terrain profile data (Figure 39). In 1943 homesteads and cultivated fields were located close to drainage lines and other depressions (Figure 40a). The homestead density decreased from the northwestern part (savannas) towards the southeastern part of the test area (woodlands). Higher elevated sandy sites, e.g. the ridges at altitudes of 1114 m, 1109 m and 1110 m a.s.l. in the western part of the test area, were not yet occupied.

In 1970 the spatial distribution of homesteads was fairly similar to that in 1943 (Figure 40b). New farms had been established near old ones, more or less on the same altitude, although previously uninhabited areas were also occupied. The most significant land occupation had taken place in the southwest, in the Oshigambo drainage, at an altitude of 1103 m a.s.l. By 1996 even the sandy ridges at altitudes of 1114 m, 1109 m and 1110 m a.s.l. in the western part of the test area were settled and divided into small-scale farms (Figure 40c).

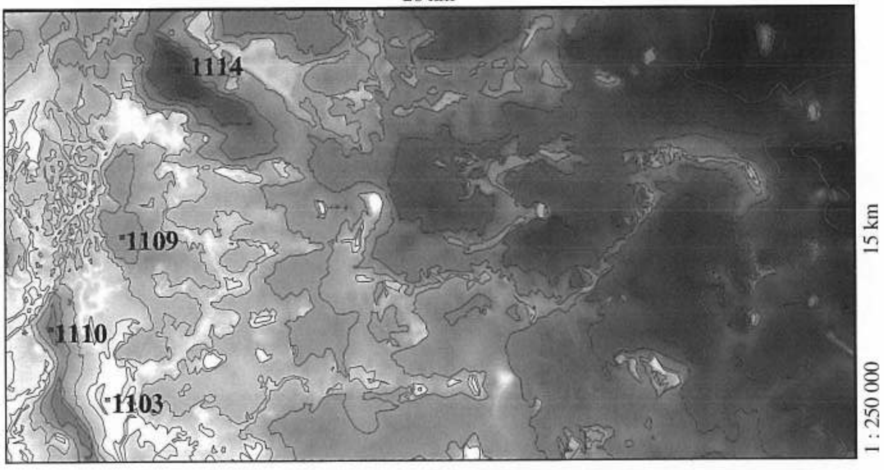


Figure 39. Grey-shaded contour map of the test area. Shading, created from a digital elevation model (DEM), indicates the elevation from 1101 m (white) to 1118 m a.s.l. (dark); vertical contour interval is 2 m.
Source of data: aerial photographs from 1992.

4.1.6 Discussion

The first estimates of the size of the Owambo population were made by early travellers and missionaries in the 1860s (Siiskonen 1990). These estimates included communities on both sides of the present Namibian–Angolan border. Official estimates of the human population in the Owambo area of north-central Namibia are available since 1921, although the reliability of these calculations is uncertain, at least until the 1960s (Siiskonen 1996). The 1991 population and housing census, complemented by the 1992 demographic and health survey (Katjiuanjo et al. 1993), provides comprehensive and reliable data on the population of Namibia and its social, demographic and economic parameters.

In the present study, estimates of population size were based on enumeration of homesteads from aerial photographs. In this method the reliability is dependent on the resolution of the aerial photography and its ability to differentiate between a homestead and its surroundings. The visual quality of the aerial photographs was lowest in 1943 and highest in 1996. The contrast was highest on the sites with light-coloured sandy soils and lowest on dark, alluvial soils. Thus, a slight underestimation is more likely in the western parts than in the eastern parts of the test area and in the earlier aerial photography. Nevertheless, counting the

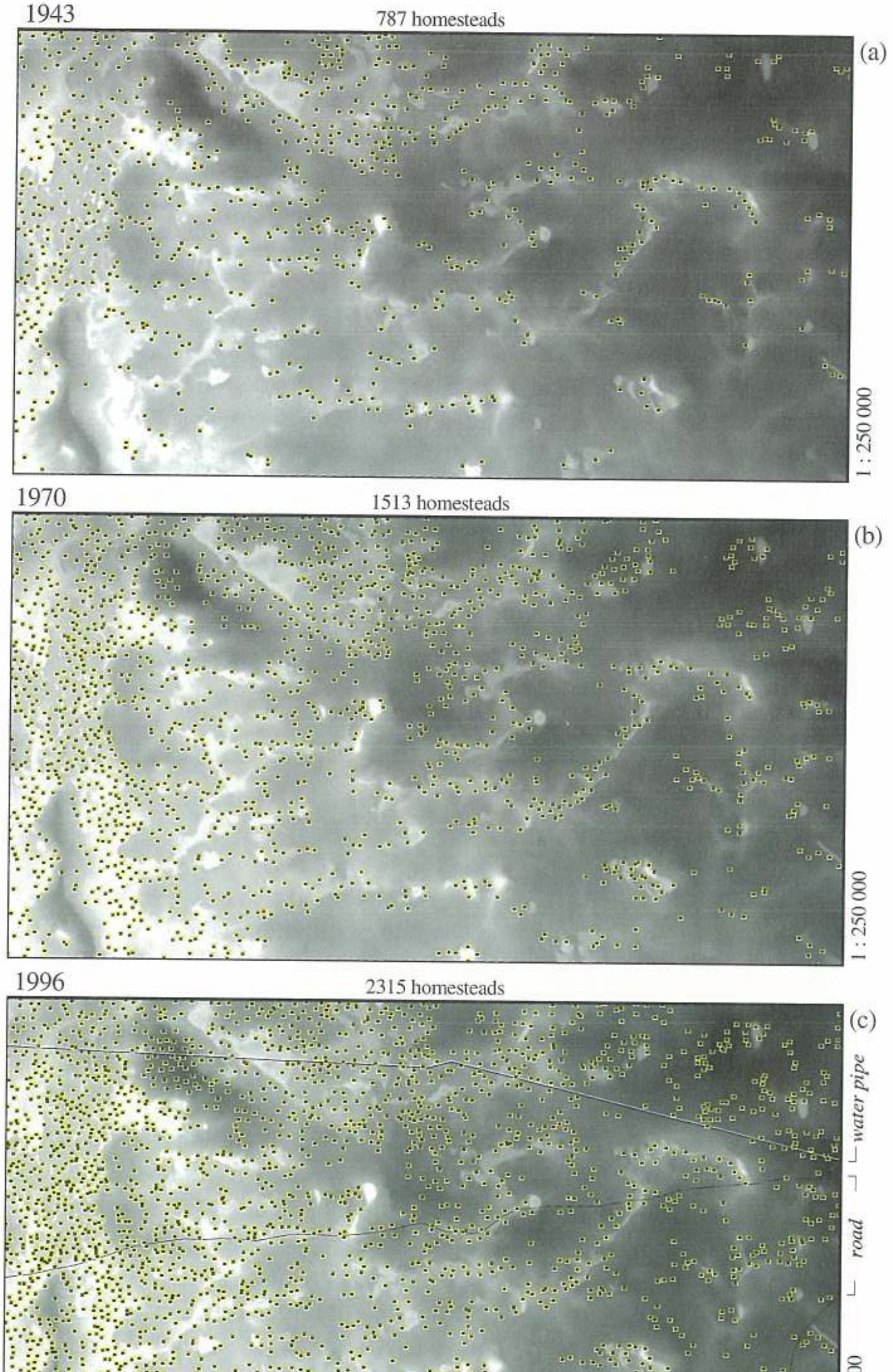


Figure 40. Location of homesteads in relation to topographic gradient in the test area. Each dot represents a homestead. Shading, created from a digital elevation model (DEM), indicates the elevation from 1101 m (white) to 1118 m a.s.l. (dark). Source of data: aerial photographs from 1943, 1970 and 1996.

homesteads on the aerial photographs from 1996, 1992, 1970 and 1943 provided high spatial accuracy. The method can be regarded as fairly reliable, not only for retrospective estimates of human populations, but also for analysing long-term changes in population density at the community level, including site selection in relation to topographic gradient.

In the test area the availability of arable land and access to potable, shallow groundwater seem to have been the most important criteria in site selection. The best sites for cultivated fields were occupied first, i.e. sites with clay-rich sandy soils on the lower part of uplands, whereas the slightly more elevated, but less fertile, sandy sites were occupied later. Until the 1970s the test area was able to accommodate a natural increase in population, probably even some in-migration. During the 1970s and 1980s the annual rate of population growth declined in the test area whereas, according to Notkola and Siiskonen (2000), the annual rate of population growth in the whole Owambo area increased over 3 %. This is probably due to numerous people moving to look for better employment prospects elsewhere in Namibia, e.g. Oshakati–Ongwediva–Ondangwa nexus region, as well as people leaving the test area and the country to go into exile.

4.2 Land cover

4.2.1 Forest

In order to assess the land cover in the test area (Figure 41), Landsat satellite images from 1996, 1992 and 1981 were classified into forest and non-forest land-cover classes using a supervised maximum-likelihood method. The detection of changes in land cover involved a procedure in which the classification data sets for the two dates of imagery were combined, and the so-called change map was produced (Figure 42). In order to assess the impact of agricultural expansion, the change maps were overlaid by the homestead data derived from the aerial photography. The percentage of forest cover was calculated for the whole test area and for 1-km wide longitudinal sectors.

Deforestation during the period 1981–1992 was most clearly distinguishable on the three sandy ridges (cf. Figure 39), while in 1992–1996 deforestation had spread west of the Eenhana centre, on both sides of the Omafo–Eenhana water pipe. Deforested areas were small and scattered, and homesteads were located in the deforested patches.

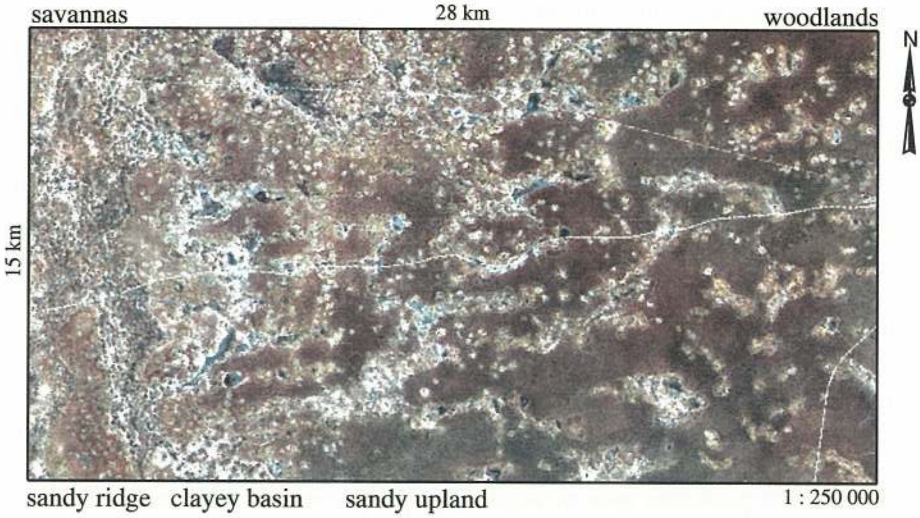


Figure 41. Landsat TM 1996 false colour composite, subscene covering the test area. © SAC, Landsat TM 1996, Novosat Ltd.

