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CONSERVATION PLAN FOR GENETIC RESOURCES OF

Zambezi teak (*Baikiaea plurijuga*) in Zambia

DANIDA FOREST SEED CENTRE

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Danida Forest Seed Centre (DFSC) is a Danish non-profit institute which has been working with development and transfer of know-how in management of tree genetic resources since 1969. The development objective of DFSC is to contribute to improve the benefits of growing trees for the well-being of people in developing countries. DFSC's programme is financed by Danish International Development Assistance (Danida).

Preface

Over the past decades awareness has been steadily increasing as to the importance of conservation of ecosystems, species and variation within-species. A number of activities have been initiated furthering conservation and sustainable use of genetic resources. Practical experiences, however, have been insufficiently documented, and lessons learned from them have been inadequately analysed and rarely applied on a larger scale.

In 1996/97 FAO, Danida Forest Seed Centre (DFSC) and national institutions responsible for *in situ* gene conservation stands of forest tree species in different countries agreed to make a common overall evaluation of a number of *in situ* conservation areas established in the respective countries. The objective of this programme was to provide practical advice and to assist countries in the planning and implementation of conservation of genetic resources of forest tree species.

It was decided to develop conservation plans for four tropical tree species, focusing on *in situ* conservation. *Baikiaea plurijuga* (Zambezi teak) is one of the four 'case studies', the others being *Tectona grandis* (teak), *Pinus merkusii* and *Acacia senegal*. The practical experience gained from the four case studies should contribute to the formulation of general guidelines for conservation of forest genetic resources of target species.

Baikiaea plurijuga was chosen as a model species because of available experience from earlier *in situ* conservation efforts for the species. The species is of commercial importance and it is threatened throughout its range. As early as 1977 *B. plurijuga* was listed by the FAO Panel of Experts on Forest Gene Resources as being in need of attention. Recently, it was listed as a priority species for conservation by the Forestry Department of Zambia and one of the top priority species identified by South Africa Development Committee (SADC).

The proposed conservation plan for Zambezi teak in Zambia was prepared as a collaborative effort between Research Division, Forestry Department, Lusaka, Zambia (FD), the Forest Resources Division of FAO and DFSC.

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Acronyms

Danida	Danish International Development Assistance
DFSC	Danida Forest Seed Centre, Humlebæk, Denmark
FAO	Food and Agriculture Organization of the United Nations, Rome, Italy
FD	Forestry Department, Lusaka, Zambia
FSC	Forest Stewardship Council
SADC	South Africa Development Committee

Abstract

This publication documents the conservation status of Zambezi teak (*Baikiaea plurijuga)* in Zambia and proposes a conservation plan for the species based on the concept of genecological zonation. Zambezi teak produces one of the world's finest timbers and is one of the most important high value timber species in Zambia. Due to logging, clearing of land for agriculture and frequent fires Zambezi teak forests are threatened throughout most of their range. In order to conserve the genetic resource of the species a sufficient number of populations must be protected. The aim of this study is to identify a number of populations from different parts of the distribution area in Zambia to be protected and managed in order to conserve the genetic variation within the species.

The method of genecological zonation is considered to be a simple, fast and a relatively cheap tool in determining conservation measures for a particular species. It may be based on already available information, even if it is often limited. This paper provides an overview of the various steps in planning conservation of the genetic resources of Zambesi teak using genecological zonation. First, the present conservation status of Zambezi teak in Zambia is reviewed. Then, the genetic variation of the species is inferred from available information on its distribution over different climates and soils. A number of genecological zones are outlined based on the inferred genetic variation. Finally, a number of populations are suggested as gene conservation stands. All genecological zones are represented in the network of conservation stands in order to maintain the genetic variation of the species to the best possible extent. A number of different conservation measures and their implementation are also discussed.

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1. INTRODUCTION

The aim of this study is to document the conservation status of *Baikiaea plurijuga* in Zambia, to present a conservation plan, and identify suitable conservation measures. The identification of stands for conservation is based on surveying the genetic variation and the concept of genecological zonation as described by Graudal *et al*. (1997). Genecological zonation is considered to be simple, relatively cheap and a useful tool in deciding on required conservation measures for a particular species even though only incomplete data is available. This paper provides an overview of the various steps in planning and implementing measures for conserving the genetic resources of *B. plurijuga* in Zambia.

The note is intended for managers, administrators, planners and researchers, but may furthermore serve as inspiration to others engaged in the conservation of forest tree species.

2. BACKGROUND

Zambezi teak or *Baikiaea plurijuga* (Harms) of the family *Leguminosae* is a deciduous tree growing up to 20 meters in height. Zambezi teak forest is found on the well-drained Kalahari sands of south-western Zambia and neighbouring parts of Angola, Botswana, Namibia and Zimbabwe (Figure 1). Here Zambezi teak is a dominant species in the dry deciduous forest. The best remaining stands of this unique forest type in Zambia are found in Sesheke District though the western and southern districts contain large relict patches, mostly consisting of Kalahari or *Baikiaea* woodland, a degraded form of *Baikiaea* forest (Piearce 1986b).

Figure 1. Distribution of Zambezi teak in Southern Africa (from Huckabay 1986).

B. plurijuga produces one of the world's finest commercial timbers, also called mukusi. Mukusi was traditionally of limited use, mainly for canoes and building poles. The limited interest in mukusi was presumably due to the difficulty of working this very hard wood (Martin 1941). With the coming of the railway and its demand of sleepers, and the increase in use of mukusi for parquet flooring and furniture, this tree became of major importance for the timber industry. Today Zambezi teak is one of the most important high value timber species in western and southern Zambia.

In most cases the commercial exploitation of Mukusi timber has led to a number of changes in the ecology of the forests. Logging has opened the forest canopy, which has increased the amount of light reaching the forest floor. Light has favoured the growth of grass and shrubs, which are more susceptible to fire than the original vegetation. The fire risk has been further increased by the presence of debris left after logging. The occurrence of more intense fires combined with increased competition from grass and shrubs has severely hampered regeneration of *Baikiaea* forests after logging (Wood 1986).

Natural regeneration has proven to be too inadequate to match the rate of exploitation taking place. In many of the logged areas on the west bank of the Zambezi river, the *Baikiaea* forest shows little regeneration some 20-40 years after logging (Wood 1986). In several areas a dense understorey of thicket shrubs (mutemwa), which greatly suppress or completely prevent the regeneration of *B. plurijuga*, has become increasingly predominant.

In addition to the effects of commercial logging, there has been considerable loss of *Baikiaea* forests in Zambia due to clearing for agriculture. With a growing commercialisation of the rural economy, sources of cash are sought by the growing rural population and as a result the demand for land suitable for cultivation of marketable crops, especially maize, has increased (Wood 1986).

Due to the factors described above, *Baikiaea* forests in Zambia are under pressure throughout most of the range. Logging followed by increased frequency of severe fires and conversion of forest to farmland has degraded and considerably diminished the forests in the past 100 years. These forests are expected to disappear over the next 50 years (WCMC 1991).

In 1977 *B. plurijuga* was listed by the FAO Panel of Experts on Forest Gene Resources as being in urgent need of attention (FAO 1977). In the mid-1970's FAO/UNEP assisted the Forestry Department of Zambia in demarcation and establishment of two botanical reserves for the *in situ* conservation of the species. The reserves are located at Malavwe and Kataba in the Western Province of Zambia and covers 31.6 and 4.0 ha respectively (FAO/UNEP 1985). It is believed that they are the first reserves in the world to have been established for *in situ* conservation of the genetic variation of a tree species. To conserve the variation of the species completely, however, additional reserves would need to be established (Piearce 1986b).

Recently, *B. plurijuga* was among the ten priority tree species selected for regional collaboration during the SADC Regional Workshop on Forest and Tree Genetic Resources, held in Arusha, June 2000 (SADC 2000). The workshop, which was attended by representatives from nine countries within the region, also discussed actions for the individual species and *in situ* conservation of B. *plurijuga* was listed as urgently needed.

The World Conservation Monitoring Centre (WCMC), which provides information services on conservation and sustainable use of the world's living resources, has included *B. plurijuga* on their 'Red list' (WCMC 2000a). Though the species as such is not in immediate danger of extinction selective logging of high quality individuals may lead to genetic erosion of economic important traits. Likewise conversion of *Baikiaea* forest to agricultural land might lead to the loss of part of the species' genetic variation. It is uncertain whether the genetic variation of Zambezi teak already has decreased. With a continued intensive exploitation it is likely to happen within a fairly short time span, unless protective measures are taken. The reduction in genetic variation will reduce the capacity of the species to respond to changing environments. Furthermore, it will limit the possibilities for future breeding programmes for the species. In order to conserve the genetic variation, a sufficient number of populations with an appropriate geographic distribution must be protected and managed.

Botanical description

Baikiaea plurijuga (Harms) is a medium to large deciduous tree, 8-20 m in height, and with a large, dense, spreading crown. The bark is smooth and pale in young specimens, later becoming vertically fissured and cracked, and brown to grey in colour. Leaves are alternate, compound, with 4 to 5 pairs of opposite leaflets. Leaflets are oblong to elliptic, 3.5-7 x 2-2.5 cm; apex rounded, often notched, bristle-tipped; margin entire, wavy or finely rolled under; petiole short. Flowers are large, attractive, in axial racemes up to 30 cm long; buds are dark brown or golden-brown and densely velvety. There are 4 sepals with dark brown velvety hairs. There are 5 petals, pinkish, 2-3 x 1-1.5 cm. Pods are woody, flattened, 13 x 5 cm, broadest near the apex and tapering to the base, with dark brown velvety hairs (Palgrave 1983). *B. plurijuga* is a dominant tree in areas of deep well-drained Kalahari sand forming a two-storeyed deciduous forest, with a canopy that may be open or closed. Underneath is a deciduous thicket, or 'mutemwa'. *Baikiaea* forests are rich in valuable timber because the two dominant species are *B. plurijuga* and *Pterocarpus antunesii* (Storrs 1995). *B. plurijuga* starts flowering in December, extending into March with a peak in the middle of the rains (Childes and Walker 1987). The species is insect pollinated. It is unknown whether selfing is possible. *B. plurijuga* does not flower every year and not all trees flower at the same time. Good rain will give good flowering the following year. Pods start ripening in April and dehisce in August and September when the relative humidity is low and temperatures increase. Seed dispersal is by the pods splitting explosively throwing the seeds some distance (Palgrave1983) possibly followed by some kind of secondary animal dispersal and burrowing of seed. Seeds are dispersed at a time when ground cover is minimal and remain dormant for several months until sufficient rain has fallen to initiate germination. Well adapted to dry sites on free-draining sandy soils the tap roots of the seedlings rapidly penetrate downwards in order to reach soil depth levels which are moist during the dry season, and to avoid competition with roots of the undergrowth (mutemwa species) (Högberg 1986). In addition the species coppice well, which is important for regeneration after disturbances and in modified habitats (WCMC 2000a).

The wood is heavy, even textured, hard, strong, durable, dark red-brown and slow drying. It is used for furniture, flooring, railway sleepers and mining timber and is exported from southern Africa in considerable quantities (Palgrave 1983).

Photo 1. Flower of Baikiaea plurijuga. H. Keiding

Photo 2. Zambezi teak produces one of the world's finest commercial timbers. A.B. Larsen

3. THE CONSERVATION STATUS OF ZAMBEZI TEAK IN ZAMBIA

Conservation status refers to the present state of the genetic resources and the risk of future erosion. To assess the conservation status of *B. plurijuga* it is important to examine past and present distribution. Have populations been lost and are remaining populations subject to genetic erosion? How does the present exploitation of natural forests affect remaining populations? How well protected are remaining populations and what are the threats?

