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Samuel Wakhusama
Director, ISAAA *Afri*Center

Benson Kanyi
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ISAAA *SEAsia*Center
c/o IRRI
DAPO Box 7777
Metro Manila, Philippines

Info on ISAAA: For information about ISAAA, please contact the Center nearest you:

ISAAA *Ameri*Center
417 Bradfield Hall
Cornell University
Ithaca NY 14850, U.S.A.

ISAAA *Afri*Center
c/o CIP-ILRI Campus
P.O. Box 25171
Nairobi 00603
Kenya

ISAAA *SEAsia*Center
c/o IRRI
DAPO Box 7777
Metro Manila
Philippines

or write to info@isaaa.org

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FOREWORD

Africa is suffering from unprecedented rates of deforestation and forest degradation. This gives cause for alarm on two counts: firstly, forests provide valuable environmental benefits including the protection of soil and water resources, the maintenance of biodiversity and the sequestration of the greenhouse gases; and secondly, they support a wide range of livelihood and subsistence needs, including the basic need for fuel. Fuelwood is the main source of energy for every country in sub-Saharan Africa. Even in oil-rich countries such as Nigeria, it accounts for over 80 percent of the total energy consumption. In Kenya, 93 percent of rural household energy needs are met from fuelwood.

Without fuel, the people of Africa will remain trapped in poverty and hunger, and economic development will not occur. The region's impending fuelwood crisis means that its countries must find ways of managing and using their forest resources more sustainably. They must stop wasteful deforestation in areas where the resulting cleared land is unsuitable for sustainable agriculture; they must develop and use new technology for converting fuelwood more efficiently; and, most of all, they must plant more trees.

The Tree Biotechnology Project described in this ISAAA Brief addresses the need for extensive tree planting through a novel approach: the use of public—private partnerships to introduce new, fast-growing varieties of trees and to speed up the production of seedlings through tissue culture and clonal technology. The project's ultimate aim is to contribute towards poverty alleviation by making fuelwood and timber more widely available to poor rural and urban people at an affordable price. The strategy is to invite private-sector participation and investment at all stages, from developing and transferring new technology, through tissue culture to ensure rapid multiplication and dissemination, to the launching of tree nurseries and forestry plantation enterprises. This strategy should ensure that project activities are sustained and widespread impact is achieved after the initial, donor-funded, project comes to an end.

Much of Kenya is located in the semi-arid zone, where fuelwood is already in short supply and the growth of trees traditionally used for fuelwood is very slow. The potential of new eucalyptus hybrids, developed by Mondi Forests in South Africa, to grow rapidly in such areas is a source of great hope throughout the dry areas of sub-Saharan Africa.

We wish to acknowledge the Gatsby Charitable Foundation for funding this project and for the continued support for the on-going activities of the project. Other institutions that are partners in the project are Kenya Forestry Research Institute (KEFRI) and Kenya Gastby Charitable Trust (KGCT), and various collaborating NGOs. Mondi Forests have been an exemplary partner throughout the project's establishment phase.

KEFRI's Forest Department has taken the lead in operationalising the research achievements through transfer of the benefits to the rural resource-challenged communities. The Tree Biotechnology Project is a success story in technology transfer of proven and adaptable research for near term benefits downstream. We will continue to foster the partnership developed to ensure sustainability of the realised benefits for the greatest good of all. Already the demand for the clonal cuttings and improved seedlings is higher than the current production and this is a clear demonstration of the success of the Project.

We look forward to the continued collaboration and extension of the similar benefits to other countries with similar challenges.

Gideon Gathaara
Chief Conservator of Forests

EXECUTIVE SUMMARY

The Tree Biotechnology Project was started in 1997 in an attempt to increase the area of forest and the supply of forestry products and services in Kenya, where land clearance for agriculture and increasing demand for wood, particularly fuelwood, is causing widespread deforestation and forest degradation. Current tree planting efforts are severely constrained by a lack of good quality seed and slow, inefficient traditional propagation methods. Unless urgent steps are taken, Kenya will soon be facing a fuelwood crisis, which is likely to have severe implications in terms of human health and welfare as well as contributing to further environmental damage.

The project brings together the Kenya Forestry Research Institute (KEFRI), the Forest Department of Kenya's Ministry of Environment and Natural Resources and Mondi Forests, a division of Mondi Ltd of South Africa. The latter is a large private company, which has around 20 years of experience in tissue culture and clonal techniques of tree propagation. Using biotechnology makes propagation faster and more efficient, producing disease-free trees that grow faster than conventionally produced tree seedlings. Building on Mondi's experience, the project aims to speed up the process of tree production by introducing the techniques of tissue culture and clonal hedge propagation and integrating these with traditional forestry practices in Kenya.

A vigorous and drought-tolerant hybrid eucalyptus (*E. grandis* x *E. camaldulensis*) has been introduced from Mondi and is performing well in seven field trial sites in different areas of Kenya. Clones provided by Mondi have been multiplied through tissue culture and used to establish a central clonal nursery at Karura, near Nairobi. The nursery is currently producing 500,000 seedlings annually, with plans to expand production to 3 million a year by the end of 2005. Hedge propagation ensures these tissue culture eucalyptus seedlings are fast growing, resistant to pests and diseases, and provide a uniform product, while maintaining clonal desirable characteristics. Vegetatively propagated plants are fast growing and due to the selection techniques utilised in the breeding and clonal programmes these clones are less susceptible to pests and diseases, whilst producing a very uniform crop.

The project aims to create a self-sustaining production and dissemination system, driven by private enterprise, in which donor support is necessary only for the first phase. Initial sales will therefore be targeted at commercial enterprises involved in forestry or using wood. As production increases and economies of scale are achieved, small-scale farmers and the urban poor will become the project's major beneficiaries. The capacity of KEFRI and the Forest Department will also be greatly enhanced and the infrastructure and skills they acquire will help them manage further technology transfer and extend the project's impact to other countries in East Africa. A similar project is already in its initial stages in Uganda, where a partnership between the Forestry Resources Research Institute (FORRI) and Mondi Forests has been established with additional backstopping from KEFRI.

While clonal propagation provides disease-free planting material, large-scale tree planting of single clones could narrow the genetic base and increase pest and disease problems, so parallel efforts will be made to step up the production and dissemination of local tree species through the propagation technology, thereby maintaining biodiversity. The project team are currently developing the methodology for improving the production of local germplasm by tissue culture and from seeds.

Access to a convenient and sustainable source of fuelwood will help to alleviate poverty in both rural and urban areas. Fuelwood and timber 'cash crops' will provide a reliable source of income for small-scale farmers, feeding wider economic growth. Commercial forestry and the timber trade will also benefit, with increased opportunities for employment in tree production and timber processing.

Providing a reliable supply of improved tree seedlings will have important benefits for the environment. By increasing and sustaining the supply of timber, the project will reduce the pressure on natural forests, helping to preserve valuable natural biodiversity and rare habitats. Tissue culture technology also has the potential to increase biodiversity by replacing the stocks of rare and endangered tree species. The wider environmental benefits of increasing tree cover include improving soil stability, reducing erosion, preventing desertification and stabilising global climate.

ABOUT ISAAA

The mission of the International Service for the Acquisition of Agri-biotech Applications (ISAAA) is to contribute to poverty alleviation by increasing crop productivity and income generation, particularly for resource-poor farmers, and to bring about a safer environment and more sustainable agricultural development. Sponsored by public- and private-sector institutions, ISAAA's objectives are the transfer and delivery of appropriate biotechnology applications to developing countries and the building of partnerships between institutions in the South, where the need is, and the private sector in the North, where most biotechnology innovations are developed and owned.

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1. INTRODUCTION

1.1 The tree crisis in Africa

Forests are one of the world's most vital natural resources, but they are disappearing at an alarming rate. Between 1990 and 2000 around 14.6 million hectares of forest have been lost every year, while annual planting rates are only around 5.2 million hectares (FAO, 2001). The major cause is population growth and the concomitant need to expand the area of agricultural land. The consequences of deforestation include loss of biodiversity, soil erosion, desertification and global climate change through the greenhouse effect.

In developing countries, most people still rely on wood as their major source of fuel. Many such countries in sub-Saharan Africa are heading for a fuelwood crisis. According to KEFRI's Strategic Plan (1999), over 95% of the total energy for domestic purposes in Kenya is provided by fuelwood and charcoal. Energy studies carried out under the auspices of the Kenya Wood Fuel Project (O'Keefe *et al*, 1984) noted that the wood base was declining rapidly because consumption was far in excess of production. Annual demand increased from 20 million tonnes in 1980 to over 50 million tonnes in 2000, and the wood supply deficit is estimated to reach three million cubic metres by 2010.

The consequences of a fuelwood crisis are acute, especially for the poorest sectors of the community. Women have to spend a large proportion of their time collecting firewood, time that would be better spent on growing and looking after their food crops. Farmers use manure and crop residues as fuel instead of returning them to the soil as fertilizer, so their land becomes less productive. The urban poor often cannot afford to buy wood or charcoal, so many of them cook less often and eat more raw food, leading to a higher incidence of disease and malnutrition. Better access to fuelwood could therefore have an enormous impact on poverty alleviation, not just financially but in all sorts of other ways that are important in improving the living standards of poor people.

In Kenya, efforts have been made to educate people in the more efficient use of fuelwood and in alternative energy resources. The formulation of a Forestry Master Plan in 1994 was a sign that the country is developing the political will to alleviate the deforestation problem. The plan signals a commitment to the needs of the poor by emphasising a shift from industrial forestry to social and farm forestry throughout the country.

Currently, tree seedlings are available through several different outlets:

- Forest Department of the Ministry of Environment and Natural Resources
- Non-government organisations (NGOs) and self-help groups
- Individual farmers
- Entrepreneurs (through roadside nurseries)
- Schools and prisons
- Private institutions, e.g. tea and tobacco plantations.

Roadside tree nursery near Nairobi, Kenya. The sellers collect seed from the bush, growing seedlings of variable quality that are often diseased.

The Forest Department operates over 250 small tree nurseries around the country, and around 35 million trees from these nurseries are planted in Kenya annually. But in order to meet future demand, planting rates need to be increased to at least 60 million, and probably nearer 200 million per year (Gathaara, 2002, personal communication).

Trees are traditionally propagated from seed or from cuttings. Seed propagation is inefficient, as trees often do not produce seed until they are several years old. Germination rates are usually low and the resulting seedlings have variable characteristics. Conventional cuttings are obtained by selecting a tree with the desired properties, cutting the stem, and allowing small shoots to regenerate on the stump. These can be harvested, rooted and planted out. This traditional technique speeds up the multiplication process, but approximately half the shoots will be discarded because they do not root successfully. In addition, the technique does not eliminate diseases and pests.

In Kenya, as in other African countries, the support system for tree propagation also leaves much to be desired. There is little or no screening of germplasm. Many nurseries are extremely small and lack proper knowledge and management. There is also a lack of knowledge among small-scale farmers; for example, many believe that only men should plant tree seedlings and that trees require no care after planting. There is therefore an urgent need to back up an improved supply of good quality planting materials of desirable species with the transfer of increased knowledge and better management practices.