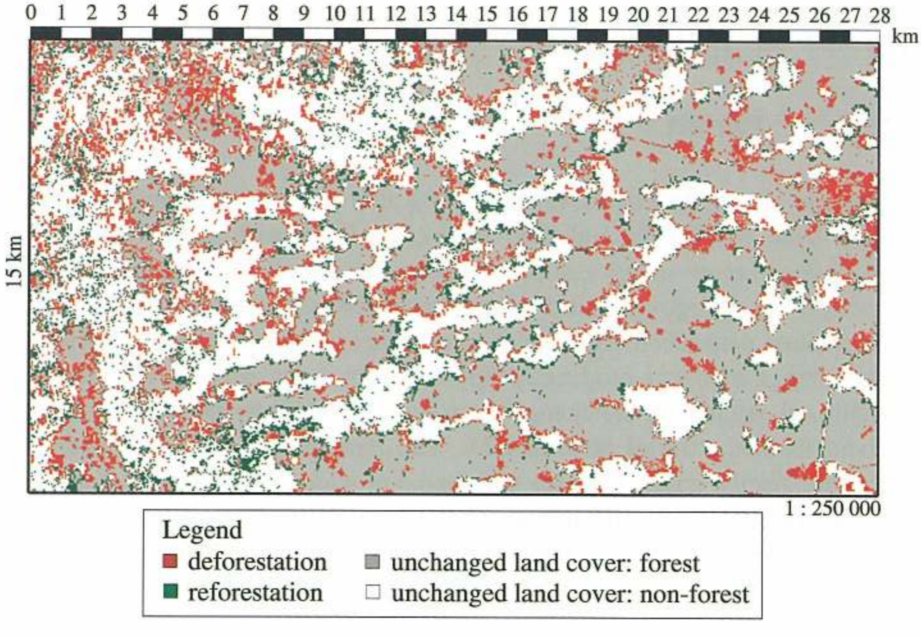


Figure 42. Forest cover change map of the test area 1981–1996. Source of data: Landsat MSS 1981 and TM 1996.

Forest cover in the test area was 23 269 ha (55 %) in 1981 and 21 491 ha (51 %) in 1996. The annual rate of change was calculated using the following formula:

$p = 100 \cdot [((X_t/X_{t-n})^{1/n}) - 1]$
where
p = annual compound rate of change,
X_t = forest cover at the end of the period,
X_{t-n} = forest cover in the beginning of the period,
n = length of the period.

The annual rate of change in forest cover was –0.2 % during the period 1981–1992 and –1.5 % during 1992–1996. In the western and eastern longitudinal sectors, the change in forest cover was fairly similar (Figure 43). In the middle sectors, changes were positive during the earlier period, which indicates net regrowth, but were negative during the more recent period, which indicates a net loss of forest cover. For the whole period 1981–1996, however, the positive and negative changes in the middle sectors cancel each other out and produce a net change of about zero.

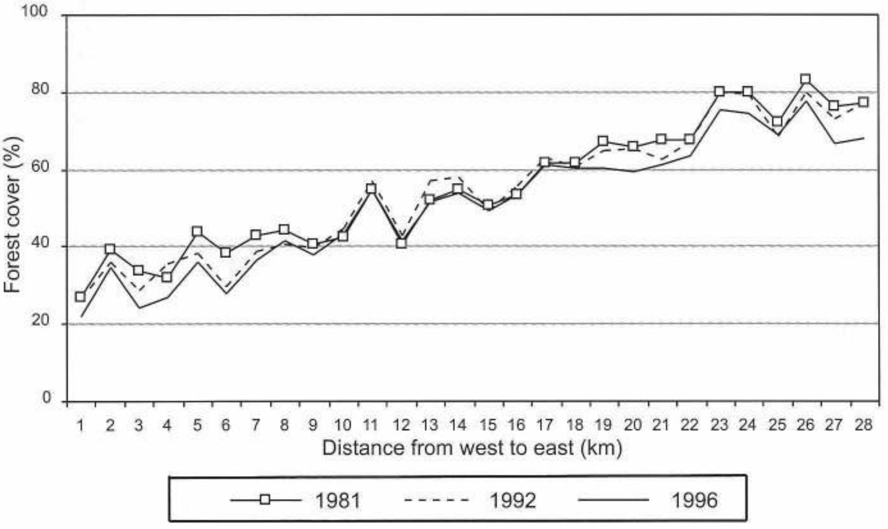


Figure 43. Percentage of forest cover in the 1-km wide longitudinal sectors in the test area. Source of data: Landsat MSS 1981, TM 1992 and TM 1996.

4.2.2 Non-forest

Non-forest land cover was studied in detail in the six sample areas by interpreting aerial photographs from 1996, 1970 and 1943. Non-forest land cover was divided into clay pans, agricultural fields (Figures 44–49) and other open land. 'Clay pans' are ephemerally flooded depressions, which are often too saline and waterlogged for woody vegetation. Thus, in the six sample areas, clay pans are unsuitable both for crop production and for household dwellings. 'Agricultural fields' consist of the area in cultivation and the "fallow" area occupied by homesteads and livestock pens. It is assumed that on a farm the homestead and livestock pens comprise 0.2 ha of the agricultural field area. 'Other open land' is typically a buffer zone surrounding agricultural fields. It is assumed that other open land has been cleared from forest land during expansion of the agricultural fields.

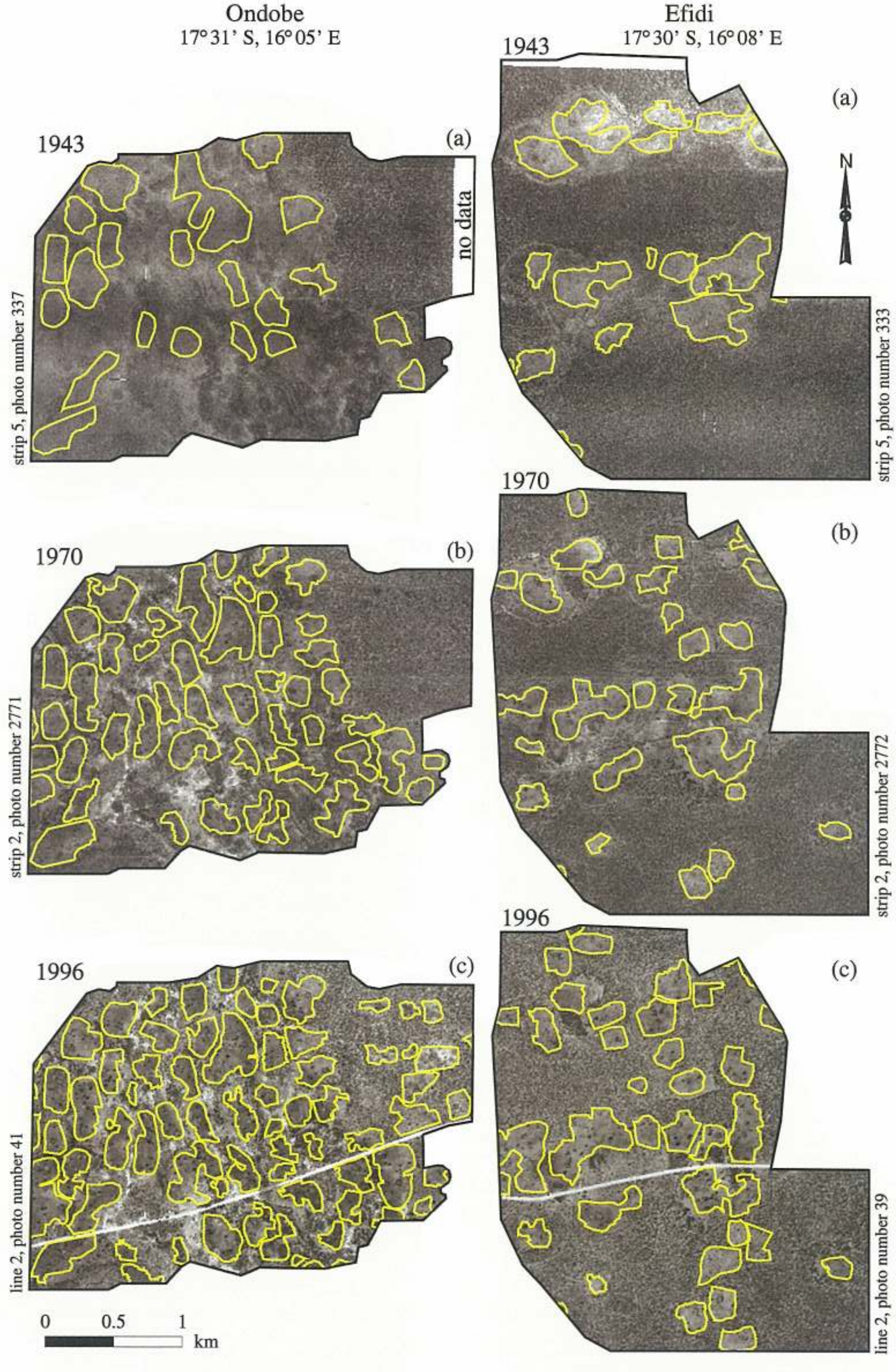
Non-forest farmland, as defined in the present study, comprises agricultural fields and other open land. Interpretation of aerial photographs shows that non-forest farmland comprised 12 ha per homestead in 1943, 8 ha in 1970 and 6 ha in 1996. Thus, non-forest farmland declined from 1.9 ha per capita in 1943 to 1.3 ha per capita in 1970, and to 1.0 ha per capita in 1996. The area of agricultural fields per homestead declined from 4.5 ha in 1943 to 3.3 ha in 1996. Field area in cultivation was 0.7 ha per capita in 1943, 0.6 ha per capita in 1970, and 0.5 ha per capita in 1996.

Permanent agriculture was practised on all six sample areas, with the exception of a site in Otaukondjele (Figure 47b) and another in Eenhana (Figure 48a).