The conservation status of a species and the future trends may be deduced from such information, but will also require consideration of demographic and economic factors, legislation, institutional framework, development, and forestry policies.

3.1 Past and present distribution of natural Zambezi teak forest

B. plurijuga is the southernmost occurring species of the genus, which is mainly confined to the tropical lowland rain forest of the Guinea-Congolian floral region. *B. plurijuga's* occurrence in the dry Zambezian region coincides with the presence of Kalahari sands. The Kalahari sands have a high capacity for moisture retention, which favours the regeneration of the species. In its present range *B. plurijuga* is restricted to an annual rainfall regime ranging from more than 1000 mm in the north to less than 600 mm in the south. It is limited to the north by competition with mukwe, *Cryptosepalum exfoliatum*, and to the south by low rainfall and increasing incidence of frost; to the west and east it follows the occurrence of Kalahari sand (Huckabay 1986).

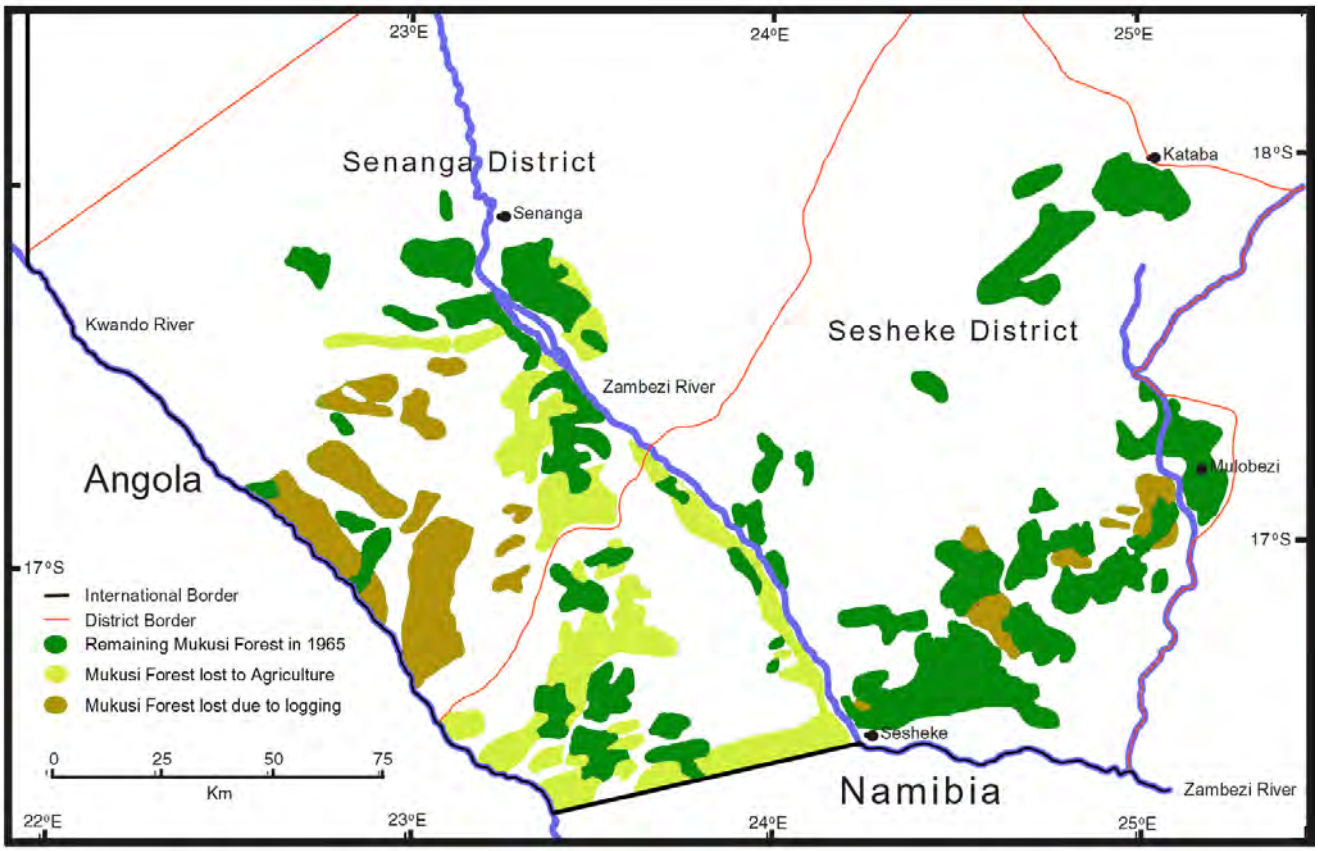

Figure 2. Past and present distribution of Zambezi teak forest in the South-West province of Zambia. Sources Maclean 1965 and National Archives.

The *Baikiaea* forest also includes species from the more arid Zambezi and Kalahari-Highveld zones. Many of these species, especially those of the shrub layer, the mutemwa, compete vigorously with *Baikiaea* seedlings for moisture in the upper layers of the sand and suppress regeneration of *Baikiaea*.

B. plurijuga has disappeared from much of its natural range in the past 100 years due to human disturbance. In figure 2 the natural distribution of Zambezi teak forests in Southwest Zambia and the areas lost due to logging or agriculture are indicated. According to the map more than 50 % of the natural forest had disappeared in the Senanga and Sesheke Districts by 1965.There is no doubt that the *Baikiaea* forests of Zambia have been further reduced since then. LANDSAT imagery appears to confirm that degradation is progressing rapidly at the edges of many of the remaining blocks of *Baikiaea* forest (Wood 1986). The most recent distribution map of *B. plurijuga* (Wood 1986) is based on the vegetation map of Zambia (Edmonds 1976). The complete actual distribution as of today is not known but according to FAO (1999) the total forest cover of Zambia was reduced by 1.3 mill ha during 1990-1995, equivalent to an annual deforestation rate of 0.8%. The commercial importance of *Baikiaea* forests suggests that the annual deforestation rate for this particular forest type may be even higher. Proposals for a national forest inventory have been made but lack of funds has held up its implementation.

3.2 Exploitation of Zambezi teak forests

3.2.1 Logging

The *Baikiaea* forests of Zambia have been logged on a commercial scale since the beginning of the twentieth century. Zambezi teak supported a major timber industry in the first half of the century and the production of timber peaked at 100,000 cubic metres per annum in the 1930s. Another peak was experienced in 1964. By 1965 huge tracts of *Baikiaea* forests were already lost as a consequence of logging (Figure 2). Since then there has been a steady decline in the production of mukusi wood (Huckabay 1986). Sales values in Zambia have been around US$ 1 million annually, 80% on the domestic market and 20% from export (WCMC 1991). Today export of logs is not allowed.

Current logging of Zambezi teak is taking place under concession in several districts within the Western and Central Province. Logging licences are issued by the FD and controlled by the local forest departments. Five types of licence are issued: sawmilling licence, pitsawing licence, concession licence, casual licence and other licences (Forest Act 1999). Under the current licences, trees from 30 cm DBH and above may be cut. Enterprises with sawmilling concessions are required to cut between 200 and 600 trees per month while holders of pitsawing concessions can cut between 20 and 60 trees per month. Licence holders must submit an annual plan of operation to FD specifying the areas where exploitation is planned and the species and quantities to be logged.

Before 1998 the demand for Zambezi teak was low but it is on the increase and today there is a considerable interest from foreign and local companies in obtaining future sawmilling licences. In late 1998 Zambia Railways invited tenders for large supplies of hardwood sleepers - in practice made from Zambezi teak. Hence, the demand for Zambezi teak is likely to increase.

In most cases logging of *Baikiaea* forests has resulted in changes in the ecology of the forests, which has led to higher frequency of severe fires and increased competition from grass and shrubs thereby severely hampering regeneration of *Baikiaea* forests. Important questions are how *Baikiaea* forests can be logged in a sustainable manner and what measures are necessary to ensure adequate regeneration after logging.

Knowledge on productivity, standing volume per hectare and regeneration under different conditions is essential for sustainable management. In 1996 a management plan was made based on an

intensive survey of the *Baikiaea* forest resources in south-western Zambia (JICA 1996). The survey showed that within the National Forest Estate in Sesheke district (120,000 ha) only 25 % were stocked with more than 75 m^3/ha. Contrary to initial assumptions, remarkable forest destruction had taken place. Nevertheless, the study concluded that selective cutting could be undertaken provided certain guidelines were followed. Hence, only trees above 40 cm DBH should be cut. A minimum of 30 trees per hectare, with DBH above 30 cm, should remain to enhance natural regeneration. Finally cutting cycles were recommended to be at least 20 years. In an earlier study it was concluded from data collected from a 10-acre sample plot that the lower felling limit for *B. plurijuga* in natural stands should be raised to about 50 cm on a rotation of 300 years (Calvert 1986c).

Most of the Zambian *Baikiaea* forests are under licence for logging; regeneration after logging is low, and effective measures to combat re-occurring forest fires do not exist. If the remaining *Baikiaea* forests are logged under the current management system, it is inevitable that over a short term the forests will become seriously degraded and over a longer term they will disappear altogether.

3.2.2 Conversion of forests to agriculture

There has been a considerable loss of *Baikiaea* forest to cultivation in Zambia (Figure 2). Forest cultivation involves a form of long-rotational fallow or shifting cultivation. Clearings are made in the forest by felling small trees, thicket and bushes. After drying, the debris is burned. Larger trees are usually not felled but because of the thin bark of *B. plurijuga*, fire seriously damages it. The growth of dense thicket on abandoned farmland and frequent fires make re-growth of *B. plurijuga* difficult. Extended periods of cultivation tend to destroy natural *Baikiaea* forest completely (Wood 1986).

There are a number of reasons to expect that the loss of *Baikiaea* forest through cultivation has grown in recent years. Population growth and concentration around the centres of economic activity have lead to an increased demand for agricultural land and even for the release of Forest Estate for cultivation (GRZ/FD 1980a,b).

With the increased importance of cash crops and agricultural policy of encouraging maize cultivation through various subsidies and extension advice, the demand for land suitable for maize has increased (Wood 1986).

The Kalahari sands preferred by *B. plurijuga* are more suitable for agriculture, and in particular maize, than the soils found in many other parts. The major importance of the Kalahari sands is their greater capacity to retain rainfall in the upper layer and so to provide crops with a continual source of moisture when dry spells occur during the rains. The water retentive capacity comes from their high proportion of sand. Furthermore, transitional sands are less acid and have a considerable ability to release nutrients. Thus they are more fertile and have the distinction of being one of the few soils in Western Province able to support maize cultivation. These important characteristics of the Kalahari sands are well recognised by farmers. As a consequence, farmers prefer to cultivate soil occupied by *Baikiaea* forests and even to clear denser blocks, despite the increased effort involved because increased yields make such sites attractive (Wood 1986).

As in other parts of the country, the population living in south-west Zambia near to the *Baikiaea* forest has grown rapidly during the last 60 years. In Sesheke District the total population grew from 25,000 in 1930 to 67,000 in 1996. It is expected to be more than 75,000 by now.

With a growing commercialisation of the rural economy, sources of cash will be sought by the enlarged rural population and as a result the demand for land suitable for cultivation of marketable crops, especially maize, will probably increase. Thus it appears that the impact of rural

population growth, which has already adversely affected the *Baikiaea* forest, will increase considerably in the future (Wood 1986).

