The acacia tree: a sustainable resource for Africa

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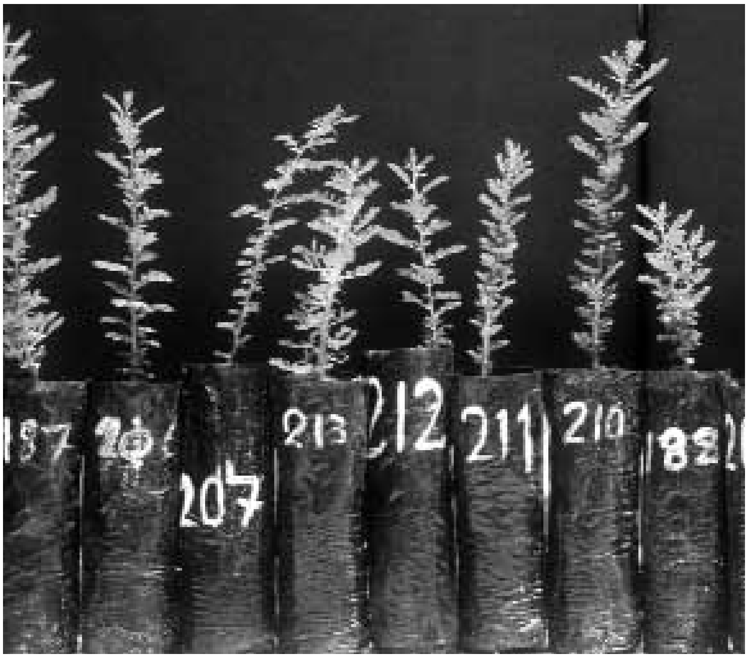

The acacia tree: a sustainable resource for Africa

An overview of research conducted by the Oxford Forestry Institute, the Natural Environment Research Council's (NERC) Centre for Ecology and Hydrology (formerly the NERC Institute of Terrestrial Ecology) and the University of Dundee with partners in Finland, Kenya, Senegal, South Africa, Sudan, the UK and Zimbabwe.

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This booklet is based on a series of 14 research projects led between 1986 and 2004 by the Oxford Forestry Institute, the Natural Environment Research Council's (NERC) Centre for Ecology and Hydrology (formerly the NERC Institute of Terrestrial Ecology) and the University of Dundee.

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Front cover: When cattle feed on *Acacia erioloba* pods, seeds pass through the gut undamaged and are ready to germinate in disintegrating cow pats after the first rains.

Frontispiece: *Acacia tortilis* seedlings of 13 provenances at 5 months from sowing in the Chesa Forest Research Station in Zimbabwe.

Back cover: *Acacia erioloba* can survive even the dry conditions of the Namibian Desert.

Foreword

The Forestry Research Programme (FRP) of the United Kingdom Department for International Development (DFID) is one of ten competitive research funds dedicated to supporting research that improves livelihoods of the very poorest in society. Research, which is undertaken by multi-disciplinary teams, addresses priority developmental problems. It focusses on the understanding of limiting factors and the development of new processing and marketing strategies and more effective policy and legislation. The FRP research cluster on African acacias is one example of such research. The projects represent a thorough examination of a resource that has particular value to village farming communities in Africa.

Acacia trees are a forgotten resource. There are about 170 species of acacias native to Africa. They have the ability to utilise nutrients from air and water and can survive the most challenging environments. Acacia pods are rich in protein and are a valuable fodder crop for livestock. Acacia wood is hard, useful for a variety of farm and household implements and can be used for charcoal. And many acacias produce a resin, gum arabic, which can be used in the food industry.

Since 1986, research teams from several UK institutions, in close collaboration with researchers in Africa, have studied the genetics, biology, ecology and economic market potential of a select six priority Acacia species in 14 FRP-funded projects. This booklet tells the story of FRP's acacia research, pieces together the projects to provide an overview and looks at the cluster from a development perspective. The research documented in this booklet has contributed significantly to scientific knowledge about *Acacia* species and their symbionts, evident in the publication of over 60 articles in peer-reviewed journals books and conference reports. More importantly, it has provided the base for thousands of rural families throughout the African continent to improve their living conditions through the understanding and use of this valuable resource.

Research began with a detailed study of the genetic variation of acacias, leading to the development of a herbarium database containing information on more than 20,000 specimens. Driven largely by the enthusiasm of partner institutions within the continent, the African Acacias Trials Network was established as a partnership including bi- and multilateral donor organisations, and national and international institutions. Through this and other partnerships, further projects were carried out to improve the growth, development and management of acacias in Africa. As the funding decade of DFID's Renewable Natural Resources

Research Strategy has come to a close, various monographs, a compendium and a field guide have completed the cluster of outputs.

It is by design that this booklet is published in the year in which the international Commission for Africa, led by the British Prime Minister, has started its work. The Commission's vision rests on five pillars, one of which is sustainable agriculture and the use of renewable natural resources. Through its project cluster on African acacias, DFID's Forestry Research Programme has made a small contribution to this vision, which will lead to improved livelihoods for those Africans trapped in poverty and depending on forests and trees for agriculture and trade.

Hannah Jaenicke

Deputy Manager

DFID Forestry Research Programme

This booklet is dedicated to the memory of Dr Richard Barnes, who died in May 2004 and deserves recognition as the prime mover and co-ordinator of invaluable research on African acacias.

Richard Delano Barnes was born in Zimbabwe in 1934 and, apart from four years at the University of Oxford following the forestry undergraduate course, spent over half his life living and working in that country. He became successively district forestry officer, tree breeding research officer and director of the Forest Research Centre. In 1980, Richard agreed to succeed me as geneticist at the Commonwealth Forestry Institute where for some years he led the Forest Genetics Research Group.

In the mid 1980s, the international approach to forestry research changed focus from commercial plantation forestry to tree-based rural development. Richard's personal research moved from the genetic improvement of tropical pines for plantations to the taxonomy, ecology and variation of Acacia species appropriate for rural development. He embraced this change with characteristic enthusiasm, thoroughness and determination, becoming one of the world's leaders in understanding the biology and applications of the group.

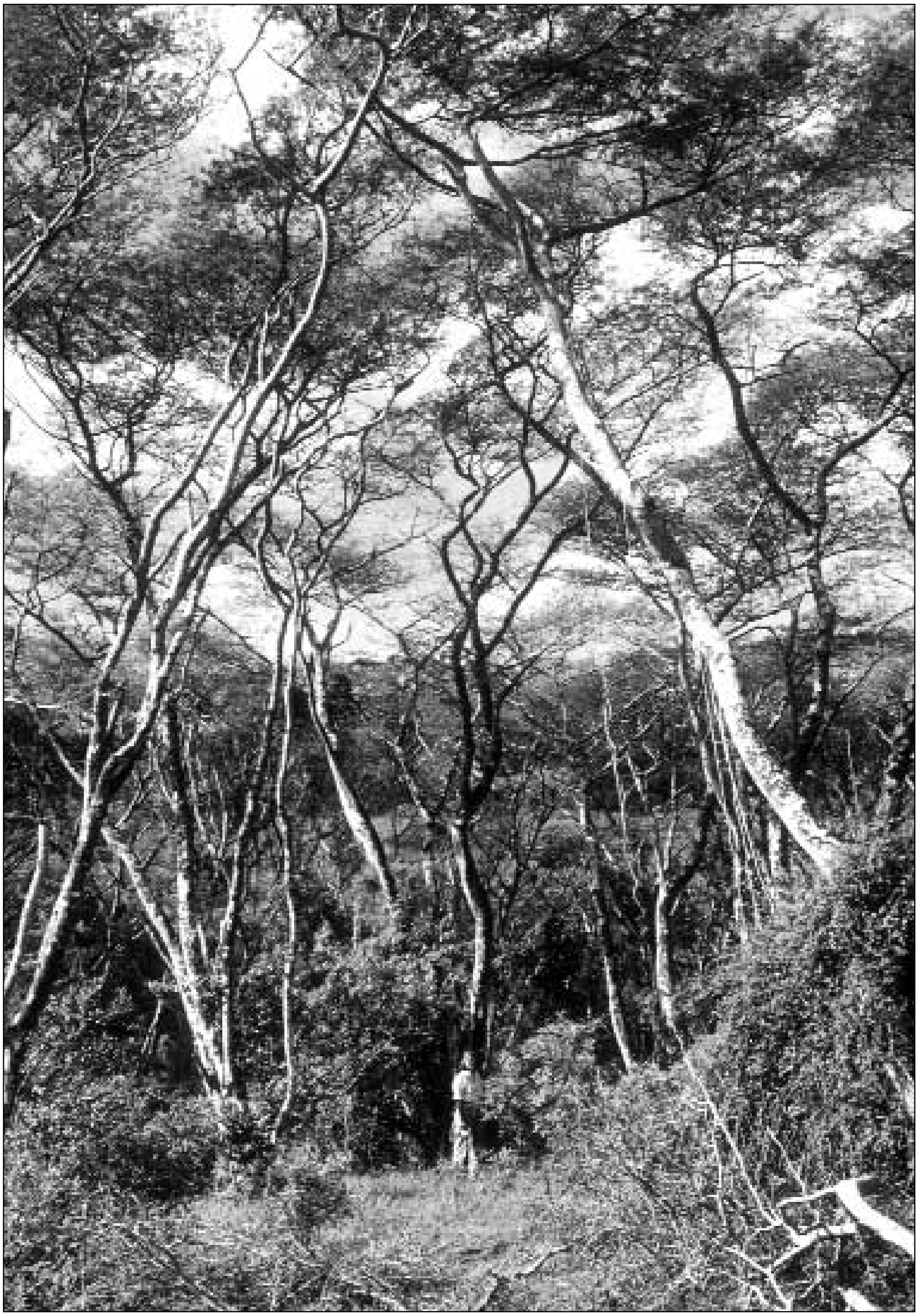
A large number of books and scientific papers have already appeared with Dr Barnes as the major author; three more major scientific contributions and one field handbook are near to completion. It is a tragedy that Richard died before he could see these publications in print, but they will long remain as standard works and as testimonies to his own research, leadership and commitment to appropriate African development.