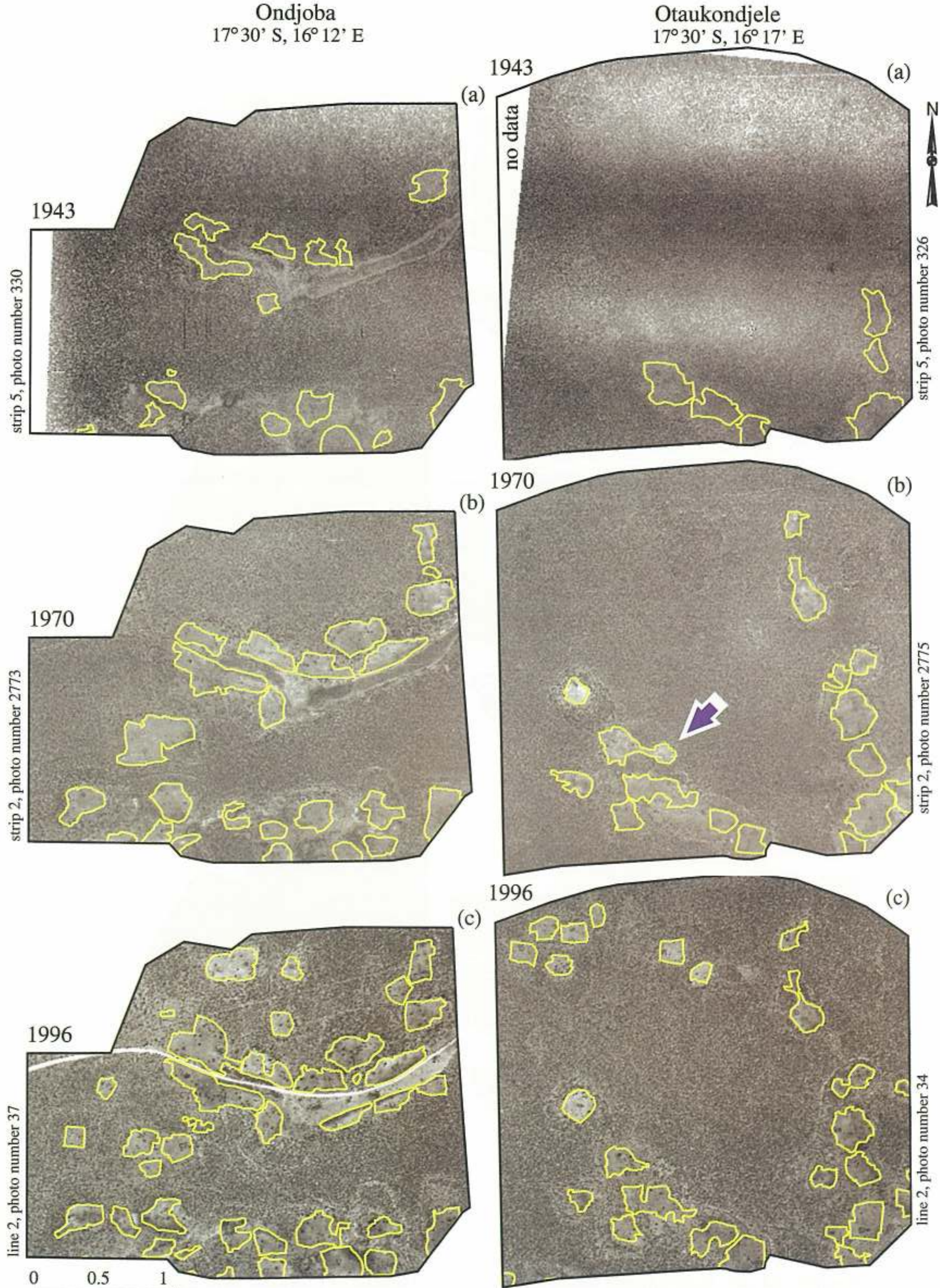
4.2.3 Discussion

Erkkilä and Löfman (1999) classified multitemporal Landsat images over an area of 37 x 42 km, which included the test area of the present study. In these classifications a high temporal fluctuation occurred in the west, probably due to the high fragmentation of forest cover. In the present study the effect of landscape variability on the spectral signature was minimised by subdividing the test area into four quadrats, which were treated separately. The possible errors in the classifications are due to misinterpretation, difficulties in image rectification, spatial misregistration and the abundance of mixed pixels.

The aerial photography used in the present study varies in terms of photo scale and visual quality. The amount of detail shown is highest in the aerial photographs from 1996 and lowest in those from 1943. Interpretation of these photographs indicates that the area of cultivated field per capita has declined slightly from 1943 to 1996. This is, however, difficult to confirm due to the lack



Figures 44–45. Agricultural fields in the sample areas of Ondobe and Efidi.
Source of data: aerial photographs from 1943, 1970 and 1996;
Office of the Surveyor-General (Namibia).


Ondjoba
17° 30' S, 16° 12' E
Otaukondjele
17° 30' S, 16° 17' E
1943
(a)
no data
N
strip 5, photo number 330
strip 5, photo number 326
1970
(b)
strip 2, photo number 2773
strip 2, photo number 2775
1996
(c)
line 2, photo number 37
line 2, photo number 34
0
0.5
1
km

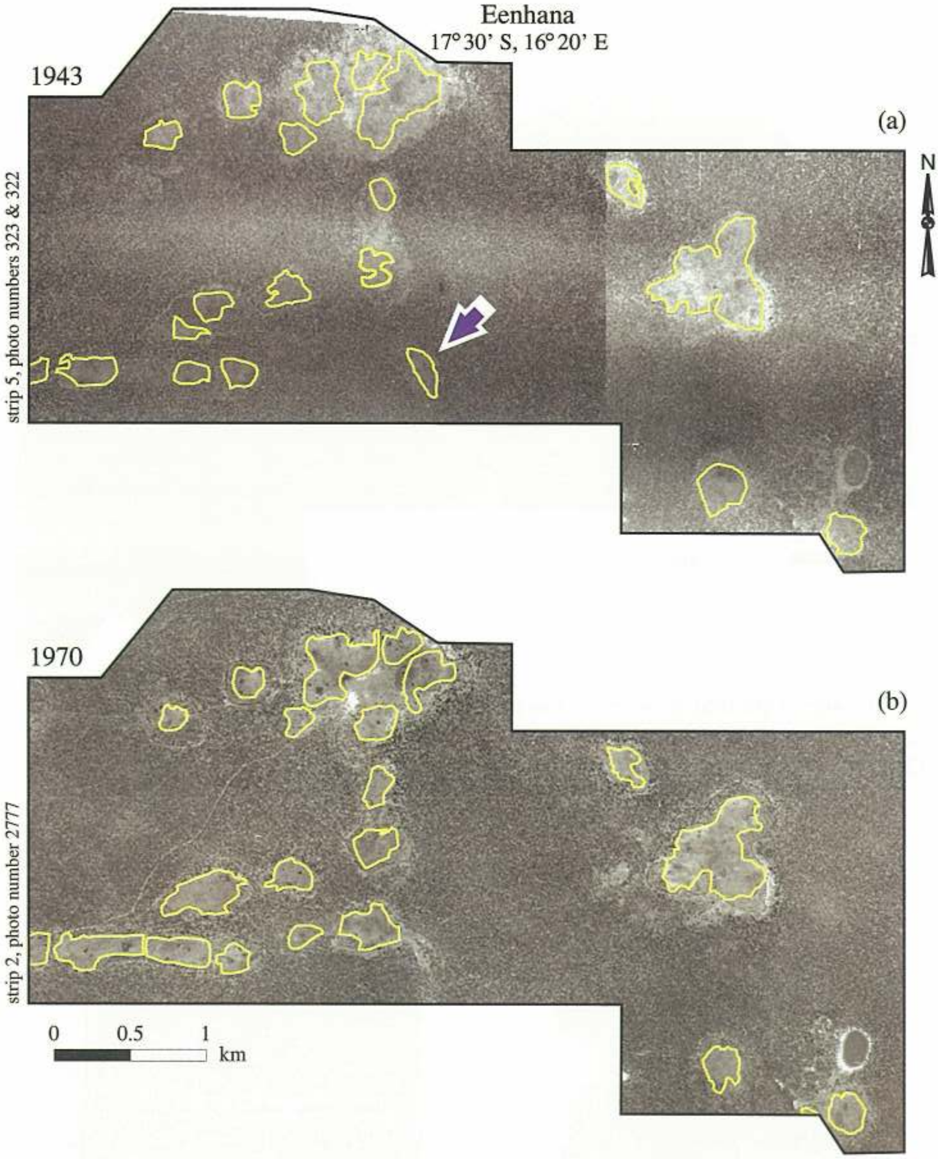


Figure 48ab (above). Agricultural fields in the sample area of Eenhana. A site cultivated in 1943 and 1996 but not in 1970 is indicated with an arrow.
Source of data: aerial photographs from 1943 and 1970;
Office of the Surveyor-General (Namibia).

Figures 46–47 (left). Agricultural fields in the sample areas of Ondjoba and Otaukondjele. A site cultivated in 1970 but not in 1996 is indicated with an arrow.
Source of data: aerial photographs from 1943, 1970 and 1996;
Office of the Surveyor-General (Namibia).

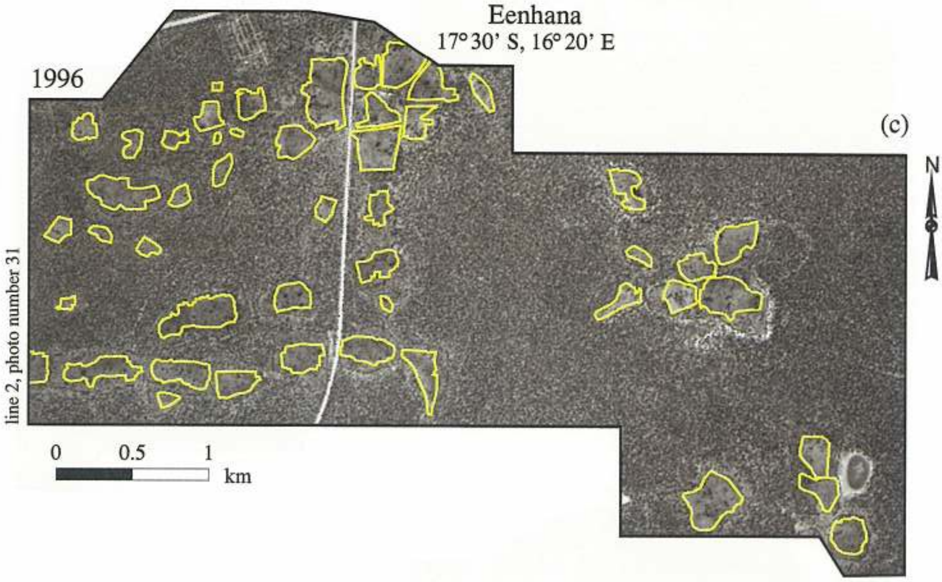


Figure 48c. Agricultural fields in the sample area of Eenhana.
Source of data: aerial photographs from 1996;
Office of the Surveyor-General (Namibia).

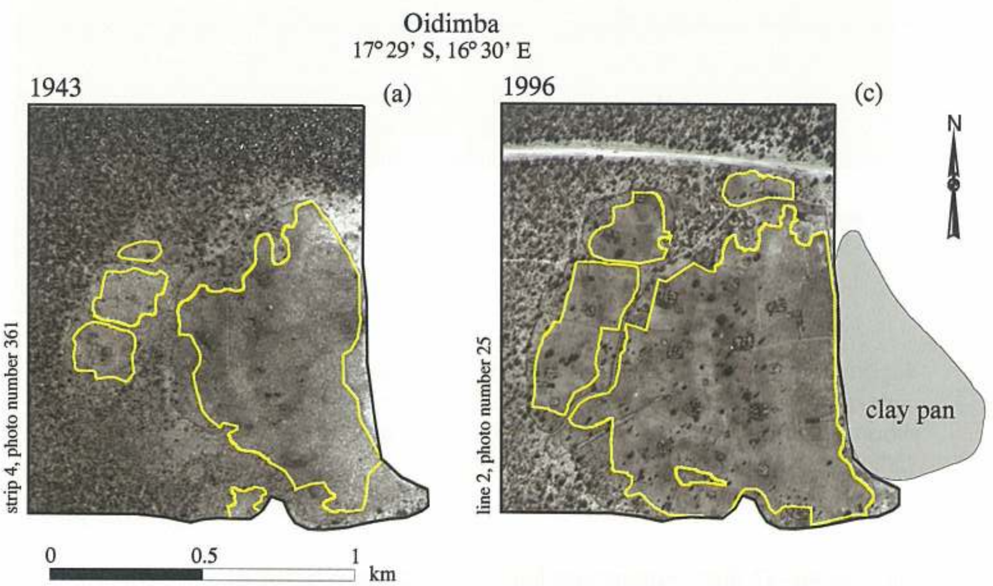


Figure 49. Agricultural fields in the sample area of Oidimba.
Source of data: aerial photographs from 1943 and 1996;
Office of the Surveyor-General (Namibia).

of synchronous population data and to the difficulty in outlining the exact boundaries of agricultural fields, since the aerial photographs used in the analysis were taken during the dry season, not during the agricultural growing-season.