1.2 Using biotechnology to produce trees

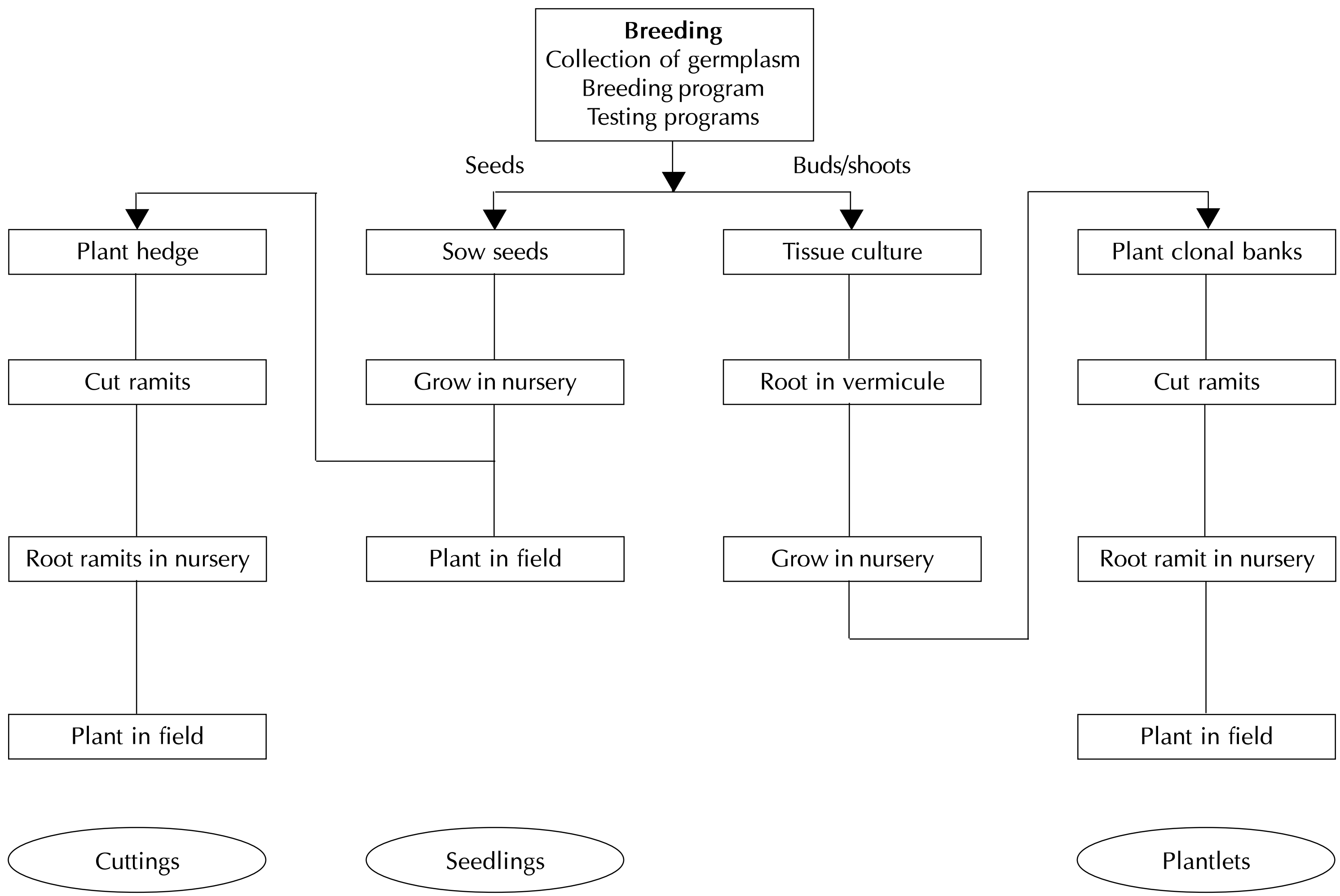
The immediate need for widespread tree planting in Kenya demands a new concept in tree production technology. Propagating trees through biotechnology has several advantages. Tissue culture produces large numbers of disease-free plantlets in a short time and the plants grow faster than conventional planting material. That of vegetative propagation, supported by clonal hedges, ensures the transfer and retention of desirable characteristics such as uniform growth in a plantation – a considerable advantage for commercial forestry. Internationally, several commercial forestry producers have adopted the use of biotechnology for tree production and have invested significant resources in it. Experience in South Africa has shown that clonal forestry is more profitable than traditional methods, provided the clones are matched to suitable sites.

Tissue culture (micro-propagation) of trees can be done in two ways. The technique of embryogenesis (organogenesis) involves placing buds in special culture media where the cells begin to grow and form calli. These can be sub-cultured (divided many times) and are then placed on different media to induce shoot and root growth. When the plantlets are a few centimetres high, they are transferred into semi-sterile soil (usually vermiculite) and slowly acclimatised to normal growing conditions. The culture of buds follows the same steps, except that the plantlets are raised directly from shoots without going through the callus stage.

Large-scale clonal tree production (macro-propagation) is achieved by planting rows of hedges established from tissue culture material, called 'clonal hedges'. After three to six months, the stems are cut at around 40cm high, and the tree regenerates by producing many coppices, which are cut and placed in vermiculite for rooting. 'Clonal banks' are established in the same way as hedges, but are not usually harvested regularly. Instead, they are carefully maintained as a source of pure germplasm for potential buyers or further research. Figure 1 illustrates the various processes for producing tree planting material.

◀ Clonal cuttings growing in controlled conditions in the rooting section of the central clonal nursery at Karura.

Figure 1. Conventional and clonal tree production



Trees for the clonal program are usually selected from seedlings of known parentage. i.e. from controlled cross pollinations. These are then multiplied into sufficient quantities to test in clonal trials across the various sites where these clones would be deployed in the future as commercially approved clones. This would happen when the clones in the trials have been assessed for volume, disease resistance and any other traits that are to be used in the selection process like high calorific values. Only once the clones have passed the evaluation tests are they commercially propagated for sale. The system of planting seedlings in the clonal hedges as we are doing at Karura will supply a wider genetic source of material for the clonal testing program.

The initial focus of the Tree Biotechnology Project is on the production of eucalyptus trees, for which tissue culture propagation techniques have already been developed. Additional species selected for the initial phase are *Grevillea robusta* and *Mellia volkensii*, popular local agroforestry trees, and *Acacia melanoxylon*, the Australian blackwood, which has potential to supply the carving industry, thereby helping to conserve the endangered ebony. Tissue cultured *A. melanoxylon* can reach maturity in ten years, while ebony takes 50-60 years. Table 1 shows the criteria for selection of these species.

Table 1. Criteria for the choice of species for the project

Species	Reasons for selection	Uses	Traditional production	Propagation by tissue culture
Eucalyptus	Fast growing Suitable for different ecological zones Drought-tolerant Regenerates easily High demand	Pulp and paper Timber Fuelwood Posts and poles	Slow propagation (~12-17 cuttings in 3 weeks) Wood tends to split 9 years to maturity Low efficiency in converting to pulp Uneven stands make harvesting difficult	Rapid propagation (35-50 cuttings in 3 weeks) Less splitting 5-6 years to maturity More energy efficient for paper production Uniform size benefits commercial forestry
Grevillea robusta	Fast growing Well adapted High demand	Fuelwood Timber Poles and posts Shade, windbreak Fodder	Slow/expensive seedling production Low germination rates Wood tends to split 8-12 years to maturity	Fast, more efficient production of seedlings Enhanced growth, increased biomass Less splitting 6-8 years to maturity
Acacia melanoxylon	Fastest growing hardwood Commercially suitable and acceptable	Carving Furniture Charcoal	Slow/expensive seedling production Low germination rates Wood tends to split 10-12 years to maturity Short shelf-life of seeds	Fast multiplication Less splitting Increased biomass 8-12 years to maturity
Mellia volkensii	Fastest growing indigenous species in arid and semi-arid lands	Fuelwood Furniture Timber Fodder Shade Posts	Poor seed regeneration Low survival rates Very few seedlings available Poor growth and form	Rapid multiplication for establishment of clonal hedges from selected elite trees Good survival rates Maturity 10-12 years in arid/semi-arid lands

1.3 The benefits of eucalyptus

The initial focus on eucalyptus arose in response to an assessment of the needs and priorities of small-scale farmers in Kenya. The assessment revealed the country's growing shortage of fuelwood especially, but also of timber and other wood products. Eucalyptus trees were introduced into East Africa from Australia around 100 years ago. In Africa, where the tree flowers throughout the year, a combination of cross-pollination and natural adaptation to a range of different climatic conditions has already given rise to considerable genetic diversity. Eucalyptus trees are popular because they grow fast. The wood, which is strong and burns well, is used by the tobacco, tea, electricity and telecommunication industries as well as by farmers for firewood, charcoal, fence poles and stakes. The project focuses on enhancing the production of several species, including the local *E. grandis, E. saligna* and *E. tereticornis* as well as the introduced hybrid *E. grandis x E. camaldulensis*, (GC), which is particularly suitable for the drier areas of Kenya.

Eucalyptus propagated through tissue culture results in disease-free material that is even faster growing and resistant to attack by common fungal diseases and insects. The trees also show an amazing uniformity of growth, making them ideal for commercial forestry. They have a good level of energy conversion, providing a relatively efficient source of fuelwood and charcoal. They grow to a size suitable for firewood and stakes after just one year, for fencing and telecom poles at four years and can be harvested for electricity poles and sawn timber after just six or seven years.

Seedling of the drought-tolerant hybrid E. grandis x *E. camaldulensis*.

2. THE TREE BIOTECHNOLOGY PROJECT

2.1 Objectives

The general objective of the project is to improve the living standards of rural families in Kenya, particularly those who are poor, by enhancing forestry production through the integration of improved tissue culture forestry biotechnologies into traditional propagation systems (FHMC, 1995).

The specific objectives are to:

- Establish a testing programme in Kenya for introduced germplasm and clones as well as nationally produced germplasm of several key tree species.
- Establish a breeding programme for indigenous species and hybrid clones.
- Set up and manage a pilot production facility for the efficient production of tissue culture clones, paying particular attention to the need to integrate the production process with locally available raw materials and appropriate technologies.
- Develop regional demonstration and distribution nurseries and establish links with partners to ensure the efficient distribution of plantlets.
- Build the capacity for making use of biotechnology applications in the forestry sector and promote interaction between government ministries, universities, NGOs and commercial enterprises so as to create a sustainable production and distribution programme.
- Pay sufficient attention to commercial enterprise to ensure the project becomes self-financing within the shortest possible time.

2.2 Partners

A considerable investment of time and money is needed to integrate biotechnology successfully with traditional forestry. ISAAA believed that the most cost-effective option would be to collaborate with established centres of excellence and to speed up production by importing improved germplasm, while concurrently establishing national capacity and developing national breeding programmes. A mutually beneficial partnership was therefore established, originally between the Forest Health Management Centre (FHMC) and Mondi Forests, a division of Mondi Ltd of South Africa. The current partners are the Forest Department of the Kenya Ministry of Environment and Natural Resources, the Kenya Forestry Research Institute (KEFRI) and Mondi Forests. The project was conceived by ISAAA, which also provided the facilitation and leadership needed to bring the partners together.

