# A REVIEW OF FOREST BIODIVERSITY RESEARCH IN AFRICA

**A.J. Pottinger & J. Burley**

*Oxford Forestry Institute, South Parks Road, Oxford OX1 3RB, United Kingdom*

*Received November 1992*

**POTTINGER, A.J. & BURLEY, J. 1992. A review of forest biodiversity research in Africa.** A brief history of the development of the vegetation of Africa is given illustrating current patterns of forest cover. The biodiversity value of the continent's forests is then discussed in terms of species richness and endemism. Threats facing Africa's forests are outlined followed by a discussion of current research initiatives aimed at studying and conserving biodiversity in Africa. Subjects covered are forest management; taxonomic studies and the role of herbaria; the role of botanic gardens; climate change; studies of genetic variation; and socio-economic studies and non-timber forest products. The final discussion focuses on where future research should concentrate and the factors governing success at conserving forest biodiversity on the continent.

Key words: Africa - vegetation - development - biodiversity - conservation - research - current - future

**POTTINGER, A.J. & BURLEY, J. 1992. Ulasan mengenai penyelidikan biodiversiti hutan di Afrika.** Sejarah ringkas perkembangan tumbuhan di Afrika yang menjelaskan corak hutan semasa diberikan. Nilai biodiversiti hutan benua ini dibincangkan dari segi kekayaan spesies dan keendemikannya. Ancaman yang dihadapi oleh hutan-hutan di Afrika dinyatakan diikuti oleh perbincangan mengenai inisiatif-inisiatif penyelidikan semasa yang bertujuan untuk mengkaji dan memelihara biodiversiti hutan di Afrika. Perkara-perkara yang dibincangkan ialah pengurusan perhutanan, kajian taksonomi dan peranan herbaria, peranan tanaman botani, perubahan cuaca, kajian mengenai perbezaan genetik dan kajian sosio-ekonomi dan keluaran hutan bukan kayu. Perbincangan akhir memberi fokus kepada arah mana penyelidikan perlu diberi penekanan dan faktor-faktor yang mempengaruhi kejayaan pemeliharaan biodiversiti hutan di benua ini.

## A brief history of vegetation changes in Africa

The climatic history of Africa has produced a more diverse flora than that in any equivalent area (White 1983), yet the total number of species present is lower than comparable regions in other parts of the world, notably South America and South-East Asia. It is estimated that the number of higher plant species present in Africa is between 40,000 and 45,000, while approximately 85,000 species are present from Mexico through South America, and 50,000 in tropical and sub-tropical Asia [(World Conservation Monitoring Centre (WCMC) 1992)]. Despite this, tropical Africa is much better known botanically than other tropical regions (Synott personal communication).

Although precise details of changes in Africa's vegetation cover are difficult to ascertain, it is generally agreed that the whole of the continent has undergone major climatic fluctuations in the past which have both greatly influenced the

vegetation patterns in evidence today and limited botanical speciation in comparison with other regions of the world. Cronk (1992) suggested the early Late Miocene (10 Myr BP) as a time when Africa, which previously had been almost completely covered in tropical and sub-tropical humid forest, first began to develop grassland, desert and maccia. Since then, the continent has experienced periods of being both warmer and wetter, and cooler and drier than at present and vegetation boundaries have advanced and retreated in response. At various times tropical forests have stretched in a wide belt from Guinea in the west to Kenya in the east during warm and wet periods and then been forced into retreat by increasing aridity which has linked the Sahara to the Kalahari (Kingdon 1990). In comparison with the timescale of such vegetation changes, the impact of human populations upon Africa's biological diversity has been relatively recent.

## Forest types

The current major forest types present in Africa can be divided into the following:

- a band of evergreen sclerophyllous forest running along part of the North African border of the Mediterranean Sea;
- a large area of tropical dry forest and woodland stretching from the Sahel to the Cape;
- a belt of tropical humid forest leading from Guinea in the west through to the mountainous borders of Zaire in the east, and down through Cameroon, Gabon and the Congo into southern Zaire, plus a strip running down the eastern side of Madagascar;
- various disjunct areas of montane forest.

## Biological diversity in Africa's forests

On a global scale, African countries do not contain the diversity of plant species evident in some other countries, for example, Brazil, Colombia, China and Mexico (WCMC 1992); however, it is assumed that past periods of increasing aridity with consequent retreats of forest boundaries led to the development of various Pleiostocene forest refugia within which major speciation, through long-term isolation, has taken place. The climatic history of the continent has therefore been responsible for producing a number of biologically rich centres of endemism. White's (1983) "Vegetation Map of Africa", identifies ten Regional Centres of Endemism, or phytochoria, defined on the basis that a phytochorion has both more than 50% of its species confined to it and a total of more than 1000 endemic species. These centres of endemism are linked by transition zones representing a gradual replacement of one flora by another. The phytochoria that include major areas of forest are as follows:

- Guinean-Congolean: including the richest tropical rain forests in Africa in terms of tree species;
- Zambezian: covering the widest range of vegetation types in Africa but dominated by miombo woodland;

- Cape: fragmented forest cover (Geldenhuys & MacDevette 1989);
- Afromontane: containing a variety of forest types;
- East Malagasy : humid and evergreen forest.