Both the analysis of the satellite images and the aerial photographs show that the change in land cover from forest to non-forest has been caused almost entirely by expansion of permanent agriculture. Since the 1940s the field area in cultivation has remained at about 3 ha per household and 0.5 ha per capita. The change from forest to non-forest land cover has been about 1 ha per capita. Thus, it can be argued that growth of the population by one person has led to about 1 ha of deforestation.

4.3 Constructions on farm

4.3.1 Farm fences

The length of farm fences was studied in the test area utilising the digital topographic-map database produced from the aerial photographs of October 1992. The mean length of farm fences per homestead was calculated for 1-km wide longitudinal sectors. The results indicate that the mean length of farm fences is about 0.5 km in the western part (savannas) and 1.0 km in the eastern part (woodlands) of the test area (Figure 50).

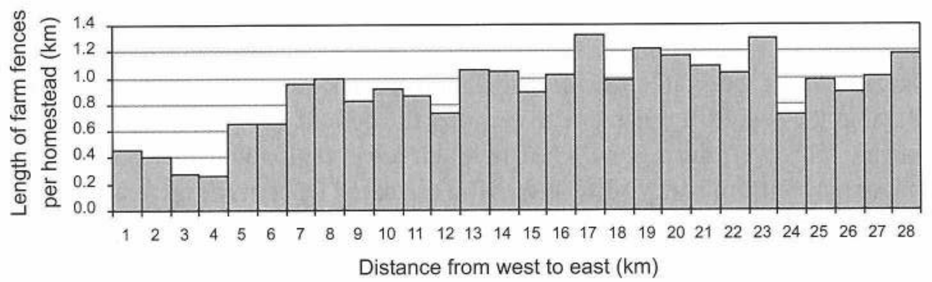


Figure 50. Mean length of farm fences per homestead in the 1-km wide longitudinal sectors in the test area.
Source of data: aerial photographs from 1992.

Farm fences were also examined in the six sample areas. The remote sensing data used in the assessment were derived from the aerial photographs from 1996, 1970 and 1943. In the sample area of Ondobe the mean length of farm fences declined from 0.8 km in 1943 to 0.3 km in 1970 and to 0.2 km in 1996, whereas in the sample areas of Efidi, Ondjoba, Otaukondjele and Eenhana the mean length of farm fences remained 1.0 km per farm. In the sample area of Oidimba the mean length of farm fences in both 1943 and 1970 was 0.5 km, but in 1996 had declined to 0.4 km. Based on interpretation of the 1996 photographs, the total length of farm fences was differentiated into brushwood (90 %) and pole fences (10 %).

During the 1996 field survey, a transect survey was conducted in the area along the Onuno–Eenhana–Oshigambo road and along the water pipe from Onambutu to Omakango. The survey covered a travelling distance of 150 km and included a total of 483 farms. It was discovered that 30 % of the farms had no fence, 32 % had a brushwood fence and 38 % had a pole fence. Unfenced farms, as well as farms using pole fences, were most common in the densely populated savannas, whereas the farms using brushwood fences were most common in the less populated woodlands. Most of the pole fences were built from untreated wooden poles of indigenous species, but there were also four fences made of steel rods, and one fence of treated *Eucalyptus* poles. One of the farms was partly fenced with a brushwood fence, partly with a pole fence. Ten farms had acquired wooden poles for fencing, but the wires between the poles were not yet connected, and one farm had just started wiring the poles. On two farms a new pole fence was under construction as a replacement for an old brushwood fence.

Eight ground truth samples of the pole fences without droppers (Figure 51a) were measured in the area along the Omakango–Onambutu water pipe between 16°05' E and 16°12' E. The samples comprised a total of 11 woody species (Table 7). The pole volume ranged from 4 to 13 $m^3 km^{-1}$ (Table 8). The mean mid-diameter of the poles was 13 cm and the mean pole length was 1.6 m. Three ground truth samples from the pole fences with droppers (Figure 51b) were investigated in the sample area of Oidimba. The results indicate that the amount of wood in a densely stacked livestock-proof fence may be up to 50 $m^3 km^{-1}$. No effort was made to measure the quantity of wood in brushwood fences. However, during the 1996 field survey it was noted that brushwood fences ranged from newly-piled and well-maintained fences to almost completely decomposed ones.

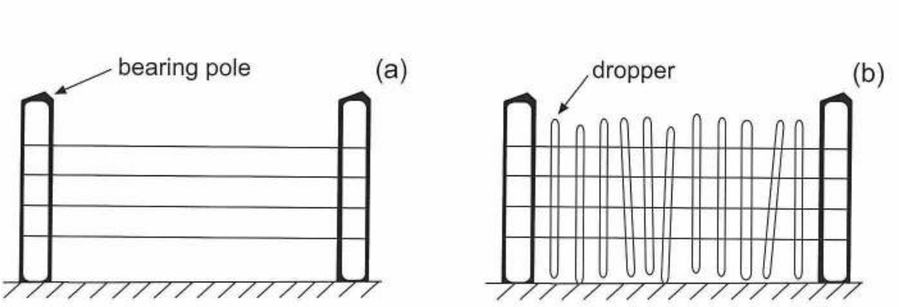


Figure 51. Pole fence without droppers (a), pole fence with droppers (b).

Table 7. Number of fencing poles by species in newly erected pole fences without droppers sampled along the Omakango–Onambutu pipeline, each sample 50 m. n=90 poles.

Distance to Omakango (km)	19	21	22	26	27	27	27	31	Total
Latitude (S)	17°37'	17°37'	17°37'	17°37'	17°37'	17°37'	17°37'	17°38'	
Longitude (E)	16°05'	16°06'	16°07'	16°09'	16°10'	16°10'	16°10'	16°12'	
Year of fencing (estimated)	1996	1996	?	?	?	1995	1996	?	
Species									
Colophospermum mopane			12		8	5			25
Burkea africana	1		1		5			6	13
Albizia anthelmintica					1	9			10
Acacia erioloba	3		1			4		1	9
Combretum imberbe		8							8
Terminalia sericea				1	2	1	4		8
Acacia hebeclada	4					1			5
Combretum collinum				4					4
Dichrostachys cinerea		2				2			4
Terminalia prunioides						1	2		3
Euclea sp.		1							1
Total	8	11	14	5	16	23	6	7	90

Source of data: 1996 field survey.

Table 8. Number of poles, distance between poles (=spacing), mid-diameter, length and volume of wood in newly erected pole fences without droppers sampled along the Omakango–Onambutu pipeline. n=90 poles.

Distance to Omakango	Location		Number of poles	Spacing		Mid diameter		Length		Volume
				min	max	mean	s	mean	s	
(km)	(S)	(E)	(poles km⁻¹)	(m)	(m)	(cm)		(m)		(m³ km⁻¹)
19	17°37'	16°05'	160	6	8	15	7	1.3	0.1	6
21	17°37'	16°06'	220	3	7	10	3	1.7	0.2	4
22	17°37'	16°07'	280	2	5	15	6	1.7	0.2	11
26	17°37'	16°09'	100	9	12	16	4	1.5	0.1	4
27	17°37'	16°10'	320	3	4	10	3	1.5	0.1	6
27	17°37'	16°10'	460	2	5	13	5	1.6	0.2	13
27	17°37'	16°10'	120	7	11	15	5	1.7	0.1	5
31	17°38'	16°12'	140	6	8	19	6	1.6	0.1	9
All sites			225	2	12	13	5	1.6	0.2	7

s=sample standard deviation.
Source of data: 1996 field survey.

4.3.2 Livestock pens

A livestock pen may be attached to a homestead, or it can be a separate entity. Often a livestock pen includes a passage fence or a drift fence leading to the enclosure. The length of the fences in livestock pens was studied in the six sample areas. The remote sensing data used in the assessment were derived from the aerial photography of 1996, 1970 and 1943. The length of fences in livestock pens – including passage fences and drift fences, but excluding any joint section attached to the outer palisade – was 70–90 m per farm. During the 1996 field survey it was found that some fences in livestock pens were made of brushwood, whereas some of the enclosures had a tightly packed wooden wall, similar to the outer palisade of the homesteads.

4.3.3 Fence around the well

Fences around shallow, hand-dug wells were examined in the six sample areas. When remote sensing data used in the assessment were derived from the 1996 aerial photographs, it was discovered that 35 % of the farms had a hand-dug well surrounded by a fence with a mean length of 60 m.

4.3.4 Homestead

The layout of the homestead owned by Elia Shipandeni, the deputy headman of Oidimba (17°29' S, 16°30' E), is presented in Figure 52. The outer palisade defines the perimeter of the homestead floor, whereas inner stockades are used to divide the area into different sections and enclosures. Palisades and stockades consist of tightly packed vertical wooden poles, occasionally strengthened by lateral beams lashed to the wall at a constant height. The outer palisade forms a continuous wooden wall, which has two narrow doorways. There are seventeen <u>thatched huts</u> and four <u>other sheds</u> enclosed by the outer palisade. Fourteen huts have a wall made of tightly packed vertical poles, and three huts have a wall built of air-dried mudblocks. One of the huts has a rectangular floor plan and the rest have a circular one. The other four sheds have a rather simple roof structure supported by a few vertical poles. Within the homestead there are six <u>granary shelters</u>, built to protect the granary baskets. Three of the granary shelters are located in the cooking area (*epata*) and the other three in a separate enclosure, near the main entrance. During the 1996 field survey, Elia Shipandeni's homestead was visited and the constructions were measured. The height of the outer palisade and inner stockades was about 2 m. The circumference of the

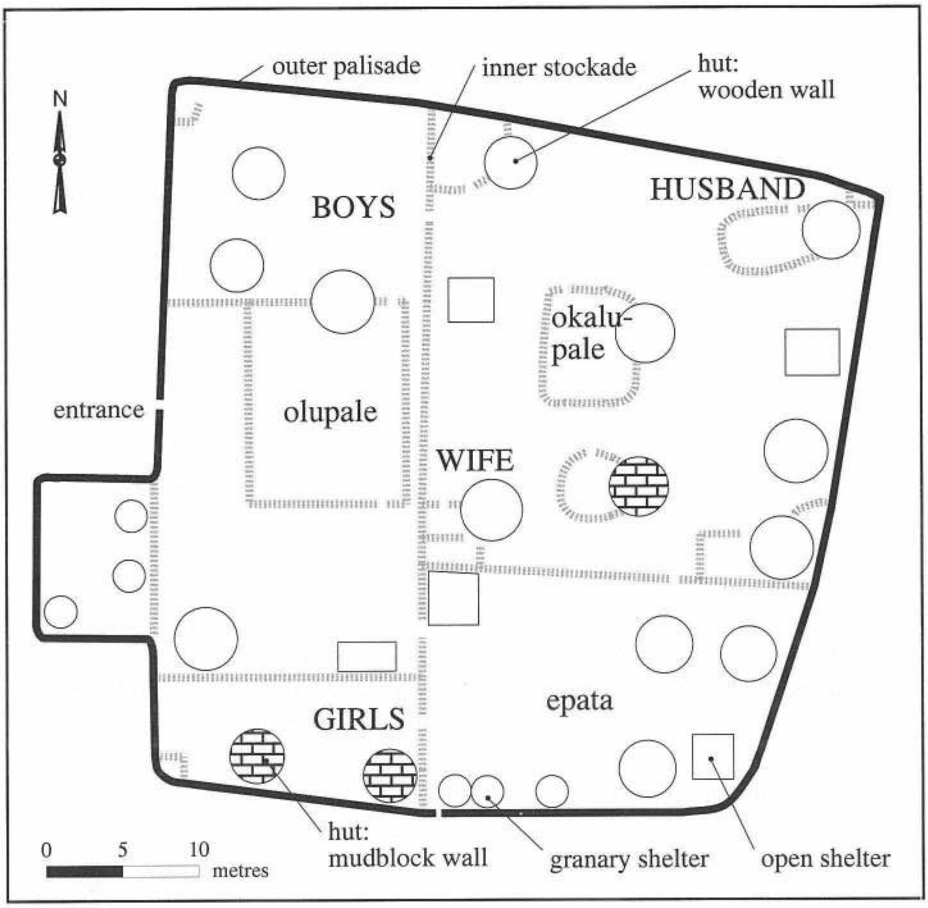


Figure 52. Layout of a homestead.
Source of data: 1996 field survey and aerial photographs from 1996.

huts varied between 11 m and 13 m, and the height of the walls between 95 cm and 170 cm. The perimeter of the homestead was 180 m.