Mondi Forests

Mondi was selected by ISAAA as the project's leading private-sector partner after an extensive survey of forestry companies around the world. Although the technology of establishing clonal banks and hedges was originally developed by a Belgian company in West Africa, it was Mondi that improved the system and adapted it to the large-scale production of pines and eucalyptus. At present, Mondi uses tissue culture for research and trial but not for commercial plantations. The company has an extensive biotechnology research programme and a large tissue culture laboratory. Mondi also has a comprehensive breeding and testing programme for commercial forestry species and it's activities cover the whole spectrum from production, through processing to distribution. Mondi's experience in an African context was another asset, as the company operates in a similar social environment to that of Kenya and knows the tree species that are appropriate for the country. Moreover, the company has an interest in development and some experience of working in this field, being a committed participant in South Africa's Rural Development Plan, which aims to improve the livelihoods of the rural poor. Lastly, the company also has strong links with the University of Pretoria, with whom it collaborates in disease monitoring and student work experience programmes.

On its side, Mondi was keen to be involved in the Tree Biotechnology Project as it had an interest and commitment to assisting the transfer of technology that it had been involved into African countries that required the technology.

FHMC

ISAAA selected FHMC, a division of the Kenya Forest Department, as the original Kenyan partner in the project. The main reason for this choice was that the organisation already had some experience in tissue culture, through studies on *G. robusta*. FHMC was felt to have the required scientific knowledge to handle the establishment of trial plots and to provide Mondi with data on the performance of its clones. In 2000, the project management structure was re-organised and the Forest Department assumed overall responsibility.

KEFRI

Originally involved in aspects of field monitoring, including pest and disease assessment, KEFRI now undertakes collecting and assessing trial data. In addition, its field staff will be involved in technology dissemination to small-scale farmers, training farmers in good forestry management practices and involving them in participatory species/varietal selection to increase the range of species available, principally through socio-economic studies.

Genetic Technologies Limited

Tissue culture services and technology are now provided by the private company, Genetic Technologies Limited (GTL), an established laboratory located in Nairobi. GTL has experience of tissue culture work in other crops and has worked with ISAAA in the production and distribution of tissue culture banana plantlets. The original plan was to develop the small existing tissue culture capacity at FHMC, but involving the private sector and using existing capacity was found to be more cost-effective (see Discussion section 6.2).

Forest Department

The Forest Department of the Kenya Ministry of Environment and Natural Resources has overall responsibility for the project and provides land for the clonal nursery and trial sites, key project staff, field extension support and office and logistical facilities.

Gatsby Charitable Foundation

Financial support is provided by the Gatsby Charitable Foundation of the UK. The Kenya Gatsby Trust administers the funds and provides financial management, ensuring efficient project planning, implementation and accountability. It is hoped that donor support will only be required for the project's initial phase, and that the Kenya Gatsby Trust will play a continuing role in managing micro-credit and marketing schemes. This role fits with its mission to stimulate local business, thereby creating employment opportunities and supporting wider economic growth in Kenya.

ISAAA

ISAAA brokered the project, conducting the initial research to determine its objectives and feasibility, then planning the project in detail, selecting the most appropriate partners, writing a project proposal and soliciting donor support. The service also plays a key role in identifying and dealing with legal and contractual issues, which can be complicated when transferring a proprietary technology.

2.3 Methodology

Importation of clones

Mondi donated 12 hybrid GC clones, a cross between *E. grandis*, a fast growing eucalyptus, and *E. camaldulensis*, a drought-tolerant species. The progeny of this cross were thought to be particularly suitable for Kenya's semi-arid zone, where the shortage of fuelwood is particularly acute. The clones were donated free of charge, in return for access to data on their performance under local conditions. Strict quarantine, to meet Kenya's national requirements, was enforced.

Field trials

The GC clones have never before been grown outside South Africa, so field trials to assess their adaptation were an essential first step. Seven representative sites in different agro-climatic zones of Kenya were selected, with assistance from Mondi experts (Table 2), in order to assess the clones' growth rates and disease status and to compare their performance with local eucalyptus germplasm (*E. grandis*, *E. saligna* and *E. tereticornis*) propagated from seed. Land for field trial sites was set aside under a provision for temporary land allocation (25 years) from the Government of Kenya.

The trial plots also act as demonstration sites and will become distribution points for marketing purposes. The sites were therefore selected not solely for their agro-climatic characteristics but also from the point of view of the potential demand for seedlings locally. For example, *Acacia melanoxylon* is being evaluated primarily in Machakos, as the area supports a large carving industry.

The field trial design is given in Table 3. Each experiment consists of three replications with a total of 30 plots. Each plot is planted with 25

Table 2. Field trial sites in Kenya

Site	Rainfall	Altitude	Current supply/demand	Species being evaluated
Karura	1100 mm	1200 m	High demand	Clones/local
Laikipia	1200 mm	1600 m	High demand	Clones/local
Timboroa	1400 mm	2000 m	Demand for eucalyptus	Clones/local
Hombe	1200 mm	1800 m	High demand for eucalyptus and *G. robusta*	Clones/local
Naivasha	800 mm	1400 m	High demand	Clones/local
Machakos	1000 mm	1800 m	Only eucalyptus and *G. robusta* currently available	Clones/local
Embu	1100 mm	1600 m	High demand for eucalyptus and *G. robusta*	Clones/local

Table 3. Field trial design

1st replication			2nd replication				3rd replication		
1 GC 10	6 GC 642	7 *E. saligna*	12 GC 10	13 GC 15	18 GC 581	19 *E. grandis*	24 GC 581	25 *E. tereticornis*	30 GC 642
2 GC 522	5 GC 14	8 *E. tereticornis*	11 *E. saligna*	14 GC 14	17 GC 12	20 GC 642	23 GC 12	26 *E. grandis*	29 GC 14
3 GC 581	4 *E. grandis*	9 GC 15	10 GC 12	15 *E. tereticornis*	16 GC 522	21 *E. saligna*	22 GC 522	27 GC 10	28 GC 15

Source: FHMC, 1998.

Trial plot at Karura, Kenya.

trees, at a distance of 0.25m, with a total of 75 trees of each species per trial. Three rows of *E. grandis* are planted around each trial plot to counteract the edge effect.

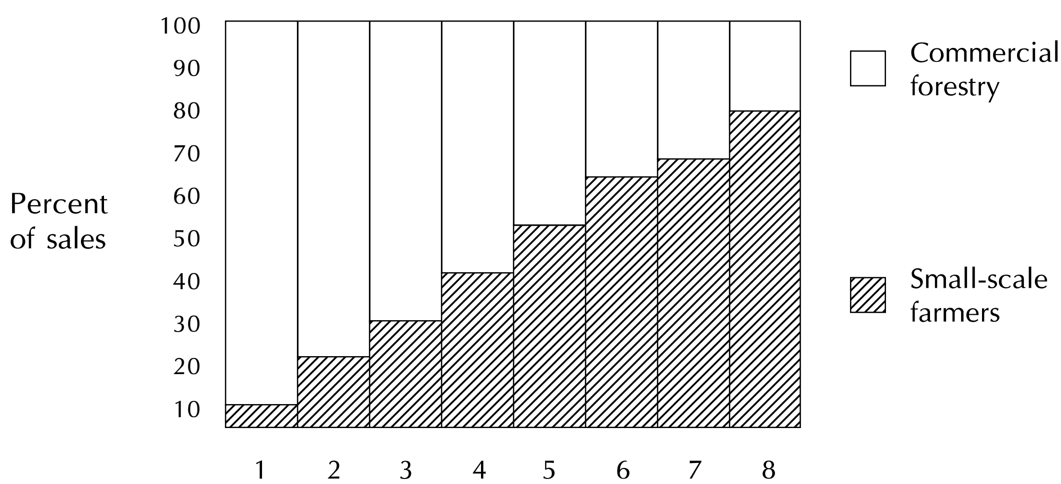
Capacity development

The project builds on existing capacity as a cost-effective way of achieving impact rapidly. This approach has proved appropriate in previous ISAAA-facilitated projects, notably the banana tissue culture project. At the start of the tree project there was very little capacity for tissue culture or clonal production of trees in Kenya. The assistance of Mondi Forests has been invaluable in this respect. For example, the Mondi Tree Breeding Manager, an expert on large-scale clonal production, has provided vital leadership and technical support, making several visits to Kenya to advise on technology transfer strategies, suitable clones and trial sites and to develop integrated breeding and clonal multiplication programmes. Mondi expertise helped to design the central clonal nursery at Karura, near the headquarters of the Forest Department. The efficient production of plantlets depends on good nursery management, so extensive staff training and technical backstopping were essential. Human capacity in Kenya has now been developed in nearly all the fields needed to build an effective production and dissemination system, including tissue culture operations, nursery production and clonal bank management. Much of the capacity has been instilled by sending Kenyan nationals on graduate courses at the University of Natal and through practical training at Mondi.

Marketing and distribution

The project has a highly commercial focus. Initial production and sales are targeted at commercial forestry institutions and at large-scale enterprises using fuelwood. Once economies of scale have been achieved, the project's nurseries will be able to reduce their prices and offset the high costs of distribution to the country's widely scattered small-scale farming communities. In addition, once the immediate needs of commercial forestry are met, this market is likely to decline, whereas demand from consumers for fuelwood is likely to increase. The target ratio for sales of plantlets is 70:30 smallholders to commercial forestry by the seventh year of the project (see Figure 2). The promotional plan includes extensive communication activities, such as exhibitions and events held at the trial and demonstration sites, participation in agricultural shows, the provision of information booklets, and the taking of editorial and advertising space in newspapers and radio. Commercial forestry companies are being approached directly, while communication aimed at small-scale farmers will be directed largely through NGOs.

Figure 2. Changes in the target market over time



3. PROGRESS AND PLANS

3.1 Early constraints to progress

The project was originally managed by FHMC, a division of the Forest Department. Despite thorough initial planning, the business of acquiring land for trial plots and installing services (electricity and borehole water) for the central clonal nursery was difficult and slow. In addition, due to other work commitments, the project manager was unable to devote sufficient time to the project. In 2000, the project was restructured and a new project manager was appointed, resulting in much more rapid progress.

3.2 Field trials

Field trials have provided very useful data on the performance and adaptability of the clones imported from Mondi. Different growth rates have been observed in different agro-ecological zones. Eight of the original 12 GC hybrids have performed well, with growth parameters exceeding those of local germplasm and with good tolerance to drought. The clones are therefore considered to be suitable for large-scale growing in Kenya, especially in the semi-arid zones where wood is now scarce and there are few alternative species that perform well. They have a high density and high calorific value, making them an efficient source of fuelwood. The clones also show excellent uniformity of growth, a feature that is highly valued by commercial operators.

Table 4 illustrates growth performance at Machakos, Timboroa and Hombe trial sites. Machakos is a site of intermediate altitude and rainfall, where the GC hybrids have adapted well and tend to out-perform the local species. However, in high elevation areas with fertile soil and good rainfall, such as Timboroa and Hombe, some clones did less well, exhibiting some forking. Here, local species also grew less well indicating that this type of agro-ecological zone is less likely to achieve the highest growth rates for eucalyptus. However, more research for high elevation *Eucalyptus* species is in progress under KEFRI. Full trial data can be found in Appendix 2.

Constant visual monitoring was carried out to identify pest and disease problems and treat them where possible. No serious pest or disease problems have yet been noted, and the GC hybrids seem less susceptible to diseases (such as *Cryphonectria* canker) than *E. grandis*. Black aphid attack occurred in Machakos on *E. tereticornis,* but local natural biocontrol agents kept pest populations far below those required to cause serious damage. Other minor damage resulted from moles gnawing on the roots and game causing damage to the bark. Termite control was necessary during planting in some areas and purchasers will therefore be advised to take suitable measures when transplanting.