3.2.3 Local use of Zambezi teak

Local communities use mukusi for firewood, building material, medicine, mortars and for tanning of leather (Storrs 1995). In the *Baikiaea* forest region of Zambia the local people mainly depend on firewood for cooking and *B. plurijuga* is the preferred species in areas where it is predominant. Much wood is wasted, as the 3-stone stoves commonly used have a very low efficiency (Musonda 1986). Increased levels of charcoal production occur, though charcoal making is prohibited in the western province according to the Barotse Royal Establishment of the Lozi, which is written law. The Forest Act necessitates a licence to produce, transport and sell charcoal and officially charcoal is not produced in the western province.

Different medicinal uses of the bark have been reported including treatment for syphilis and for making a fortifying tonic (Storrs 1995). But altogether, the impact of local use of *B. plurijuga* is low compared to the impact of commercial logging (Sekeli, pers. comm.).

3.2.4 Plantations

Plantation establishment may contribute to the conservation of genetic resources if they represent valuable gene pools. Likewise, breeding programmes based on broad genetic material may contribute significantly to the conservation of genetic resources through the retention of genetic material.

Even though Zambezi teak is one of the most important commercial species in Zambia, only negligible areas have been planted and mainly for research purposes. At present there are no planting programmes for the species.

The use of Zambezi teak in plantations has hitherto not proved very successful. Seedlings are easy to raise in the nursery but they are difficult to transplant because the tap-root grows very deeply from the outset, reaching 1.5 m after one year. In contrast the shoot attains a height of no more than 15 cm over the first three years (Fanshawe 1961, Calvert 1986c). The tap-root has to be severed before planting out, which renders the seedling vulnerable to drought stress. In some trials the survival of transplanted seedlings have been as low as 10 % after the first year mainly due to drought and browsing by duikers (Piearce 1986b).

Overall, drought, fires, weed competition, and grazing of seedlings by duikers and rodents, lack of proper nursery techniques, and to a lesser extent damage by frost and poor establishment practices have been responsible for the poor performance in plantations (Chitempa & Shingo 1986).

Trial plantings were established in 1962 at Masese, Katombola and Dabwa in order to determine early height and diameter development of mukusi and to assess whether the estimated 100 years rotation in natural forests could be reduced in plantations (Saramäki *et al*. 1986). Unfortunately fire and drought damaged all three plantings in 1993 and it was difficult to draw conclusions concerning the potential of mukusi as a plantation species. However, it is obvious that effective fire management is a major challenge for successful management of *Baikiaea* plantations. Piearce (1986a) doubts whether it would be possible to establish mukusi in plantations with anything like the success of 40 years ago. It seems that the intensive management used at that time including the use of guards to scare away animals and watering of seedlings will not be possible today.

To the as yet unresolved silvicultural problems must be added the fundamental matter of the slow growth rate of mukusi. Even under the best conditions, its rotational length to reasonable

timber size of 30 cm DBH is estimated at 80-100 years (Piearce 1986a) while Calvert (1986c) estimates a rotational length of 300 years for a diameter of 50 cm at breast height. Planting trials within the natural range have indicated that the slow growth of plantings makes plantations unprofitable and thus it was concluded that the species is not suitable for plantation programmes because of its slow growth and fire sensitivity (African Regional Workshop 1996). Instead it was recommended to focus on restoration of existing but degraded forests and on sustainable management of the remaining forests.

The possibility of growing mukusi outside the species' range was assessed by a trial in Chati in the Copperbelt Province where rainfall is about 1275 mm per year compared to about 700 mm per year in its natural range. In the trial plot established at Chati a mean height of 17.1 meters was attained at age 33 whereas a mean height of only 6.7 m was obtained at Masese within the natural range at the same age (Sekeli 2000). Furthermore, seed setting was found to be high at Chati and seedlings became well established in the area (DFSC 1998). Hence, plantation production of Zambezi teak in areas of higher rainfall might be an option.

Mubita (1986) discussed the possibility for a short-term Zambezi teak breeding scheme, involving the establishment of forest reserves for seed collection, short-term research on local populations and for conservation of genetic variation as a basis for selection, breeding and production. Considering the present limited experience with Zambezi teak in plantations, it is unlikely that breeding activities will be initiated in the near future.

3.3 Protected areas

Zambia has a protected areas system consisting of national parks and game management areas. The game management areas are often adjacent to the national parks and function as buffer zones. Furthermore forest reserves and protected forest areas are also granted some legal protection. National parks and game reserves in Zambia are shown in figure 3.

Some of the remaining *Baikiaea* forests are found within national parks and are thus assured a good legal protection. It is not known to which extent *B. plurijuga* occurs in forest reserves and protected forest areas in Zambia. However, the different categories of protected areas containing *B. plurijuga* would undoubtedly play an important role in the establishment of a protected area system for Zambezi teak.

It should be kept in mind that national parks are designed to protect ecosystems, which do not necessarily maintain the presence of a particular species. Active management in order to enhance the presence of a specific target species is generally not permitted in a national park. Furthermore, the natural relationship between large herbivores and vegetation is often disturbed in protected areas. Elephants may cause heavy damage to woodlands where increased populations have been forced into smaller areas as a result of human activities. However, Zambezi teak is not a preferred species for browsing by elephants and their impact on it is low, even at high elephant densities (Ben-Shahar 1996).

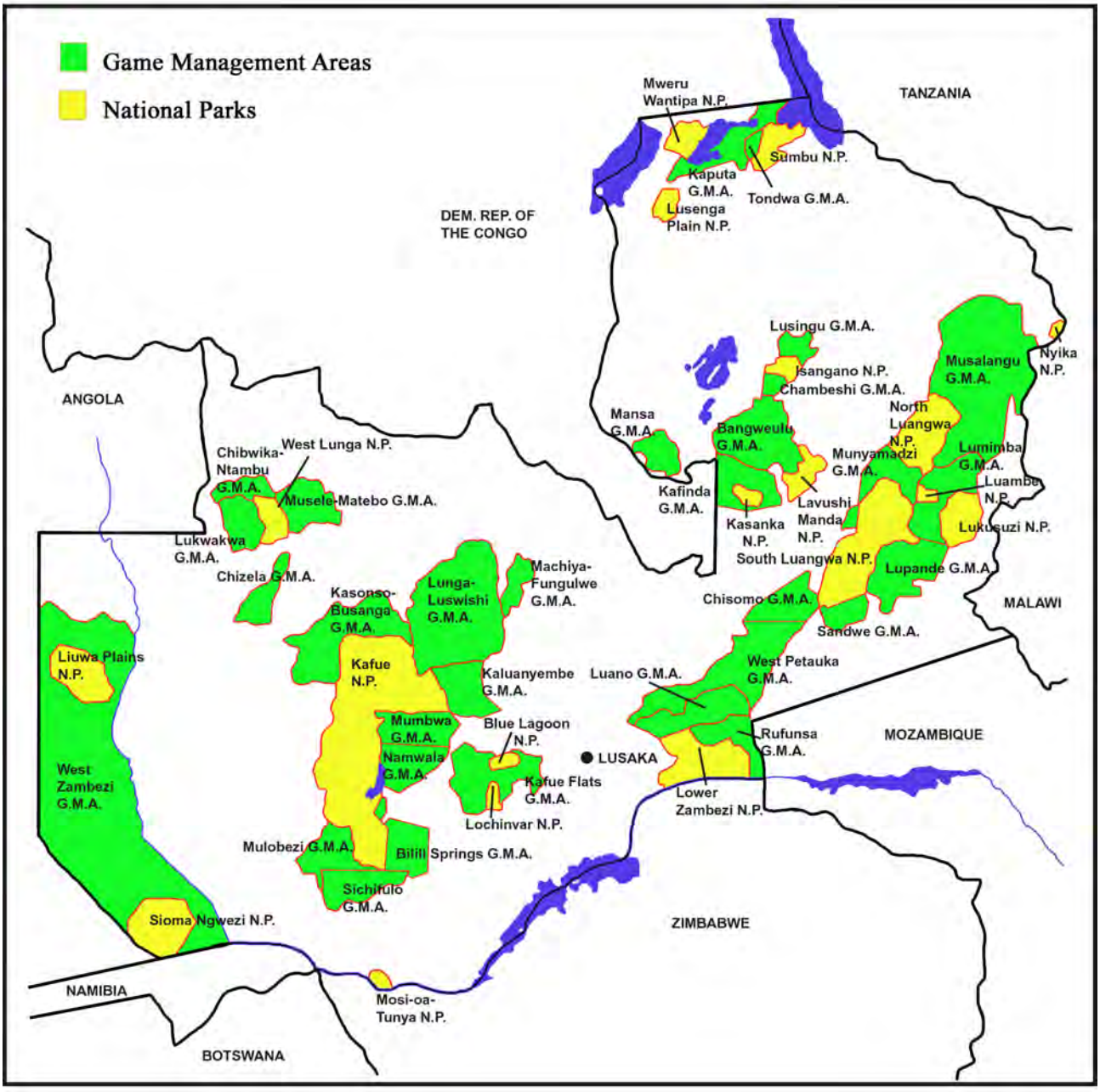

Figure 3. National Parks and Game Management Areas in Zambia. (From Spectrum Guide to Zambia).

3.4 Threats to Zambezi teak

3.4.1 Fire

Fire is the overriding threat to the remaining Zambezi teak forests. An average of about 1600 ha is destroyed by fire each year (Zimba 1986). The primary causes are uncontrolled fires started by farmers, honey gatherers and hunters. Fire is used to create clearings for agriculture and provides nutrients for the crops to be grown. Honey gatherers use fire to smoke out bees. Hunters use fire to provide good visibility and wildlife is attracted to the new grass shoots in recently burned areas. Fire is widely used to clear vegetation near settlements and paths while cattle owners usually burn grassland in July or August to encourage regeneration of the grass. In all these cases, fires frequently get out of control and spread into forest land. The fire risk is especially serious for Zambezi teak in thickets where the fire may reach the canopy, which can lead to complete loss. With repeating fires the vegetation might ultimately degenerate into grassland (Figure 4).

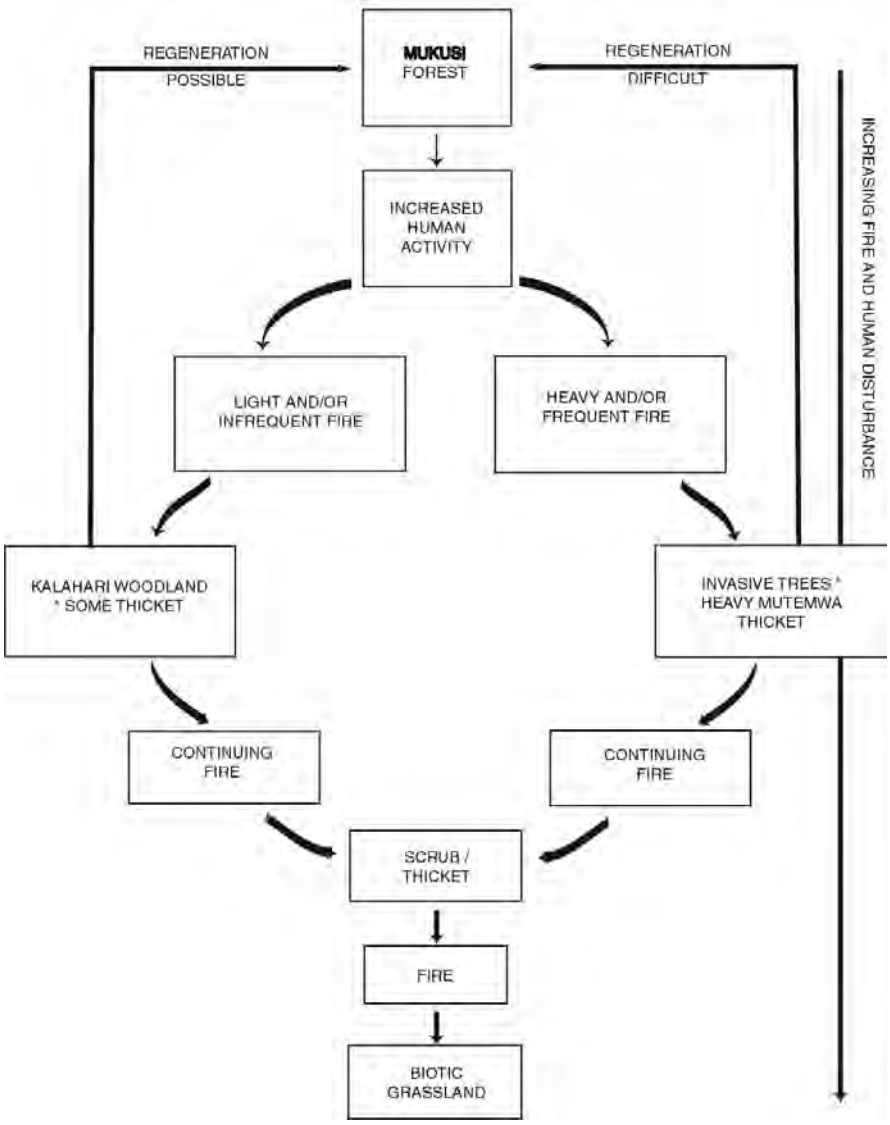

Figure 4. Vegetation sequence following increased human activity (from Wood 1986).