Several attempts have been made to classify higher plant biodiversity value in Africa, the most significant of which have employed centres of endemism to a varying extent. The results of the more comprehensive of these are outlined below:

- Myers (1988, 1990) identified 14 tropical forest areas and 4 Mediterranean-type areas worldwide containing high levels of species endemism which appeared to be under threat of habitat modification. Four of these sites were situated in Africa.
- Kingdon's (1990) detailed study of "islands of endemism" within Africa provided a view of priority areas for conservation based on the presence of rare and endemic species of plants, birds and mammals.
- The most comprehensive attempt to classify areas of higher plant endemism has recently been undertaken by the IUCN (International Union for the Conservation of Nature and Natural Resources) Plant Conservation Programme. This major international collaborative project has identified 250 sites worldwide which, if protected, would safeguard the majority of the world's wild plants. All of the sites included in the survey contained more than 1000 species, of which more than 100 were endemic or restricted to that phytogeographic region [IUCN-WWF (Worldwide Fund for Nature) in preparation]. Of the 32 sites identified in Africa, 31 include forest areas.

All these studies have dealt with higher plants; however, as far as conservation priorities are concerned, it is a site's overall biodiversity value in terms of different taxa that is likely to win international recognition and hence financial support. In this respect a combination of studies covering different taxonomic groups for all sites provides the strongest foundation for assessing biodiversity values and subsequently setting priorities. Unfortunately, attempts at making more thorough biodiversity assessments are hampered by a lack of data for different taxa on common sites. The notable exception to this is the study by the International Council for Bird Preservation (Bibby *et al*. 1992). By cataloguing Endemic Bird Areas (EBAs) worldwide they produced a list of sites in Africa of particular importance to birds with limited ranges, many of which coincided with IUCN centres of plant diversity. Furthermore, they concluded that the principal habitat used by birds in the EBAs was forest and, within this, tropical montane forests were particularly important.

Species endemism is, however, only one approach to assessing biodiversity values, and although a particularly useful one in the African context, should not be viewed in isolation. The diversity of species within a defined area, itself a much overused measure of biodiversity value, can be useful in highlighting the value of habitats containing common but well distributed taxa, a situation commonly found in tropical forests. The IUCN (Stuart & Adams 1990) classification of African forest areas in particular need of conservation used this dual approach by

looking at levels of endemism and species diversity of several taxa coupled with an assessment of threat to the area, and produced a list of sites within Africa of particular need of conservation on grounds of their biological diversity.

If the results of all of these studies are combined, an overview of forest areas of particularly high biodiversity importance in Africa can be produced (Table 1).

**Table 1.** Forest areas in Africa of particularly high biodiversity value
[Compiled from IUCN (Stuart & Adams 1990); Kingdon 1990; Myers 1988, 1990; Sheil 1992]

| Forest type | Forest area | Country |
|---|---|---|
| Tropical dry forest | Cape region | South Africa |
| | Somali-Masai region | Djibouti, Somalia, Ethiopia, Sudan, Kenya, Uganda, Tanzania |
| | Zambezian region | Zambia, Zimbabwe, Malawi, Angola, Mozambique, Tanzania, Namibia, Botswana, South Africa |
| Tropical rainforest | East Madagascar | |
| | Guinean rainforests | Ivory Coast |
| | Congolean rainforests | Cameroon, Gabon, Congo, Central African Republic, Zaire |
| Montane forest | Cameroon highlands | Cameroon |
| | Eastern Arc mountains | Tanzania |
| | Guinean forest block | Guinea, Liberia, Ivory Coast |
| | Ethiopian highlands | Ethiopia |
| | Albertine Rift highlands | Eastern Zaire, western Uganda, Rwanda, Burundi into western Tanzania |
| | Uluguru-Mulanje | Eastern Tanzania to northern Malawi |
| | Angolan highlands | Angola |
| | Drakensberg mountains | South Africa |
| Coastal forest | Tanzanian coastal forest | Tanzania |
| | Kenyan coastal forest* | Kenya |

* Hamilton personal communication

## Changes in Africa's forest cover and current threats to forest biodiversity

As in other tropical areas, the last century has borne witness to the most rapid transformation in Africa's tropical forest cover. With the exception of the Congo basin and some areas in West Africa, intact tropical moist forest has been reduced to relatively small areas (Botkin & Talbot 1992), while less humid regions have suffered equally (Skoupy 1991). Although current deforestation rates vary widely over the continent, influenced by factors such as population pressure, accessibility and amount of forest cover remaining (Barnes 1990, WCMC 1992), there is no doubt that the general picture is one of a natural forest resource that is severely threatened, and the situation is worsening rapidly as time passes.

Threats to the biological diversity of the forest also vary depending on a combination of the historical use of the forest, current land pressures and the degree of protection bestowed on the forest. For example, commercial logging practices, both illegal and legal, have severely reduced the genetic diversity present in many timber species. The extent of the protected area system, including national parks, nature reserves, hunting reserves, *et cetera*, covering forests in each country in Africa varies enormously (WCMC 1992) and is illustrated in detail in Sayer *et al.* (1992). The consensus of the authors who provided information for the compilation of Table 1 is that the threats to these areas must be recognised as a matter of urgency and effective measures of protection put in place if the biodiversity they contain is to be adequately conserved.