Professor Jeffery Burley

Director-Emeritus

Oxford Forestry Institute

8th June 2004



Acacia karroo is a pioneer species on coastal dunes in KwaZulu-Natal, South Africa.

Section One **Background**

Acacias have extensive root systems, shown here on an exposed specimen of *Acacia karroo*.

Section One **Background**

Acacias in Africa

In sub-Saharan Africa, rainfall is erratic, amounting to no more than 800mm throughout the year. Despite this, the region has been inhabited by humans for thousands of years. For these inhabitants, survival depends on an intimate relationship with a dust-ridden land that yields little nourishment. In many areas, a key contributor to this survival is the acacia tree: a group of resilient plants found right across the African continent.

Unfortunately, many of the farming practices that incorporate the planting of acacias have been dying out. As single crop arable systems have replaced traditional agroforestry methods, the acacia tree has taken a back seat in African farming. But by spurning acacias, farmers of sub-Saharan Africa are neglecting an important ally. In times of drought, when cereals and grass can fail, acacia trees can still be relied on to provide fodder crops for livestock as well as a range of products for domestic and economic use.

The population of sub-Saharan Africa is predicted to double to 1.3 billion by 2025 and the region will face massive deficits in food supplies if production is not increased.[1] The development of sustainably productive farming techniques has therefore never been more urgent. Acacia trees, which grow in virtually all environments (see Plates 1 and 2) including deserts, coastal dunes, savanna woodland and the fringes of tropical rain forests, could be invaluable in meeting this challenge.

Natural pioneers

Acacias are robust pioneer plants comprising 1,250 species of mainly evergreen trees and shrubs. Of these species, about 170 are native to Africa, where 18 species are widespread and the remainder are more localised. Many *Acacia* species are tolerant of fire, coppice readily, are resistant to attacks by termites and germinate copiously after passing through the gut of browsing animals (see front cover). These pioneering attributes stem primarily from the species' ability to fix nitrogen from the air (see Box 1), to extract water and nutrients from deep down in the soil (see Plate 3), to conserve moisture in their foliage and from their relatively fast growth.

Box 1

Rhizobia, mycorrhizae and acacias – a biological partnership

Acacia trees are successful pioneers partly because, like many other members of the legume plant family, they have associations with two types of micro-organism: rhizobia and mycorrhizae.

Rhizobia are a group of small, soil-dwelling bacteria that produce nodules on the roots of leguminous plants (see Plate 4). Within these nodules, rhizobia fix nitrogen from the soil atmosphere, thereby supplying the legume with an essential element. The relationship between rhizobia and legumes is symbiotic, that is mutually beneficial. The bacteria obtain food (in the form of sugars) and amino acids from the plant and are provided with a beneficial environment in which to form their protective nodules. In return, the plant obtains nitrogen from rhizobial activity. Since nitrogen is often lacking in depleted soils, rhizobia allow many legumes, including acacias, to thrive in conditions that other plants cannot tolerate.

Mycorrhizae are specialised soil fungi that attach to the roots of many plants, including acacias. These fungi form an elaborate network of fine threads, or "hyphae", through which they are able to absorb phosphorus and other relatively immobile nutrients. These nutrients are passed on to the plant via its roots and, in return, the mychorrhizal fungi obtain sugars and amino acids. Phosphorus is a vital nutrient for plants as it facilitates the absorption of water and other nutrients, encourages root growth, improves disease resistance and thereby increases plant growth and yield.

An agricultural asset

All over Africa, acacias have been grown traditionally as farm trees within and adjacent to arable crops and livestock. The main reason for this agroforestry system is that some *Acacia* species, such as *Faidherbia albida*,[i] produce green leaves, which are in full growth during the dry season and are, unusually, dropped during the wet season. This means that the trees provide shade to cattle and farm workers when the sun is hottest but do not obstruct the light needed by many field crops during the wettest part of the year.

Acacias also provide more long-term benefits to neighbouring plants. Because of their association with rhizobia bacteria, acacias are rich in nitrogen and, when parts of the trees die and decay, fertilise the surrounding soil. On the poor sandy soils of arid areas in sub-Saharan Africa, this cycle can help improve the growth and yield of field crops.

Acacias provide nourishing browse for domestic animals, nectar for honey bees and canopies, beneath which nutritious grasses suitable for livestock grazing are

[i] Previously known botanically as *Acacia albida*.

able to grow. Acacia pods and seeds are themselves an important source of protein-rich fodder for both livestock and humans in times of food scarcity. In addition, the thorny armament of acacia trees can provide brushwood fencing to protect crops, gardens and livestock (see Plates 5 and 6).

Marketable products

Many acacias are valued for fuel and make high quality charcoal. Although most species of *Acacia* do not grow large enough to make good sawlogs, they do provide an important source of wood for furniture, fences, canoes and tools, as well as ornate carvings. The bark and fruits of many African acacias have been used traditionally to produce dyes, and tannins for preserving and softening leather.

Acacias produce substances used in both African and Western foods and medicines. Recently, medical researchers have found that favanoids and catechins from the heartwood of *Acacia karroo* and *Acacia polyacantha* may prove useful in the regulation of blood pressure or even in the treatment of cancer and HIV infections.

Some species, such as *Acacia senegal*, are tapped by smallholders for their high quality gum. Gum arabic is widely used both locally and commercially as a stable, transparent and tasteless food thickener. It is an important constituent of many products including confectioneries such as wine gums and marshmallows, soft drinks, frozen foods, glues, cosmetics and pharmaceuticals.

Why have acacias fallen from favour?

Despite their economic uses, acacias have, over the last century, lost favour with smallholder farmers in Africa. The reasons behind this bad reputation are many and varied. In some African countries, governments and farmers have perceived acacia woodlands to be a reservoir of insects carrying diseases that afflict humans and livestock; for example, tsetse flies carrying the cattle disease trypanosomosis and its human equivalent, sleeping sickness. In other cases, farmers have felled the trees in order to allow access for mechanical cultivation of pasture and grain crops such as millet and maize.

Modern accountancy has also played a part in the demise of acacias; it is much more straightforward for farmers to measure the direct yields of field crops such as maize than to calculate the complex and long-term benefits provided by acacia trees. Faced with biased but persuasive statistics of field crop versus acacia yields, farmers all over Africa have clearfelled acacias and have attempted to hinder any natural regeneration by burning the land or using herbicides. It is no surprise then that, in many African countries, certain species of *Acacia* are regarded as little more than weeds. In South Africa, for example, *Acacia karroo* is included on the country's national weed list.[2]

Problems facing the rural poor in Africa

Academics and farmers alike are now recognising that the routine destruction of tree cover, and of acacias in particular, is having a negative impact on the farmlands of Africa. The main problems facing farming communities on the continent are a lack of fuel, shortages of fodder for livestock during the dry season, limited cash income and land degradation.

Lack of fuel

Dry forests in Africa tend to provide between 60 and 90 per cent of the energy required by rural communities for cooking. The impact of deforestation is therefore felt most immediately in the widespread shortage of wood and charcoal. People have to walk such long distances in search of fuel that it leaves them with less time to spend on more productive farm activities. The problems are increased when villagers are forced to cook with alternative sources of fuel such as dung and crop residues. By using these agricultural residues for fuel, rural communities deprive their land of an important source of nutrients and soil conditioning. This leads to reduced crop yields for farmers who can ill-afford such losses.

Shortages of livestock fodder

Most small farmers in Africa have no more than 2 hectares of land on which to produce everything they need: food crops for their own use, fodder for their livestock and any cash crops. Traditionally, the only fodder grown on many farms is grass, but livestock that feed on this food source alone suffer from protein deficiencies and produce low yields of meat and milk.