The field trials have also provided data to suggest which species are most suited to different agro-ecological zones (Table 5).

Table 4. Height (m) of GC clones and native eucalyptus species at Machacos, Timboroa and Hombe trial sites

Trial Species	Machakos (1.8 years)	Timboroa (2 years)	Hombe (1.67 years)
GC 10	12.1	Not planted	9.0
GC 14	12.3	6.2	8.3
GC 15	12.3	5.7	8.1
GC 522	12.1	Not planted	9.1
GC 581	11.5	8.6	8.9
GC 642	11.7	6.7	8.6
E. grandis	11.8	3.9	8.7
E. tereticornis	7.9	4.0	6.4
E. camaldulensis	5.5	3.0	7.7
E. saligna	8.5	5.8	8.2

Table 5. Eucalyptus species and their optimum growing conditions.

Species	Annual rainfall	Altitude
E. grandis	> 900 mm	1200 - 2000 m
E. camaldulensis	450 - 900 mm	0 - 1200 m
E. tereticornis	450 - 900 mm	0 - 1200 m
E. urophylla	> 900 mm	0 - 1600 m
GC hybrids	600 - 1400	0 - 1200 m

3.3 Clonal nursery

The clonal nursery was established at Karura, on land owned by the Forest Department. The six-hectare site was chosen for its deep soil, gentle slope, its proximity to a main road and the fact that water and electricity seemed to be within easy reach of the project offices. Although the site has access to river water, a borehole was drilled to provide a more reliable source of good quality water. This was needed to ease the task of irrigating the clonal hedges, plantlets and seedlings and to provide the purity required to ensure maximum survival rates. The team also installed a rain gauge so that rainwater can be accurately supplemented by computer-controlled irrigation, thereby maximising water use efficiency. Most consumable inputs are available locally, but some, such as vermiculite, are expensive because they have to be imported, and more cost-effective options are therefore being explored. The nursery has experienced problems in finding a reliable source of rooting trays and inserts and is currently importing these from South Africa. Again, the project team are investigating alternative sources.

Clonal hedges have been established from the GC hybrids donated by Mondi, which have been multiplied through tissue culture at GTL, and from macro cuttings (Table 6). By July 2002 there were 17,265 established mother plants, which can be harvested every two weeks. After harvesting, the coppices are placed in a rooting medium and kept in the rooting house under conditions of controlled temperature, pH and humidity. A 50% shed net was used at first, but this was found to provide insufficient shade, so a double net is now in place. Cuttings are then 'hardened off' outside before they are ready for sale at around three months after harvesting. Rooting success is currently around 56%, which is slightly below Mondi's of 60-70%, but this is expected to increase as the nursery personnel become more knowledgeable and competent. The annual output of the nursery for 2002 is estimated at 0.5 million cuttings, while the target for 2005 is 3 million.

◀ Clonal hedges of GC hybrids at Karura nursery.

Table 6. Composition of the clonal nursery

Species	Number of mother plants
GC hybrids (tissue culture)	3,100
E. grandis (from seed)	1,307
GC hybrids (from macro cuttings)	12,736
A. melanoxylon	72
G. robusta	50
Total	**17,265**

In addition to importing quality seed from Mondi (*E. grandis* and *E. urophylla*), nursery staff have made significant progress in collecting and germinating seeds from local eucalyptus species (*E. grandis*, *E. saligna* and *E. tereticornis*), from *G. robusta* and from *A. melanoxylon*. The resulting seedlings form parent stock that will be multiplied through tissue culture and clonal banks. The individual trees from which seed were collected were selected on the basis of fast rate of growth, adaptation to desired agro-ecological conditions and large biomass production.

The nursery also produces seedlings from seed for sale to commercial outlets or individual farmers. Different methods of sowing seed were tried, including direct sowing and sowing into germination beds. The nursery team found that direct sowing by hand into a mixture of 2:1 forest soil and sand in locally available containers was the most cost-effective method. Germination rates of 80% for imported seed and 60% for local seed have been attained, which are higher than the usual rates (40-60%) reported by traditional tree nurseries. This is just one example of the way in which the effort put

Hand sowing of seed at Karura nursery.

into capacity building and experimentation has paid off.

Seedlings and plantlets are usually sold at the beginning of the long or short rainy season (March/April and October), so the production system has to meet demand at the right time. Space has therefore been allocated for storing and nurturing the seedlings so that these are ready for peak buying times. Current prices are KSh10 per clonal cutting and KSh6 for a seedling raised from seed. These prices are very competitive and much lower than commercial sellers, particularly in urban areas.

Pests and diseases are kept under control by manual weeding, removal of dead leaves and spot spraying of insect pests. Mild attacks of fungal blight and powdery mildew have been controlled by spraying with a fungicide, while termite control was necessary in the early stages of establishment.

The nursery now employs 16 full-time staff and up to 180 casual staff at busy times. Besides boosting the supply of trees around Nairobi, it has thus become a significant local employer.

3.4 Farmer trials

Current farmer trials are summarised in Table 7. Growth rates of up to two metres have been recorded in a period of four months, while survival rates of 98-100% have been achieved. A particular area of note is the semi-arid Kajiado district, where the GC hybrids are showing good tolerance to drought in a region where rainfall is generally below 500mm per year and is very unreliable. Farmers in this area have traditionally relied on livestock to provide them with an income, and have little opportunity for diversification. The natural open acacia forest has been severely degraded and fuelwood is becoming very scarce. One farmer has found that GC hybrids will survive if given as little as one litre of water per week for the first four weeks, then nothing but rainfall, and that the hybrids grow almost twice as fast as *E. grandis*. His woodlot is already acting as a demonstration plot and a talking point for other farmers in the area, who are very interested in the potential of these trees both for fuelwood and as a cash crop. Another use of the trees, found by these farmers and not originally thought of by the project, is to coppice them to form a stock-proof hedge as well as a ready supply of fuelwood, posts and poles. This development confirmed the value of involving farmers as active participants early in the project's life.

3.5 Personnel and training

The partnership with Mondi Forests and FABI of the University of Pretoria has contributed greatly to the development of human capacity. The Karura clonal nursery manager attended a six-week training course at Mondi. On his return, he was able to train his staff in the techniques of clonal propagation, such as felling, cleaning cuttings and preparing media, in addition to the general principles of plant hygiene.

Table 7. Location of on-farm trials and varieties being evaluated

Contact Farm	Location/District	Varieties planted
1. Muguku	Kikuyu, Kiambu	GC 785, 584, 581, 15 and *E. grandis*
2. Richard Bett	Bomet	GC 15, 796, 785,581, 167, 584 and *E. grandis*
3. Grete Davey	Athi River, Machakos	GC 581, GC 12, *E. camaldulensis, E. tereticornis* and *E. grandis*
4. Njenga	Uthiru/Kiambu	*E. grandis*
5. Cirio Delmonte	Thika	*E. grandis*
6. Peter Bett	Ngata/Nakuru	*E. grandis*
7. African Highlands	Londiani, Kericho	GC 167, 584, 581, 15, 14, 642, *E. grandis* and *E. urophylla*
8. Kakuzi Ltd.	Makuyu/Thika	GC 167, 785, 796, 581, 584, *E. urophylla, E. grandis* and *E. camaldulensis*
9. David Muraya	Kitengela, Kajiado	*E. grandis, E. camaldulensis* and *E. tereticornis*
10. Kisima Farm	Timau/Nanyuki/Meru	GC 796, 785, 167, 581, 584 and *E. grandis*
11. East Produce Kenya Ltd.	Nandi Hills/Nandi	GC 581, 10, 14, 642, *E. grandis* and *E. urophylla*
12. Mwangi Njuru	Githunguri, Kiambu	GC 167, 785, 581, 14 and *E. grandis*
13. Peter Mutharia	Ol-Jororok/Nyandarua	*E. grandis*
14. Waigwa Murage	Ngong/Keserian/ Kajiado	GC 642, 12, 14, 785 and 167
15. Peter Kinyanjui	Njoro	*E. grandis*

A 'living hedge' grown from the drought-tolerant hybrid *E. grandis* x *E. camaldulensis*.

The drought-tolerant hybrid *E. grandis* x *E. camaldulensis* after just 9 months growth in the semi-arid Kajiado district of Kenya.

Preparing cuttings for rooting is another area in which the Karura team has benefited greatly from training. This is a delicate process, requiring a good level of knowledge from the technician. The core of trained production staff at the nursery will later be able to train others, providing a resource that can be drawn upon when establishing additional nurseries.

Acquisition of knowledge has helped the nursery manager to experiment with different growing conditions and to ascertain the most cost-effective methods for the Karura situation. Other personnel have attended post-graduate courses at the University of Natal and a scientist from FHMC was trained by Mondi in tissue culture techniques. Table 8 illustrates the training courses attended by project staff.

Table 8. Training courses

Name	Training Undertaken	Institution	Current Placing
Pauline Mbabu	B. Sc Biology (Tissue culture of hardwoods)	University of Natal and Mondi	Attending M.Sc course in Germany
Muraya Minjire	Clonal Nursery Management	Mondi in house	Clonal Nursery Manager, Karura
Benson Kanyi	Commercial clonal operations and value adding processes	Mondi in house (ICFR and FABI)	Project Manager Tree Biotechnology Project
Eston Mutitu	Entomology and Diagnostic techniques in eucalyptus	FABI/Mondi/TPCP (in house)	Entomologist at KEFRI
Linus Mwangi	Pathology of eucalyptus and diagnostic techniques	FABI/TPCP (in house)	Pathologist at KEFRI

ICFR = Institute of Commercial Forestry Research
FABI = Forestry and Agricultural Biotechnology Institute
TPCP = Tropical Pathological Cooperation Programme

3.6 Tissue culture

GTL has been successful in adapting its tissue culture facilities to tree propagation and has multiplied the GC hybrid material supplied by Mondi. A total of 3100 GC plants have been raised by tissue culture at GTL so far. In addition, GTL is establishing protocols for the tissue culture multiplication of *G. robusta* and *A. melanoxylon* obtained from local germplasm.

Plant parts undergoing tissue culture (ex-plants) require sterilisation to kill all micro-organisms. Sterilisation protocols have been obtained from Mondi and GTL has achieved low levels of contamination. The only major problem appears to be with the clone GC 642, which shows serious bacterial contamination with the result that the plantlets do not thrive in culture. Experiments with rooting treatments revealed that some clones root better when placed in the dark, while others respond well to rooting in activated charcoal. Overall, the rooting rate is low (around 45%). Early attempts to multiply *G. robusta* and *A. melanoxylon* by micro-propagation were disappointing, with high losses due to endogenous bacterial contamination.

The project operates with GTL under a commercial agreement, based on meeting their research and development costs. Tissue culture plantlets are now needed only to supply clonal hedges for the nursery and are not used for commercial planting.

3.7 Marketing

The project team commissioned an independent marketing consultant to study the potential demand for the imported hybrid clones and improved local materials. This was useful for planning, segmenting the market and identifying the areas where need and demand are greatest, as well as for forecasting sales and budgets.