Since grass biomass declines sharply as tree cover increases, a period of undisturbed re-growth by woody plants would lead to gradual canopy closure and the suppression of grass growth and decreasing amount of inflammable material (fuel load). Lower fuel loads result in less intensive fires, less damage to woody plants, uninterrupted woody re-growth and continued canopy closure. Conversely, decline in woody plant cover results in increasing grass and thicket, which, in absence of herbivores, provide more fuel for potential fires. Higher fuel loads in turn mean more intense fires, greater suppression of woody plant re-growth and therefore, more grass (Campbell 1996).

The Zambian FD has designated the *Baikiaea* forests Concentrated Fire Protected Areas meaning that fire is prohibited. Experiments showed that controlled burning in the early part of the dry season (June-July) reduces damage caused by late fires (Kasumba 1986, Piearce 1986a). Therefore, Zambia's policy has changed to prescribed 'early burnings', that is to burn areas with low-intensity fire at a time when the trees are becoming dormant, so regeneration is not adversely affected. However, management of Concentrated Fire Protected Areas is expensive and essential equipment is often unavailable.

As an alternative to prescribed burnings, cattle grazing or game ranching has been proposed elsewhere in order to control the grass and thicket. This system has been practised in Zimbabwe, but is less applicable in Zambia as *Baikiaea* forests are often far from watering places (Piearce 1986a). Nevertheless, the experience from Zimbabwe could provide important information on a 'close to nature' management system (Calvert 1986b).

Until now, difficulties in forest extension work in the *Baikiaea* forest have been linked to the changes in land ownership implemented through the 1973 Forest Act, which withdrew the right of the traditional chiefs to own land. Therefore, the local people no longer felt that they benefited from the forest (Matakala 1986). Indeed, some fires have been started because of feeling of resentment against the forest administration. Furthermore, some people concluded that the easiest way to get land was to burn it several times until it had no value as a Forest Reserve (Banda 1986). In areas such as for instance the Nalulu Forest in Senanga, the local communities have been involved in management of the forest and they increasingly recognise benefits from the forest. Hence, less fire damage is observed than in neighbouring forests (Mulenga, pers. comm.).

3.4.2 Lack of natural regeneration

There are many factors limiting natural regeneration of Zambezi teak. Fruiting of the remaining seed trees is considered to be erratic (Malaya 1986) while rodents, duikers, monkeys and birds consume a high proportion of germinating seeds and seedlings (Sekeli 1997). From studies on regeneration of Zambezi teak in Western Province of Zambia it was concluded that the competition for moisture and light from undergrowth makes survival beyond the first dry season very low, whereas in some areas adequate numbers of seeds and seedlings survive the depredation of animals (Calvert 1986a).

In the past, game animals, especially elephants and buffalos, kept the mutemwa from becoming too dense by trampling, uprooting and browsing the shrubs. Many of the shrubs are highly palatable to livestock as well as game (Palmer & Pitman 1972). The browsing almost completely removed inflammable material and opened up the thicket. The fire hazard was considerably reduced over large areas and the understorey thinned out to allow the establishment of seedlings (Mitchell 1961). Not only did game animals keep the competitive mutemva under control and reduce fire hazard so that *B. plurijuga* could colonise, but trampling by herds of elephant and buffalo planted the *B. plurijuga* seeds into the sand away from depredation of rodents, baboons and seed eating birds (Lawton 1986, Piearce 1986b). Thus large game seem to be an important ecological factor for the natural regeneration of *Baikiaea* forest by keeping the mutemwa in check and facilitate regeneration of mukusi. In the absence of these large herbivores, natural regeneration of *Baikiaea* is in many localities dependant on human control of the mutemwa.

Various methods of artificial regeneration such as direct sowing in the field and use of potted seedlings have been tried, but the germinating seeds or seedlings were usually destroyed by rodents (small rats and squirrels) and browsing animals such as duikers (Malaya 1986, Sekeli 1997). This might be a response to increased density of smaller herbivores caused by the elimination of their predators.

3.5 Future trends

During the past one hundred years the Zambezi teak forests in Zambia have been steadily depleted as a result of human activity. Today, it probably covers less than fifty percent of the area found hundred years ago.

With the present economic recession and the poor prospects for an improvement in the urban economy it seems likely that growth of the rural population will continue. Further, sources of cash will be sought by the rural population and it is expected that the demand for land suitable for cultivation of marketable crops will increase (Wood 1986). Furthermore, threats from increased levels of charcoal production, establishment of illegal settlements in forest reserves and increased logging activities both licenced and unlicenced render the future of *Baikiaea* in Zambia uncertain (Sekeli 2000). It is evident that the current forest legislation and management of forest reserves do not provide adequate protection to the remaining Zambezi teak forests.

The new Forest Bill was enacted in 1999. One of the intentions of the new bill is to provide for establishment of joint forest management areas where local authorities and communities will prepare joint forest management plans. Further, part of the revenues from the forest reserves should be channelled to the local communities (Forest Act 1999). It is hoped that these changes will create incentives for a more sustainable use of the forests and help reverse the present trend of deforestation.

4. GENETIC VARIATION IN ZAMBEZI TEAK

In order to establish an effective network of conservation stands, all major patterns of genetic variation should be included, but the number of conservation stands should on the other hand be limited to a manageable level. In this respect reliable information on the distribution of genetic variation - within and between geographic regions - is important. Based on available information on the genetic variation a conservation plan can be drawn up. The plan should be reviewed whenever new information becomes available.

The genetic variation of a species can be assessed by different techniques. It is possible to study morphological and metric characters in field trials, biochemical and molecular markers in the laboratory, and to some extent to predict possible genetic variation patterns from ecogeographic variation.

The study of metric characters or adaptive traits in field trials was earlier the dominating technique and it is still today the most robust and valid way of assessing genetic variation. Information from such studies is essential when assessing adaptive genetic variation as a basis for conservation activities (Eriksson 1995). For *B. plurijuga* no morphological studies, provenance trials or other field tests that could have provided information on genetic variation have been carried out.

Molecular markers are often used for fast surveys of genetic variation within and between populations (Hamrick 1994). However, molecular markers do not identify patterns of genetic variation and are therefore of limited value in guiding gene conservation activities. At present, no genetic marker studies of Zambezi teak exist.

It is generally assumed that similarity of ecological conditions implies similarity of genetic constitution. A comparison of a species' distribution with well-defined ecological zones therefore provides an indication of the genetic variation within the species. Ecogeographical surveys can be used for several purposes. In forestry they have primarily been used to define tree seed zones with specific recommendations for seed collection and utilisation of seed sources. In the absence of genetic studies on Zambezi teak, ecogeographic knowledge is used to outline genecological zones for conservation of genetic variation of the species.

5. HOW TO ESTABLISH A GENECOLOGICAL ZONATION FOR ZAMBEZI TEAK

A genecological zone can be defined as an area within which it is acceptable to assume that populations are genetically similar. Such zonation is based on a compromise between the variation in ecological factors and expectations of gene flow. The zone should have sufficiently uniform conditions to assume that none divergent selection has taken place. The zones should not be too small, because pollen flow between neighbouring zones would then be likely to counteract evolution of genetic differences between populations from the different zones. On the other hand, zones should not be too large, because then important genetic differences may exist between populations within each zone. The construction of genecological zones is described by Graudal *et al*. 1997.

Genecological zonation is a practical tool in the selection of populations to be conserved. It consists of identifying areas with uniform ecological conditions and subject to none or limited gene flow from surrounding areas. Genecological zonation may be prepared as one common system for several species or as a specific system for one species. It is usually based on existing data on natural vegetation, topography, climate and soil. If available, information from provenance trials and genetic marker studies may be used to test the validity and adjust the zonation.

Compared to ecogeographic zones, genecological zones differ in at least one aspect. An ecogeographic zone may be composed of a group of ecologically similar but geographically separate areas. If the geographic separation constitutes barriers to gene flow, such areas should most likely be considered as different genecological zones. The close relationship between ecogeographic zones and genecological zones implies that the latter can be used as a starting point to develop genecological zones for Zambezi teak in Zambia. However, geographically separate areas included in the same ecogeographic or agro-ecological zone have to be considered different genecological zones.

Genecological zonation should ideally be specific for individual species, or at least for major groups of species. Different target species in a given gene resource conservation programme may diverge in several ways. They may vary in reproduction biology, they may react differently to environmental clines, and they may reflect entirely different life histories in terms of evolution, migration, hybridisation events, or human utilisation. Thus species with the same distribution may show entirely different pattern of genetic variation within that area. Species-specific zonation will require the same basic data as common zonation. For economic reasons, and due to lack of species-specific data, such specific systems will generally be limited to species of major economic importance.

It should be noted that genecological zonation is not something fixed, but subject to continuous revision as more information becomes available. Additional information from morphological studies, provenance trials and genetic marker studies may be of particular value for such revision.

A genecological zonation for *B. plurijuga* is suggested based on the natural vegetation, climate and soils. In addition, the present distribution of Zambezi teak into more or less distinct populations and probable gene flow between populations was taken into account in the delineation of the genecological zones.

5.1 Natural vegetation

The natural vegetation reflects the combined effect of the most important ecological factors. Knowledge of natural vegetation types is therefore a good starting point for drawing up genecological zones. However, humans have often profoundly influenced natural vegetation. For example, degradation of *Baikiaea* forest results in a secondary forest dominated by *Acacia giraffae, Combretum collinum,* and *Terminalia sericea* in which *Baikiaea* may or may not be present. Further, many species are characterised by continuous distribution over a wide range of climates and sites, which may have resulted in genetic variation in adaptive traits. The natural vegetation may therefore not truly reflect the information necessary to infer likely genetic patterns. Specific ecological factors therefore have to be considered. Differences in climate and soil within the natural distribution of Zambezi teak is discussed below.

5.2 Climate and agro-ecological zones

The distribution of Zambezi teak in Zambia has an annual rainfall between 1000 mm in the north to about 600 mm in the south. The south-western region of Zambia has experienced a drier climate over the past century. Thus, the average annual precipitation in Livingstone was 800 mm from 1930 to 1975 decreasing to 620 mm in 1975-1996.