Without tree fodder crops as a feed supplement, the only available source of extra protein is commercial feed concentrates, which many farmers cannot afford. The problem of livestock under-nutrition is greatest in the dry season, when grass barely grows and farmers have no choice but to give their animals poor quality dried feeds such as maize stalks and husks, bean stalks and banana stems.

Limited cash income

Although barter systems can help alleviate cash shortages, money is still very important in many rural economies, especially for those people who have little that they can afford to barter with in the first place. Trees, including acacias, can provide marketable products but without such a source of cash, farmers cannot buy or rent mechanical equipment for their farms, cannot afford school fees or hospital bills, cannot transport bulky farm products to market and have no way of improving their livelihoods beyond subsistence levels. Lack of finance also means that farmers cannot buy food for themselves or their livestock, leaving them vulnerable in times of poor harvests.

Land degradation

Forests in the arid and semi-arid regions of Africa are of vital importance in preserving the structure and fertility of the soil and limiting the spread of desert areas. In some regions, especially upland areas, removal of protective tree cover may lead to uncontrolled water runoff that erodes the soil and washes away nutrients. This can effectively shorten the growing season, again reducing crop yields. Excessive runoff can also reduce the amount of water that collects underground so that, in certain areas, rivers can disappear during the dry season, posing further problems of drought.

The potential of acacia trees in Africa

As robust pioneer species, acacias can survive under harsh conditions. They are able to colonise disturbed sites rapidly and act as natural "repair kits" on depleted soils. Acacias, therefore, offer great potential in areas of Africa where increasing population and livestock, together with a series of droughts, have led to deforestation and severe land degradation. This potential extends to southern Africa, where farmers are traditionally less familiar with the benefits of acacias, perhaps because climatic conditions are less severe there than in the more arid north.

Acacias stabilise the microclimate, providing shade under which grass can grow and livestock can feed. They also provide pods for animal fodder, fuelwood, seeds, timber and gums, all of which can be used locally or exported to provide a cash income for smallholder farmers and their families.

Since the 1980s, rural development agencies have encouraged local people to plant and manage indigenous tree such as acacias. Planting of African acacias has been hampered, however, by lack of information on the most appropriate species, variety or seed source for a particular locality.

Another major constraint has been handed down from history. In the past, colonial agricultural advisers recommended that trees be cleared from grazing and arable areas so that that farming communities should achieve maximum productivity from the land. As recently as 20 years ago, this negative attitude towards trees, which did not discriminate between species, was common practice and was written into farming handbooks. In addition, the management of acacia woodlands is complicated by the systems of communal ownership that dominate large areas of land in Africa (see Box 2).

To address these problems, the Department for International Development's (DFID) Forestry Research Programme (FRP) provided funding for a series of research projects to investigate how acacias can help rural communities in Africa (see Box 3). The research projects were carried out by a collaboration led by the Oxford Forestry Institute, the Institute of Terrestrial Ecology (now entitled the Centre for Ecology and Hydrology) and the University of Dundee. This collaboration included various African academic institutions, most notably the Forest Research Centre of the Zimbabwe Forestry Commission, the Kenya Forestry Research Institute and l'Institut Sénégalais de Recherches Agricoles.

The FRP-funded research focussed on six species: *Acacia erioloba, Acacia karroo, Acacia nilotica, Acacia senegal, Acacia tortilis* and *Faidherbia albida*. Each of these species has several varieties and all are drought resistant and suitable for planting on arid degraded sites (see Box 4). The research also included an investigation into the current and potential economic value of acacias to local African people. By engaging in participative research, the FRP-funded team sought to raise awareness among farmers, foresters and development workers of the benefits of planting acacias in Africa.

Box 2

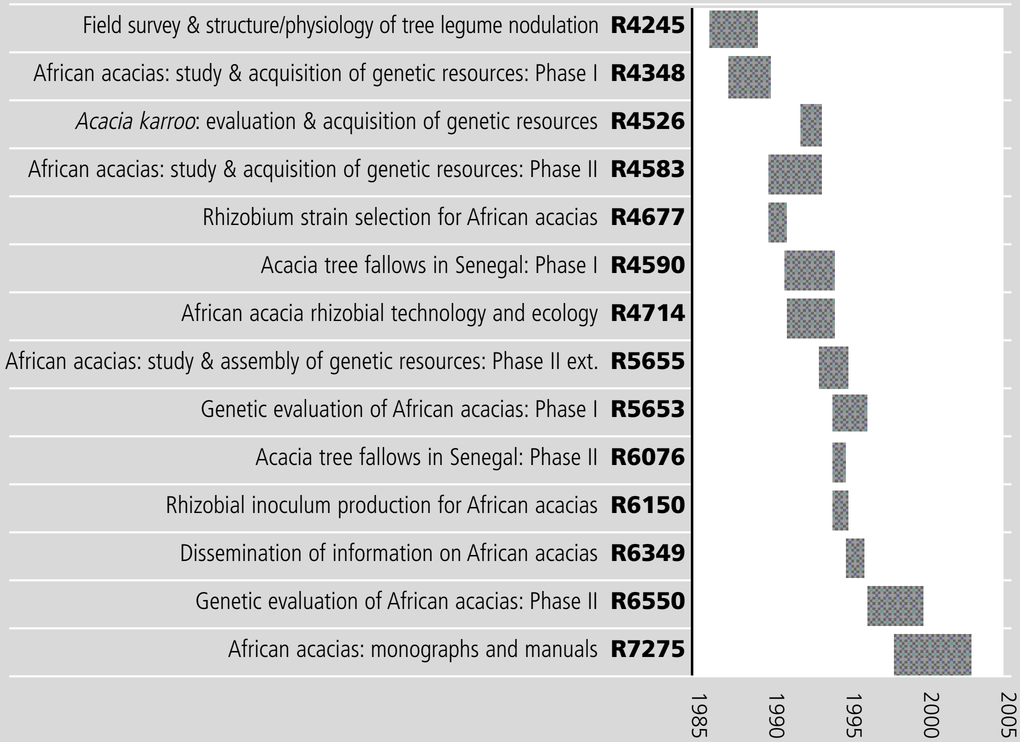
Communal land management in rural Africa

Much land in Africa is communally owned, with farmers living on individual smallholder farms on communal land. Traditionally, control of communal lands has been held by local chiefs in trust for their communities. Today, however, many African countries are undergoing radical reforms in their land tenure systems and policies, with control of communal lands beginning to move from tribal chiefs into the hands of local communities.

In Malawi, Lesotho and Tanzania, governments and development agencies are beginning to implement programmes of community involvement in locally forested land. Elsewhere, tree planting is becoming an important part of community-based land management projects. In Mozambique, for example, on-farm tree planting dominates at least 5 of 18 such projects.[3]

Within Africa's communal lands, tree planting and management can be difficult to co-ordinate fairly. There is the danger that the "tragedy of the commons" will ensue whereby some people will choose not to contribute to the management of trees on communal land, but will be happy to help themselves to the benefits. However, in the long term, community stewardship in the management of acacias and other tree plantations is essential if agroforestry techniques are to be genuinely adopted and the benefits reaped by those African farming families most in need.

Box 3
History of FRP acacia projects



Box 4
Environmental conditions tolerated by *Acacia* species

Faidherbia albida	Arid areas with periodic flooding and an underground water supply.
Acacia erioloba	True desert dune conditions with water at great depth.
Acacia nilotica	Both heavy, dry soils and flooding.
Acacia tortilis	Fertile soils in arid climates.
Acacia karroo	Extremes of both climate and soil type including salinity.
Acacia senegal	High temperatures, dry winds and sand storms.

Acacia seedlings are planted in deep pits on the trial sites in Zimbabwe.

Section Two **Research findings and recommendations**

Understanding public opinion

The Forestry Research Programme project R6550 featured a study of current perceptions and uses of local acacias in the rural economy of Zimbabwe.[4] Sociologists from the Zimbabwe Forestry Commission and the Oxford Forestry Institute consulted with farmers in various regions of the country. The sociologists recorded that farmers dislike acacias as their ferocious thorns make the trees difficult to harvest and use. The farmers also considered acacias to be troublesome weeds that invade land cleared for other forms of agriculture.

This disregard for acacias is hardly surprising, given that most benefits that come from planting the trees are not immediately realisable. Pods, gums, fuelwood, shade and improvements in soil condition, for example, only come several years after planting. Furthermore, benefits are often indirect and their association with acacias may not be obvious; for example, livestock may gain weight when fed on acacia pods or on grass grown on enriched soil under the acacia canopy.

The research team found that any existing management of acacia trees in Zimbabwe was minimal and carried out in accordance with traditional practices. It also noted that the potential of acacias for generating direct income was a more persuasive incentive for planting trees than less conspicuous long-term conservation benefits.