The consultant estimated that after five years of production the central nursery would be producing two million seedlings per year and that revenue from sales would exceed the costs of production (Table 9 and Figure 3). However, continued investment will be needed to develop new species for production, and different species will have different break-even points. The first of the original three species studied to break even will be eucalyptus, as the clones are already in place as clonal hedges. In addition, there is already a high demand for eucalyptus plantlets. The second species to break even will be *G. robusta*, for which tissue culture production protocols have been developed and clonal hedges will be in production by the end of 2002. With *A. melanoxylon*, tissue culture protocols have yet to be developed and clonal materials still need to be identified, while the target market for this species will need to be sensitised to its potential and end-use, a major task requiring at least two years.

Pricing studies showed that most people would be prepared to pay between KSh5 and KSh6 for a eucalyptus seedling, compared with the current prices of KSh10 for a clonal cutting and KSh6 for a seedling. However, when farmers see the demonstration plots they are sufficiently impressed by the improved growth rates and are prepared to pay more for clonal cuttings.

Economies of scale have been calculated for clonal production (Figure 4). The calculations show that a level of production of 4.5 million a year or more is needed to bring the price down to a level affordable by small-scale farmers.

The marketing study concludes that, if the project is to be self-sustaining, it must be managed as a commercial venture. That means it must maintain a high level of management efficiency, minimizing production time and fulfilling all orders on time while maintaining the quality of the product. It must also invest in marketing activities, particularly promotion, and respond to changing demand, for example switching to different species according to need.

Marketing activities to date include production of brochures and technical bulletins, visits by project staff to target organisations and private companies, announcements on local radio and advertisements in Kenya national newspapers. As a result of these activities,

Table 9. Projected cash flow

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 and Beyond
Projected Production	**0.25M Ksh. 6.00 & 14.00**	**0.5M Ksh. 6.00 & 14.00**	**1M Ksh. 7.00 & 14.00**	**2M Ksh. 7.00 & 17.00**	**3M Ksh. 8.00 & 22.00**	**4M Ksh. 8.00 & 22.00**
CAPITAL COST						
Borehole						
Building						
Electrical Installation						
Nursery structures						
SUB-TOTAL	**21,881,749**	**90 %**	**80 %**	**70 %**	**60 %**	**50 %**
RUNNING COST						
Fixed Costs						
Nursery Variables	1,823,000	3,646,000	3,646,000	3,646,000	3,646,000	3,646,000
Labour and Admin.	613,213	1,226,425				
Transport	10,428,000	10,428,000				
Laboratory	800,000	800,000				
Miscellaneous	420,000	420,000				
Every extra 0.5M	200,000	200,000				
			2,452,850	4,905,700	7,358,550	9,811,400
			14,736,155	14,736,155	14,736,155	14,736,155
SUB-TOTAL	**14,086,613**	**16,522,825**	**20,835,005**	**23,287,875**	**25,768,010**	**28,193,555**
REVENUE						
Sale of Seedlings						
Community						
Companies/Pirate	150,000	300,000	1,400,000	2,800,000	9,600,000	16,000,000
	3,150,000	6,300,000	13,600,000	27,200,000	39,600,000	44,000,000
SUB-TOTALS	**3,300,000**	**6,300,000**	**15,000,000**	**30,000,000**	**49,200,000**	**60,000,000**
NET REVENUE	**-10,768,613**	**-9,922,825**	**-5,835,025**	**+6,712,125**	**+23,431,990**	**31,806,445**

Figure 3. Projected break-even point

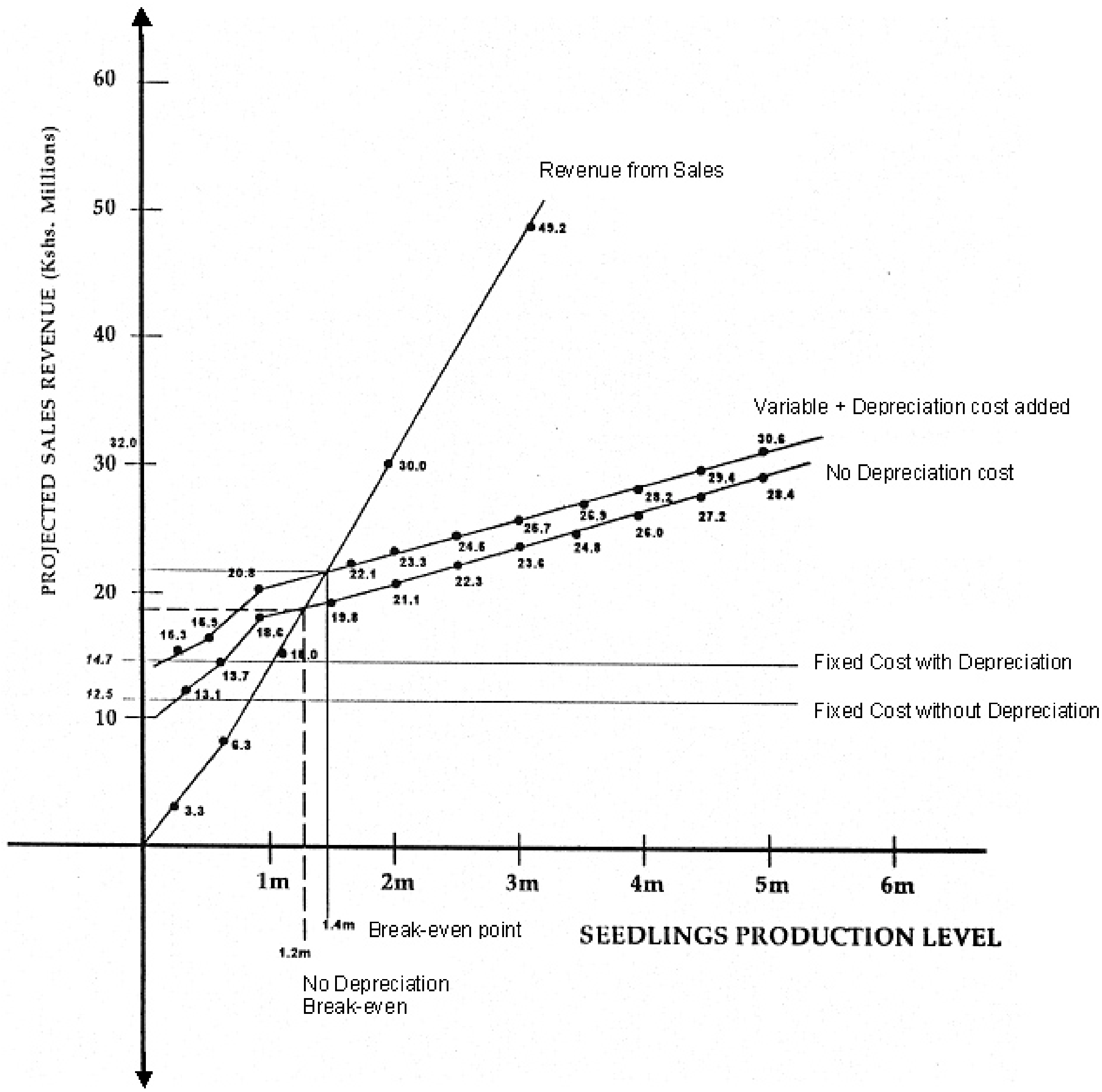
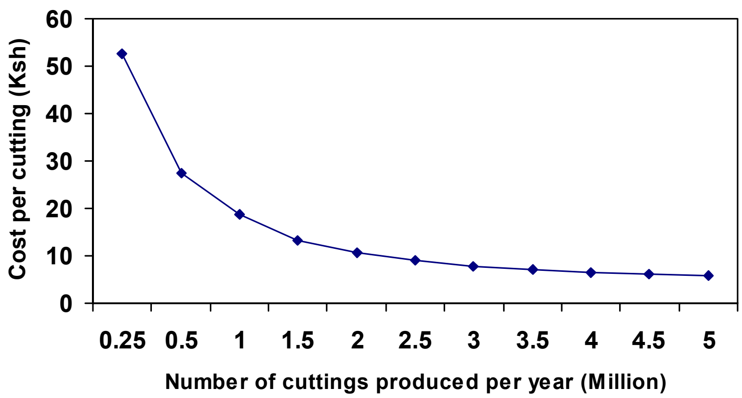


Figure 4. Economies of scale



Source: Modified from Mwendandu and Musuvi (1999)

many orders have been secured, from individual farmers, NGOs and private companies. A single sale of 400,000 seedlings to the Kiambu Dairy and Pyrethrum Cooperative Union was achieved in 2001. A stakeholders' workshop was held in April 2001 with the objective of raising awareness among corporate organisations. The technology was received with enthusiasm and additional enquiries and purchases were received after the workshop.

3.8 Management and administration

The Project Board (see Appendix 1) provides leadership and vision to keep the project on track towards achieving its objectives. A technical committee, comprising scientists from ISAAA, the Forest Department, KEFRI and Mondi, advises the board and guides the conduct of the project. For example, this committee developed the policy framework paper for the marketing and distribution of clones in Kenya, which is being used as a basis for marketing strategies. The Board is in the process of setting up a private marketing and management company to address the challenge of wide-scale dissemination. This company will be a subsidiary of the Kenya Gatsby Trust and will be funded by its shareholders. The company will handle legal issues, especially relating to material transfer agreements (see section 6.7). Agreements will need to be negotiated before further clones are imported from Mondi.

3.9 Future plans

Additional clones will be introduced from Mondi to broaden the genetic base and provide a wide range of materials adapted to each agro-ecological zone. These will include hybrids of *E. grandis* x *E. urophylla* (GU clones) suited to highland areas, *E. grandis* x *E. nigrens* (GN clones) for frost-prone areas and further GC clones for areas prone to drought. It is hoped to expand the original base of 12 clones to 40 or 50. However, Mondi wish to retain ownership of the additional clones, whose introduction will be subject to a material transfer agreement. Further selection, collection and multiplication of Kenya's own eucalyptus germplasm will be conducted through breeding programmes undertaken by KEFRI. Representatives from commercial forestry and the smallholder farming community will be involved in selection and evaluation activities to ensure the trees meet their needs, and that a wide range of varieties are made available.

Six additional trials have been established to evaluate the new clones, with two more planned (Table 10).

The trial and demonstration plots will also host grow-out nurseries and provide distribution points in the areas previously identified to have the highest demand (e.g. Nyeri and Nakuru, see Figure 5).