The rainy season is from mid November to the end of March. Heavy dews occur in the winter months. During the winter months, night radiation from the sand results in very low night temperatures so that low lying areas and depressions suffer from frost.

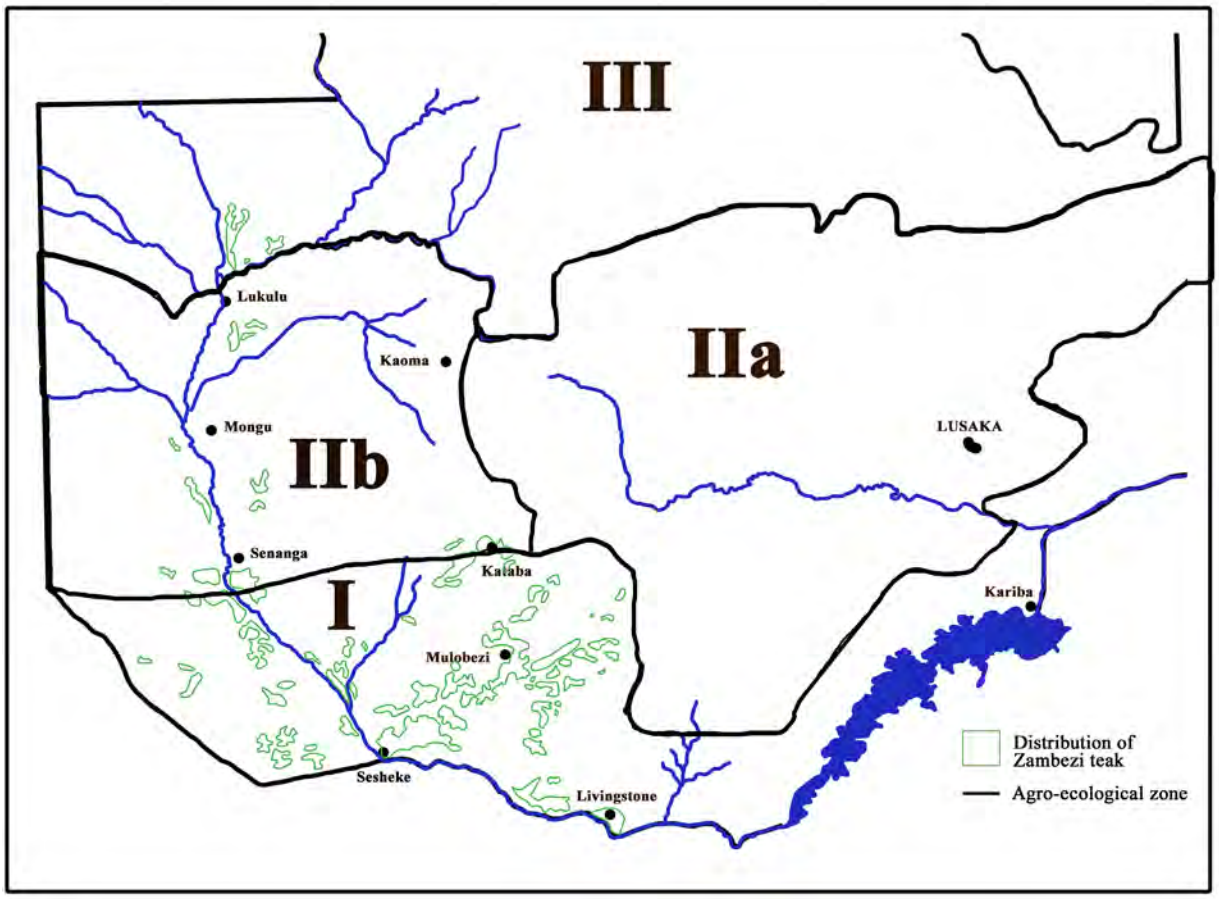

Figure 5. Agro-ecological regions in western Zambia (Veldkamp 1986) overlaid with the distribution of Zambezi teak.

Based on differences in the length of the growing season, occurrence of drought, number of days of frost, amount of sunshine during rainy season, minimum-, maximum- and night temperatures, Zambia has been divided into 3 agro-ecological regions and 36 agro-ecological zones. The agro-ecological regions overlaid with the distribution of Zambezi teak are shown in Figure 5.

Zambezi teak is found within the western part of agro-ecological region I, in agro-ecological region IIa it is found within Kafue National Park, in agro-ecological region IIb along the Zambezi River and north of Kataba, and in agro-ecological region III just north of Lukulu.

The agro-ecological regions of Zambia based on a multitude of climatic features have been used as a starting point for a genecological zonation for Zambezi teak in Zambia. Information on continuous distribution of the species across agro-ecological zones and specific soil properties has also been taken into account.

5.3 Soils

Variation in soil characteristics may cause pronounced differences in vegetation within areas of similar topography and climate. The distribution of Zambezi teak overlaid with the soil map of Zambia (FAO-Unesco 1979) is shown in figure 6. It is seen that all major stands are found on Kalahari sands. The deep loose and well-drained Kalahari sands favour Zambezi teak as they catch and conserve in the lower horizons the entire season's rainfall making moisture available all year around. Kalahari sands are remarkably uniform and the main reason for the azonal

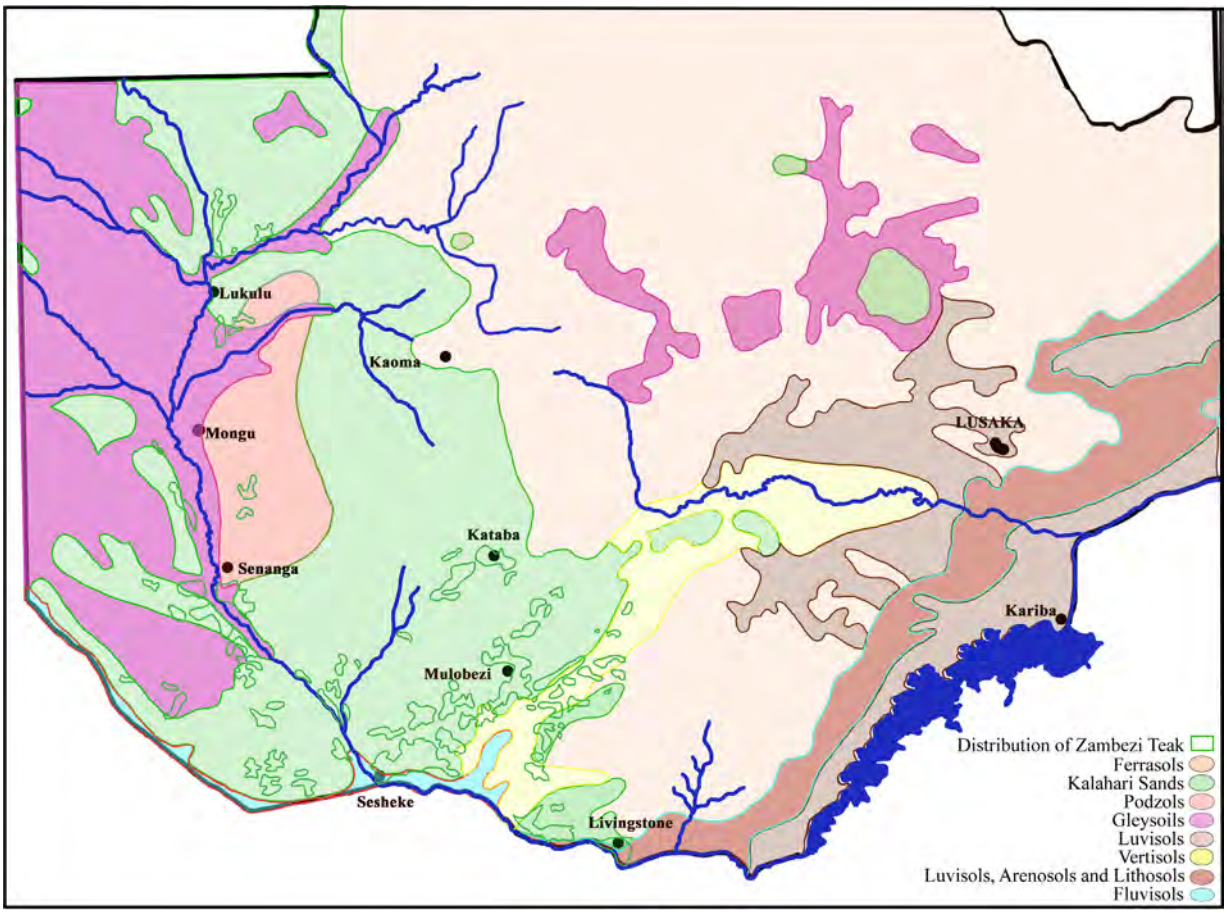

Figure 6. Soil map of Zambia (modified after FAO-Unesco 1979) overlaid with the distribution of Zambezi teak.

distribution of Zambezi teak across a wide range of annual rainfall (Huckabay 1986). The natural vegetation on Kalahari sands is tree savanna and these regions are mainly used for extensive animal husbandry. Where poor drainage conditions exist the Kalahari sands give rise to various gleysols. A few stands are probably found on gleysoils. Usually these soils are not cultivated but reserved for extensive grazing during the dry season. However, the eutric gleysoils of South-west Zambia are usually rich in bases and organic matter and proper drainage makes it possible to establish permanent agriculture. Zambezi teak has almost disappeared from these soils.

Some scattered stands to the south and east of Mulobezi are possibly found on fine textured vertisols, some with a high concentration of exchangeable sodium, which makes them alkaline. These soils are sometimes inundated, heavy and difficult to work due to the fine texture; they are rarely used for agriculture but rather for livestock pasturage.

Patches of Zambezi teak are found throughout Kafue National Park but are more common in the south (WCMC 2000b). Except for the southern part of the park, found on Kalahari sands, the remaining part is on ferrasols, which are poor soils that have often undergone severe erosion. They are mainly suitable for grazing.

It should be noticed that the soil map indicates the dominant soil type for a given area. Pockets of Kalahari sands might very well exist within areas designated with different soil types. However, if stands on soils different from the typical Kalahari sands are identified in the field, specific steps to conserve them are recommended.

5.4 Genecological zonation for Zambezi teak

The range of Zambezi teak is characterised by fairly uniform ecological conditions, apart from the climate, which changes gradually from north to south, becoming drier, hotter and with more frequent night frosts. The natural vegetation in the distribution area is dominated by mixed Zambezi teak forest, with varying occurrence of other species. The occurrence of Zambezi teak is closely linked to the Kalahari sands throughout the whole distribution area. No mountain ranges or other distinct topographic features, which could act as barriers to gene flow, are found within the distribution area. Therefore, the genecological zonation for Zambezi teak is mainly based on the differences in rainfall, the existing agroecological zones and the distance between distinct forested areas.

Based on the 3 agro-ecological *regions* and 9 agro-ecological *zones* where *B. plurijuga* is found, a genecological zonation for *B. plurijuga* has been drawn up. Seven genecological zones are distinguished (Table 1, Figure 7). The genecological zonation is somewhat different from the agro-ecological zones reflecting the geographical isolation of some stands and proximity and expected gene flow between others. Boundaries were drawn so that separation of continuous forest areas was avoided.