> "[in Zimbabwe] the best means of promoting tree planting is to focus on species that will have a product that can bring immediate cash returns."
>
> Dzidzayi Maruzane, JoAnn McGregor and Maxwell Mukwekwerere, 1999.[4]

Gathering genetic and plant data

Plant species, especially perennials such as trees, depend on variation between individual plants in order to survive in a constantly changing environment. Acacias, with their extensive geographical range and extreme diversity of habitat, exhibit particularly high levels of variation within each species.

To enable the genetic variation of African acacias to be explored, botanists at the Oxford Forestry Institute began establishing an information and seed bank.[5] This work (project R4348) was continued under projects R4583, R4526 and R5655, and focussed on the six species thought to have particular potential: *Acacia erioloba, Acacia karroo, Acacia nilotica, Acacia senegal, Acacia tortilis* and *Faidherbia albida*.[6-8]

For each of these *Acacia* species, the team compiled details of geographic and ecological distribution and breeding systems along with basic information on tree varieties and their rhizobia. They also collected, from a broad range of sites, seeds, gum, nodule and wood specimens, as well as examples of insect pollinators and predators.

Assessing species performance and breeding potential

Project R5653 assessed how different seeds of *Acacia erioloba, Acacia karroo, Acacia nilotica, Acacia senegal, Acacia tortilis* and *Faidherbia albida* perform under different conditions (see Plates 7-9).[9] Plant geneticists at the Zimbabwe Forestry Commission's Forest Research Centre in Harare co-ordinated preliminary trials using different seed sources, or "provenances", of each species on eight sites, selected to cover the main soil and climate conditions under which the acacias are likely to benefit local communities (see Box 5). The team found that growth and survival rates varied enormously between each species, variety and seed source.

This research was continued under project R6550 with the establishment in Zimbabwe of a full series of field trials.[10-11] Perhaps surprisingly, these trials demonstrated that the seed source with the greatest potential for growth in a particular area is not necessarily that which is indigenous to it. The trials also showed that the interaction between the seed source and the environment was very variable, with plants growing most successfully in frost-free situations.

The findings from the acacia trials provided valuable insights into which species and seed sources should be planted to provide maximum productivity in any given locality. In addition, the very high degree of variation indicated that there is definite scope for enhancing productivity through plant breeding (see Plate 10).

> "[African acacias] are extremely variable over their natural range in all their important traits. They are, therefore, ideal subjects for rapid genetic improvements through selection and breeding."
>
> Newton Spicer, Richard Barnes and Jonathan Timberlake, 2003.[12]

Acacias: pioneering species in Africa

Plate 1) Acacias can thrive in a range of different environments. This specimen of *Acacia karroo* grows on the beach on Bazaruto Island in Mozambique.

Plate 2) Acacias can grow to extreme heights, as demonstrated by this specimen of *Faidherbia albida* in the bed of the Omaruru River in Namibia.

The vigorous root systems of acacias

Plate 3) The survival of acacias in arid environments is largely due to the plants' deep taproots, which are shown on the *Acacia tortilis* and *Acacia erioloba* seedlings first and third from the left.

Plate 4) Nitrogen-fixing rhizobia produce nodules on the roots of leguminous plants such as *Acacia karroo*.

Acacias provide effective fencing materials

Plate 5) The thorny spines of *Acacia karroo* make it a cheap and natural alternative to barbed wire fencing.

Plate 6) The thorny branches of *Acacia tortilis* provide cheap but effective fencing for farmers in the Sabi valley of Zimbabwe.

Assessing *Acacia* species performance and breeding potential

Plate 7) Seedlings at 2.5 months from sowing in the nursery at Chesa Forest Research Station in Zimbabwe.

Plate 8) Acacia seedlings in the Chesa Forest Research Station ready for planting in the main trials.

Assessing *Acacia* species performance and breeding potential

Plate 9) Seedlings are planted out for field trials at the Matopos Research Station in Zimbabwe.

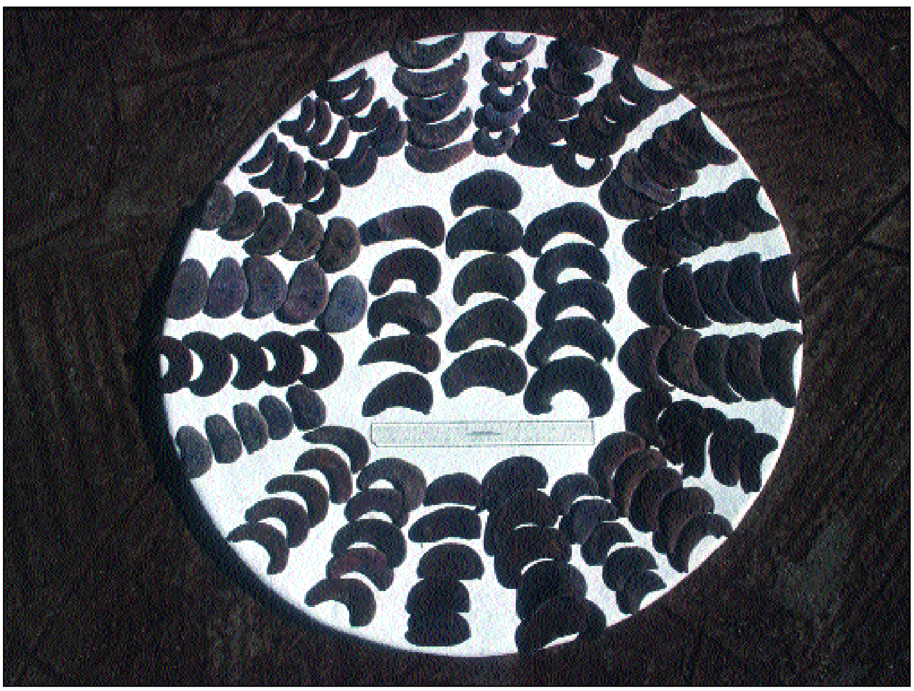


Plate 10) Pod size and shape varies from tree to tree in *Acacia erioloba*. This large degree of variation is open to improvement through plant selection and breeding.

Acacias can provide dry season fodder for livestock

Plate 11) Goats browse on the foliage of a young *Acacia erioloba* tree.

Plate 12) Under the shade of a flowering *Acacia karroo*, perennial grasses provide nutritious grazing for livestock.

Acacias produce gum arabic and crystal growth rings

Plate 13) ***Acacia senegal*** produces gum arabic two years after planting in the field.

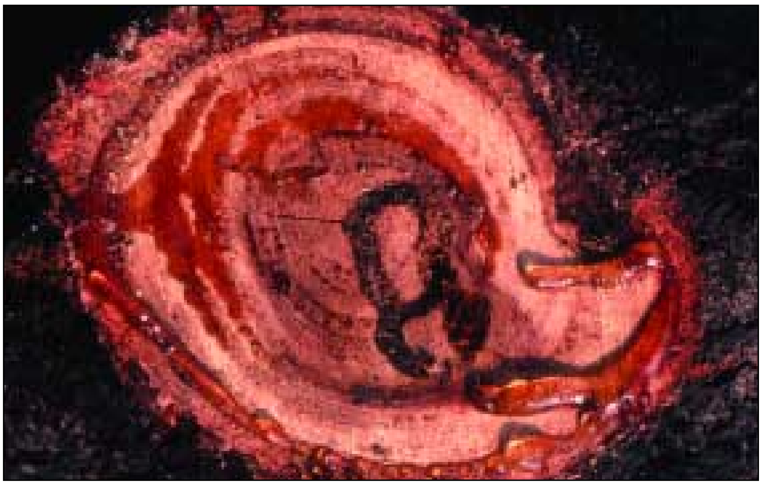


Plate 14) Gum exudes from the inner bark of *Acacia karroo* in response to insect attack.

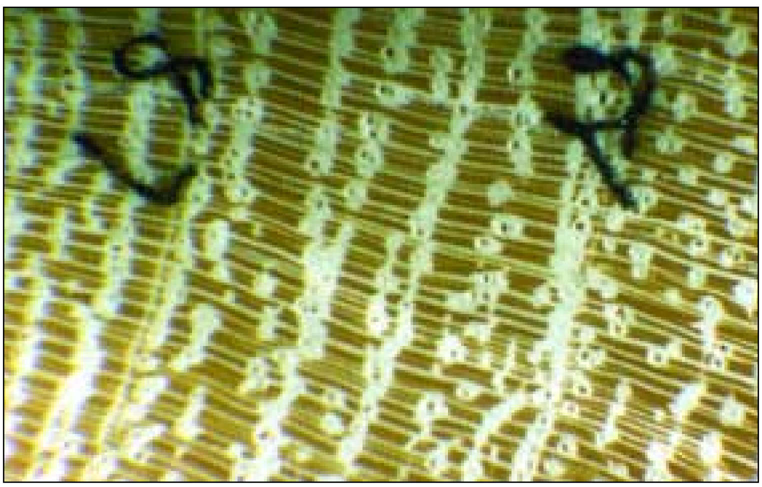


Plate 15) Crystal growth rings reveal the age of this specimen of *Acacia erioloba*. © Ian Gourlay

Gum arabic is an important economic product

Plate 16) *Acacia karro* gum collectors queue at the factory door in Bulawayo in Zimbabwe to sell their loads.