In the six sample areas the length of the palisades was estimated by means of aerial photographs from 1996, 1992, 1970 and 1943. The length of the inner stockades and the number of huts and other roofed shelters, as well as the number of 'modern' houses, were examined only on the aerial photographs from 1996. A typical 'modern' house was a rectangular construction with corrugated iron roofing and had a basal area of about 40 m^2.

Nearly all homesteads had a perimeter wall with a continuous wooden palisade. In some homesteads an obvious reason for a large, temporary opening in the outer palisade was ongoing construction work, whereas in other homesteads the opening was blocked by a 'modern' house. The mean length of the continuous outer palisade was 130 m, the range being 50–310 m. The mean length of the outer palisade did not differ significantly in 1996, 1992, 1970 and 1943 (Figure 53 and Table 9). About one sixth of the homesteads had no inner stockades. The total length of the inner stockades in a homestead correlated positively with the length of the outer palisade (Figure 54). In the homestead enclosed by a continuous outer palisade there were, on average, 13 huts and other roofed shelters (Figure 55). The number of huts and other roofed shelters correlated positively with the length of the outer palisade (Figure 56). Homesteads with at least one 'modern' house made up 17 % of the total number of homesteads. In most cases, 'modern' houses were built among the traditional huts and were thus surrounded by the outer palisade. Homesteads with a 'modern' house were most common in the sample area of Eenhana (17°30' S, 16°20' E), which is located near the major growth centre in the Ohangwena Region.

A total of 19 ground truth samples, from both outer palisades and inner stockades, were measured in five homesteads located in the sample areas of Ondobe, Ondjoba, Eenhana and Oidimba. It was discovered that the largest poles in the homestead were usually found at the *olupale*, particularly on the western wall, just behind the householder's sitting place. At the *olupale* the mean aboveground height of poles was 2.0 m and the mean mid-diameter 9 cm, and in all other walls accordingly 1.8 m and 6 cm. The estimated volume per 100 m of wall was 20 m^3 in the walls at the *olupale* and 15 m^3 in other walls. The mid-diameter of most of the counted poles was between 2 cm and 12 cm (Figure 57). The aboveground height of the poles varied between 1 m and 3 m (Figure 58). Only a few poles were shorter than 1.0 m. *Terminalia sericea* made up 42 % and *Burkea africana* 27 % of the counted poles (Table 10). In the outer palisade both species were equally common, but in the inner stockades *B. africana* was preferred in the *olupale* and in other inner stockades *T. sericea*. Locally available tree species were used frequently in the palisades and stockades: e.g. *Colophospermum mopane* was used extensively for poles in the sample homestead of Ondobe, but not in the homesteads further east.

During the 1996 field survey, householders were able to provide some information concerning the durability of the poles. Moses Nghikongelwa was able to specify that some of the poles at the *olupale*, especially those erected behind the householder's sitting place, were more than 23 years old. Martha Cornelius recalled that in her homestead there were no poles from the first household dwelling of the 1940s, but she was confident that some of the poles were older than 16 years – at the time when her husband died. At his *okalupale* Elia Shipandeni identified a thick pole of *Baikiaea plurijuga*, which had stood behind the householder's sitting place for at least 50 years; in 1996 the aboveground height of the pole was 1.8 m, but it had originally been 1 m longer. David Paulus reported that some poles at his homestead dated back to 1962, the year when he had established his first homestead. He identified a few poles which were 0.5 m shorter than those at his first dwelling site.

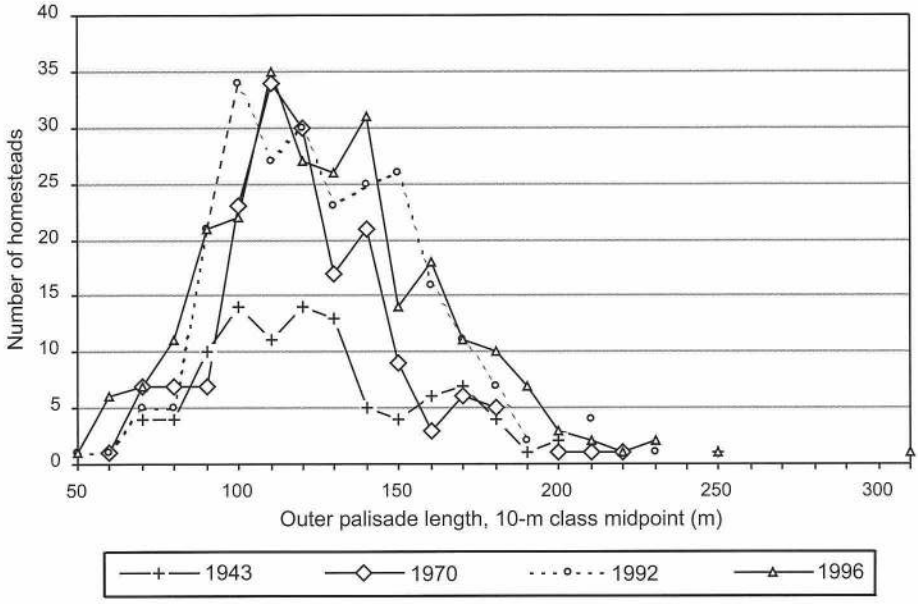


Figure 53. Length distribution of continuous outer palisade. n(1943)=100, n(1970)=173, n(1992)=239, n(1996)=257 homesteads. Source of data: aerial photographs from 1943, 1970, 1992 and 1996.

Table 9. Mean length of continuous outer palisade.

Sample area			Year of aerial photography							
			1943		1970		1992		1996	
	Latitude	Longitude	Outer palisade length (m)							
	(S)	(E)	mean	s	mean	s	mean	s	mean	s
Ondobe	17°31'	16°05'	136	30	116	29	119	27	115	29
Efidi	17°30'	16°08'	128	35	123	23	127	27	123	33
Ondjoba	17°30'	16°12'	125	27	121	19	127	29	139	41
Otaukondjele	17°30'	16°17'	147	21	110	21	114	22	117	22
Eenhana	17°30'	16°20'	107	26	142	35	139	35	142	41
Oidimba	17°29'	16°30'	138	51	111	18	147	39	149	43
All sites			126	34	121	28	127	31	128	36

s=sample standard deviation.

Source of data: aerial photographs from 1943, 1970, 1992 and 1996.

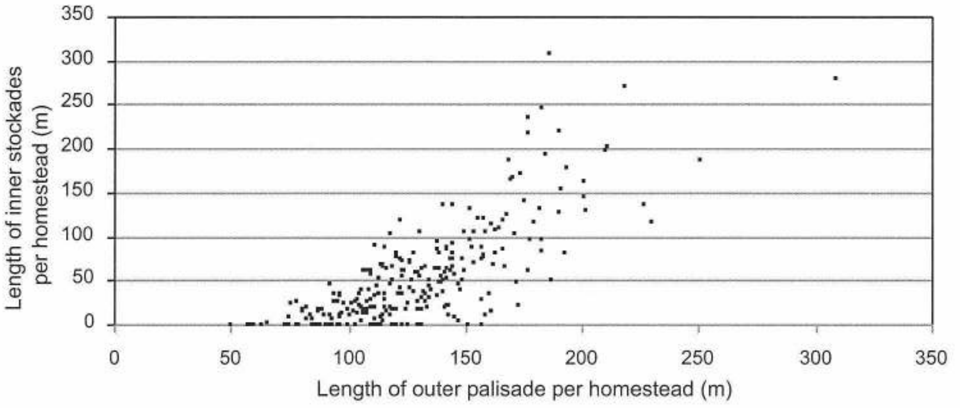


Figure 54. Relationship between the length of inner stockades and length of the continuous outer palisade. n=257 homesteads.
Source of data: aerial photographs from 1996.

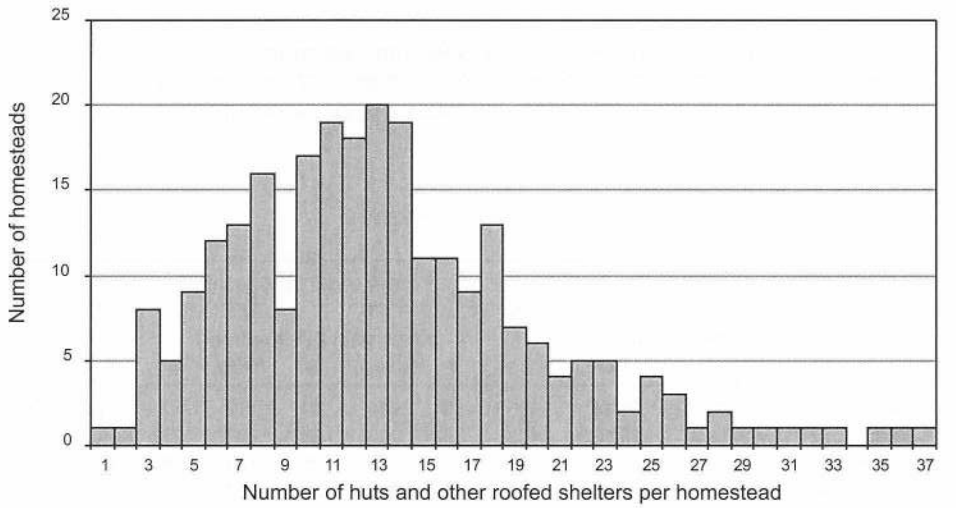


Figure 55. Distribution of homesteads by the number of huts and other roofed shelters. n=257 homesteads.
Source of data: aerial photographs from 1996.

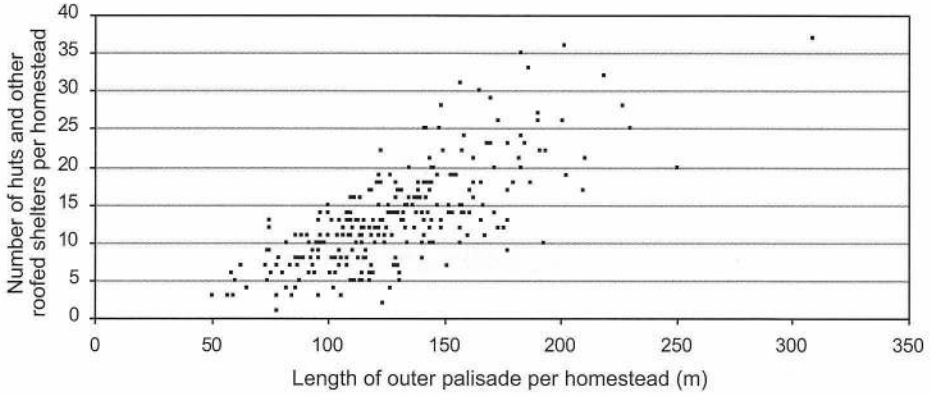


Figure 56. Relationship between the number of huts and other roofed shelters, and the length of the continuous outer palisade. n=257 homesteads.
Source of data: aerial photographs from 1996.