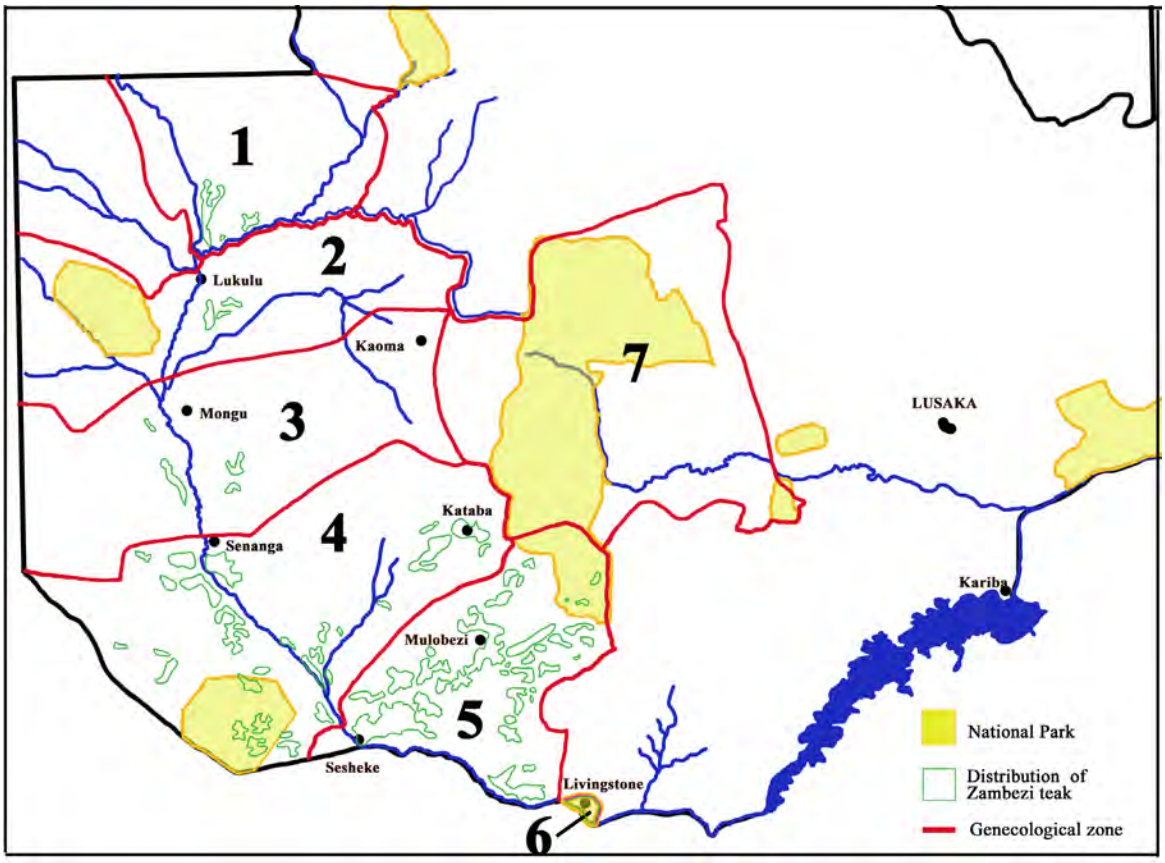

Figure 7. Genecological zonation of Zambezi teak in Zambia overlaid with national parks and the natural distribution of the species.

Table 1. Genecological zonation of *B. plurijuga* in Zambia.

Zone	Area	Delineation and description of zone
1	Lukulu	North of Lukulu, Agroecological region III, subzones 32w and 32c
2	Liuwa Plain	Liuwa National Park and stands south of Lukulu. Agroecological region IIb, subzones 22 and 21w. Stands on gleysols.
3	Mongu area	Agroecological region IIb, subzones 13w, 13f and 13c.
4	Sioma-Senanga-Kataba	Sioma National Park, stands around Senanga and Kataba. Agroecological region I, subzones 7w, 7e extended to include stands just north of Senanga and Kataba in 13w, 13c and 8w continuous with stands in 7.
5	Sesheke-Mulobezi-Kafue National Park South	Stands around Sesheke, Mulobezi, southernmost part of Kafue National Park and south towards Zambezi River. Agroecological region I, subzones 4ws, 4wn and 3w.
6	Livingstone	Stands around Livingstone within Mosi-Oa-Tunya National Park. Stands in Dambwa and Simonga Forest Reserve Agroecological region I, subzones 3ss and 3sc.
7	Kafue National Park North	Patches throughout Kafue National Park North. *Baikiaea* forest in Nkala Game Management Area. Agroecological region IIa, subzones 8c, 8e, 10, 14, 19. The only stands found on ferrasols.

6. IDENTIFICATION OF POPULATIONS TO BE CONSERVED

In the selection of populations to be conserved the aim is to secure the genetic variation. The specific criteria for the identification of conservation stands of *B. plurijuga* in Zambia are:

- Genecological variation: secure representation in all genecological zones.
- Population size: should be large enough to conserve the genetic variation and provide conditions for adequate regeneration.
- Legal conservation status: stands within legally protected areas preferred.
- The socio-economic context: forests far from heavily populated areas preferred. Alternatively areas with prospects for involving the local people in appropriate management and benefit sharing under Joint Forest Management.
- Management options and costs: necessary conservation measures must be realistic in extent and costs.

In general, selection of conservation measures for a given population depends on the conservation status and the nature of the biological material to be conserved. Where all criteria are fulfilled *in situ* conservation will be possible. In case conservation status or population size is low, one may have to identify another population or resort to *ex situ* conservation. However, in the case of Zambezi teak *in situ* conservation is considered an option in all genecological zones. A representative set of stands can be identified for conservation and the most appropriate conservation measures chosen. Each criterion for selection of stands is briefly assessed below.

6.1 How to secure the genetic variation?

A comparison of the geographical distribution of *B. plurijuga* with the genecological zones provides the overall framework for sampling of conservation populations in order to cover the expected patterns of genetic variation. At least one population per zone should be conserved and whenever possible, more than one population per zone should be identified to minimise the risk of loss due to unforeseen external events (Graudal *et al*. 1997). The number of stands should be seen in relation to the actual conservation status, the number of zones and their size.

Where a genecological zone contains only one isolated stand, and the size of that population is just about sufficient to maintain genetic stability, there is no choice of selection; conservation must necessarily encompass the only stand available. This is possibly the case in zone 6.

6.2 Consideration of population size

The size of a conservation population depends on species and site-specific aspects. Where a particular species grows in mixed stands, the conservation area has to be larger than where the species occurs in pure stands. As a rule of thumb, an *in situ* stand should initially consist of at least 150 and preferably more than 500 interbreeding individuals. The final stand size should be 500-1500 individuals or more per species (Graudal *et al*. 1997).

6.3 Legal Conservation status of areas with Zambezi teak

The practical possibilities for protection should be considered in selection of stands to be conserved. Thus, stands within protected areas have been preferred whenever possible.

Most *Baikiaea* stands in Zambia are found outside the protected area system but some good *Baikiaea* stands are found within national parks or game management areas. Important stands are found within the national parks of Kafue, Liuwa Plain, Mosi-Oa-Tunya, and Sioma Ngwezi (WCMC 2000b). Stands of *B. plurijuga* found within already protected areas form a good basis for a network

of conservation stands covering most genecological zones. However, the conservation status in Zambia's national parks varies. The fact that a stand is found within a legally protected area does not always secure its survival. The current situation in the national parks that contain Zambezi teak illustrates this point.

The central part of Ngoma Forest, situated in the south of Kafue National Park, is dominated by Zambezi teak. The forest hosts a large but probably stable elephant population, which apparently does not cause serious damage to the vegetation. On the contrary, the Zambezi teak might benefit from the presence of elephants as they clear the competing thicket and thereby also reduce fire risk. Furthermore, elephants might be helpful in the regeneration of Zambezi teak by 'planting' the seeds into the ground by trampling. Poaching takes place in the park, but not to an extent that affects the elephant population significantly. Fire management is carried out, though uncontrolled bush fires occur according to WCMC (2000b). According to the park management, none of the revenues from entrance fees to the national park are returned to local communities. However, part of the fees for hunting licences for the adjacent GMA are used for management of the GMA and services to communities within the area (Zeko, pers. comm.). In all, Ngoma Forest within Kafue National Park is considered one of the most well protected in Zambia.

The situation is quite different in Sioma Ngwezi National Park, which contains patches of mixed forest with Zambezi teak. A string of villages are found within the boundaries and along the South-West boundary of the national park. Illegal cutting of Zambezi teak and uncontrolled bush fires occur. The location of the park management office some 45 km from the park adds to the difficulties in controlling illegal activities in the park.

In Liuwa Plain National Park uncontrolled bush fires, grazing by domestic animals and settlements within the park boundary threaten the natural vegetation.

Mosi-Oa-Tunya/Victoria Falls National Park has one of the world´s most spectacular waterfalls. There has been quite a development within the park, long before its establishment. Buildings include hotels, lodges, museum, housing for national parks staff, power generation facilities etc. In addition, cattle grazing and gradual encroachment of small-scale farmers together with the expanding town of Livingstone constrain the management of the park (WCMC 2000b).

In Zambia, 32 Game Management Areas (GMA) serve as buffer zones to the country's national parks. Local people are allowed to live and farm in the GMAs, while hunting is controlled. Due to poor local economies and lack of economic incentives to conserve wildlife some poaching does take place. *Baikiaea* forests are known to occur in the following Game Management Areas: Bilili Springs, Mulobezi, Nkala, Sichifula and West Zambezi. Additional stands might occur in other Game Management Areas as well. Most *Baikiaea* forests within Game Management Areas have been, or are currently, under licence for logging. As such, *Baikiaea* forests within Game Management Areas are not given any particular legal protection and their present status is unknown. Provided the right management practices were adopted, these areas could contribute to the conservation of Zambezi teak.

Furthermore, a number of Botanical Reserves within forest reserves have been delineated in Zambia. Two of these, Malavwe and Katabe in Sesheke District, were established to conserve genetic resources of *B. plurijuga*. The Botanical Reserves are described in detail by FAO (1985). The stand in Malavwe Botanical Reserve was assessed in 1997 and found undisturbed and well stocked but threatened by an increasing number of fires in the adjoining areas (DFSC 1998). Kataba Botanical Reserve has not been surveyed due to inaccessibility. Both areas are located relatively far from human settlements.

Despite the difficulties faced in the management of many protected areas, their legal status makes active conservation efforts more likely to succeed than if undertaken outside protected areas.

6.4 Socio-economic aspects

The chief system, which still remains in the western province of Zambia, is a traditional and customary class system of the Lozi tribe, which has continued since the days of the Lozi Kingdom. The Barotse Royal Establishment of Lozi has six senior chiefs, who are under a paramount chief, the Litunga. The senior chiefs are stationed throughout the western province. Under them, sub-chiefs and village headmen are placed to form the hierarchy. The chief system provides guidelines for local community life.

The administrative system is made up of province, district and city. An administration does not exist for the village, and the village headman assumes a substantial part of the responsibility. In this way, western province has a dual constitution of power, so the provincial government cannot disregard the chief system. Usually the village headman deals with various matters in consultation with the sub-chiefs (JICA 1996).

According to the Barotse Royal Establishment of Lozi, which is written law, all fruit-bearing trees are protected. In addition, certain trees including Zambezi teak are protected for their wood.

Regardless of the early conservation efforts, the *Baikiaea* forests are steadily degraded and disappearing. This is mainly due to the increasing population in these areas and failure to involve the local people in the conservation and benefit sharing of the species. In areas with heavy human pressure on the remaining forests it is an imperative to take socio-economic aspects into consideration and as far as possible engage the local communities in the conservation efforts as well as share benefits derived from the forests with the communities.

6.5 Management options and costs

The management measures necessary for a given population depends on the protection status of the area, the size and status of the stand, plus the actual or potential threats. In general, areas that require less costly management should be chosen. Thus, stands found in national parks, wildlife reserves or at gene conservation stations can often be included in a conservation plan as an additional benefit. However, the general status of Zambia's National Parks may call for active conservation measures also for stands found within park boundaries.