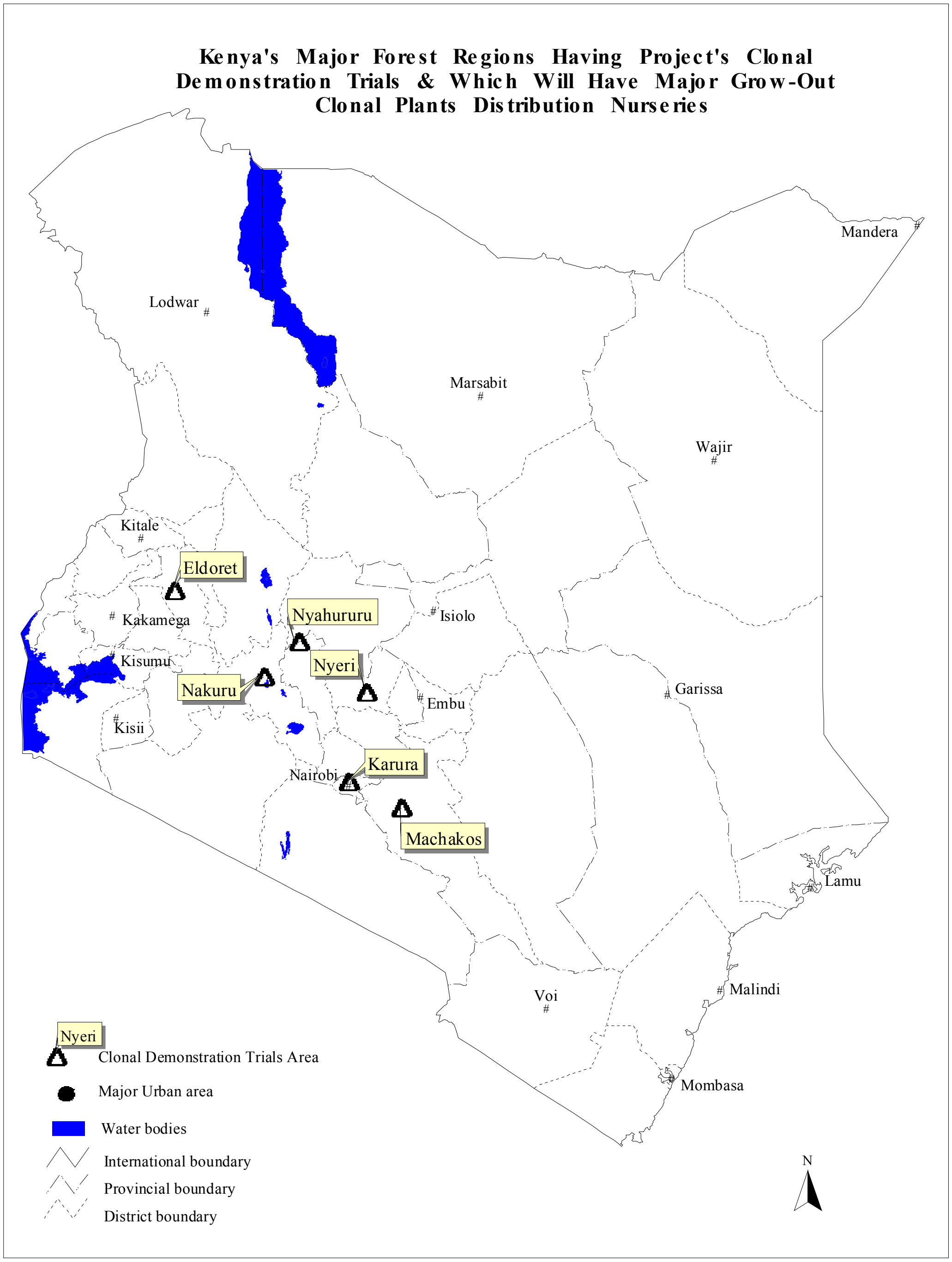
There are plans for Kenya to join the Central America and Mexico Coniferous Resources Programme (CAMCORE), an international non-profit making organisation that deals with conservation aspects of tree biodiversity as well as collecting and distributing tree germplasm. The project would benefit from access to breeding programmes and additional resources, such as seeds and information.

Table 10. Trials established in 2002

Location	District	Trial species
Kabage	Nyeri, Central	GC, GU, TAG and *E. grandis*
Marigat	Baringo, Rift Valley	GC, *E. camaldulensis* and *E. tereticornis*
Kakamega	Kakamega, Western	GC, GU, TAG and *E. grandis*
Msambweni	Kwale, Coast	GC, GU, TAG, *E. urophylla, E. tereticornis,* and *E. camaldulensis*
Sokoke	Kilifi, Coast	GC, GU, TAG, *E. urophylla, E. tereticornis,* and *E. camaldulensis*
Gede	Malindi, Coast	GC, GU, TAG, *E. urophylla, E. tereticornis,* and *E. camaldulensis*
Additional Planned Trials		
Kiboko	Makueni, Eastern	GC
Kitui	Kitui, Eastern	GC, *E. urophylla, E. tereticornis* and *E. camaldulensis*

TAG = Transvaal, second generation *E. grandis*

Figure 5. Major forest-growing regions of Kenya where clonal trials, demonstration plots and distribution nurseries will be located.



4. BENEFITS AND IMPACT

4.1 Benefits to resource-poor farmers

The project is unusual in that it will provide a broad range of benefits to incomes, living standards, food security, human health and the environment, as well as addressing the needs of both larger-scale commercial enterprises and small-scale farmers. The increased availability of fuelwood will greatly benefit the well being of the poorest sectors of the community in both rural and urban areas. Instead of foraging for scarce firewood, women will be able to concentrate on more productive uses of their time, such as growing crops and taking them to market. The rapid growth of trees raised through tissue culture means that woodlots will become a viable alternative form of land use to the growing of conventional cash crops, since they will yield relatively quick returns. For example, the fastest growing eucalyptus can be harvested after as little as one year for both fuelwood and poles, and can be coppiced regularly. There are several other important interactions with conventional crop production. Poles, for instance, can be used to support climbing crops (such as beans), making better use of limited agricultural land, while animal dung and crop residues need no longer be used as fuel but will be returned to the soil, increasing soil fertility and improving crop yields. For the urban poor, a reduction in the cost of fuelwood and charcoal will enable them to cook more often, improving their nutritional status and hence their health. Cooked food allows much easier absorption of most nutrients than does raw food; and more frequent meals will also better sustain the energy levels of both children, who will concentrate better at school, and hard-working adults.

Many small-scale farmers have fragmented land holdings and waste time travelling between them, while at the margins of crop production, in the wetter highlands, steeper and steeper slopes are being brought into cultivation. These types of land are ideally suited to forestry, as established trees are not labour intensive and require little weeding or inputs. The trees will also help to stabilise slopes by reducing rainwater runoff and soil erosion.

The high demand for forest products, the rapid returns, low labour cost and the agro-ecological adaptability of trees (e.g. their tolerance to drought) mean that clonal forestry is a relatively low-risk investment for small-scale farmers. This bodes well for the use of micro-credit schemes as a means of enabling farmers to make the necessary initial investment. All in all, clonal forestry seems a promising route out of poverty for subsistence farmers, as well as being something that could protect and enhance Kenya's fragile natural resource base (see Discussion section 6.4).

4.2 A model of sustainable development

In both economic and ecological terms, the project is a fine example of what should soon prove to be sustainable development. The initial commercial emphasis and high degree of private-sector involvement ensures that the project should become self-funding within the shortest possible time. In addition to providing a sustainable source of timber, 'add-on' benefits include the creation of business and employment opportunities such as private clonal nurseries, contract production and the transport needs implied, at least initially, by distribution. Several nursery consumables are currently imported, and the project team is investigating alternatives that could be produced locally, providing further opportunities for local business. The dissemination of knowledge on such topics as nursery and seedling management will create more trained nursery staff and tree farmers, helping them to improve productivity and profitability.

Wider ecological benefits will result as faster tree production increases the area under forest cover. These include the protection of existing native forest, together with its natural biodiversity and rare habitats, and the reduction of soil erosion and downstream flooding. In addition, trees store more carbon than do annual crops, so there could be benefits in terms of reduced global warming – at least while the trees still stand. In addition, the eucalyptus clones provide good quality wood of high calorific value, which produces less smoke than conventional material.

4.3 Maintaining biodiversity

Planting large areas of single clones will have the effect of decreasing rather than increasing biodiversity, and the risk of narrowing the genetic base needs to be managed to avoid growing pest and disease problems. Mondi has a policy to restrict planting of a single clone to no more than 5% of any planting area, and the project is adhering to this policy. In order to maintain biodiversity, the project team will select a wide range of local tree species of economic value and will feed these into the clonal production system through adaptive tissue culture research. Once the capacity to adapt the techniques of micro-propagation to different species is fully in place, there will be great potential for the project to multiply and disseminate a wide range of improved germplasm of different tree species, including those that are under threat of over-exploitation and extinction, such as ebony.

4.4 Capacity building and institutional strengthening

Close collaboration has been maintained between the project and Mondi Forests, with several visits per year of Mondi staff to Kenya and project staff to South Africa. The project contributes to capacity building within several institutions and creates infrastructure as well as human capacity. By donating, sharing and transferring proprietary biotechnologies to meet the needs of resource-poor populations, the project is strengthening South-South cooperation. The experience gained could act as a model for sharing experience and technology with other developing countries.

4.5 Extending to new areas

Expansion of the project and extension of its benefits will be planned carefully and based on the experience, knowledge and capacity developed during the early phases. It is hoped that other private nurseries in Kenya will adopt the clonal technology, based on a commercial assessment of its profitability. Thus dissemination of the technology will be driven in an entirely sustainable way. Mondi Forests are supportive of new ventures in other African countries and the first step in extending the benefits internationally have already been taken by the implementation of a Tree Biotechnology Project in Uganda, also funded by the Gatsby Charitable Foundation. ISAAA is also encouraging the diffusion of the technology in Tanzania. Future projects are likely to require initial donor funding, unless entrepreneurs are willing to invest in such a venture. In Kenya, new forest legislation may encourage more private entrepreneurs to invest in tree production.

5. EXTENDING TO NEW AREAS: UGANDA

5.1 Background

Forest resources in Uganda have been severely depleted, due mainly to clearing for agricultural land, a high demand for fuelwood, and a severe lack of tree planting efforts over a long period – at least 30 years. Lack of political will and insufficient government funds during this period resulted in a high dependency on donors to support tree-planting programmes, but the country's instability during the 1970s and 1980s discouraged donors from contributing. The implications of the 30-year gap in tree planting are alarming, given that 96% of national energy requirements are supplied by fuelwood. The national stock of conifer plantations, planted to supply the sawn wood industry, are likely to become exhausted within the next ten years and saw mills are already operating at a minimal level due to wood shortage.

Although private enterprise is beginning to emerge to meet the need for forest products, Ugandan growers, like their Kenyan counterparts, are constrained by a lack of good quality seed, poor nursery techniques and inefficient processing, including low rates of recovery for charcoal and sawn wood. Pest and disease attack are common: for example, termites are a particular problem on eucalyptus, with losses of up to 100%. However, there is a ready market for tree seedlings and people are becoming more interested in planting trees. This is due to greater awareness of conservation issues, including fear of desertification, coupled with the strong political will of the present government and the national policy to modernise agriculture and make it more sustainable. There is great potential for fast growing eucalyptus species, with growth rates of up to 6m per year expected in the wetter parts of the country.

The project partners in Uganda are Mondi Forests and the Forestry Resources Research Institute (FORRI), with the Kenya Forest Department also providing valuable technical advice and backstopping based on their own experience. The project objectives mirror those of the Kenya programme: *To improve the living standards of rural communities in Uganda, particularly those of the resource poor segment of the population, by enhancing forestry production. This will be done through the transfer and application of proven tissue culture and clonal technology for large-scale multiplication of selected elite materials using proprietary eucalyptus clones from Mondi, South Africa, and later Ugandan tree biodiversity, modelled after successful experiences in Kenya and South Africa* (FORRI, 2000).

5.2 Progress

A small clonal nursery (about 100 square metres) at Kifu, near Kampala has been started, primarily as a demonstration and training site. The infrastructure was completed in early 2002 and clonal hedges were established with 3000 plants. Multi-location trials have been

The site of the Uganda Tree Biotechnology Project at Kifu in February 2002.

planted in different agro-ecological sites (Abi, Ikulwe, Kifu, Ngetta and Serere) to evaluate performance and monitor pest and disease attack. Species will include 12 clones imported from Mondi (mostly GC and GU hybrids), together with the local *G. robusta*, an acacia hybrid (*A. mangium* x *A. auriculiformis*), which could be very useful in the semi-arid Karamoja region of the northeast, and *Melisia excelsa*, an endangered native hardwood.