Plate 17) Gum from *Acacia karroo* is weighed before purchase at a merchant's factory at Bulawayo in Zimbabwe.

Box 5

Seed provenance trials

The term "provenance" simply means the place from which a plant or seed was collected. The genetic "fingerprint" of each species provenance is, through the process of natural selection, specifically adapted to the place where it grows naturally. This means that seed from one provenance will be genetically different from that of the same plant species collected from another provenance.

By collecting seed from as many different provenances as possible, botanists and ecologists are able to carry out trials to find out which seed source grows best, or becomes most biologically productive, in different environments. For the FRP-funded acacia research, this information was invaluable in identifying which seed source is most appropriate for providing healthy acacia trees in different parts of sub-Saharan Africa. It has also provided important information for plant breeding programmes.

Provenance seed trials do have certain limitations. For example, intense pressure from mutually adapted pests and diseases may mean that an indigenous provenance is not necessarily as biologically productive as other provenances when grown in seed trials in its own locality.

When a seed provenance is transferred to a new environment, any period of success may be limited. For example, in the case of eucalyptus trees translocated from Australia to Brazil, the pest-free potential lasts for only two or three generations. Long-term trials are therefore necessary to produce results that can accurately inform the planting programmes of development organisations.

Project R4526 focussed on *Acacia karroo*, one of the most widespread acacia trees of southern Africa (see Box 6).[2, 7, 13-17] *Acacia karroo* is a good general-purpose tree, resistant to drought, frost, fire and salinity. However, *Acacia karroo* was, until the last decade, considered an invasive weed in the pastures and farmland of southern Africa and little was known of its genetic variation or of its management and productivity.

In order to investigate the genetic variation of *Acacia karroo*, botanists and geneticists at the Oxford Forestry Institute worked with African organisations, including Umguza Valley Estates and the National Herbarium and Botanical Gardens of Zimbabwe, to assemble seed from various provenances. This collection represented the full range of *Acacia karroo* in terms of its geographic, climatic, ecological and physical variation.[7]

Plant cell specialists Phanuel Oballa, from the Kenya Forestry Research Institute, and Patrick Olng'otie, from Moi University in Kenya, found significant genetic variation in *Acacia karroo* across different environments, particularly between coastal and inland provenances.[15-16] Later trials, conducted as part of project R6550, showed that these inland provenances produced faster growing plants than coastal provenances.[11]

The FRP-funded research revealed that *Acacia karroo* crosses naturally with other acacias, producing hybrids. This confirms the possibility of breeding plants to produce hybrid acacias, the characteristics of which could be adapted to meet the specific needs of local people and to match local environmental conditions.[11, 14-17]

Box 6

***Acacia karroo*: a species of contradictions**

Acacia karroo is a species full of contradictions. In its external appearance, it is so variable at its extremes that taxonomists repeatedly propose that it should be divided into as many as six different sub-species. However, none of these proposals has ever matured because the plant varieties are linked by so many intermediate forms.

Economically, *Acacia karroo* is a species with an almost unlimited number of uses. The tree's wood, which burns brightly and evenly with little smoke and no odour, is a popular fuel source and its bark can be made into twine and rope. Yet, most research on *Acacia karroo* has focussed on its eradication. The tree species is accused of invading grassland and reducing productivity, despite the fact that cattle which browse on the trees yield large quantities of red meat.

Nutritionally, *Acacia karroo* is a preferred browse for livestock. Yet, it has a high tannin content that appears to render proteins indigestible. Gum from *Acacia karroo* has also been used locally for many years as a thickener for food and pharmaceuticals. But although this gum has been consumed locally without harm for generations, it has not been formally proven to be non-toxic and therefore is not accepted by international trade law.

Identifying how acacia fallows can improve soil fertility

Traditionally, farmers in Africa practised an agricultural system based on a repeated cycle of a limited cropping period, for example three to five years, followed by a fallow period of around 20 years during which time they could grow trees, such as nitrogen-fixing acacias. In Senegal, for example, rotational cropping with acacia fallows was practised for centuries but has recently been neglected because of severe droughts and indiscriminate clearing of *Acacia senegal* in favour of continuous cultivation of cereal crops.

Intensive agricultural methods, such as mechanical cultivation and continuous cropping, constantly remove nutrients from the soil, allowing no time for replenishment by natural means. By contrast, traditional crop rotation that incorporates acacia fallows maintains fertility in the soil. Much deforested land would therefore benefit from a return to more traditional methods of farming and acacia planting.

Projects R4590 and R6076 included experiments to confirm that continuous cereal cropping of a site, without the aid of fertilisers, reduces soil fertility. Ecologists at the Institute of Terrestrial Ecology (ITE) and l'Institut Sénégalais de Recherches Agricoles, looked at soil quality in plantations of *Acacia senegal* in Senegal.[18-20]

The ecologists revealed a clear pattern: the level of nitrogen in the soil increased by approximately 900 per cent as the acacia plantation grew from 3 to 18 years in age. Nitrogen levels also decreased with distance from, or depth beneath, each acacia tree. In contrast, the research team found that phosphorus did not accumulate in the soil under *Acacia senegal*. This indicated that alternative strategies are required for replenishing the phosphorus taken from the soil by cereal cropping.

Under the umbrella of project R5651, ecologists at the Institute of Terrestrial Ecology used the *Acacia senegal* results to develop a simple simulation model.[21] This model predicts the changes in soil fertility that will occur with different periods of alternating *Acacia senegal* fallow and cereal cropping. The model enables agriculturists to determine the most productive method of incorporating tree planting into a rotational farming system.

The ITE model applies largely to acacias in Senegal. However, ecologists at the Centre for Ecology and Hydrology and the University of Helsinki in Finland have since adapted this model so that it can be applied to the differing soil and climate conditions of Sudan.[22]

Identifying how acacias can provide dry season fodder

Project R6550 recorded that a major constraint for livestock farmers in semi-arid areas of Zimbabwe is a shortage of fodder in the dry season. The research team looked at acacia pods as an alternative protein-rich livestock feed and found that *Acacia erioloba, Acacia tortilis* and *Acacia nilotica* are the species most palatable to cattle and goats (see Plate 11).[4]

Project R6349 included an assessment of the suitability of *Acacia erioloba* (see Box 7) as a fodder crop.[23] Botanists at the Oxford Forestry Institute found that

Acacia erioloba can yield an annual pod crop with a crude protein level substantially higher than the maximum expected from smallholder grain crops, such as maize. For example, the crude protein content of milled *Acacia erioloba* pods is around 16.5 per cent, whereas that of maize is less than 10 per cent. However, cattle cannot easily digest these pods, which have hard seed coats. To overcome this problem, farmers can mill the pods into a meal and add sulphur or molasses to neutralise any toxins.

The botanists also noted that *Acacia erioloba* produces large quantities of pods from an early age and that the number of pods and their nutritional value varies from tree to tree. As a large proportion of this variation is likely to be under genetic control, pod production is open to improvement through selection and breeding.[23]

> "A parkland of 15 mature [*Acacia erioloba*] trees per hectare can produce more than twice as much crude protein … as the average smallholder grain crop without any input costs except for the collection of pods."
>
> Richard Barnes, Chris Fagg, Crispin Marunda, Janet Stewart and James Chimbalanga, 1996.[24]

Many smallholders in semi-arid and arid parts of Africa are not wealthy enough to own cattle. Instead, their staple livestock animal is the goat. The major constraint for these farmers is high mortality of goat kids between birth and weaning, which can easily be between 30 and 50 per cent. In order to tackle this problem, the Forestry Research Programme, in association with the Department for International Development's Livestock Production Programme, funded a research team based at the Universities of Reading and Zimbabwe to investigate how acacia pods could be grown and collected as a supplementary feed for goats on smallholder farms.[25]

The projects proved that farmers can easily manage and grow acacias as a high protein animal feed at very low cost. An added benefit is that livestock can graze on the nutritious grasses that grow under the shade of acacia trees (see Plate 12). However, FRP-funded sociologists found that many farmers in Zimbabwe are reluctant to plant acacias purely for their own use. A greater incentive was the opportunity to sell the pods to nearby markets, such as large commercial cattle farms.[4]

Box 7

***Acacia erioloba*: a true desert tree**

Acacia erioloba grows on sand dune formations in sub-Saharan Africa where it is sometimes the only tree species present. The tree produces a regular crop of nutritious pods and browse and thrives under arid conditions because of its capacity to root down to water and nutrients at great depths.