Areas where natural regeneration is good should be chosen rather than those were intensive management is required. Likewise, areas under heavy pressure should be avoided, as the conservation is likely to demand large budgets and very strict enforcement in order to succeed.

6.6 Selection of conservation stands

In order to select stands for conservation the status of *B. plurijuga* populations in all zones is reviewed zone by zone below. Based on the available information on population size, legal protection, social aspects, management options and costs, one or more stands in each genecological zone are proposed for conservation.

For some of the genecological zones, information is wanting and further surveys and inventories should be carried out in order to confirm presence, size and status of stands before the final selection for conservation is made.

The final number of stands for which active conservation efforts are to be implemented will depend on available funds and an overall prioritisation of *B. plurijuga* compared to other forest tree species in Zambia. Below one or more stands in each genecological zone have been identified for conservation (see also figure 8).

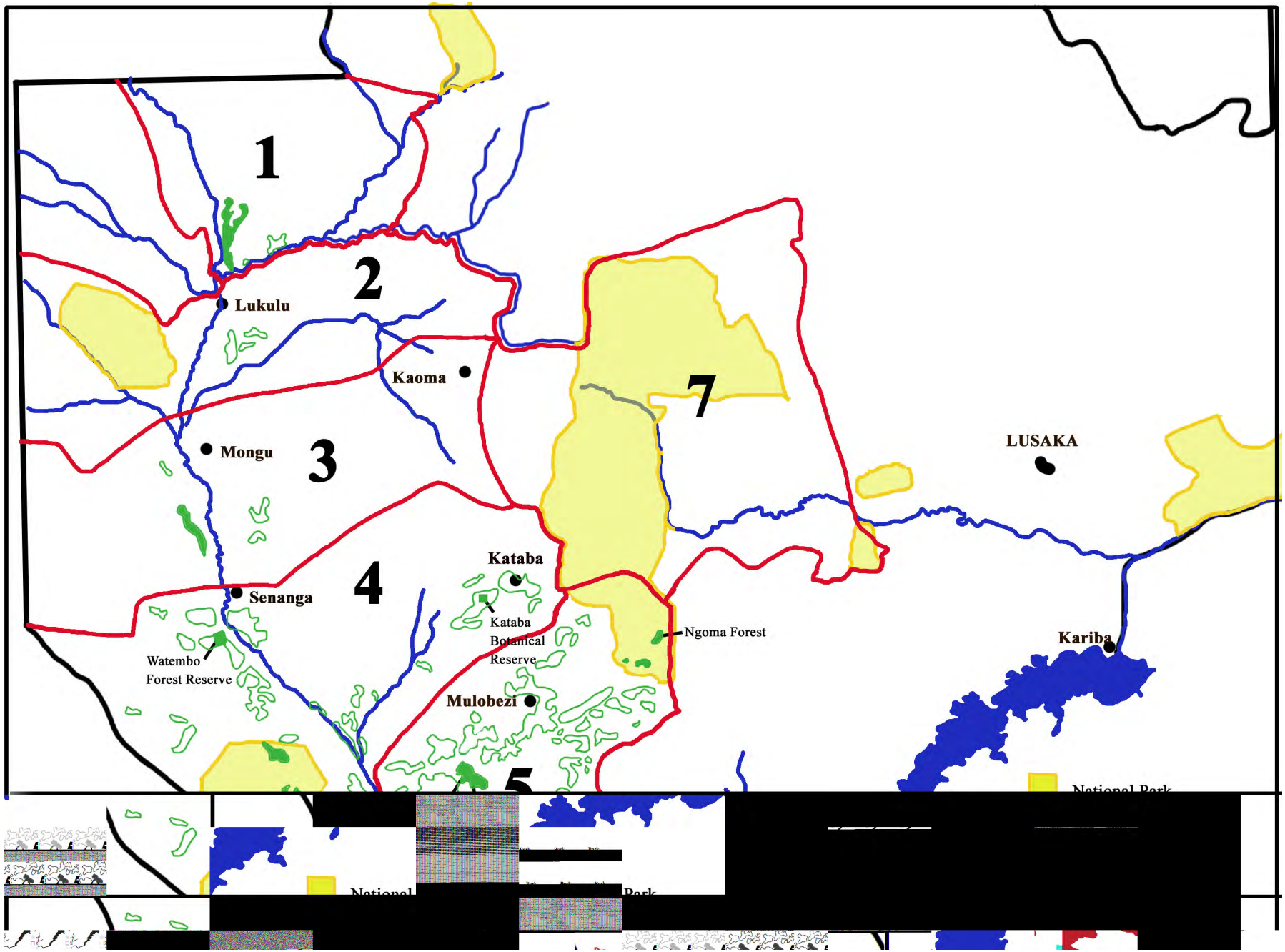

Figure 8. Areas identified for the network of gene conservation stands of Zambezi teak in Zambia.

Zone 1. At least one of the stands north of Lukulu should be protected. These stands are found at the edge of the species range with the highest precipitation (together with stands in Angola). Only stands in agro-ecological zone 3. Selection depending on conservation status. Stands to be assessed by FD.

Zone 2. Stands in Liuwa Plain National Park. To be assessed.

Zone 3. At least one of the stands south of Mongu should be selected depending on conservation status. Stands to be assessed by FD.

Zone 4. Stands in Sioma-Ngwezi National Park. Stands possibly found on eutric gleysoil should be considered for conservation. Watembo Forest Reserve near Senanaga. Kataba Botanical Reserve.

Zone 5. Sikubingwa Forest and Malavwe Botanical Reserve within Masese Forest Reserve. Ngoma forest in Kafue National Park South.

Zone 6. Stands in Mosi-Oa-Tunya National Park. Alternatively stands in Dambwa or Simonga Forest Reserves Livingstone District, though these Forest Reserves are encroached.

Zone 7. Scattered stands in Kafue National Park North. Zambezi teak forest in Nkala Game Management Area east of Kafue National Park. The occurrence and abundance within the northern part of Kafue National Park is unknown and should be assessed.

Based on additional field surveys the final set of populations to be conserved and the conservation measures to apply is made.

7. CONSERVATION MEASURES AND THEIR IMPLEMENTATION

The conservation measures to apply in the selected areas depend on the status of the areas and the threats to the genetic resource. With proper protection and management it should be possible to maintain sufficient natural regeneration of *Baikiaea* in the selected areas. A more ambitious initiative would be to restore closed forest in areas degraded to *Baikiaea* woodlands. Such an activity should be second to protection of the existing stands and is hardly realistic within the nearest future.

Stands within national parks are legally provided full protection from human interference while stands found in forest reserves and protected forest areas normally are subject to licencing for timber extraction (Table 2). The botanical reserves are found within forest reserves under the auspices of Forest Research Division that has the authority to approve intervention.

Table 2. Selected conservation stands and their legal status.

Selected stands within national parks	Selected stands within forest reserves
Liuwa plain	Stands north of Lukulu
Sioma Ngwezi	Stand south of Mongu
Ngoma Forest in Kafue	Watembo near Senanga
Mosi-Oa-Tunya	Kataba Botanical Reserve
Kafue North Malawve	Botanical Reserve
	Sikubingwa near Sesheke

Though stands in national parks and botanical reserves are legally secured, their conservation status should be evaluated in each case and conservation efforts stepped up where required. Management plans for the sustainable use of stands within forest reserves and protected forest areas should be drawn up. This might include setting aside part of the forest to serve as seed source, research- and gene conservation area but in most cases management intervention aimed specifically at conservation may be necessary.

Regarding the management of forest reserves, two different approaches are being considered. Smaller areas far from villages are little disturbed except for timber extraction. The conservation measures in these areas could be early burning and fire protection and enhancement of regeneration by removal of thicket and enrichment planting. For larger areas close to human settlements and under pressure from human use, joint forest management should be considered an option. In most cases vigorous fire protection programmes will have to be put in place, which will require the co-operation of the local people. In return, a benefit-sharing scheme must be established. It is envisaged that income from licences should be put into community funds for schools, clinics, etc. to be administrated by a local committee.

7.1 Joint Forest Management

'Joint Forest Management' means the participation of stakeholders in the sustainable management of forest resources and the sharing of benefits derived therefrom (FD 2000a). A joint forest management area shall be used for a) improved forest resources management at local

level, b) meeting the social, cultural and economic needs of the local community, and c) protection of biological diversity especially endangered plant species and fragile ecosystems.

A forest area intended to be a Joint Forest Management Area shall:

a) not have the status of a National Forest, National Park or National Monument
b) not be less than 2000 ha in size
c) be of socio-economic and ecological importance to the local community
d) be easily accessible to the local community and
e) have a local community population of not less than 100 households.

A Forest Management Committee shall be established to manage the Joint Forest Management Area and distribute the benefits amongst the local communities.

As an example Sikubingwa Forest Reserve has been suggested for JFM. As the Forest Reserve has already been heavily logged, benefits for the community for protecting the forest will have to be derived from concessions in the surrounding forest reserves.

7.1 Sustainable harvest

The current system of felling entails controlled periodic removal of most of the mukusi over a predetermined diameter limit based on field measurements and estimates of volume production. According to the most recent survey carried out by JICA in a 500,000 ha study area between Sesheke and Mulobezi the present cutting is well under the estimated growth rate and it was suggested that the *Baikiaea* forest destruction is due to causes other than cutting (JICA 1996). Frequent forest fires was considered the most important reason for deforestation. However it was recommended to raise the diameter DBH from 30 cm to 40 cm, to assure that adequate seed trees are left after logging. Further, if the number of saplings or young trees is less than 100 per ha, reforestation or enrichment planting in the stand must be carried out. It was concluded that restoration of the extensive (~40%) deforested and degraded lands within the forest reserves was important in sustaining the resources and environmental protection.

In the development of sustainable harvesting systems for Zambian *Baikiaea* forests important lessons might be learned from neighbouring Zimbabwe. Here, 24,000 ha of natural *Baikiaea* forest (Pumula Protected Forest Area in Matabeleland North) has been certified by Forest Stewardship Council (FSC) as sustainably managed. On the basis of inventory results, assumptions were made regarding total increment. Harvesting is based on a minimum DBH of 31 cm and a maximum annual allowable cut that should not exceed total increment. A number of seed trees above the diameter limit are retained in each hectare as a seed source. In addition, social aspects like land tenure, employee welfare and community relations are also considered in the certification. Timber committees, comprising community members, were established in 1999, when the district council's commitment to pay 15% of timber royalties directly to local communities was implemented. Timber committees have an integral role in the management operations in the forest. They act as custodians of royalties, facilitators of meetings and of grievance procedures. No illegal timber harvesting and poaching has been reported since the formation of the committees. The direct income for local communities and formal consultation structures have resulted in support by local people for conservation of the forest resources. Thus, local people now actively protect the forest (Qualifor 2000).

In Zambia, assessment of stocking and distribution to size classes of mukusi in Sikubingwa, Malawve and Watembo have already been undertaken (Sekeli 2000). These assessments will contribute to the development of practical management guidelines for the conservation areas.

7.2 Fire management

For most of the selected conservation areas a fire protection programme would be essential for continued survival and natural regeneration. This is probably as much the case for stands in national parks as for those found in forest reserves.

A fire protection scheme might include measures such as clearing of fire lines, early burning, removal of thicket, some kind of grazing and trampling by cattle or game in addition to some kind of awareness programme among local people. Fires spread unintentionally by hunters, honey gatherers and slash and burn should be minimised. Where an area is subject to logging, practices might have to be altered not to leave excessive inflammable debris.

