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Forest Management Working Paper

Experience in the elaboration, implementation and follow-up of forest management plans using computers, computer software and other technological packages

The Case of Mt Elgon UWA/FACE Carbon Sequestration Project in Uganda

Based on the work by:

Sean White and Frederick Wanyama
with inputs from Associate Prof. Joseph Obua

April 2006

Forest Resources Development Service
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SUMMARY

This case study describes the use of computers and software in the management of a carbon sequestration forestry project in eastern Uganda. The forest forms part of Mt Elgon National Park and is managed by the UWA/FACE project, which is a partnership between UWA, representing the Ugandan Government, and the FACE Foundation, which represents industrial clients in the Netherlands. The project began in 1994 and is reforesting heavily encroached areas of Mt Elgon and Kibale National Parks in Uganda. Its objective is to establish new forests as carbon sinks. The FACE Foundation will claim carbon credits for carbon sequestered as a result of the project. In return, the Foundation provides the funding required for reforestation. The Ugandan Government retains ownership of the forests and has agreed to prohibit logging for a period of 99 years and allocate the carbon credits exclusively to the Dutch partner. Only indigenous forest trees are being planted and the aim is to restore the forest to its natural condition following decades of degradation and agricultural encroachment.

The FACE Foundation has similar forest restoration projects in the Netherlands, the Czech Republic, Ecuador and Sabah-Malaysia that are implemented with project partners in those countries. The Foundation has developed management and planning systems that are standardized across all the projects including those in Uganda. The UWA/FACE Uganda project is operating on two sites but this paper deals with the Mt Elgon site only. However, the systems used in Mt Elgon are representative of those used on the Kibale site and the FACE Foundation sites in other countries.

This paper describes the use of computers and other technological devices in planning and implementing the management of the UWA/FACE project forest at Mt Elgon. The FACE Foundation has developed a computerized monitoring and information system called MONIS that is installed in computers at all the FACE project sites and at the headquarters in the Netherlands. The system is designed to store a wide range of information on the projects such as compartment maps and associated attribute data, records of silvicultural operations carried out, costs and material inputs, site conditions, physiography, status of the forests and trees, progress of the projects against targets, photos, etc. It can also store background documents and agreements between FACE and its partners and reference manuals on project procedures. The system contains data entry forms for inputting field and financial data at the project sites on a monthly basis. This provides up-to-date management information both to the headquarters in the Netherlands and to the projects themselves.

At Mt Elgon many elements of the database have not yet been populated with data and this limits its usefulness. The most useful aspects of the MONIS system are the compartment map data and associated attribute data that are regarded as extremely useful by project management staff. However, the attribute data are limited, a major weakness being the absence of silvicultural and cost data for each compartment, which is not entered at present because of problems with the software. This is being addressed and a new version of MONIS is expected to be installed at the project shortly. Whereas some important data such as silvicultural and cost data are missing, some other data which are not used, such as detailed slope and aspect data, are included. However, these data are generated as a by-product of the ILWIS area conversion analysis and may be of use in the future. The project documents and agreements between FACE and its partners have not been entered into the system, very few site photos have been entered, and nor have manuals on procedures and methods for mapping, parameters to be measured, etc. been entered. However, the system does provide good information, including regularly updated maps, on the status of the reforestation programme.

The use of GPS units has enabled staff to produce accurate compartment maps very cheaply in the mountainous terrain of Mt Elgon. GPS units are also used as hand-held data entry devices in the field. A data dictionary is defined in advance and attribute data can be entered using combo boxes and drop down lists. The method helps to reduce errors in data collection. The GPS data are downloaded direct to the desktop computer back at the project office. The full potential of this method is not being realized because the amount of attribute data collected at present is quite limited.