## Current research in forest biodiversity in Africa

### *Forest management*

Management practices have a significant effect on the level of biological diversity maintained within African forests. While many traditional systems of forest use have always attempted to use multiple resources in a sustainable manner, more recent industrial approaches have generally focused upon extraction of particular species of economic value, frequently severely depleting its genetic diversity if not removing it from the forest altogether. The value of maintaining forest biodiversity is, however, becoming increasingly recognized by forest managers in Africa and management plans that aim either to manage forests with biodiversity as a key objective or to re-establish previous levels of species diversity are becoming more common.

Approaches to management aimed specifically at conserving biological diversity are currently being formulated for the following forest areas: the coastal forests of Kenya, through collaboration between WWF, the British Overseas Development Agency (ODA) and the National Museum of Kenya; in Tanzania's coastal forests, with funding from WWF; the Gola Rain Forests in eastern Sierra Leone, with assistance from the Royal Society for the Protection of Birds (RSPB); Cameroon, where two new rain forest conservation reserves are being established under the joint Government of Cameroon-ODA forestry initiative; and in Kenya, where three pilot forests, chosen for their ecologically and socially contrasting situations, will be used to investigate different approaches to forest conservation, with financial support from ODA. The Man and the Biosphere programme, operated by UNESCO (United Nations Education, Scientific and Cultural Organisation), is also involved in several projects investigating the conservation of forest biodiversity in association with improvement of the standard of living of local populations. They will be the executive agency for a group of six proposed conservation and sustainable development projects within Biosphere Reserves and National Parks in African forests, organised jointly with the national governments of the countries concerned (Semple personal communication).

Investigations into the ability of dry forests to meet the timber needs of rural populations in Africa have suffered in the recent past from an emphasis on establishing village woodlots of exotic species. Interest is, however, increasing in exploring the potential of indigenous dry forests, with their diverse range of species, to both assist in conservation and provide a much wider range of products than a single species woodlot. An example of this approach is an ODA- funded project in Malawi looking at approaches to management of the native miombo woodlands (Werren personal communication).

The influences of current forestry practices upon the levels of biodiversity are being assessed in many countries. Within the forest reserves of Ghana the Department of Forestry is currently able to build on their detailed knowledge of forest types and species composition to monitor intensively, through permanent sample plots, changes in species composition and stand dynamics of both timber trees and those plants which provide non-timber forest products. Computer models predicting growth and yield have been produced with the aim of yield allocation within an overall objective of maintaining species diversity (Ghartey personal communication).

Studies of the influence of timber extraction methods on biodiversity and approaches to sustainable methods are either completed, underway or due to start soon in Gabon (White 1992), Cameroon (Wainwright personal communication ) and Ghana (Adjei-Kusi personal communication).

The protection of forest reserves depends heavily on the land use practices in the areas surrounding the reserves and the consequent pressure that rural populations put on protected forests. Although the potential value of maintaining buffer zones around protected forest areas for the provision of forest products, both timber and non-timber, is well accepted, as Sayer (1991) pointed out it is not always possible to achieve in practice. Shepherd (1992), in her review of management approaches to Africa's dry forest, emphasized the crucial relationship that needs to develop between foresters and villagers in moving away from excluding people from woodlands adjacent from their homes to a greater involvement in management of the resource. She concluded that the starting point of good forest management is the recognition of the needs and interests of local people, including an understanding of local tenure systems, along with an appreciation of local knowledge of forest management. Such an approach has been adopted by WWF in the Korup National Park in Cameroon, and the adjoining Cross Rivers State Forest in Nigeria, where they (as the implementing agency in an ODA-funded project) have sought the involvement of local villagers in the formulation of forest management plans (Wicks personal communication). The objective is that the Park will form an integral component of regional development plans to support forest utilization, the use of indigenous forest products and agricultural development (Train 1991). The need to integrate local people into forest management of areas surrounding forest reserves in order to safeguard their future has also been recognized by the ODA-funded "Forest inventory and management project" in Ghana. In this programme, a participatory management system for forest areas outside the reserve is currently being investigated in order to reduce pressure on

the remaining forest (Nolan & Ghartey in press).

The potential of agroforestry in buffer zones to provide products that will in turn relieve pressure on forest reserves is currently being investigated in Cameroon, supported by EEC and ODA, and in Sao Tomé as part of IUCN's programme for the sustainable utilization of rainforest resources (Jones personal communication). The RSPB is also looking at buffer zone management by financing a socio-economic survey of the needs and aspirations of the rural communities around the mountain forests of the Uluguru mountains in eastern Tanzania in an attempt to reduce pressure on the forests famed for their high levels of endemism (Burgess personal communication).

### *Inventory, taxonomy and herbaria*

From a botanical perspective, Africa is the best documented region in the tropics. This can be accounted for partly by the fact that the period of colonization by European powers coincided with a great interest in classification of the natural world, and also to the early instigation of plant inventories by the newly establishing forestry departments set up by the colonial powers. These early attempts at classification, although valuable at the time, have since been superseded by the combined efforts of generations of taxonomists in the production of more detailed and comprehensive works.

Examples of initial floristic inventories currently being undertaken prior to compilation of management plans are: in southeast Zimbabwe's medium altitude rainforest (Forest Research Centre and ODA); the humid forests in Guinea (Direction National des Forêts et Chasses, World Bank and Kreditanstalt für Weideraufbau); in Kenya's indigenous forests (ODA and National Museums of Kenya); and various areas in Cameroon including Mount Cameroon and Mount Kilum (Cameroon Government and various agencies including ODA, TROPENBOS, WWF and ICBP).