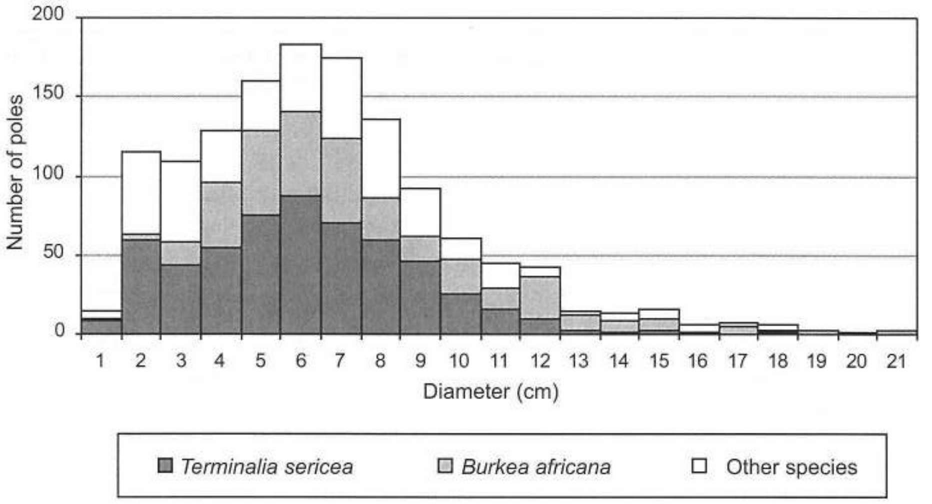


Figure 57. Diameter distribution of vertical and lateral sample poles measured in five homesteads. n(vertical)=1281 poles, n(lateral)=47 poles.
Source of data: 1996 field survey.

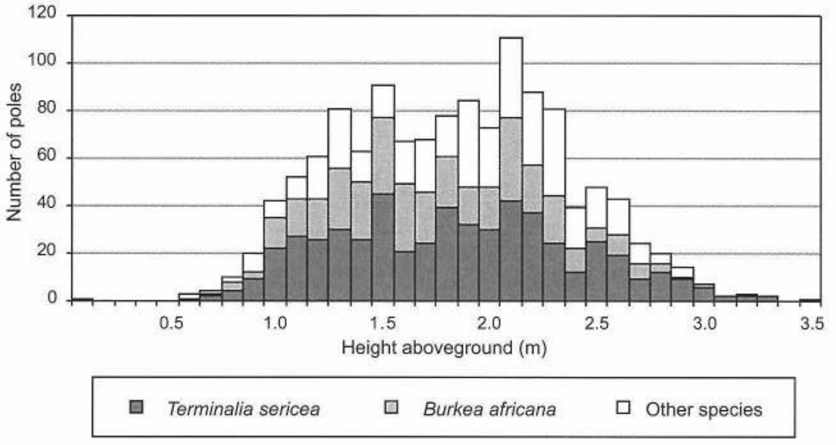


Figure 58. Height distribution of vertical sample poles measured in five homesteads. n=1281 poles. Source of data: 1996 field survey.

Table 10. Percentage of poles by species in sample poles enumerated in five homesteads. n=1328 poles.

Community	Ondobe	Onjoba	Eenhana	Oidimba	Oidimba	Total
Latitude (S)	17°31'	17°30'	17°30'	17°29'	17°29'	
Longitude (E)	16°05'	16°12'	16°20'	16°30'	16°30'	
Initials of the householder	M.N.	J.P.	M.C.	E.S.	D.P.	
Species						
Terminalia sericea	37	29	37	64	49	42
Burkea africana	9	14	57	15	10	27
Baikiaea plurijuga		39		7	20	10
Colophospermum mopane	35		0			7
Combretum collinum	5	14	4	3	12	6
Acacia erioloba				10	8	3
Erythrophleum africanum	4	2				1
Combretum hereroense	4					1
Mundulea sericea	4					1
Dichrostachys cinerea			0	1		0
Combretum zeyheri			1			0
Berchemia discolor	1					0
Combretum imberbe	1					0
Commiphora sp.	0			0		0
Croton gratissimus	0	1				0
Ochna pulchra		1				0
Peltophorum africanum			0			0
Pterocarpus angolensis		1				0
Unidentified	0					0
Total[(1)]	100	100	100	100	100	100

[(1)] Totals may not tally due to rounding.
'0' means a percentage <0.5, and an empty place means 'no poles'.
Source of data: 1996 field survey.

4.3.5 Discussion

The aerial photography used in the present study varies in photo scale and visual quality. The amount of detail shown is greatest in the aerial photographs from 1996 and lowest in the aerial photographs from 1943. The outer palisade and brushwood fences are fairly easy to distinguish from the aerial photographs. Interpretation of aerial photographs is more difficult for pole fences with strands of wires. There is a risk of underestimating the length of pole fences, especially in dark, alluvial soils. A homestead and the attached livestock pen can be differentiated fairly reliably in the aerial photographs from 1996 and 1970 because of the dark soils in the animal enclosures. With the aerial photographs from 1943 the task is more difficult. It is possible that in the present study the resolution of scanned aerial-photograph images was too coarse to distinguish all pieces of inner stockades. Thus, there might be some underestimation of the length of inner stockades in the interpretation of the 1996 photographs. 'Modern' houses were differentiated from huts and other roofed shelters on the basis of their rectilinear shape and distinct roof structure. However, it was not possible by means of the photographs to confirm whether 'modern' houses were used for residential purposes or not. Nor was it possible to sort out different types of roofed shelters.

The estimates of the volume of wood used in constructions on farms were based on the ground truth data and on interpretation of the aerial photographs. The volume of indigenous wood was about 55 m^3 per farm: 10 m^3 farm fences, 5 m^3 livestock pens, 1 m^3 fences around the well, 25 m^3 outer palisade, 10 m^3 inner stockades, 5 m^3 huts and other shelters. It is assumed that only a minimal amount of indigenous timber is used in 'modern' houses. The fellings represent an over-bark volume close to 65 m^3 per farm, equivalent to 45 tons of oven-dried wood. If the poles were replaced every 15th year, the annual fellings would be 4.3 m^3 per farm, equivalent to 3.0 tons. For an average household of 6.2 persons, the annual fellings for maintenance would thus be 0.5 tons per capita. The volume estimates of the present study are higher than those presented for the densely populated Oshakati–Ongwediva–Ondangwa nexus region (Klaeboe and Omwami 1997), but lower than estimates for the Outapi constituency of the Omusati Region, 80 km northwest of Oshakati (Hailwa 1996).

The results of the interpretation of aerial photographs indicate that in the study area the basic layout of the farm and the architecture of a household dwelling have remained fairly similar throughout the period 1943–1996. The mean length of the outer palisade was about 130 m, and the enclosed homestead floor occupied 1100 m^2. A major change in constructions on farms was the introduction of pole fences to replace traditional brushwood fences. The change from brushwood to pole fences <u>increases</u> the pressure on indigenous tree species suitable for poles and droppers. A fairly recent factor that <u>reduces</u> wood consumption has been the introduction of mudblocks in hut construction. Mudblocks in north-central Namibia are air-dried; thus no wood energy is used in their production.

4.4 Homestead site change

4.4.1 Transfer process

The Owambo farming system is characterised by frequent moving of the homestead and livestock pens. Household litter and other debris gradually fertilise the homestead floor, and therefore a change of site is a way of ensuring that cultivated fields are equally fertilised. Moreover, a site change can be motivated by the inclination to change the layout and increase the size of the homestead to meet new needs, as well as the need to replace decaying constructions, a desire to move to a clean site, a need to move away from a water-logged area, and the wish to have a forthcoming wedding in a freshly built homestead. Preferably, the location of the new dwelling in the field should not be on any of the previously used sites (Elonheimo 1967, Mills 1984). Pinehas Aindongo, a farmer in the Omusati Region, added to the explanations for change in homestead site: the trees of *Sclerocarya birrea*, which started to grow inside the homestead (The Forest... 1996). A change in the homestead site is a specific way to use land, which should not be confused with other farming systems, e.g. shifting cultivation.

The transfer process begins at the new dwelling site by digging a furrow for the outer palisade (Figures 59–60). Poles are pulled up and carried to the chosen site, where they are again erected to form an outer palisade and inner stockades. Huts and other shelters are removed from their old location and rebuilt at the new site. Deteriorated poles and ragged roof structures are replaced with new ones. The old, vacant homestead site is put back into crop production. The homestead and livestock pens are moved independently, which means that livestock pens may be transferred to a new location in the field, even if the homestead is not moved. Sometimes livestock pens are moved from one side of the homestead to the other (Erkkilä, pers. obs.).

Change in homestead site was studied in the six sample areas. The remote sensing data used in the assessment were derived from the aerial photography. The changes that occurred between 31 August 1996 and 9 October 1992 were detected by merging the two geo-referenced homestead map layers. The transfer distance was measured between the two centres defined by the outer palisade. The changes between 19 April and 9 October 1992 were detected by overlaying the transparent 1 : 30 000 topographic map sheets from 9 October 1992 on the aerial-photograph contact prints from 19 April 1992.

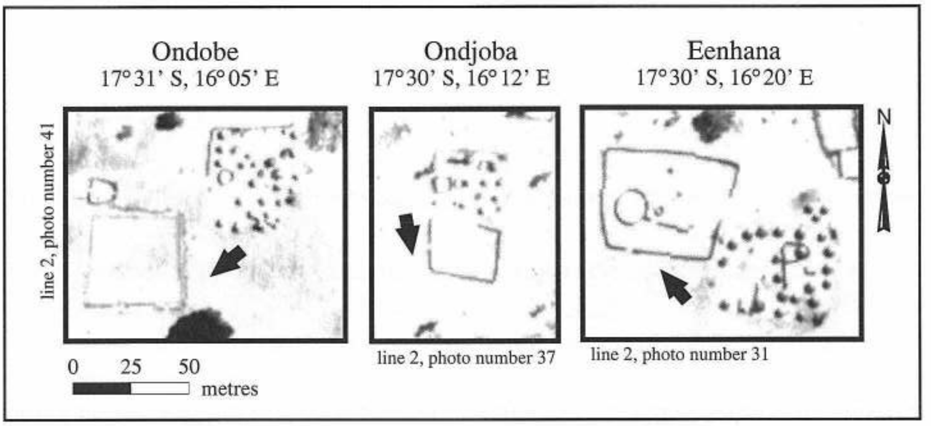


Figure 59. The process of homestead site change. The direction of transfer is indicated with an arrow.
Source of data: aerial photographs from 1996;
Office of the Surveyor-General (Namibia).