Coordinate data collected in the field with GPS units are used to produce compartment maps in ArcView GIS. The project is fortunate in that there is a large body of pre-existing ArcView theme maps available for the Mt Elgon area such as contours, rivers, roads, administration boundaries, gazetted areas, vegetation classification, etc. In addition, there are geo-referenced population census data available that are potentially useful in managing the interface with local communities. ArcView is regarded as a very useful tool by the project. However, at present its use is largely confined to mapping and little or no use is made of its data analysis functions. A disadvantage of using ArcView is that it requires a highly trained staff. In Uganda, it is difficult to recruit and retain skilled GIS staff as they are in strong demand.

The project has been developing methods of measuring carbon assimilation, which are appropriate to the conditions at Mt Elgon. The methods being developed use biomass as an index of carbon content. Using stratified sampling techniques, biomass in sample plots is measured and equations are used to calculate the equivalent quantity of CO_2. The total biomass must be measured, including root biomass, and carbon accumulation in the soil due to litter-fall must also be measured. The project has been testing and developing computerized systems for measuring biomass in sample plots. In 2000 the Field-Map system was tested with promising results. The system involves the use of a field computer to which measuring devices are attached.

In Uganda, the justification for using computer systems comes not from labour cost savings, but rather from the capacity of those systems to provide the type of accurate and verifiable data that would otherwise not be possible or easy to collect manually. The FACE Foundation in the Netherlands requires ready access to detailed and accurate data on its projects and a computerized monitoring and information system such as MONIS is the only feasible way of achieving this. The headquarters requirement for accurate and up-to-date data is probably the primary motivation for the computerized systems in use at Mt Elgon. However, local management also benefits greatly from the data generated for planning and day-to-day management.

The costs involved in using computer technology at the project include the cost of the hardware, software licences, staff training costs and specialist computer staff costs. It would be difficult to justify this cost on the basis of management efficiencies achieved at the project. The reforestation programme could be implemented effectively and efficiently using traditional systems, but the requirements for ready access to accurate and verifiable data mean that these systems are necessary.

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Abbreviations used in the document

CTR	Crop tree release
dbh	Diameter at breast height
DFS	District Forestry Services
GIS	Geographic Information System
GPS	Global Positioning System
FACE	Forests absorbing carbon dioxide emissions
ha	Hectare
ILWIS	Integrated Land and Water Information System
IUCN	World Conservation Union
JI	Joint implementation
MONIS	Monitoring and Information System
MUIENR	Makerere University Institute for Environment and Natural Resources
NFA	National Forestry Authority
NORAD	Norwegian Development Assistance
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
UWA	Uganda Wildlife Authority

Experience in the elaboration, implementation and follow-up of forest management plans using computers, computer software and other technological packages

The Case of Mt Elgon UWA/FACE Carbon Sequestration Project in Uganda

1. BACKGROUND

1.1 Introduction

Formal management of forests in Uganda began with the establishment of the Scientific and Forestry Department in 1898 (Webster and Osmaston, 2003). Since then Uganda's forests have been managed on the basis of management plans that lasted 10 years. The management plans were based on information partly collected from the field and from review of documents. For nearly 50 years, forest data were collected manually and used to develop the management plans. The process was slow and the accuracy of data debatable. In spite of the shortcomings, formal management of forests was necessary because of increasing pressures for land to cultivate agricultural crops, together with the effects of economic and political changes that often reduced the availability of forest resources for use by local people. In the recent past, the use of computers has been introduced to enhance collection, handling, processing, storage and retrieval of forest data to guide forest management.

Forest management planning is not a single event; it is a series of continuous steps leading to a desired goal. It is a process that helps in the identification of resources and opportunities available in order to maximize long-term economic, financial, social and environmental benefits of a forest (Perez, 1998). A forest management plan is a guide and a tool to aid decision-making in forest management. The plan guides activities over time, is implemented in phases and provides a record of activities (Hamilton, 1999). The plan can be detailed with short-term recommendations or general with long-term recommendations. The first step is to determine priorities, set goals and identify management activities to reach those goals and to define who are the stakeholders involved and/or affected by the management. As such, forest management planning is guided by the following questions: What do we want from a forest? What should be the forest condition in the future? As such, forest management planning provides a means of identifying what can be done to enhance and protect the values and important aspects of forests. These aspects may include wildlife, biodiversity, recreation and tourism, timber, non-timber forest products, cultural values and many others. Forest management plans traditionally follow a common format. They should be in writing and then revisited periodically for updates or changes. The basic steps in developing a forest management plan are securing professional assistance, determining the goals and objectives of the plan, carrying out an inventory and evaluation of the resources, formulating an activity schedule, implementing activities and monitoring progress towards meeting the goals and objectives, and reviewing the plan every 10 or more years.