One of the most advanced programmes of documentation of forest floras has been undertaken in Ghana where conservation is high on the agenda (Hall & Swaine 1981, Hawthorne 1992). Species distributions, forest structures and protected areas have been documented to varying extents, and current work is being supported by a 5-year initiative, funded by ODA. Computerization of inventory data and assigning of biodiversity values to forest trees based on their ecology, taxonomy and distribution value on a local and regional basis has subsequently been achieved (Hawthorne 1992). Through this work it is now possible to group values for communities thereby producing indications of biodiversity hotspots.

Computerization of inventories is also underway in Uganda where attempts are being made to compile a "National Biodiversity Data Bank" (Pomeroy personal communication). When completed, it will contain substantial quantities of data on birds, mammals and trees mainly in protected areas, with particular reference to forests.

Classification of Africa's flora has led to the production of four different types of publication: regional floras, national floras, monographic studies, and regional checklists. However, the comprehensiveness of documentation and stage of completion of each varies substantially throughout the continent.

The main herbaria that have taken leading roles in the compilation of African flora (in addition to African national institutions) are: the Royal Botanic Gardens, Kew (RBG); Muséum National d'Histoire Naturelle, Paris (P); Université Libre de Bruxelles (BRLU); Herbarium Vadense, Wageningen (WAG); Instituto de Investigaçao Científica Tropical, Lisbon (LISC); and the Botanical Museum, Uppsala (UPS).

The RBG, Kew is currently involved in the production of regional floras, whose boundaries are those demarcating major phytogeographic regions, for the area covering Botswana, Malawi, Mozambique, Zambia and Zimbabwe (Flora Zambesiaca), and for east Africa (Flora of Tropical East Africa), which are both expected to be completed this decade (Kew 1991). Once finished, they will accompany the Flora of Tropical West Africa which was published between 1954 and 1972 and covers the whole tropical region from Senegal to West Cameroon.

Projects to compile national floras are underway in many countries (for example, Gabon and Cameroon coordinated by P; Zaire coordinated by BRLU; and Ethiopia and Somalia coordinated by UPS). These have sometimes followed on from work initiated in the compilation of regional floras. In general, detailed taxonomic studies are further advanced in anglophone regions of Africa (for example, Nigeria and Ghana) in comparison with French speaking areas, where some significant gaps are evident (for example, the Central African Republic). Many of the national floras are particularly strong with regard to woody species, reflecting the traditional involvement that foresters have had in classifying forest vegetation in Africa.

Monographic studies have been compiled for many taxa containing woody species in Africa (for example, *Crotalaria* - Polhill 1982; *Tabernaemontana* - Leeuwenberg 1991), and contain the most detailed descriptions and keys available.

Species checklists are available in most countries compiled by organizations ranging from the national forest authority to interested amateurs and provide, for many, the most accessible form of plant identification and classification. As such, their value to the non-scientific community in encouraging interest and understanding of forests should not be underestimated.

A complete list of floras and published checklists for each country is provided by Davis *et al.* (1986).

Taxonomic work can be supported most efficiently if there is a strong national herbarium. In Africa, many of these were established by forestry departments and consequently have a good representation of specimens of forest trees and plants. Two of Africa's major herbaria are found in South Africa: the National Herbarium of South Africa, in Pretoria, and the Herbarium of Kirstenbosch Botanic Gardens in Cape Town; the continent's other important herbaria include those in Nairobi (Kenya), Harare (Zimbabwe), Yaoundé (Cameroon) and Ibadan (Nigeria).

Although during their early years many herbaria played an important role in the management of forests, the general trend since then has been one of gradual decline. Many have suffered from a lack of funding and are in need of financial support in order to fulfill their essential role in biodiversity research and conservation. Funds are required specifically for the renovation of buildings, supplies and improvement of storage facilities, and for the training and support of staff.

The International Diploma Course in Herbarium Techniques held at Kew, through its significant intake of students from Africa, is assisting in meeting the need for maintenance and development of local and regional herbaria. Kew is also currently involved in a joint programme with the National Museums of Kenya to assist in building on the expertise and experience already available in the East African Herbarium for biodiversity research.

Improvements to herbarium management through computerization of specimen records have recently been made possible through the production of the OFI-produced database BRAHMS (Botanical Research And Herbarium Management System: Filer 1992). This will not only enable all data from plant specimen labels to be easily stored and retrieved, but will also be able to produce species distribution maps and checklists for countries, regions or small areas that could be of direct value in assessing threats to biodiversity posed by changes in land use. Furthermore, such information will be of use to seed collectors attempting to sample natural ranges for *ex situ* conservation purposes. Plans are currently underway to install BRAHMS in the National Herbarium of Zimbabwe, which is not only the major herbarium for the greater part of the SADCC region but also the principal herbarium for the compilation of the Flora Zambesiaca. Furthermore, a proposed merging of computerized information involving records stored at the National Herbarium of Zimbabwe and the National Herbarium of South Africa will soon produce a comprehensive floristic account of the entire southern African region.

### *Botanic gardens*

Botanic gardens should be seen as natural resource centres for education, conservation and research related to biodiversity. Their collections have a vital role to play in providing a living representation of a country's flora for the benefit of scientists and general public alike and could form links between conservation and utilization of plant genetic resources. In this respect they play a complementary role to herbaria, and the development of each greatly benefits the other.