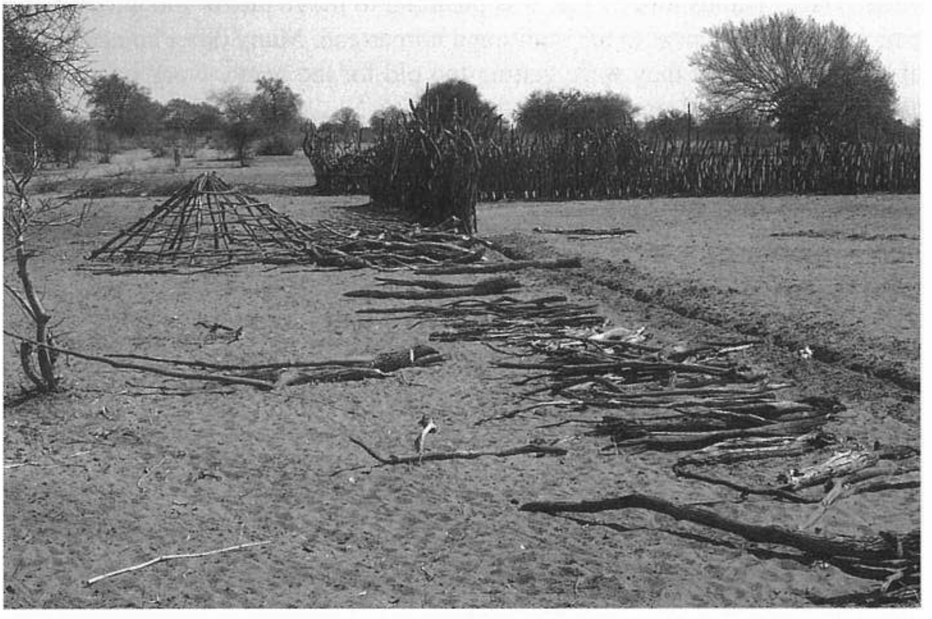


Figure 60. A homestead under construction. Photo: Antti Erkkilä 18.10.1996.

4.4.2 Transfer interval

During the period from 9 October 1992 to 31 August 1996 the frequency of change in homestead site in the six sample areas varied from 26 % (Eenhana) to 69 % (Otaukondjele). A total of 4 homesteads were transferred twice, first between 19 April and 9 October 1992 and again between 9 October 1992 and 31 August 1996 (Table 11).

Information based on oral sources confirmed that the transfer interval varies between households. Martha Cornelius stated that she had occupied the farm since the 1940s and had moved her homestead 12 times with a mean transfer interval of 4 years. Moses Nghikongelwa recalled that his homestead had been transferred 3 times between 1960 and 1973, and 4 times since 1973, when the first hut with a mudblock wall had been built – a mean transfer interval of 5 years. Elia Shipandeni stated that between 1966 and 1996 he had changed the location of his homestead 5 times – a mean transfer interval of 6 years. David Paulus, a neighbour of Elia Shipandeni and a farmer since 1962, had transferred his homestead 3 times, most recently in 1991 – a mean transfer interval of 10 years. David Paulus told that he was planning to move into a 'modern' house, which he had built next to his traditional homestead. Many other householders also mentioned that they were getting too old for the heavy work involved in changing homestead site.

4.4.3 Transfer distance

Most of the transfers in the six sample areas involved moving the entire outer palisade, but in a few cases the homestead was transferred to the other side of one of the stockaded walls, perhaps to minimise the amount of work. The transfer distance varied from 20 to 210 m, the mean being 60 m.

4.4.4 Discussion

Due to the high visual quality and the high cartographic accuracy of the aerial photographs, it was easy to detect changes in the location of homesteads. The results of aerial-photograph interpretation revealed that in the study area change in homestead site was still a common practise in the 1990s. A few homesteads were moved every second or third year, although most of the homesteads seemed to have had a transfer interval of four years or longer. It is evident that a 'modern' house attached to the traditional household dwelling reduces interest in changing the location of the homestead. Presumably this is the reason for the low percentage of transfer in the sample area of Eenhana.

Table 11. Change in homestead site.

Sample area	Ondobe	Efidi	Ondjoba	Otaukondjele	Eenhana	Oidimba	Total
Latitude (S)	17°31'	17°30'	17°30'	17°30'	17°30'	17°29'	
Longitude (E)	16°05'	16°08'	16°12'	16°17'	16°20'	16°30'	
A. CHANGE IN HOMESTEAD SITE BETWEEN 9.10.1992 AND 31.8.1996							
Number of homesteads in the same agricultural field both in 1992 and in 1996							
	81	39	38	26	43	19	246
Number of transferred homesteads							
Complete transfer	37	15	19	15	9	9	104
Transfer in process in 1992	-	-	-	-	1	-	1
Transfer in process in 1996	1	-	-	3	1	-	5
Total	38	15	19	18	11	9	110
Transfer (%)							
Total	47	38	50	69	26	47	45

Source of data: aerial photographs from 9.10.1992 & 31.8.1996.

B. CHANGE IN HOMESTEAD SITE BETWEEN 19.4.1992 AND 9.10.1992	Ondobe	Efidi	Ondjoba	Otaukondjele	Eenhana	Oidimba	Total
Number of transferred homesteads							
Total	4	4	2	3	-	-	13

Source of data: aerial photographs from 19.4.1992 & 9.10.1992.

C. CHANGE IN HOMESTEAD SITE BETWEEN 19.4.1992 AND 31.8.1996	Ondobe	Efidi	Ondjoba	Otaukondjele	Eenhana	Oidimba	Total
Number of homesteads transferred two times							
Total	1	1	-	2	-	-	4

Source of data: aerial photographs from 19.4. & 9.10.1992 & 31.8.1996.

The durability of the poles depends on factors such as tree species and the diameter of the poles, the transfer interval and soil characteristics. The underground part of the pole is most vulnerable to deterioration. If the pole is lifted and moved to another site, the lower part of the pole may crack in the process. Therefore, a change in homestead site reduces the service life of the poles used in palisades and stockades. In the maintenance of constructions on a farm, replacement of old poles with freshly cut poles is, however, an individual decision made by the householder and, therefore the service life of similar poles may vary considerably. Presumably, the short poles, together with other deteriorated poles, are used as firewood.

4.5 Trees and shrubs in agroforestry

4.5.1 Frequency and distribution of species

The 35 agricultural field unit samples were examined in order to study the role of woody species in the indigenous farming systems. During the 1996 field survey, trees and shrubs were located and identified, whereas the crown projections were digitised from the 1996 aerial photographs. The digitised data comprised 782 crown projections representing 34 indigenous and 3 introduced species. During the survey, some of the trees and shrubs were not spotted, or they were too far from the observation route to be identified. Unidentified trees and shrubs represented 14 % of the counted plants and 6 % of the total crown coverage. It can, however, be assumed that the majority of the unidentified trees and shrubs represented the same species as the identified plants.

Trees and shrubs that produce highly valued, edible fruits (see Rodin 1985) comprised 13 indigenous and 2 introduced species. This category does not include *Boscia albitrunca*, which produces edible, but not tasty, fruits (Palmer and Pitman 1972). Nevertheless, *B. albitrunca* is a highly valued, multipurpose tree used for curdling milk (roots) and for fodder (leaves, twigs and bark). Of the identified trees and shrubs, *Sclerocarya birrea* occurred with the highest frequency (27 %). Other fruit trees that occurred with high frequency were *Berchemia discolor* (14 %) and *Hyphaene petersiana* (10 %). The indigenous fruit-producing species represented 73 % and the three introduced species made up 1 % of the identified trees and shrubs. The introduced species, *Citrus* sp. and *Psidium guajava* L., produce fleshy, edible fruits, whereas *Melia azedarach* L. has probably been planted for its ornamental or shade value. The fruit of *M. azedarach* is, according to Wyk and Wyk (1998), toxic, not only for humans but also for poultry and livestock.

Hyphaene petersiana and *Sclerocarya birrea* were well represented in the six sample areas. Although *Berchemia discolor* occurred throughout the sample areas, its frequency was highest in Ondobe. *Diospyros mespiliformis* occurred almost entirely in Ondobe, and *Strychnos* spp. only in Eenhana and Oidimba. During the 1996 field survey it was discovered that in the vegetation region defined as woodlands the fruit trees of *B. discolor*, *H. petersiana* and *S. birrea* occurred only on or near agricultural fields.

4.5.2 Crown coverage

The mean stocking density of trees and shrubs was 3.5 ha^{-1}. Large trees (crown projection > 200 m^2) had a stocking density of 0.3 ha^{-1}, medium-sized trees (crown projection 100–200 m^2) 0.5 ha^{-1}, and small-sized trees and shrubs (crown projection < 100 m^2) 2.7 ha^{-1}. The fruit trees, *Berchemia discolor, Diospyros mespiliformis*, *Ficus sycomorus*, *Schinziophyton rautanenii and Sclerocarya birrea,* represented 72 % of the total crown coverage of the identified trees and shrubs. The crown coverage in the six sample areas varied from 4.4 % (Ondobe) to 1.6 % (Eenhana), the mean being 2.5 %.

The spatial distribution of the crown coverage was studied separately in two zones: near the perimeter and in the centre of the agricultural field, the threshold distance being 20 m from the field perimeter. In the 35 agricultural field unit samples, fruit trees had higher crown coverage (m^2 ha^{-1}) in the field centre, which is obviously the oldest section of the cultivated field area (Figure 61).

Figure 61. Spatial distribution of crown coverage in the 35 agricultural field unit samples. Fruit trees are highlighted in **bold**. Frequency is indicated next to the species. n=602 trees.
Source of data: 1996 field survey and aerial photographs from 1996.

4.5.3 Discussion

The results indicate that indigenous fruit trees are the most valued woody species in the Owambo farming systems. It can be argued that in the cultivated lands the traditional systems of land use have increased the number of indigenous fruit trees. Although the 35 agricultural field unit samples were covered systematically, the interpretation of aerial photographs may slightly underestimate the stocking density of small-sized trees and shrubs, especially juvenile, unstemmed palms of *Hyphaene petersina*.

During the 1996 field survey, householders indicated that some of the trees had been regenerated in the household dwelling without any specific intention, but in other cases the seeds had been sown intentionally. Martha Cornelius mentioned that the seeds of *Hyphaene petersiana* had been sown between the palisade poles in order to produce palm leaves for basket making. The same method had been used to raise the first seedlings of *Berchemia discolor*, a tree species valued for edible, fleshy fruits. Elia Shipandeni confirmed that on his homestead *B. discolor* regenerated naturally. He added that it had taken 15 years before this plant produced the first fruit. In his homestead David Paulus showed three plants: a seedling of *B. discolor*, which had germinated after 1991, the year of the last change of homestead site, and two juvenile, unstemmed palms of *H. petersiana*, which had been regenerated before 1991. Elia Shipandeni emphasised that the fruit trees of *B. discolor*, *H. petersiana* and *Sclerocarya birrea*, which are currently common in the cultivated fields of Oidimba, had been established after 1923. In that year, according to Thomas Nainguedja, the 4th headman of the ward, the first fields had been cleared and the area was settled permanently. Jeremia Hamutenya from Efidi recalled that he had cleared the fields for cultivation about 60 years ago. He had cut down several big trees, many of them *Acacia* spp. and *Burkea africana*, and then built his first homestead. At that time there were no *Ficus sycomorus* or *S. birrea* on the farm. About 10 years later, seeds of *F. sycomorus* had been brought to the farm by a visitor, and a seed had been germinated within the household dwelling. Jeremia Hamutenya emphasised that this specific plant was the first *F. sycomorus* on his farm. The tree was measured during the 1996 field survey showing a crown diameter of 25 m, a diameter at breast height (dbh) of 150 cm, and a height of 13 m.