In many areas early burnings are not necessary every year but rather every third year or so (Sekeli pers. comm.). There might be a need to evaluate the early burning system at present used in the management of forest reserves as follow-up surveys conducted in Kalama forest and Samatela woodland showed that seedlings of mukusi and mukwa *(Cryptosepalum exfoliatum)* were damaged and withered after early burnings (JICA 1996). Furthermore, there is a concern that with present staffing early burnings cannot be expected to be well controlled. In areas suffering from constant fires the benefits of early burning has to be scientifically documented.

7.3 Effect of grazing

Domestic stock or game ranching has the threefold purpose of reducing fire hazard by eating grassy fuel, producing meat and promoting regeneration of desirable species by trampling down seed and by eating competitors. Stock can be moved around readily, but has the drawback of total number being dependant upon poor-year carrying capacity and available water (Calvert 1986b). Game ranching poses some difficulties but it has high economic value from direct use by safaris, trophy hunting and/or sustained yield meat production, or indirectly via public amenity and recreation. More research is needed to elucidate the effect and importance of mammals on seed dispersal and regeneration of Zambezi teak.

7.4 Implementation and monitoring

Implementation will comprise the following activities:

1. Long-term planning of activities, and budgeting.
2. Survey of remaining candidate stands to make final selection of the populations to be included in the conservation plan.
3. Decision of conservation measures to be taken including consideration of local stakeholders.
4. Management and monitoring of conservation stands.

Monitoring consists of regular inspections and less frequent thorough assessments. The local forest offices as part of their ordinary services should do inspections. It is recommended that FD takes part in more thorough assessments every fifth year. General guidelines for such assessment are provided by DFSC (1998). In areas where local people's participation is essential, they should be involved in the monitoring too. Seeing and documenting the effect of one's conservation efforts is usually a good incentive for continuous commitment.

CONSERVATION OF GENETIC RESOURCES OF *BAIKIAEA PLURIJUGA* IN ZAMBIA

Site 1. Stands north of Lukulu

Genecological zone: 1

Site selection and history*:*

Size of area:

Demarcation and maintenance*:*

Conservation status*:*

Threats*:*

Not yet inspected

Site 2. Likonge National Forest

Genecological zone*:* 3

Site selection and history: From surveys undertaken in both Likonge National Forest and Kaoma Local Forest, only one part of Likonge National Forest was found to contain good stocks of *Baikiaea plurijuga*. This area also contained stocks of two other threatened hardwoods *Guibourtia coleosperma* and *Pterocarpus angolensis*. The area appears to be logged about 30 years ago.

Size of area: 50 x 50 meters (0.25 ha).

Demarcation and maintenance:

Conservation status: Present conservation status is good. The stand was found to have very good regeneration and seems to be well protected from fires as it is far away from communities.The stocking for *B. plurijuga* was 332 stems per ha in the selected plot.

Threats: Wood consumption rate was found to be increasing fast in Western Province due to increase in investors from South Africa. Western Province has the highest number of forest concession licences in the country. The number of trees cut through licencing was 3,556 in 1998 and had risen to 49,917 in year 2000. *B. plurijuga* accounted for about 30% of the cut timber. The current exploitation levels are not commensurate with the growth rate of *B. plurijuga*. There has also been a sharp increase in the illegal exploitation of timber in the Province.

Inspected by: P.M. Sekeli in 2000.

Site 3. Kataba Botanical Reserve

Genecological zone: 4

Site selection and history: Kataba Botanical Reserve was established in 1973. It is a rectangular block of 4 ha sited in the centre of the northern block of Katabe Forest immediately south of the main railway line extension, 8 km from the main Kataba camp in Sesheke district. The area is gently undulating with a slight slope on the south boundary towards the head of a dambo (grassy flood plain), which runs to the Likabula plain. It was left untouched when Zambezi Sawmills exploited Kataba Forest in 1959-61.

Size of area: 4 ha.

Demarcation and maintenance: There is no accessible road to Kataba Botanical Reserve and it has not been visited since 1980.

Conservation measures: Katabe Botanical Reserve is a small area far from human settlements and it is not believed to be under immediate threat. However, fire protection should be carried out as part of the fire protection scheme for the forest reserve.

Threats: The main threat is degradation due to uncontrolled fires.

Recommendations: Kataba Botanical Reserve should be inspected and surveyed in order to assess the need for active conservation measures.

Inspected by: Kataba Botanical Reserve was surveyed in 1980 and the results published by Malaya in 1986.

Site 4. Watembo

Genecological zone: 4

Site selection and history: Watembo Forest Reserve covers 8600 ha and is located in Senanga District. Zambezi Sawmills was granted licences for logging in 1971-1974. Several villages including Sitoti, Kalengola, Sioma, Likondwana are located close to the boundaries of the forest reserve. In 1984 locals applied for permit to use part of the forest reserve for agriculture. Many paths are leading into the forest showing a comprehensive use of the forest by locals and conflicts have arisen between locals and forest authorities with respect to collection of firewood and poles.

In 1998, 10 ha. were demarcated in Watembo by Forest Research Division and DFSC to be included in the network of in situ conservation areas of Zambezi teak.

Size of area: 10 ha

Demarcation and maintenance: As interim measure the area was demarcated by poles. A clean trace about 3 m wide should be cleared round the plot. Villagers to be informed about the conservation project.

Conservation status: Watembo was recommended for conservation by the local forest office due to its relatively good conservation status and according to FD the area has not yet been encroached upon by farmers (FD 2000b). However, logging followed by recurrent fires has degraded the forest, which is open *Baikiaea* forest with a crown cover of less than 15%. The locals from nearby villages use the forest for collection of fire wood, poles and bark in addition to grazing. At present little or no regeneration of *Baikiaea* takes place.

The stocking is low in regard to commercial timber extraction. A stratified sampling covering areas with highest stocking showed about 50 individuals/ha. No seedlings and very few saplings were recorded in 5 plots of 30 x 50 metres (DFSC unpublished data).

Threats: Uncontrolled fires and some cutting.

Recommendations: Watembo is located close to several villages and is at present used by the villagers for firewood collection, grazing, collection of bark, gathering of honey, etc. It is being considered a potential area for Joint Forest Management. Regeneration should be closely monitored and possibly actively enhanced. A fire awareness/protection programme is essential for the natural regeneration and rehabilitation of the Watembo forest.

Inspected by: Sekeli, Mulongwe, Canger & Larsen, 1997.

Site 5. Malavwe Botanical Reserve

Genecological zone: 5

Site selection and history: In 1973 FAO's Forestry Department assisted the Forestry Department of Zambia in demarcation and establishment of two botanical reserves for the in situ conservation of Zambezi teak. The reserves established under the FAO/UNEP Project on Conservation of Forest Gene Resources, are located at Malavwe and Katabe (FAO/UNEP 1985). They were the first reserves in the world to be established with the specific objective of in situ conservation of intraspecific genetic variation of a tree species. The site was selected as a conservation area because there had been no exploitation since 1940, and because the area contains a high proportion of mature *Baikiaea* trees. The conservation area occupies a typically flat area on well-drained Kalahari sand.

Size of area: 16 ha, though 31.6 ha according to FD list 2000.

Demarcation and maintenance: A clean trace about 3 m wide has been cleared round the plot. The forest station is conveniently located should fire-fighting teams be required although it is uncertain whether they are still operational.

Conservation status: Malavwe Botanical Reserve is situated quite far from human settlements and the area is subject to relatively low pressure from local people. In the villages located near the Malavwe Botanical Reserve the sawmill activities stopped some years ago and the main type of land use is now agricultural production outside the buffer zone of the reserve. In general, the relationship between the Forest Estates and the villagers has not been close. The custom of forest being burned by villagers has led to considerable destruction around the Botanical Reserve. The occurrence of forest fires has been especially pronounced in recent years hindering regeneration of forest (DFSC 1998).

The effective population size is high within the conservation area due to the fact that it is part of a larger area with Zambezi teak and it is sufficient from a genetic point of view. The germination from seed (0-5 cm class) is very high, but there is very little stocking of the next size-class. This is possible due to almost 100 percent crown cover, low ability for mukusi seedlings to compete for water resources and high density of rodents.

A comparison of the surveys of 1980 and 1997 showed increased stocking of diameter size classes above 30 cm (DFSC 1998).

Threats: The main threat is uncontrolled fires.

Inspected by: Wood, Meki, Zulu, Mulowa 1979. Malaya 1980. Larsen, Sekeli, Graudal, Mulongwe, Kalonga 1997.

Site 6. Ngoma Forest in Kafue National Park

Genecological zone: *5*

Site selection and history*:* The Kafue National Park covers an area of approximately 22,500 square kilometres which spread into part of central, southern and north-western provinces of Zambia. Situated on a plateau, Kafue has an elevation ranging between 900 and 1,000 metres above see level. The terrain is flat to gently undulating with some hills, situated along the mid reaches of the Kafue river and its two main tributaries, the Lufupa and Lunga, which flow into the park from the north. There is a perennial swamp in the extreme north-west, which drains into the Lufupa. Karoo sediments occur in the centre and north-east with Kalahari sands forming the underlying geology in the west (WCMC 2000b).

The vegetation in the south is mainly miombo or *Brachystegia* dominated woodland with areas of mopane *Colophospermum mopane*. In the north, the miombo-termitarian woodland surrounds areas of open grassy flood plains or 'dambos'. Patches of Zambezi teak such as the Ngoma Forest occur throughout, but are more common in the south.

Site area*:* 22,500 square kilometres of which Ngoma Forest covers an unknown area.

Conservation measures*:* To reinforce the protection and management of the park especially in the southern part where the main *Baikiaea* stands are found.

Threats: Uncontrolled bush fires occur in the park (WCMC 2000b).

Recommendations*:* To survey the occurrence of Zambezi teak throughout Kafue National Park. Undertake a proper survey of Zambezi teak in Ngoma Forest. Assess the need for active conservation measures.

Inspected by*:* Ngoma Forest was visited by a joint DFSC/FD team in 1998. The scattered stands throughout the park has not been surveyed.

Sites remaining to be inspected:

Site 7. Sikubingwa

Genecological zone: 5

Site selection and history: Sikubingwa is within the Masese Forest Reserve, which is situated north-east of Sesheke. 10 ha was selected and demarcated in Sikubingwa by Forest Research Division and DFSC in 1998 to be included in the network of in situ conservation areas of Zambezi teak.

Size of area: 10 ha

Conservation status: An estimated 80% of the area is covered by forest of medium sized mukusi trees and few other upper storey trees. Crown cover in forested parts is approximately 60%. A plot located in the south-eastern corner of the demarcated *in situ* conservation area showed 220 stems/ha and 36 % stems above 30 DBH (Sekeli 2000). The area has been quite heavily logged and the stocking is too low for any commercial timber extraction to take place. As interim measures the area (250m x450 m) was demarcated by poles at a spacing of 100 m and by yellow paint on bordering trees. A clean trace about 3 m wide should be cleared round the plot.

Threats: The main risk is uncontrolled fires.

Recommendations: Sikubingwa forest is located quite close to several villages. At present it is considered as a potential area for Joint Forest Management. The area has been quite heavily logged and the stocking is too low for any timber extraction to take place. It is discussed whether benefits from concessions in surrounding areas should be funnelled to the communities near Sikubingwa until the area is restored and hopefully a limited harvest of *Baikiaea* can be resumed.

Inspected by: (Sekeli, Mulongwe, Canger & Larsen, 1997)

Stands north of Lukulu (genecological zone 1)
Liuwa Pain National Park (genecological zone 2)
Sioma Ngwezi National Park (genecological zone 4)
Mosi-Oa-Tunya National Park (genecological zone 6)
Kafue North National Park (genecological zone 7)

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