This paper discusses the use of computers and computer applications in planning and implementation of a forestry project in Uganda. The project is establishing the forests as carbon sinks in line with proposals (not yet agreed) by the UN Framework Convention on Climate Change (UNFCCC) to allow industrialized nations to use carbon sinks as one of the ways of achieving net reductions in greenhouse gas emissions. The forests are being restored in Mt Elgon and Kibale National Parks in Uganda, which were seriously degraded or cleared by agricultural encroachment in the 1970s and 1980s. The project is one of the earliest carbon sequestration forestry projects in the region and was initiated shortly after UNCED that in 1992 first drew international attention to the role of greenhouse gases in climate change. The project was initiated in anticipation of an international agreement on reducing emissions and, although the principle was agreed in the Kyoto Protocol in 1997, the issue of whether carbon sinks such as forests will be allowed to contribute to reduction targets continues to be debated internationally.

The Government of Uganda, in partnership with the FACE Foundation of the Netherlands, implements the project. The project is known as the UWA/FACE project and is managed on behalf of the government by the Uganda Wildlife Authority (UWA), which is the authority responsible for national parks in Uganda.

The project aims to restore the original forest cover using indigenous species in 25,000 ha of encroached land in the two national parks, namely, Mt Elgon and Kibale. The FACE Foundation is financing the project and will claim carbon credits equivalent to the amount of carbon sequestered by the forest, which can be certifiably attributed to the project's intervention. The credits will then be offset against CO_2 emissions in the Netherlands and help the Foundation's clients, which include power-generating companies in the Netherlands and other industrial and business clients, to comply with emission reduction targets that have been set by UNFCCC.

The project in Uganda is one of five carbon sequestration forestry projects already undertaken by FACE, which was set up with the objective of planting 150,000 ha of new forest within 25 years to sequester 75 million tonnes of carbon dioxide from the atmosphere. The existing FACE projects are located in the Netherlands (5,000 ha), the Czech Republic (14,000 ha), Sabah-Malaysia (14,000 ha), Uganda (27,000 ha) and Ecuador (75,000 ha). The Uganda project was started in 1994 and is now in its third phase. Approximately 5,867 ha have been planted to date at Mt Elgon National Park and approximately 5,000 ha in Kibale National Park.

This paper focuses on the use of computers and computerized technology in planning and implementing the project in Uganda. The computer systems used for planning, implementing and monitoring are standardized throughout all the forestry projects initiated by FACE. The Mt Elgon site in Uganda is used as a case study, but the description of methods used in Mt Elgon is representative of methods used at the other site in Uganda and at the forestry projects undertaken by FACE in other countries.

1.2 Ugandan forests

Ugandan forests and woodlands cover an area of about 4.94 million ha, which amounts to 20.5 percent of the area of the country (Ministry of Water, Lands and Environment, 2002). Most of this area (4.02 million ha) consists of woodland, while 884,600 ha are classified as tropical high forest (both fully stocked and degraded) and 34,500 ha are plantations. Most of the forests and woodlands in Uganda occur outside protected areas but 1,277,684 ha fall within forest reserves and approximately 790,000 ha occur in national parks such as Mt Elgon (1995 statistics).