Personnel from Mondi have been on field trips to Uganda to establish which clones are most suitable for which areas and to advise on the nursery design. The Ugandan project manager and nursery technician have visited Mondi to be trained in clonal production.

Contact has been made with several NGOs and government projects (e.g. Peri-urban Forestry and Lake Victoria Environment Management Project), which have expressed an interest in collaboration. They will be assisted in setting up their own demonstration plots and may become useful distribution points.

5.3 Potential benefits

The project will positively affect the overall economy of Uganda through commercial forestry and reforestation, creating new income earning opportunities at the same time as environmental benefits. Uganda's forestry research capacity will be greatly strengthened by improved knowledge and new technology that can be integrated with traditional propagation methods.

The Ugandan project relies on private sector involvement to a greater degree than in Kenya. It is intended that FORRI will provide initial planting material and knowledge, while the private sector takes on all multiplication and distribution activities. This approach is timely, as agriculture in Uganda is starting to become more commercial and farmers are beginning to specialise. Growing eucalyptus represents a low-risk investment for farmers, as the improved germplasm is tolerant to diseases and fast growth is more or less guaranteed, even in a low-input context. In addition, the rising demand for wood products creates a ready market.

Collaboration between the project teams in Kenya and Uganda will bring mutual benefits. The teams can share data on field trials and the performance of different clones in different areas, Uganda can build on the experience of the Kenya clonal nursery and use it to demonstrate the technology to potential commercial investors, while the Kenyan team can learn from Uganda as they establish private clonal nurseries and distribution mechanisms.

6. DISCUSSION

6.1 Needs-driven project

The ISAAA philosophy in planning and facilitating projects is always to begin with a clearly defined need – to ensure the project will be well focused and will create maximum impact. In this case, addressing the shortage of fuelwood has huge implications in terms of poverty alleviation and environmental protection. However, an equally huge donor investment would be required if tree planting efforts were to be focused on small-scale farmers alone. Instead, an initial focus on commercial forestry is considered necessary in order to provide wider benefits to resource-poor farmers and the urban poor. Continued assessment and monitoring will be required to ensure the right balance between commercial and small-scale enterprise is maintained.

If smallholders are to benefit fully from the products of biotechnology in tree production, they must be fully involved in its development, giving them a sense of ownership and empowerment. This is why on-farm trials have been started at an early stage in Kenya. As the project progresses, farmers will be involved further in the exchange of knowledge and in selecting new varieties that are most appropriate to their needs. Effective demonstration and knowledge dissemination will be vital to encourage them to regard trees as a source of income, a perception that is not traditionally held.

6.2 Involving the private sector

Private sector involvement is another integral part of the ISAAA strategy, the aim being to create a self-sustaining production and dissemination system without the need for long-term donor or government support. Working with the private sector brings major advantages, as the need for a profit orientation ensures speedy and efficient operations in response to the pressure to produce results and impact within the shortest possible time. The development of tissue culture in Kenya illustrates this point well. The project originally planned to build on the existing facilities and capacity at FHMC – a public institution funded by the Government of Kenya. However, it soon became apparent that, as a public body, FHMC did not have the institutional framework needed to operate a national project and was unlikely to be able to boost its production sufficiently to meet the growing demand for plantlets created by the project. ISAAA therefore brought in Genetic Technologies Limited, a private company that was already set up for mass production of selected agricultural crops and that would maximise efficiency through its commercial orientation. Involving the private sector also lays the foundations for a more sustainable production system in the long term by creating partnerships that will be mutually beneficial and that will be maintained through commercial advantage.

Mondi Forests have been instrumental to the project's success so far, as they had the knowledge and experience that were lacking in Kenya. Negotiating with ISAAA helped Mondi to realise the great potential for commercial forestry in Kenya, giving them an incentive to become involved. In addition to providing the technology needed to improve the profitability of commercial forestry, the project is likely to create a wide range of opportunities for private investment, such as clonal nurseries, tissue culture laboratories, sales outlets and distribution systems for plantlets and seedlings, manufacture of nursery consumables, and wood processing enterprises for the production of charcoal, sawn timber, pulp and paper.

6.3 Building strong partnerships

Partnerships between the public and private sector can enhance the comparative advantages of each partner, ensuring that the impact of a project greatly exceeds the sum of its parts. However, partnerships do need to be mutually beneficial if they are to work. In addition, a good project management structure is needed, with regular meetings between the partners to ensure effective communication.

In the case of the tree project, a mutually beneficial partnership between the Forest Department/KEFRI and Mondi Forests has laid the foundations for success. Mondi needed specialist knowledge to access the Kenyan market and to reduce the risk of international expansion, while the Forest Department/KEFRI needed technical training and backstopping in clonal forestry. Strong leadership from the project board and ISAAA has overcome the initial problems with FHMC, motivated the present partners to take the project forward and maintained the direction of the project towards its intended objectives.

Additional partnerships have evolved and will be encouraged, for example with universities in South Africa, where project staff have received training, and with other private organisations, such as GTL, where existing tissue culture facilities and capacity have been further developed to allow the company to diversify into tree propagation. Throughout its activities, the project aims to make the most of collaborative activities, to minimise the duplication of effort and to make the best possible use of scarce resources. Commercial enterprises and small-scale farmers are already working together: for example, the project has encouraged some of the large tea plantations to work with local farmer groups. The farmers grow improved eucalyptus, which is sold to the tea factory to provide fuel, providing a sustainable new enterprise with guaranteed supply and demand.

6.4 Addressing constraints

Credit

Although economies of scale will lead to lower prices, the cost of plantlets and improved seedlings may still be prohibitively high for many small-scale farmers, with the result that a credit scheme may be needed. The project lends itself to the development of such a scheme, since growing improved eucalyptus (and local material propagated by clonal techniques) is a relatively low-risk investment. The scheme could be managed by the Kenya Gatsby Trust, which has a mandate to promote local enterprise in Kenya, and could also be self-funding.

One such scheme that has already proven successful is Mondi Forests' Khulanathi Programme, started in 1989 in the KwaZulu area of South Africa to encourage the production of additional wood fibre for the nearby Mondi pulp mill. Khulanathi is a Zulu word meaning 'grow with us,' an expression that epitomizes the nature of the scheme: Mondi has formed partnerships with local rural communities whereby land owners are helped to establish commercial woodlots, with Mondi supplying fast-growing, high-yielding planting materials, finance, technical expertise and a guaranteed market. An initial loan covers the cost of establishing and maintaining the woodlot. The timber is harvested when it has reached maturity (6-10 years) and Mondi buys the entire harvest. The total loan amount accrues simple interest at 10% per year (well below bank rates) and the loan and interest are paid once the timber is sold. Loans generally amount to around US$ 200, while the harvest is worth US$ 4,000 – 5,000.

Schemes of this kind could be replicated in Kenya, although Mondi would not be a buyer so other sponsors must be found. Kenya has an abundance of self-help groups at community level – women's groups, church groups and youth groups – that could form the institutional bases for credit schemes modelled along the lines developed by the Grameen Bank in Asia. ISAAA and other institutions already have experience in launching such schemes, notably in the case of bananas.

Capacity building

There will be a continuing need to develop sufficient local physical capacity as the demand for improved trees grows. Essentially this means not just suitable space for regional nurseries – and it should not be forgotten that fertile soils and a reliable, clean water supply are both essential for this and may be hard to find in semi-arid areas – but also the infrastructure and staff to operate these nurseries, which must perform just as efficiently as the central nursery at Karura. Staff competence is another potential bottleneck, as local staff will have to be trained in advance to meet the rising demand for plantlets in each new area covered by the project. There will be a continuing need to develop new clonal materials and improved varieties of local species, especially as farmers become more involved and start to demand different species to meet their needs.

The project has already trained a core group of nursery technicians and will play an increasingly important training role in the future, helping to establish new clonal nurseries as well as improving the knowledge level of farmers. As the need for training increases, the option of establishing it as a profit centre will become feasible. However, the project will continue to offer a free service to the small-scale and informal sectors to transfer knowledge on tree propagation.

Inputs

Forestry is generally a low-input production system and, if simply left to grow to maturity (7-10 years) before harvesting, the eucalyptus hybrids need few inputs other than water to ensure they become established. However, if the trees are to be treated as a cash crop and harvested every 3-6 years or coppiced annually, they may need inputs to maintain soil fertility. Knowledge dissemination among commercial producers and small-scale farmers will therefore become important, to guard against soil degradation and diminishing yields. The micro-credit schemes discussed above may provide a means of enabling small-scale farmers to afford sufficient inputs for their trees.

Pests and diseases

The emergence of pests and diseases is another potential constraint. However, as discussed earlier, efforts are already being made to increase the genetic diversity of plantlets grown in the central nursery in order to reduce vulnerability to large-scale epidemics.

Production costs

The costs of clonal production are still high, due to several factors. Growing trays and inserts are specialised items not currently available in Kenya and have to be imported from South Africa. At present, the project board has considered several options, but the items still add considerably to the costs of production. It is hoped that, once production increases, there will be sufficient demand to encourage local manufacturers to invest in the machinery required to produce the growing trays locally. Regarding growing media, Mondi advises vermiculite and perlite mixture for raising the eucalyptus cuttings, but both are expensive in Kenya. The project is currently testing alternatives such as coco-peat, a derivative of coconut coir, which has been used by flower producers in Kenya. This material, which has good drainage, aeration and water retention properties and does not require mixing (unlike vermiculite and perlite), will reduce production costs considerably if it proves a viable alternative. Electricity is another major cost, incurred largely through the need to pump water from the borehole. Project staff are continually testing and assessing methods of conserving water. All the experience gained in reducing production costs will be available to investors who are interested in establishing commercial clonal nurseries, helping them to improve profitability and reduce risk.

Distribution

Distributing improved tree plantlets and seedlings to small-scale farmers is problematic, as they are widely scattered, access is difficult and most have no means of transport. This all adds to the cost of supply. Regional nurseries and demonstration plots will act as outlets for seedlings and clones and as a source of information for farmers and rural communities. In areas of greatest demand they will also provide a training resource. The funding of these is still unclear, but it is hoped that partnerships between the public and private sector will help to build on existing infrastructure and information networks to demonstrate the superiority of the eucalyptus clones. In the poorest areas, where demand is high but there is little existing infrastructure, partnerships with NGOs and community organisations together with funding via micro-credit facilities will be needed.

6.5 Creating an enabling policy environment

The international community's concern for global issues, such as deforestation and climate change, has helped to create the political will to support this project, with its extensive environmental benefits. The project is also in line with national policy in Kenya, which explicitly encourages research and information transfer on new methods and technologies for forestry improvement and management in order to contribute to increased forestry production. The country's 1994 Forestry Master Plan emphasises a shift from commercial to on-farm forestry to maximise the social and environmental benefits of tree planting. The project Board has visited the Permanent Secretary of the Ministry of Environment and Natural Resources to secure his support for the project and its aims. This support has been demonstrated in various ways, for example providing government vehicles for distribution, enhancing awareness building through field extension staff and signing the Material Transfer Agreement to secure the Mondi clones.