There are 82 botanic gardens in Africa and surrounding oceanic islands. With the notable exception of South Africa, where the well-developed network of 17 botanic gardens covers a high proportion of the native flora of the region, most have experienced a decline in funding since the colonial period similar to that encountered by many herbaria. Unfortunately, funding for their rehabilitation has usually not been considered a high priority either within the country or by outside donors.

There are some success stories, however, particularly in the oceanic islands of the Indian Ocean. Perhaps the most notable of these is the newly established botanic

garden in Reunion where approximately 60% of the endangered flora of the island has been successfully established within the past three years. Unfortunately, most gardens' attempts to rehabilitate their collections are severely hampered by lack of funds. Two botanic gardens where this problem is currently being addressed and restructuring is underway are Limbe, in Cameroon (with support from ODA), and Tsimbazaza, in Madagascar (through the assistance of Missouri Botanic Garden and RBG, Kew), but there are many other gardens in equal need of assistance in order to support their efforts to make a significant contribution to the conservation of biodiversity. Key areas of support include institution building, technical cooperation and training and support for staff. The highest priority gardens to receive such support, based on their location and representation of material, include: Kisantu (Zaire), Amani (Tanzania), Zomba (Malawi) and Harare (Zimbabwe).

The Botanic Gardens Conservation International (BGCI) has taken a leading role in coordinating information on current developments in African botanic Gardens through both their work and their annual publication, "Tropical African Botanic Gardens Bulletin", which is sent to all African botanic gardens and a further 300 around the world.

## *Climate change*

The general scientific consensus that global climatic changes, resulting from increased emissions of greenhouse gases, will alter patterns of rainfall and temperature regimes worldwide means the potential implications for African forest ecosystems need to be assessed. However, due to uncertainties in the variables involved, resulting largely from the lack of detailed knowledge available, no clear picture has emerged (Western 1991). Despite this, the currently available information does point towards certain trends likely in climatic patterns and what their significance may be.

Different predictive models of global warming have been suggested based on certain rises in $CO_2$, and various rainfall and temperature regimes, and, although the resulting scenarios are varied, all indicate that significant changes in the amount and type of forest cover in Africa are expected in the next century. Studies carried out by the US Environment Protection Agency (Anonymous 1990), comparing different models of climate change and mapping the resulting borders of the main vegetation types, and those of Magadza (1991), both predicted that the areas particularly susceptible to changes in vegetation cover following climatic changes were those currently experiencing semi-arid conditions. While the extent of area able to sustain tropical rainforest is not expected to be greatly influenced by changes in temperature and rainfall, it is expected that increasing aridity in other regions will lead to replacement of less humid forests by dry forests, and dry forests by savanna. This will be in addition to the changes already encountered due to the dry period that many regions in Africa have suffered over the past 20 years. This clearly has severe implications for the forest resources of these areas and the millions of people currently depending on them for goods and services. The

expected reduction in biodiversity accompanying changes from humid to dry forest could be exacerbated by an increased demand for forest products by an expanding population in Africa's dry areas. How this scenario unfolds can, at this stage, only be imagined but it is clear that many plant and animal species will be threatened.

A combination of human pressures and those imposed, primarily by a change in rainfall, on the continued survival of plant species in a particular area will inevitably lead to habitat fragmentation. The rate at which this occurs and its severity will depend upon the speed of change in climatic patterns and the extent of continuous vegetation cover available for migration of species to new areas. Historical changes in vegetation cover occurred over long periods of time and without human pressures, but the situation facing the forests of Africa today is quite different. Significant climate changes are expected to occur in a matter of decades rather than be spread over thousands of years, and the effects of an increased demand for forest products are already being felt in many areas. Many plant species, particularly those with longer generation times, will not have the opportunity to adapt to changing conditions and could be severely threatened. It is difficult to predict exactly what changes can be expected in forest biodiversity following changes in climate patterns as there is limited information available both on likely climatic changes and on the ecology and reproductive biology of the species concerned. It is likely, however, that the system of protected area coverage will play a vital role in a species potential to adapt to such changes through the provision of opportunities to migrate into adjacent habitats.

### *Genetic variation*

Attempts to evaluate the biodiversity value of a certain area have often relied on measures of species diversity due to its straightforward quantitative nature. This approach, however, has major drawbacks in that it takes account of neither the range of habitats present, and the consequent variation in species supported and their degree of relatedness, nor the level of genetic variation that may be contained within the species present.

Understanding patterns of genetic variation when assessing biodiversity is important for the following reasons:

1. To illustrate evolutionary pathways and processes, thereby assisting our overall knowledge of the influences that have created current patterns of vegetation cover in Africa, particularly in respect to the creation of refugia.
2. To indicate population structure. This is not only essential to an understanding of viable population size, and hence provision of information on sizes of areas needed for protection of species (a subject of particular relevance with regard to current pressures on forest areas leading to habitat fragmentation), but also provides information on populations within a species of particular value that may be best equipped to respond to changes in climate and habitat disturbance.

3. To safeguard and evaluate populations that may be of particular use in provision of goods or services to humans, which, in some cases, could have the effect of reducing pressure on the natural forest.

Unfortunately, detailed studies of patterns of genetic variation present in African trees are few. This can be accounted for by the lack of basic scientific knowledge of the distribution of many species, the necessity for long and detailed studies required for a thorough understanding of patterns of genetic variation, the cost of such studies and a general uncertainty regarding the value of acquiring such knowledge. Consequently, the species which have received most attention are those with a perceived direct value to humans. In this regard, the work of the Oxford Forestry Institute (OFI) through its programme of investigating and evaluating patterns of genetic variation present in African acacias is a good example of current initiatives.