Unusually for a plant of the legume family, *Acacia erioloba* does not nodulate.[23] Instead, this species obtains most of its nitrogen from groundwater rather than from the soil atmosphere and so does not need rhizobia. This alternative source of nitrogen does not make *Acacia erioloba* any less valuable. Indeed, since the nitrogen in the groundwater is not accessible to any other plant in the surrounding ecological community, *Acacia erioloba* performs a valuable service by bringing this nitrogen into circulation at the soil surface.

Identifying how acacias can generate cash income

Project R6550 identified a number of acacia products, including wood carvings, dyes, tannins and medicinal substances, that could provide income to small-scale farmers and foresters in Africa. Of these products, gum arabic, which is imported as a food additive by Western and Asian countries, has the most economic potential.[4]

The main exporters of gum arabic are Sudan, Chad and Nigeria. In Sudan, up to 15 per cent of total foreign exchange earnings is from exports of gum arabic, almost all of which is collected from *Acacia senegal* by people living in rural areas. In Zimbabwe, however, gum from *Acacia karroo* can be traded only locally due to international trade restrictions, which maintain that the product has not formally been proven to be non-toxic (see Box 6). The research identified that production of gum arabic from *Acacia karroo* has been constrained by the lack of an organised local trading system and that the greatest potential for future regional trade lies in South Africa.[4]

> “By providing a source of cash to local farmers, gum arabic could provide an incentive for enhanced woodland management and tree planting, as well as raising the standard of living for farmers and their families.”
>
> John Coppen, 1999.[4]

botanists were able to confirm that the bands were formed annually. They also discovered that the width of the growth rings correlated with annual rainfall recorded in each wet season. The team used the ring data to calculate that *Acacia karroo* is relatively short-lived, although it is still more productive than many other trees found in semi-arid conditions.[27]

Investigations of other African *Acacia* species have supported the conclusion that the bands define growth phases and can therefore be used to determine age. This ageing technique provides agriculturalists with the information they need to calculate sustainable rates of harvest for *Acacia* species across the African continent.

Using rhizobia inoculation to enhance tree growth

Acacia planting programmes are most successful when seedlings are given supplementary rhizobia, a technique known as "inoculation", while they are in the nursery. This inoculation can enable nursery plants to get a head start in their growth before being transplanted into the field. The beneficial effects of inoculation are greatest in degraded environments where naturally occurring rhizobia are scarce or absent from the soil altogether.

Microbiologists at the University of Dundee demonstrated that the relationships between African acacias and their rhizobia are very specific (projects R4245 and R4677).[29-30] Later research, carried out as part of project R4714 by microbiologists at the University of Dundee and the Kenya Forestry Research Institute, found that the performance of rhizobial strains varies with environmental factors in the soil, such as temperature, acidity and moisture.[31]

To facilitate inoculation in the nursery, the team developed an inoculant cocktail, composed of many rhizobial strains, to nodulate effectively several important *Acacia* species in a variety of environmental conditions.[32] In a series of nursery trials, the microbiologists tested both single-strain and mixed-strain inoculants for their effects on plant growth and nitrogen content of seven species of *Acacia*.[32-33]

The majority of the species did not nodulate in the nursery of their own accord. However, once inoculated with rhizobia, all seven species increased in dry weight and nitrogen. The dry weight of nodulated plants was between five and ten times greater than that of non-nodulated plants. Although some species performed better when inoculated with a single rhizobial strain, the strategy of applying an inoculant cocktail was generally effective.

As part of project R6150, the microbiologists at the University of Dundee and the Kenya Forestry Institute carried out experiments to establish optimal methods of storage, maintenance and application of tropical rhizobia. The team also identified which rhizobial and mycorrhizal strains together provide the most productive inoculation mixtures.[34]

Box 8

Gum arabic: a key player in the modern food industry

Gum arabic is a substance exuded by acacia trees as a defence against fungal and insect attack (see Plates 13 and 14). This gum is edible, possesses important anti-fungal and anti-bacterial properties and has been used in inks, paints, adhesives, cosmetics, perfumery and medicine for at least 2,000 years.

Today, the term gum arabic usually refers to the yellow or orange-brown glass-like substance harvested from *Acacia senegal*. The vast majority of gum arabic from this species that enters world markets originates in the "gum belt" of Sub-Saharan Africa, which stretches from northern parts of West Africa eastwards to Sudan and Ethiopia.

Unlike other natural gum substances from, for example, locust bean or seaweed, gum arabic dissolves in water without becoming viscous. This means that gum arabic has good emulsifying, stabilising, thickening and suspending properties, making it highly valuable to the food and drink, pharmaceutical and cosmetic industries.

Today, 80 per cent of gum arabic produced around the world is used as a food additive. As a natural substance with zero calories, gum arabic is likely to retain favour as a food additive in the future.

Identifying how to calculate and enhance tree growth

Using crystal rings to calculate tree growth

Sustainable management of any plantation requires an understanding of the rate at which trees grow. For most temperate tree species, this information can be obtained by counting annually produced rings, which appear as concentric circles in the wood. In the tropics and sub-tropics, where there is less marked seasonality, this growth periodicity is less clear. Project R4526 aimed to discover whether there is any other anatomical feature that marks annual periods in the African *Acacia* species.[26-28]

Plant cell specialists at the Oxford Forestry Institute examined wood samples of individual *Acacia karroo* trees from diverse locations across southern Africa. The team found distinctive narrow bands of specialised cells containing calcium oxalate crystals. The number of these bands corresponded closely to the ages of the trees (see Plate 15).

By pricking the wood of the trees at regular intervals throughout the year, the

Cattle feed on nutritious pods of *Acacia erioloba*.

Section Three **Impact of the research**

Informing the scientific community

The research funded by the Department for International Development through its Forestry Research Programme responds to a need within the scientific community in Africa and beyond for easily accessible information on acacias. More than 60 papers on this acacia research have been made publicly available in scientific journals, books and conference reports. Information on specific *Acacia* species has been published in the form of monographs and annotated bibliographies (see Box 9).

The monographs contain information on the identification, ecology and biology of particular *Acacia* species. They also include field photographs and details of management practices, economic products and markets. Monographs for *Acacia karroo* and *Acacia erioloba* have already been published[2, 23] and similar publications are in press for *Faidherbia albida*[35] and *Acacia senegal* and the gum trade.[36]

Box 9

Acacia monographs and bibliographies funded by the Forestry Research Programme

Acacia karroo: monograph and annotated bibliography[2]

Acacia erioloba: monograph and annotated bibliography[23]

Faidherbia albida: monograph and annotated bibiography[35]

Acacia senegal: monograph, annotated bibliography and a history of the gum trade[36]

Acacia tortilis 1925-1988: annotated bibliography[37]

Acacia nilotica 1869-1988: annotated bibliography[38]

Information databases and maps

Information on acacias has been made readily accessible in the Botanical Research and Herbarium Management System (BRAHMS) database. BRAHMS, which was initially developed within project R4526 during the early 1990s, is an information system for storing and processing botanical data and can be accessed at www.brahms.co.uk or http://storage.plants.ox.ac.uk/brahms/

A team of database specialists based at the Oxford Forestry Institute began by loading onto the BRAHMS database details of 800 dried plant specimens of

Acacia karroo. Now, the database contains information on 20,000 specimens and is the most comprehensive data set available on African acacias. The data set includes information on the ecology of each specimen and has been used to prepare unique maps, indicating species diversity and distribution, to guide future exploration and seed collection. As part of project R7275, these maps are now being incorporated into *A conspectus on the African acacias:* a major definitive work on the genus in Africa.[39]

The African Acacia Trials Network

The Forestry Research Programme projects led to the formation of the African Acacia Trials Network, which included the Oxford Forestry Institute, the Zimbabwe Forestry Commission, the Kenya Forestry Research Institute, l'Institut Sénégalais de Recherches Agricoles, CIRAD-Fôret, the Food and Agriculture Organization (FAO), The World Agroforestry Centre (ICRAF) and the Forest Seed Centre of DANIDA (the Danish International Development Agency). This network prevented wasteful duplication of effort, facilitated sharing and comparison of results and enabled organisations to pool their seed collections into complete representations for all varieties and provenances of each species.

The African Acacia Trials Network has played an important role in strengthening research institutions in developing partner countries. Although the network is not formally in existence now, the collaboration it catalysed has led to continuing research into the economic and environmental attributes of acacias in several African countries.