6.6 A clear vision

A clear vision is needed to give direction to a project, as well as the motivation to carry it through. ISAAA has provided the vision and is driving the project to be self-funding and self-sustaining without losing its mission to provide superior planting material and fuelwood to the poor and disadvantaged. Before the project began, ISAAA spent a year planning it – a vital process that involved intensive efforts to select the right partners and lay the foundations for success. Attributes needed by the project team include good planning and communication skills together with an ability to spot bottlenecks in advance and take action to circumvent them. Thus far, these attributes have been demonstrated, although it would be prudent to point out that the project is still in its early stages and much remains to be done before its anticipated widespread impact is realized. Meanwhile, the value of a committed and able project manager has been demonstrated, both by its absence, during the early stages, and through its presence, in the rapid progress made since the recent change in leadership. The project board is vital in maintaining the direction and vision of the project, especially given the multiple partners involved and their different interests in the project.

6.7 Legal and contractual issues

Introducing a proprietary technology involves complicated legal issues concerning intellectual property rights (IPR). Clones developed by Mondi are considered to be their property, and any other organisation seeking to use or develop them must obtain Mondi's permission. The original 12 clones provided by Mondi were donated free of charge and no restrictions are associated with the growth, multiplication or sale of material originating from these clones. An additional seven clones were received in 2001, but these and any additional clonal material provided by Mondi will be subject to a material transfer agreement, which covers research purposes only. This means that the clones can be planted in trial plots and used for demonstration purposes free of charge, but multiplication and commercial sale of material derived from them will be subject to a commercial license and will add to the cost of production. The Government of Kenya and Mondi have now signed a material transfer agreement to provide clones from Mondi for trial in Kenya until 2012.The issue of royalties will be discussed and possibly negotiated after suitable clones have been selected from the trials.

The local eucalyptus and *G. robusta* provided by FHMC are considered to be a public good. The tissue culture methodology used for micro-propagation is also non-proprietary. This can be readily applied to local tree species, which can thus be offered to small-scale farmers without the need for contractual agreements.

The original project contract was signed in April 1997 between the Gatsby Charitable Foundation, the Kenya Gatsby Trust, FHMC and ISAAA. FHMC was to develop the project for eventual sale or lease to the private sector, with a payment or royalty returning to the Kenya Gatsby Trust. It is now planned that the commercial marketing company will be involved in distribution and marketing while the propagation nursery will remain within the public domain.

6.8 Marketing and funding issues

Due to Kenya's fuelwood and timber shortage, the demand for plantlets and seedlings is likely to remain high for the foreseeable future. Economies of scale and competition between nurseries will help to reduce prices. However, the improved material should still fetch a higher price than conventional seedlings due to its considerable advantages (fast growth, disease-free, etc.) Competition from alternative fuels such as electricity is likely to be insignificant for many years yet.

Effective distribution of seedlings and the handling of contractual issues both require new skills. Rather than seek to develop these at KEFRI, the project board has decided to appoint a privately funded marketing company. The company will be managed by the Kenya Gatsby Trust, which will seek to ensure that smallholders, as well as commercial buyers, benefit from the technology. The company will ensure regular and fair distribution of the seedlings and clones and any profit will be used to subsidise sales to small-scale farmers. The company will be funded by its shareholders and the Kenya Gatsby Trust will be free to offer shares to any interested investor.

The project was designed, right from the initial planning stage, to be self-financing, with a phased donor exit strategy. However, in reality, a bridging period is likely to be needed, as some parts of the project will become self-funding before others (see Section 3.7). Budgetary constraints have been identified and the project partners have initiated negotiations with the Gatsby Charitable Foundation for additional funding to meet the set target by 2005.

7. CONCLUSIONS

Although only in its early stages, the Tree Biotechnology Project has already laid strong foundations for its future success and illustrates several key points that could benefit other similar development projects:

1. It focuses on a clearly defined need (lack of fuelwood), in order to target resources and maximise impact.
2. It builds on existing capacity (e.g. Mondi and GTL) in order to maximise cost-efficiency.
3. It creates mutually beneficial partnerships, between the public and private sectors, as the major strategy for delivering project benefits.
4. It combines a commercial objective with that of poverty alleviation, so as to minimise dependence on donor or government funding and create a self-sustaining production and distribution system with widespread impact.

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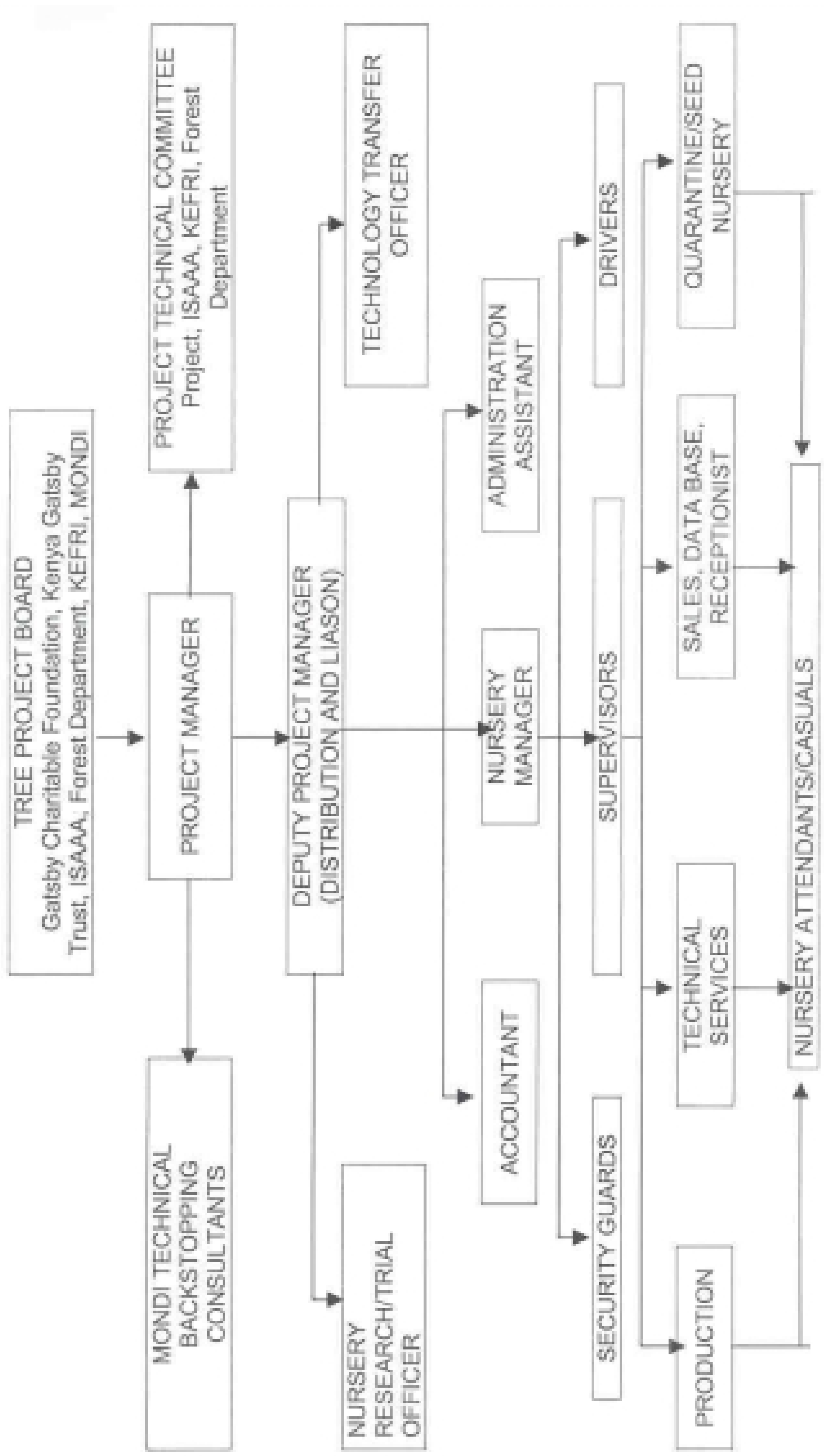
ACRONYMS

CAMCORE	Central America and Mexico Coniferous Resources Programme
DBH	diameter at breast height
FABI	Forestry and Agricultural Biotechnology Institute
FHMC	Forest Health Management Centre
FORRI	Forestry Resources Research Institute, Uganda
GC	hybrid eucalyptus: *E. grandis* x *E. camaldulensis*
GN	hybrid eucalyptus: *E. grandis* x *E. nigrens*
GTL	Genetic Technologies Limited
GU	hybrid eucalyptus: *E. grandis* x *E. urophylla*
ICFR	Institute of Commercial Forestry Research
IPR	Intellectual property rights
ISAAA	International Service for the Acquisition of Agri-biotech Applications
KEFRI	Kenya Forestry Research Institute
KGCT	Kenya Gatsby Charitable Trust
NGO	Non-government organisation
TAG	Transvaal, second generation *E. grandis*
TPCP	Tropical Pathological Cooperation Programme

APPENDIX

Appendix 1. Project management structure



Appendix 2. Growth performance data

Trial / Site	Mean measurements	Naivasha (at 2.25 years)	Timboroa (at 1.67 years)	Hombe (at 1.67 years)	Embu (at 1.8 years)	Machakos (at 1.8 years)	Karura (at 3.25 years)
GC 3	**DBH (cm)**	*	6.7	+	+	+	+
	Height (m)	2.5	7.0	+	+	+	+
GC 10	**DBH (cm)**	*	+	9.7	+	9.6	9.4
	Height (m)	*	+	9.0	+	12.1	13.2
GC 12	**DBH (cm)**	*	+	+	+	+	10.2
	Height (m)	*	+	+	+	+	12.8
GC 14	**DBH (cm)**	*	7.6	8.2	4.7	9.6	10.0
	Height (m)	4.0	6.2	8.3	4.8	12.3	13
GC 15	**DBH (cm)**	*	7.4	8.6	5.0	10.4	10.5
	Height (m)	3.2	5.7	8.1	5.5	12.3	13.3
GC 522	**DBH (cm)**	*	+	9.5	+	10.1	8.7
	Height (m)	2.7	+	9.1	+	12.1	13.4
GC 581	**DBH (cm)**	*	9.3	10.2	6.4	10.0	9.6
	Height (m)	*	8.6	8.9	6.3	11.5	12.8
GC 642	**DBH (cm)**	*	7.9	8.5	4.1	9.4	8.1
	Height (m)	2.5	6.7	8.6	4.4	11.7	12.7
E. grandis	**DBH (cm)**	*	4.5	9.7	4.5	9.4	5.0
	Height (m)	2.0	3.9	8.7	4.7	11.8	12.5
E. tereticornis	**DBH (cm)**	*	5.1	6.6	5.6	6.0	9.4
	Height (m)	2.1	4.0	6.4	5.8	7.9	7.8
E. camaldulensis	**DBH (cm)**	*	3.4	6.8	4.2	3.5	+
	Height (m)	2.0	3.0	7.7	6.7	5.5	+
E. saligna	**DBH (cm)**	*	7.4	9.3	5.4	8.4	+
	Height (m)	1.4	5.8	8.2	5.5	8.5	+

DBH = diameter at breast height
* Trial plants were too slender for DBH measurement
+ Indicates where particular species/clones were not included in the trial
N.B. Laikipia trial was irreparably damaged by elephants and hence abandoned in 2001

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