In this programme, seed has been collected from the ranges of six widespread *Acacia* species, which between them, have over 22 known taxa. In each case seed was taken from populations and bulked, while in some situations seed from individual trees was kept separate. Future evaluations from field trials to be established throughout Africa will indicate patterns of genetic variation and highlight populations of particular value. Furthermore, classical taxonomic studies and the application of molecular genetic techniques are currently being used to determine the inter- and the intra-population variation patterns.

The role of national tree seed centres in identifying and conserving natural tree seed sources and maintaining *ex situ* collections is crucial to the overall conservation of genetic variation of African trees. As the ranges of most species of interest cross national boundaries a cooperative approach to conservation, seed collection and storage is beneficial. An example of current activities is the sub-regional FAO project, "Development of Genetic Resources of Multipurpose Trees and Shrubs in the Sahelian and North Sudanian Zones of Africa". This programme, which covers technical assistance to 17 countries of West and Eastern Africa, has facilitated plant exploration and coordinated seed collection between national institutes and has resulted in the establishment of conservation priorities, production of technical manuals on seed collection and handling and provision of well-documented genetic materials for evaluation and conservation purposes. Further north, FAO is also working with national institutes in Algeria, Egypt and Morocco on the collection and exchange of seed of Mediterranean pines and of *Cedrus* species (Souvannavong personal communication).

Bringing a wider range of indigenous species into production also requires information on their silviculture and propagation. Appropriate management systems and use of high yielding clones of various local species in East and West Africa have been investigated by the Institute of Terrestrial Ecology, U.K. (Leakey *et al.* in press), which suggested approaches to conserving biodiversity while improving productivity within appropriate management systems.

### *Socio-economic surveys and non-timber forest products*

The value of conserving forest biodiversity has recently been well documented (McNeely *et al.*, 1990, Flint 1991, Botkin & Talbot 1992), yet it is still seen by many in the tropics as an abstract concept of interest mainly to scientists and politicians in the developed world and, consequently, having little relevance to the major environmental issues facing those living in the developing world. This is due largely to the non-market benefits of future security of resources that underpins much of the justification of conservation, and the fact that the most visible result of research is often the creation of reserves that have not always brought direct benefits to local populations. However, the long-term security of all forest conservation programmes ultimately depends upon the participation of local communities and is likely to become increasingly so (Kemp 1990). Although much of the basic research needed to understand and manage forest biodiversity is inevitably long-term in nature and can therefore appear slow to deliver tangible results, many major biodiversity projects in Africa have taken positive steps to investigate the cultural context of the forest to local communities through the employment of socio-economic surveys (for example, in Cameroon and Kenya, funded by ODA; and in several other West African countries funded by ESRC).

For many people living either in or close to the forest the value inherent in the diversity of plants and animals found within the forest is not only appreciated but is fundamental to their livelihood. In Ghana, for example, up to 100% of the rural population, and a high percentage of urban dwellers, rely on traditional medicines derived from the forest (World Bank 1988, cited in Sayer *et al.* 1992). Clearly, any programme aimed at evaluating conservation options has to take account of the value of non-timber, and "minor" forest products. While detailed information on uses and properties of native plants is available for some areas, for example, West Africa (Abbiw 1989, Falconer 1990), and is being actively researched, for example, the Centre for the Study of Medicinal plants in Cameroon (Njikam & Mbi 1986), for others there is little if any published information. Current initiatives in this area include work by the Centre for Social and Economic Research on the Global Environment, Norwich, UK, which has completed several projects including an assessment of the potential of medicinal plants for local community development, and the use of medicinal plants in East Africa (Brown personal communication). Also, the joint WWF-UNESCO-RBG Kew ethnobotany programme aims to investigate the viability of harvesting the bark of *Prunus africana* (which has both local and international medicinal value) in Cameroon, and estimate the sustainability of minor forest product use by local people in montane forests in Uganda. An important element of both these programmes is the provision of opportunities for training and developing the skills of local populations (Semple personal communication).

## Discussion

Despite the need to conserve the biological diversity found in Africa's forests, the economic pressures facing the countries concerned cannot be overlooked. The

World Resources Institute (WRI 1990) predicted a 35 % increase in Africa's population between 1990 and 2000, with a further expectation that the population in 2025 will be almost 2.5 times higher than in 1990. The need for development in the face of such tremendous population growth must be addressed with respect to conservation policies and their sustainability. It is likely that only those protected areas that manage to justify themselves on economic grounds will fend off competing land use options (Tabor *et al.* 1990). A broad approach is needed in designing management plans that recognize conservation priorities, where areas of high species endemism are protected along with habitats containing significant species diversity, with sustainable production of timber and non-timber products; both production and biodiversity conservation must be viewed within the context of the needs and aspirations of local human populations. In this respect, local people, not just officials, must be involved in the planning and management stages of such programmes.