The forests within national parks are protected rather than managed in the standard forestry sense and no silvicultural operations or logging are permitted in those forests. The forests are generally managed for their biodiversity or water catchment values although limited subsistence use by local communities is permitted under certain conditions. UWA manages the national parks while the National Forestry Authority (NFA) and the District Forestry Services (DFS) manage central forest reserves and local forest reserves, respectively.

1.3 Background to carbon forestry and the UWA/FACE project

It is widely accepted that the build-up of greenhouse gases in the atmosphere is contributing to climate change and leading to global warming. Much of this comes from burning fossil fuels in industrialized countries and the amounts are increasing annually in both developed and developing countries. Currently, there is a huge disparity in the amount of CO_2 being generated per capita between industrialized and developing countries and there is growing consensus that industrialized countries need to reduce emissions to mitigate the effect of greenhouse gases on climate change. International agreement on this was reached at UNCED in 1992 when the UNFCCC was signed. The convention included a proposal on the part of industrialized nations to reduce greenhouse gas emissions to 1990 levels by the year 2000. In 1997, this target date for reductions was revised to 2008. It was assumed that emissions from developing countries would continue to increase but no targets were set because of the low levels of current emissions as well as the impact that emission caps would have on development. Those countries, however, were encouraged to use clean development mechanisms to reduce the emission of greenhouse gases and their effects on climate.

The reduction in emissions of greenhouse gases in industrialized countries was to be achieved mainly by installing more efficient fossil fuel burning technology in existing "dirty" industries or conversion to cleaner energy mechanisms such as replacing coal-burning power generation with hydro or wind power.

The idea of establishing new forests as "carbon sinks" was first introduced at UNCED. It was hypothesized that the quantity of CO_2 in the atmosphere could be reduced by establishing new forests that absorb CO_2 and store it on a long-term basis as carbon in forest biomass. Carbon dioxide absorbed from the atmosphere could then be offset against emissions and the reduction targets achieved by a combination of emission reductions and/or offsets.

The notion of carbon sinks has been controversial and is still hotly debated. UNFCCC has not yet agreed that CO_2 sequestered in carbon sinks such as forests can be offset against emissions in achieving the 2008 emission reduction targets.

Initially UNCED proposed the concept of "joint implementation" (JI) between two or more countries as a mechanism for establishing carbon sink forests in developing countries. Typically, this involves a partnership between an industrialized country, which has agreed to emission reduction targets, and a developing country, which is not required to reduce emissions. Under this mechanism, a number of afforestation projects, including that of UWA/FACE, were initiated in developing countries. The industrialized country would make the investment and claim the carbon credits against any carbon taxes or reduction penalties that might be imposed in the future at home.

The concept of carbon sequestration forests gained ready acceptance in some industrialized countries, as it was clear that the cost of reducing emissions would be much greater than the cost of sequestration. The economic rationale was that the carbon sequestration, especially in developing countries, could be much more cost-effective than emission reductions in developing countries and lead to the same overall result as regards the carbon balance. Investment in carbon forestry projects increased dramatically after UNCED. Most new projects were located in developing and more developed countries but not all. For example, the FACE Foundation's first project (5,000 ha) was implemented in the Netherlands.

However, there were concerns that industrialized countries were not doing enough to control their own emissions and using JI projects as a way of avoiding their emission reduction responsibilities. At the first Conference of Parties (COP-1) to UNFCCC (Berlin, Germany, 1995), developing countries rejected the concept of JI. Issues were raised also about potential negative socio-economic impacts of such projects. There was concern at that time about the FACE approach but its partners from the governments of Ecuador, Czech Republic and Uganda voiced support for the projects in their countries. They argued that the projects were contributing to socio-economic development, nature conservation, biodiversity protection and tourism development. At the Berlin conference, it was agreed that the existing projects should continue. The FACE Foundation, as well as a number of others, was accorded the status of pilot project from which experience gained would feed into the debate on the development of criteria and rules for activities to be implemented jointly. However, the rejection of JI led to increased uncertainty regarding the future availability of forests as carbon sinks and this resulted in a substantial reduction in new carbon forestry projects after the 1995 conference.