The traditional household dwelling is a favourable environment for growing trees. The outer palisade of the homestead protects tree seedlings from browsing animals. In addition, seedlings may receive household waste water and organic fertilisers. It is evident that change in homestead site has been an important factor in creating the rural landscape of the Owambo area, which is characterised by *Berchemia–Hyphaene–Sclerocarya* trees and cultivated fields.

5. CONCLUSIONS

The objective of the present study was to analyse the change in forest cover in the Owambo area of north-central Namibia, focusing especially on the domestic use of wood in constructions on farms. The aerial photographs from 1996, 1992, 1970 and 1943, and the satellite images from 1996, 1992 and 1981, amplified by ground truth data gathered in 1996, were used to monitor and analyse the expansion of the settled area and its effects on forest cover in the Ondobe and Eenhana constituencies of the Ohangwena Region. The major results were as follows:

a) In the Owambo areas, wooded land was first cleared for cultivation in the *oshana* delta of the Cuvelai drainage basin. The primary criteria for the settlement were accessibility to potable water resources and availability of arable land. The settled area spread first within the vegetation region defined as savanna, and later expanded to the eastern woodlands. Near the Namibian–Angolan border, in the present Ohangwena Region, the settled area reached woodlands in the beginning of the First World War. Thereafter, the influx of people and livestock from the southern parts of Angola caused an additional pressure on forested land. Consequently, the settlement frontier was pushed further east, to more remote and marginal areas. The digital elevation model (DEM) combined with multitemporal aerial-photograph data indicated that in the Ondobe and Eenhana constituencies clay-rich sandy soils on the lower part of uplands were occupied first, whereas the slightly more elevated, but less fertile, sandy sites were occupied later.

b) The analyses of remote sensing data showed that the loss of forest cover in the Ondobe and Eenhana constituencies was caused almost entirely by clearing of land for agricultural and residential purposes. Land was cleared for permanent agriculture, and there was no evidence of complete field rotation by slash and burning. It was estimated that a population increase of one person led to about 1 ha of deforestation, which can be regarded as the cost of survival and human development in a harsh environment.

c) The results of the aerial-photograph interpretation indicated that the basic layout of a farm and the architecture of a household dwelling have remained fairly similar throughout the period 1943–1996. The ground truth data gathered in 1996 indicated that the preferences of householders for building material were selective, especially in terms of species and size of poles. The greatest demand was for small- and medium-diameter poles. Locally available wood resources were favoured, if possible. *Colophospermum mopane* was the most desired tree species in savannas and *Terminalia sericea*, *Burkea africana* and *Baikiaea plurijuga* in woodlands. On the basis of the ground truth data and aerial-photograph interpretation, it was estimated that the quantity of indigenous wood in constructions on a typical farm represented an over-bark removal of about 45 tons, and the annual fellings for maintenance were 0.5 tons per capita. The results support earlier observations on high consumption of wood in the densely populated central Owambo area, where a shortage of wood resources suitable for poles is inevitable. The annual consumption of indigenous wood in the whole Owambo area can be estimated at 600 000 tons, which is lower than the sustained yield (Table 12).

Table 12. Human population, aboveground woody biomass, yields and consumption of indigenous wood resources in the Owambo area of north-central Namibia.

Vegetation/ administrative region	Area surface(1) (ha)	Human population(1) (N)	Biomass density(2) (tons ha^{-1})	Total biomass (tons)	Mean Annual Increment(3) (%)	(tons)	Consumption per capita(4) (tons a^{-1})	Total consumption (tons a^{-1})
Savannas								
Oshana	529 100	190 000	1	529 100	4	21 164	0.7	133 000
Oshikoto	458 200	68 700	2	916 400	4	36 656	0.8	54 960
Omusati	1 791 400	223 900	3	5 374 200	4	214 968	0.8	179 120
Ohangwena	228 300	150 600	3	684 900	4	27 396	0.8	120 480
Sub total	3 007 000	633 200	2	7 504 600	4	300 184	0.8	487 560
Woodlands								
Oshikoto	1 352 800	53 800	10	13 528 000	2	270 560	1.2	64 560
Ohangwena	829 900	53 000	15	12 448 500	2	248 970	1.0	53 000
Sub total	2 182 700	106 800	12	25 976 500	2	519 530	1.1	117 560
Total	5 189 700	740 000	6	33 481 100	2	819 714	0.8	605 120

(1) Based on Tötemeyer et al. (1997), Mendelsohn et al. (2000), Central Bureau of Statistics (Namibia).
(2) Cf. Geldenhuys (1992), Angombe et al. (2000), Selanniemi et al. (2000a, 2000b).
(3) Cf. Rutherford (1984), ERL... (1985), Scholes and Walker (1993), Geldenhuys (1996).
(4) Cf. Erkkilä and Siiskonen (1992), Hailwa (1996), Klaeboe and Omwami (1997).

d) The aerial-photograph interpretation showed that in the Ondobe and Eenhana constituencies the location of a homestead is rotated frequently, usually every fourth or more years, from one place in an agricultural field to another. The frequent change of the homestead site has been an important factor in creating the characteristic agroforestry landscape of the Owambo area.

e) The ground truth data of 1996 together with the aerial-photograph interpretation indicated that the local farming systems have increased the number of indigenous fruit trees and spread some of the species to new habitats. The forest cover has changed towards on-farm tree cover, and the species composition in the agricultural fields has gradually changed towards trees producing edible fruits.

In the Owambo area of north-central Namibia, despite the fact that many tree and shrub species are valued for non-wood forest products, the wood supplies have been equally important in the human subsistence strategy. Due to the great demand for wood products in the densely populated savannas, the pressure on the eastern woodlands is likely to increase. Other reasons for deforestation and forest degradation are the increasing number of small- and large-scale farms, improvement of the economic situation, and the development of local road conditions. Charcoal production, if introduced to the Owambo area, would contribute considerably towards large-scale deforestation. In order to fill the domestic need for wood products, management of indigenous wood resources should be encouraged rather than investments in plantation forestry. It is evident that the existing agroforestry systems provide an excellent starting point for further enhancement and promotion of sustainable resource management, including the management of woody resources beyond the farm boundaries.

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Total of 171 references

Trees and shrubs: families, genera, species and author citations

Source: see Craven (1999), Leistner (2000).
* = introduced species.

Anacardiaceae
Sclerocarya birrea (A.Rich.) Hochst.

Arecaceae (Palmae)
Hyphaene petersiana Klotzsch

Bombacaeae
Adansonia digitata L.

Burseraceae
Commiphora Jacq.

Capparaceae
Boscia albitrunca (Burch.) Gilg & Benedict

Combretaceae
Combretum Loefl.
Combretum apiculatum Sond.
Combretum collinum Fresen.
Combretum hereroense Schinz
Combretum imberbe Wawra
Combretum zeyheri Sond.
Terminalia prunioides M.A.Lawson
Terminalia sericea Burch. ex DC.

Ebenaceae
Euclea Murray
Diospyros mespiliformis Hochst. ex A.DC.

Euphorbiaceae
Croton gratissimus Burch.
Schinziophyton rautanenii (Schinz) Radcl.-Sm.
Spirostachys africana Sond.

Fabaceae (Leguminosae)
Subfamily: Mimosoideae
Acacia erioloba E.Meyer
Acacia fleckii Schinz
Acacia hebeclada DC.
Albizia anthelmintica (A.Rich.) Brongn.
Dichrostachys cinerea (L.) Wight & Arn.

Subfamily: Caesalpinioideae
Baikiaea plurijuga Harms
Bauhinia petersiana Bolle
Burkea africana Hook.
Colophospermum mopane (J.Kirk ex Benth.) J.Kirk ex J.Léonard
Erythrophleum africanum (Welw. ex Benth.) Harms
Guibourtia coleosperma (Benth.) J.Léonard
Peltophorum africanum Sond.

Subfamily: Papilionoideae
Baphia massaiensis Taub.
Lonchocarpus nelsii (Schinz) Heering & Grimme
Mundulea sericea (Willd.) A.Chev.
Pterocarpus angolensis DC.

Meliaceae
**Melia azedarach* L.

Moraceae
Ficus sycomorus L.

Myrtaceae
**Eucalyptus* L'Hér.
**Psidium guajava* L.

Ochnaceae
Ochna pulchra Hook.

Olacaceae
Ximenia americana L.
Ximenia caffra Sond.

Rhamnaceae
Berchemia discolor (Klotzsch) Hemsl.
Ziziphus mucronata Willd.

Rutaceae
**Citrus* L.

Strychnaceae
Strychnos cocculoides Baker
Strychnos pungens Soler.

Tiliaceae
Grewia L.

Aerial photography: specifications, list of photo numbers

Aerial photography 1943/ job number 27, scale 1 : 30 000 [according to flight plan 1 : 25 000], camera number F.8 Eagle 7, focal length 7", strip 2: photo numbers 9–27, strip 3: photo numbers 158–143, 141, strip 4: photo numbers 175–193 and 360–361, strip 5: photo numbers 337–321, strip 6: photo numbers 236–235, 232, 225–211, strip 7: photo numbers 252–269, Surveyor-General, Surveys and Land Information, Mowbray, South Africa/ Office of the Surveyor-General, Windhoek, Namibia.

Aerial photography 02-08-1970/ job number 678, scale 1 : 50 000, camera/lens Wild RC 9 No. 376 SAg No. 23, focal length 88.33 mm, film type panchromatic, film base polyester, strip 1: photo numbers 2707–2700, strip 2: photo numbers 2770–2777 and 2780–2781, strip 3: photo numbers 2795–2787, Surveyor-General, Surveys and Land Information, Mowbray, South Africa/ Office of the Surveyor-General, Windhoek, Namibia.

Aerial photography 19-04-1992/ 'Engela Project', scale 1 : 30 000, camera Zeiss RMK A 23 / 15, lens 21171, focal length 152.54 mm, strip 3: photo numbers 170–184 and 188–189, Aircraft Operating Company (Pty) Ltd, Johannesburg, South Africa/ MT-Survey Ltd, Järvenpää, Finland/ Office of the Surveyor-General, Windhoek, Namibia.

Aerial photography 09/10-10-1992/ 'Engela Project', scale 1 : 30 000, focal length 152.71 mm, strip 1B: photo numbers 1057–1090 date 9.10.1992, strip 2: photo numbers 1145–1112 date 9.10.1992, strip 3: photo numbers 1153–1184 and 1188–1189 date 9.10.1992, strip 4: photo numbers 3102–3095 and 2022–2019 date 10.10.1992, strip 5: photo numbers 3051–3062 date 10.10.1992, Aircraft Operating Company (Pty) Ltd, Johannesburg, South Africa/ MT-Survey Ltd, Järvenpää, Finland/ Office of the Surveyor-General, Windhoek, Namibia.

Aerial photography 31-08-1996/ 'Eenhana', scale 1 : 30 000, flight height appr. 4500 m, forelap 60%, sidelap 25%, camera Zeiss RMKTOP 15, S.NR. 144127, lenses Pleogon A3, S.NR. 144145, film type Agfa Pan 50, EM.NR. 67001251, line 1: photo numbers 3–13, line 2: photo numbers 42–30 and 26–25, line 3: photo numbers 47–57, line 4: photo numbers 87–77, Kirchner & Wolf Consult Gmbh, Hildesheim, Germany/ Kampsax Geoplan, Hvidovre, Denmark/ Office of the Surveyor-General, Windhoek, Namibia.

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