Over the whole continent there are tremendous differences in possibilities for conserving forest biodiversity, governed by factors such as the amount of remaining forest cover, the level of knowledge of forest biodiversity, current pressures on forests, the perception of conservation amongst the population and government, and the level of scientific links with outside organisations. Those countries where conservation of biodiversity is high on the agenda and that are taking active steps in its promotion should have their commitment recognised by both the international donor agencies and the economic community. Hawthorn (1992) suggested that this could be achieved either by arranging funding for conservation projects or by paying premiums for sustainably produced timber and other goods produced from such forest reserves.

The value of detailed taxonomic studies in providing scientific criteria for choice of conservation sites and assisting in the development of appropriate management plans cannot be overemphasized (Kemp 1990), yet there is a shortage of qualified scientists able to carry out the work required to provide a thorough understanding of Africa's forest flora. Financial support is urgently required for training taxonomists to post-graduate level at European institutes, combined with support for knowledgeable local technicians. Furthermore, significant levels of funding are required to upgrade both buildings and facilities in many herbaria. Financial support to assist in completion of floras in Sahelian areas is of particular importance as they contain many plants under threat from desertification and are particularly vulnerable to climate change.

Potential changes in climate must be taken into account when planning protected networks in order to provide corridors for species migration. In addition, seed collection strategies and genetic testing must also aim to identify populations under particular threat, and also those of potential use, in the event of changes in rainfall and temperature patterns.

Many botanic gardens are in a potentially strong position to assist in national and regional biodiversity research but cannot undertake this role due to inadequate staffing and facilities. Support is needed to rehabilitate these botanic gardens in order that they may become more involved in biodiversity initiatives.

Despite the current interest in tropical rainforests, the biological diversity of many areas of dry forest are under much greater threat, and conservation programmes should recognise the potential value of the genetic resources that they contain, particularly in relation to potential effects of habitat fragmentation resulting from climate change.

Conservation of the diversity of biological resources contained within Africa's forests requires a multidisciplinary approach involving local people, taxonomists, geneticists, ecologists, economists and forest managers. With increasing pressures being placed on forests it is essential that biodiversity research initiatives are supported in order to identify priority areas and to direct funds towards them. Results from such studies can then be used to develop or modify management plans to take full account of the value of Africa's forest biodiversity.

## Acknowledgements

The authors wish to thank Brian Styles and David Harris for their major contributions to the section, "Inventory, taxonomy and herbaria", and Peter Wyse-Jackson for the information included in the section, "Botanic gardens".

## References

ABBIW, D. 1989. *Useful Plants of Ghana: West African Uses of Wild and Cultivated Plants.* Intermediate Technology. 304 pp.

ANONYMOUS. 1990. Draft progress reports on international case studies of climate change impacts. Reports to the US Environmental Protection Agency Office of Policy Analysis. 54 pp. (Unpublished report).

BARNES, R.F.W. 1990. Deforestation trends in tropical Africa. *African Journal of Ecology* 28: 161-173.

BIBBY, C.J., COLLAR, M.J., CROSBY, M.J., HEATH, M.F., IMBODEN, C., JOHNSON, T.H., LONG, A.J., STATTERSFIELD, A.J. & THIRGOOD, S.J. 1992. *Putting Biodiversity on the Map: Priority Areas for Global Conservation.* International Council for Bird Preservation. Burlington Press, Cambridge, United Kingdom. 90 pp.

BOTKIN, D.B. & TALBOT, L.M. 1992. In Sharma, N.P. (Ed.) *Managing the World's Forests: Looking for Balance Between Conservation and Development.* Kendall/Hunt, Iowa, United State of America. 605 pp.

CRONK, Q.C.B. 1992. Relict floras of Atlantic islands: patterns assessed. *Biology Journal Linnean Society* 46: 91-103.

DAVIS, S.D., DROOP, S.J.M., GREGERSON, P., HENSON, L., LEON, C.J., VILLA-LOBOS, J.L., SYNGE, H. & ZANTOVSKA, J. 1986. *Plants in Danger: What do We Know?* IUCN, Gland, Switzerland, and Cambridge, United Kingdom. 461 pp.

FALCONER, J. 1990. *The major significance of 'minor' forest products: the local use and value in the West African humid forest zone*. FAO Community Forestry Note 6. FAO, Rome, Italy. 232 pp.

FILER, D.L. 1992. *BRAHMS: Botanical Research and Herbarium Management System. Installation Notes and Tutorial Exercises (Version 3.0)*. Oxford Forestry Institute, United Kingdom. 20 pp.

FLINT, M. 1991. *Biological Diversity and Developing Countries. Issues and Options.* Overseas Development Administration, United Kingdom. 50 pp.

GELDENHUYS, C.J. & MACDEVETTE, D.R. 1989. In Huntley, B.J. (Ed.) *Biotic Diversity in Southern Africa: Concepts and Conservation.* Oxford University Press, Cape Town, South Africa, & Oxford, United Kingdom. 380 pp.

HALL, J.B. & SWAINE, M.D. 1981. *Distribution and Ecology of Vascular Plants in a Tropical Rain Forest: Forest Vegetation in Ghana.* Junk, The Hague, The Netherlands. 383 pp.

HAWTHORNE, W. 1992. Forest conservation in Ghana: forestry, dragons, genetic heat. In *Conservation of African Forests: Interdisciplinary and Applied Perspectives.* Proceedings of the meeting held by Wildlife Conservation International, United States of America. (In press).

IUCN-WWF. Centres of Plant Diversity: A Guide and Strategy for their Conservation. IUCN Threatened Plants Unit, London, United Kingdom. (In preparation).