Much of the ongoing research into African acacias is taking place in Zimbabwe. For example, at the Matopos Research Station, agricultural scientists are currently carrying out research to identify those varieties and seed sources of *Acacia* that have low tannin levels and can therefore be used as fresh browse for livestock.[40]

Research into acacias is also continuing in other African countries. For example, in South Africa, forestry researchers at the University of Natal are examining how *Acacia karroo* can be integrated into small-scale farming systems in northern Kwa Zulu-Natal;[41] in Sudan, research is continuing on yields of gum arabic from natural stands of *Acacia karroo*;[42] and in Senegal, the work of l'Institut Sénégalais de Recherches Agricoles on acacia fallows is being extended, via CORAF (le Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles), to cover the whole of West Africa.

Informing smallholder farmers and development workers

All the Forestry Research Programme projects involved training local staff in trial design, establishment, maintenance and management and in information gathering and analysis. These African research teams encouraged interested foresters, agriculturists, farmers and politicians to visit research centres and witness the acacia trials first hand. As a result, techniques such as inoculating seedlings with a cocktail of rhizobia are now widely used in commercial nurseries throughout the tropics and subtropics of Africa.

To make the results of the FRP-funded research formally available to farmers, development workers and other interested parties, project R6349 was set up to promote new information about the forestry potential of the African *Acacia* species, in an accessible format.[43]

Acacia field guide

As part of project R6349, Jonathan Timberlake, an ecologist working for the Forest Research Centre in Harare, and a team at the Oxford Forestry Institute produced a field guide on the acacias of Zimbabwe.[44] This guide includes detailed, clear illustrations and information on acacia distributions, ecology, uses and common names. The team distributed around 750 free copies to collaborating organisations, libraries, forestry development workers and farmers in Zimbabwe as well as individuals and organisations in neighbouring countries.

The field guide is the first readily available and usable practical guide on African acacias, bringing together information that was previously scattered and inaccessible to the layperson. The guide is currently on sale from CBC Publishing, PO Box 5611, Harare, Zimbabwe. The success of this publication has stimulated interest in producing field guides for other countries or regions in Africa. As a result, botanists at the Royal Botanic Gardens, Kew are planning to produce a guide for the acacias of Uganda, Kenya and Tanzania.

Management handbook

To help smallholder farmers make direct use of acacias, botanists at the University of Oxford are working with Jonathan Timberlake to produce a handbook on how to identify, propagate, plant and manage the most useful *Acacia* species in Zimbabwe and surrounding countries in south central Africa.[12] This handbook, which will be published in 2004, will be very easy to use, featuring diagrams and pictures as well as text. It will also contain guidance notes for teachers to help them educate children about the value of acacias, thereby instilling an appreciation for these crucial species from the earliest age.

To complement the handbook, a colour poster explaining the virtues of *Acacia erioloba* has been widely distributed in Zimbabwe.[24] The handbook itself will be distributed by non-governmental organisations (NGOs) in Zimbabwe, and other countries in southern and central Africa, to farmers, forest workers and teachers across the region.

Box 10

Comments on the *Field guide to the acacias of Zimbabwe*

"This is a very useful reference book and we have already retrieved vital information and have circulated it to our Environmental Education Officers for use in their campaign for the establishment of indigenous tree nurseries."

Shirley Cormack, President, The Wildlife Society of Zimbabwe.

"This is a delightful book with lots of very interesting information. It is certainly the easiest guide to field identification of any trees that I have ever seen. Please don't stop now but do some more guides on other trees that grace our land."

Nic Stipinovich, farmer, Zimbabwe.

"Your book is exactly what is needed not only for African communities but also for many kinds of people in our part of the world. I will use it in my ongoing course in ethnobotany to show my students what should and can be done in our field."

Inga Hedberg, Department of Systematic Botany, University of Uppsala, Sweden.

Stimulating agricultural change

Development work in transforming the lessons learned from research into changes in farming practices on the ground has been constrained by political instability in Zimbabwe. However, as a result of the participative approach taken by the FRP-funded researchers, communal farmers in parts of Zimbabwe have begun to recognise the value of acacias both in agricultural systems and for producing economic products.

For example, in Ntabazinduna, a small rural communal area in Zimbabwe, Mr Maviva, a local councillor, has played a leading role in promoting management of woodland acacias in his ward. Initiated by Mr Maviva, pruning of stands of *Acacia karroo* takes place through organised group work, as well as on a day-to-day basis. Villagers obtain firewood and brush fencing and harvest acacia pods as browse for livestock.[45] Acacias are also used for livestock browse in parts of

Matebeleland and in the Gwanda District of Zimbabwe. Here, pods of *Acacia erioloba* and *Acacia tortilis* are collected and sold to livestock owners for feed at the end of the dry season when grass becomes scarce.

Management of acacia trees for gum arabic is also increasing. Following on from the FRP-funded research, the Zimbabwe Forestry Commission is working with farmers to assess the quality of gum arabic, which is sold to merchants locally (see Plates 16 and 17), produced by plants grown from different seed sources of *Acacia senegal*.[11] To help communicate the benefits of gum arabic, the Commission has set up demonstration plots in various locations including the Save Valley of Masvingo Province.

One farmer who has been inspired by the work of the Zimbabwe Forestry Commission to plant *Acacia senegal* himself is Mr Rukini who lives in the Gonakudzingwa area, close to the Gonarezhou National Park. Mr Rukini has bought *Acacia senegal* seed with the intention of planting up 2 hectares to produce gum arabic for sale to gum brokers in the region. Other farmers have been encouraged to plant *Acacia senegal* by the faith-based NGO, the Zimbabwean Institute of Religious Research and Ecological Conservation (ZIRRCON), which also works in Masvingo province.

The reputation of *Acacia senegal* is also improving in Sudan. For example, Sheikh Nasreldin, who lives in the village of El Himaira in North Kordofan, is just one of many farmers who are tapping *Acacia senegal* for gum arabic during a specific two-week period in order to obtain greater yields. This change in practice has led to an increase in income and has particular benefits for women who are responsible for much of the collection of this important economic product.

The FRP-funded acacia research provides valuable scientific backing to the work of key NGOs involved with tree planting and development projects in Africa. Tree Aid, for example, is working with local communities in Burkina Faso to raise and transplant seedlings of *Acacia nilotica* and *Acacia senegal* (see Box 11). The charity is also working in the Tamale province of Ghana on a project that includes the planting of 80 hectares of neem, acacia and teak to provide windbreaks, fences and fuel wood.

Acacias may, at last, be resuming favour with the African people. However, work both in the laboratory and in communal farmlands needs to continue if smallholder farmers are to reap fully the potential benefits of acacia trees. Improved plant breeding, more effective management practices, development of production and marketing systems and, most importantly, initiatives that encourage smallholder farmers to plant and use acacias, are all essential if these invaluable trees are to grace the communal lands of Africa once again.

Box 11
Acacias in action
Case study one:
Fada N'Gourma Tree Nursery and Windbreak Project

In the Fada province of Burkina Faso, the Association Base Fandiman, with the support of the UK charity Tree Aid, is working with 12 local villages to establish a sustainable woodland resource.[46] As part of this project, local communities are raising and transplanting seedlings of *Acacia nilotica* in order to provide live fencing, firewood, animal fodder, medicinal products and pods for tanning leather.

One of the people involved in the Fada N'Gourma Tree Nursery and Windbreak Project is Issaka Guitanga. Issaka is 47 years old, has 3 wives and 15 children and, like his neighbours, makes his living from the land. Issaka has planted 600 trees including a live fence of *Acacia nilotica*.

"I know this work will be important for my children…The money they will earn will help to stop them leaving to work in cities…"

Issaka Guitanga, small-scale farmer and forester, Nangré, Burkina Faso.

Case study two:
Women's Participation in the Fight against Desertification

In the Nayala province in the Toma region of north west Burkina Faso, the Association of the Toma Region and Tree Aid are working with women's groups in ten villages to establish tree nurseries and provide market garden training.[47] As part of this project, local women are planting live fences of *Acacia senegal* and *Acacia nilotica*.

One woman involved with the project is Awa Yelemou. Awa is 47 years old and lives in Yaba with her husband, Karim Sia, and their nine children. Having received training, Awa has planted a live fence of nearly 100 metres of *Acacia senegal* which has enabled her to see better returns from her market garden and save enough money for her children's school fees.

"With the technical training I can now plant my fence [of *Acacia senegal*] and it is a lasting way of keeping the animals from damaging our vegetables."

Awa Yelemou, market gardener, Yaba, Burkina Faso.

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43. Fagg, C W, Barnes, R D and Wise, R (1997) *Dissemination of information on African acacias.* Final Report. Oxford Forestry Institute, UK. FRP R6349.

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46. Guigma, P (2002) Fada n'gourma tree nursery and windbreak project. In *Update* Winter 2002. Tree Aid, UK.

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Appendix

Forestry Research Programme projects on African acacias.

R4245: Field survey and structure/physiology of tree legume nodulation. 1986-1989.
Key researcher:
Janet Sprent, University of Dundee, UK.

R4348: African acacias: study and acquisition of genetic resources: Phase I. 1987-1990.
Key researchers:
Christopher Fagg and Richard Barnes, Oxford Forestry Institute, UK.