COP-2 (Geneva, Switzerland, 1996) agreed that binding commitments on emission reductions should be included in the agreement that was to be formulated for ratification at COP-3 (Kyoto, Japan, 1997). It was now clear that industries in industrialized countries would have to incur substantial emission reduction costs and, although there was no agreement yet about the role of forests as carbon sinks, there was renewed interest in carbon forestry investment.

COP-3 (Kyoto, Japan, 1997) was a landmark conference. After two and a half years of intense negotiations, the Kyoto Protocol was adopted at COP-3. Although 84 countries signed the Protocol, indicating that they intended to ratify, many were reluctant to actually do so and bring the Protocol into force (February 2005) before having a clearer picture of the treaty's rulebook. As of February 2006, 162 countries have either ratified, accepted and/or approved it as a binding agreement to reduce progressively between 2008 and 2012 their greenhouse gas emissions to levels below those of 1990. The mechanisms for achieving the reduction were agreed and included carbon sequestration by forests. The Kyoto Protocol focused attention on the role of forests as carbon sinks and resulted in a vast increase in investment in carbon forests and the area under carbon forests. By then, millions of hectares of carbon-funded forests existed and carbon credits were valued as high as USD 20-25/ton, based on project implementation costs being incurred and expected quantities of carbon sequestered (Costa, 1999). It was estimated that, once the international market for carbon credits became fully operational, the value of credits traded and investment in carbon sequestration projects would reach billions of dollars annually and result in huge investment in forestry projects in developing countries through the clean development mechanism (CDM) specified in the protocol.

At Kyoto, countries agreed upon emission reduction targets but the operational details had yet to be decided. A schedule for reaching agreement on operational details for the Kyoto Protocol was agreed at COP-4 (Buenos Aires, Argentina, 1998). The schedule is known as the Buenos Aires Plan of Action. The plan set a deadline for agreement on a range of issues by COP-6, including rules on crediting countries for carbon sequestration by tree planting and forestry. Numerous meetings and conferences were held, including COP-5 (Bonn, Germany, 1999), in the following two years to negotiate and reach agreement on a range of issues before COP-6.

Seven thousand participants from 182 governments and 323 inter-governmental and non-governmental organizations attended COP-6 (The Hague, Netherlands, 2000). The meeting was expected to finalize the operational rules and conditions for implementing the Kyoto Protocol. However, considerable differences remained between delegates on several issues. Those relating to forestry and land use change were among the more contentious issues. Some of the details on which delegates differed were accounting rules, the relative importance of emission reductions and sequestration activities, definition of “forests”, north-south leakage, whether or not “sinks” should be allowed, the limits on the scale of carbon uptake allowable annually to each country, how natural effects may be factored out and permanence. The conference failed to reach a consensus and was suspended without agreement. Negotiations were expected to continue and the issues were to be discussed further at COP-7 (Marrakech, Morocco, 2001). Until an agreement is reached on operational rules and what is permissible under the Protocol, uncertainty will remain regarding the potential value of carbon credits and the scale of investment in carbon sequestration projects will be limited. Despite the financial risks of the parties rejecting carbon sinks and carbon sequestration forestry projects, the UWA/FACE project in Uganda has continued its reforestation programme.

2. DESCRIPTION OF THE AREA/REGION OF THE CASE STUDY

2.1 Location and geology

The UWA/FACE project is located at Mt Elgon in eastern Uganda. Mt Elgon is a solitary extinct volcano lying on the border of Kenya and Uganda. The mountain is located at approximately $1^{o}09'$ north latitude and $34^{o}33'$ east longitude. The summit is approximately 100 km NNE of Lake Victoria and 235 km ENE of Uganda’s capital city of Kampala (Figure 1).