KEMP, R.H. 1990. Overseas Development Administration Biodiversity Strategy: Forestry. ODA Natural Resources and Environmental Department. (Unpublished).

KEW. 1991. Tropical African and Madagascan plant diversity research at the Royal Botanic Gardens, Kew. Kew, London, United Kingdom. 14 pp. (Unpublished).

KINGDON, J. 1990. *Island Africa: The Evolution of Africa's Rare Animals and Plants.* Collins, London. 287 pp.

LEAKEY, R.R.B., WILSON, J., NEWTON, A., WATT, A.D., & DEANS, J.D. Indigenous tropical tree species: clonal approaches and maintenance of biodiversity as keys to sustainable development. In *Proceedings of Planning Meeting of Commonwealth Science Council on Biological Diversity and Genetic Resources Networks.* Commonwealth Science Council, London. (In press).

LEEUWENBERG, A.J.M. 1991. *A Revision of Tabernaemontana. 1. The Old World Species.* Kew, London, United Kingdom. 211 pp.

MAGADZA, C.H.D. 1991. Some possible impacts of climate change on African ecosystems. Pp. 385-390 in Jager, J. & Ferguson, H.L. (Eds.) *Climate Change: Science, Impacts and Policy. Proceedings of Second World Climate Change Conference.* Cambridge University Press, United Kingdom. 578 pp.

MCNEELY, J.A., MILLER, K.R., REID, W.V., MITTERMEIER, R.A. & WERNER, T.B. 1990. *Conserving the World's Biological Diversity.* IUCN, Gland, Switzerland; WRI, CI, WWF-US, and the World Bank, Washington, D.C. 193 pp.

MYERS, N. 1988. Threatened biotas: 'hot-spots' in tropical forests. *The Environmentalist* 8(3):187-208.

MYERS, N. 1990. The biodiversity challenge: expanded hot-spots analysis. *The Environmentalist* 10:243-256.

NJIKAM, A.P. & MBI, C.N. 1986. The role of the Centre for the Study of Medicinal Plants (CEPM) in the exploitation of the renewable resources from tropical rain forests in Cameroon. Pp. 41-48 in Gartlan, S., & Macleod, H. (Eds.) *Proceedings of the workshop on Korup National Park, Cameroon.* WWF/IUCN: 41-48.

NOLAN, T.M. & GHARTEY, K.K.F. Management of the tropical high forests of Ghana. In Miller, F. R. & Adam, K.C. (Eds.) *Wise Management of Tropical Forests. Proceedings Oxford Conference on Tropical Forests, 1992.* Oxford Forestry Institute, Oxford, United Kingdom . 300 pp. (In press).

POLHILL, R.M. 1982. *Crotalaria in Africa and Madagascar.* Balkema, Rotterdam . 400pp.

SAYER, J. A. 1991. *Rainforest Buffer Zones: Guidelines for Protected Area Managers.* IUCN Forest Conservation Programme, Gland, Switzerland. 94 pp.

SAYER, J.A., HARCOURT, C.S. & COLLINS, N.M. 1992. *Conservation Atlas of Tropical Rainforests, No. 2*: Africa. Macmillan, London, United Kingdom. 280 pp.

SHEIL, D. 1992. Tanzanian coastal forests - unique, threatened, and overlooked. *Oryx* 26 (2):107-114.

SHEPPARD, G. 1992. *Managing Africa's tropical dry forests.* Overseas Development Institute Agricultural Occasional Paper 14. ODI, London, United Kingdom. 117 pp.

SKOUPY, J. 1991. *Forestry - an integrated part of the United Nations Environment Programme.* UNEP, Desertification Bulletin No. 19.

STUART, S.N. & ADAMS, R. J. 1990. *Biodiversity in sub-Saharan Africa and its islands: conservation, management and sustainable use.* Occasional Paper No. 6 of IUCN Species Survival Commission. 242 pp.

TABOR, G.M., JOHNS, A.D. & KASENENE, J.M. 1990. Deciding the future of Uganda's tropical forests. *Oryx.* 24(4): 208-214.

TRAIN, R.E. 1992. *Our people.* In WWF News. Spring 1992. WWF, United Kingdom.

WESTERN, D. 1991. Climatic change and biodiversity. Pp. 87-96 in Ominde, S.H. & Juma, C. (Eds.) *A Change in the Weather. African Perspectives on Climatic Change.* English Press, Nairobi, Kenya. 210 pp.

WHITE, F. 1983. *The Vegetation Map of Africa.* Descriptive memoir to accompany the UNESCO/ AETFAT/UNSO vegetation Map of Africa.

WHITE, L.T.J. 1992. The effects of mechanised commercial logging on vegetation and rain forest mammals in the Lopé Reserve, Gabon. In *Conservation of African Forests: Interdisciplinary and Applied Perspectives.* Proceedings of meeting held by Wildlife Conservation International, United State of America. (In press).

WORLD BANK. 1988. *Staff Appraisal Report: Ghana Forest Resources Management Project (No. 7295-GH).* World Bank, Washington, DC, United State of America. 119 pp.

WORLD CONSERVATION MONITORING CENTRE (WCMC). 1992 . *Global Biodiversity: Status of the Earth's Living Resources.* Chapman & Hall, London. 594 pp.

WORLD RESOURCES INSTITUTE. 1990. *World Resources 1990-91.* Oxford University Press, United Kingdom. 383 pp.