R4526: *Acacia karroo*: evaluation and acquisition of genetic resources (plus extension). 1990-1993.
Key researchers:
Denis Filer, Richard Barnes, Linda Lockhart and Ian Gourlay, Oxford Forestry Institute, UK.

R4583: African acacias: study and acquisition genetic resources: Phase II. 1990-1993.
Key researchers:
Christopher Fagg, Richard Barnes, Ian Gourlay and Linda Lockhart, Oxford Forestry Institute, UK.

R4590: Acacia tree fallows in Senegal: Phase I. 1991-1994.
Key researchers:
David Lindley and Douglas Deans, Institute of Terrestrial Ecology, UK.
Ousman Diagne, l'Institut Sénégalais de Recherches Agricoles, Senegal.

R4677: Rhizobium strain selection for African acacias. 1990-1991.
Key researchers:
Janet Sprent and Joan Sutherland, University of Dundee, UK

R4714: African acacia rhizobial technology and ecology. 1991-1994.
Key researchers:
Joan Sutherland and Shona McInroy, University of Dundee, UK.
David Odee, Kenya Forestry Research Institute.

R5653: Genetic evaluation of African acacias: Phase I. 1994-1996.
Key researchers:
Richard Barnes, Oxford Forestry Institute, UK.
Crispin Marunda, Oliver Makoni, Dzidzayi Maruzane and James Chimbalanga, Zimbabwe Forestry Commission.

R5655: African acacias: study and assembly of the genetic resources: Phase II extension. 1993-1995.
Key researchers:
Christopher Fagg and Richard Barnes, Oxford Forestry Institute, UK.

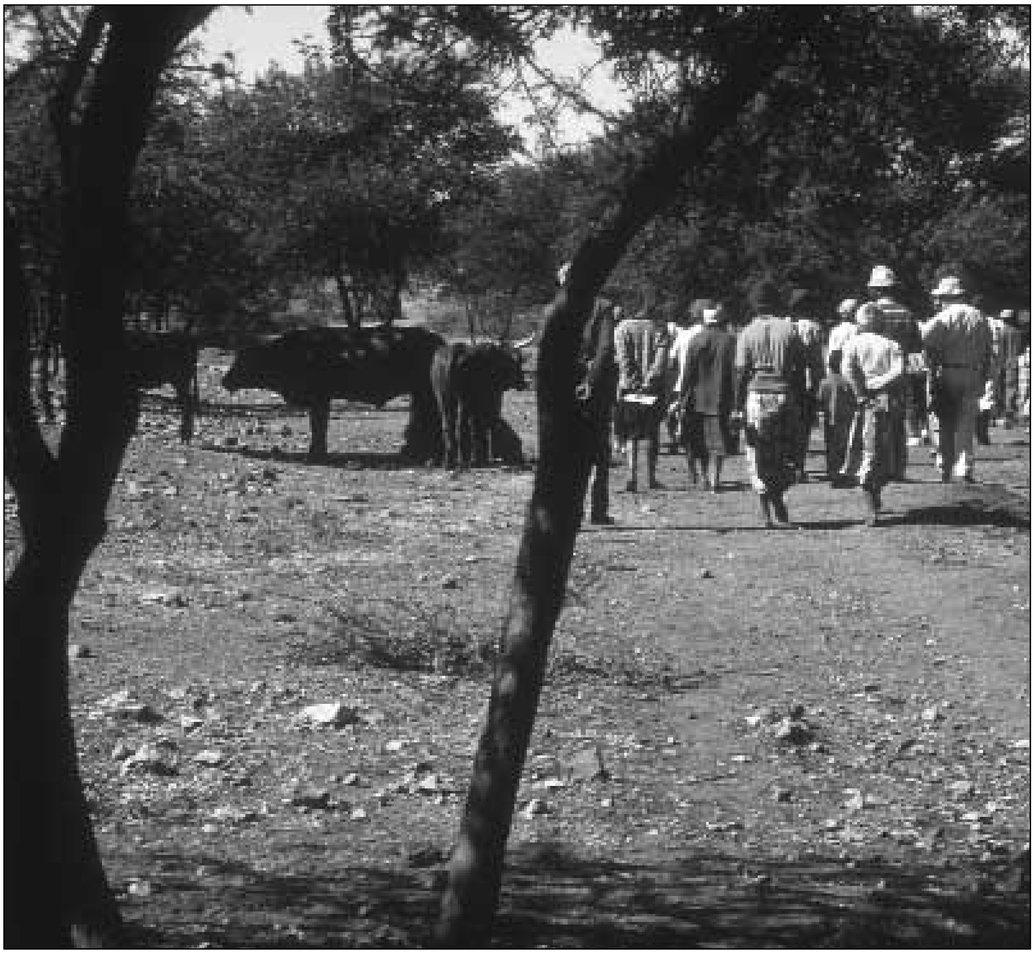
R6076: Acacia tree fallows in Senegal: Phase II. 1994-1995.
Key researchers:
David Lindley and Douglas Deans, Institute of Terrestrial Ecology, UK.
Ousman Diagne, l'Institut Sénégalais de Recherches Agricoles, Senegal.

R6150: Rhizobial inoculum production for African acacias. 1994-1995.
Key researchers:
Joan Sutherland and Shona McInroy, University of Dundee, UK.
David Odee, Kenya Forestry Research Institute.

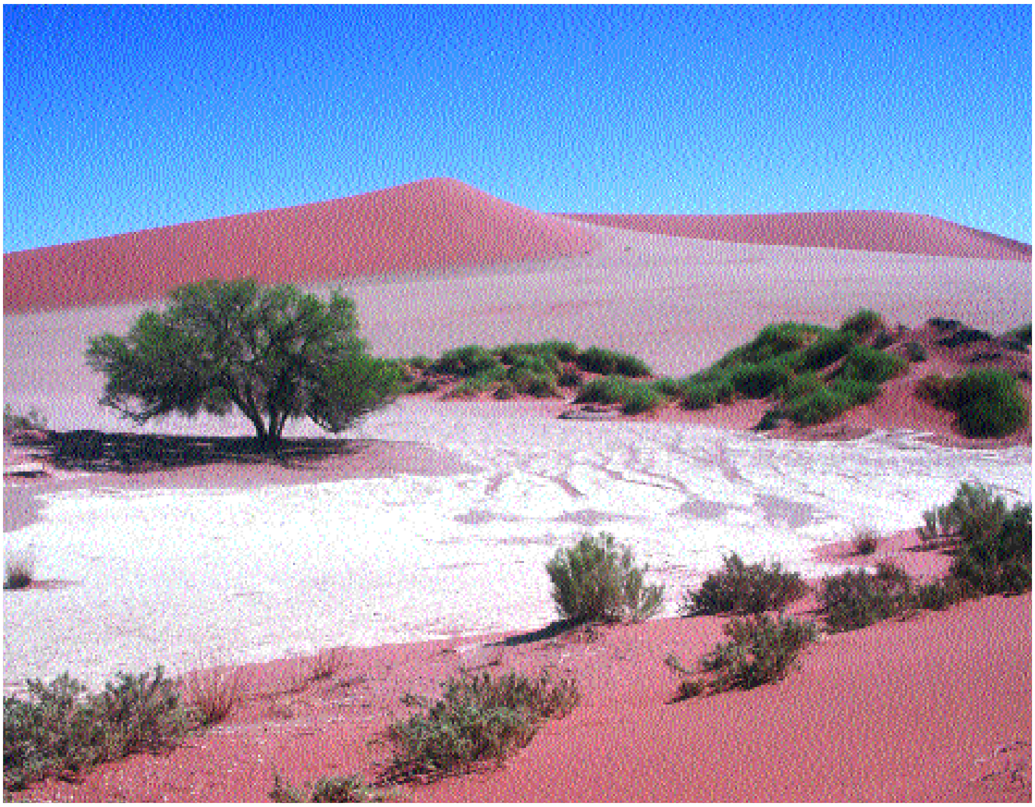
R6349: Dissemination of information on African acacias. 1995-1996.
Key researchers:
Christopher Fagg, Richard Barnes and Rosemary Wise, Oxford Forestry Institute, UK.

R6550: Genetic evaluation of African acacias: Phase II. 1996-1999.
Key researchers:
Richard Barnes, Oxford Forestry Institute, UK.
Crispin Marunda, Dzidzayi Maruzane and Memory Zirobwa, Zimbabwe Forestry Commission.

R7275: African acacias: monographs and manuals. 1998-2004.
Key researchers:
Richard Barnes, Christopher Fagg and Gaia Allison, Oxford Forestry Institute, UK.
Newton Spicer and Jonathan Timberlake, consultants based in Zimbabwe.



Acacia karroo provides shade and fodder for livestock in the Ntabazinduna Communal Area in Zimbabwe.



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