The mountain ecosystem is protected in both countries for water catchment and biodiversity and as a source of subsistence forest products for a large surrounding community. The protected area is over 200,000 ha in extent, split roughly equally between Kenya and Uganda, with an altitude range between 1,450 and 4,321 metres above sea level. The Ugandan side is managed by UWA as Mt Elgon National Park, with technical and financial support from the World Conservation Union (IUCN) and Norwegian Development Assistance (NORAD).

Mt Elgon is one of a series of similar, though much younger, mountains in East Africa that include the Rwenzori in western Uganda, Aberdare and Mt Kenya in Kenya and Kilimanjaro and Mt Jeru in Tanzania. The age of these mountains varies and their current height is largely a function of age as volcanic material is soft and weathers easily. The rocks of Mt Elgon are entirely volcanic in origin, and include tuffs, coarse agglomerates, basalts and mudflow materials. The volcanic activity associated with Mt Elgon is dated to late Miocene/early Pliocene, about 15 million years ago.

Mt Elgon has a very large base that is about 80 km from north to south and 50 km from east to west. The angle of slope is gentle (average 4^{0}) and rises to a summit at 4,321 metres. At the top is a very large collapsed caldera with a diameter of 8 km across. The floor of the caldera lies at about 3,500 metres, or some 800 metres below the highest point on the crater rim. Differential weathering of the various volcanic materials in the lower parts of the mountain on the Ugandan side has resulted in a characteristic terrain consisting of a series of benches separated by prominent cliffs.

Unlike Kilimanjaro and Mt Kenya, Mt Elgon has no active glaciers as its summit is well below the snowline. However, there are many signs of glaciation on the upper parts of the mountain. It is estimated that the glaciers disappeared about 10,000 years ago.

Figure 1: Location of UWA/FACE sites in Uganda at Mt Elgon and Kibale National Parks

2.2 Climate and hydrology

The rainfall in Mt Elgon forest is due partly to the altitudinal effect of the mountain massif itself and to the proximity of Lake Victoria in the south-west. Rainfall in the forest ranges from 1,500-2,500 mm per year depending on location and altitude. Locations at elevations between 2,000 and 3,000 metres tend to receive the most rainfall with less falling on the lower slopes and on the summit. The main moisture-bearing winds come from the direction of Lake Victoria in the south-west. Therefore, the south-west slopes of the mountain tend to receive the most rainfall. Rainfall occurs every month with a peak in April-June and but there are relatively dry periods between July-August and January-March.

2.3 Soils

The soils of Mt Elgon are primarily volcanic in origin. The forested zone has fertile brown to red-brown clay-loams with shallow black humus soils predominating above 3,000 m. In places where the forest has been cleared through agricultural encroachment, the soils support highly productive agriculture. The farmland adjacent to the forest has recently been classified into agroecological zones (Wortman and Eledu, 1999). The zones adjacent to Mt Elgon forest on the south side are described as “very productive with fertile soils, high rainfall and moderately cool temperatures”. The zone adjacent to the forest on the northern side is described as “highly productive”. Soil erodibility is very low but in the west and south-west frequent landslides occur on steep slopes during periods of heavy rain. This is related more to underlying geological formations than to soil properties.

2.4 Flora and fauna and conservation status

Like the other large volcanic mountains in East Africa, Mt Elgon has a distinctive fauna and flora that includes endemic species found nowhere else in the world and which are mainly associated with the higher elevations where night-time temperatures descend to freezing. The flora and fauna at these elevations are quite distinct from the surrounding plains. They have evolved in isolation and the degree of endemism depends on a number of factors including the age and location of the mountain and neighbouring floristic influences. Mt Elgon is old enough to have developed a number of distinct species such as the giant *Lobelia elgonensis* and *Senecio elgonensis,* the dwarf shrub *Alchemilla elgonensis* and the umbellifer *Heracleum elgonensis*.

2.5 Forest types and vegetation zones on Mt Elgon

The vegetation zones of Mt Elgon resemble those of the other high altitude East African volcanic mountains. The dominant factors of rainfall and temperature cause the development of distinct altitudinally influenced vegetation zones (Figure 2).

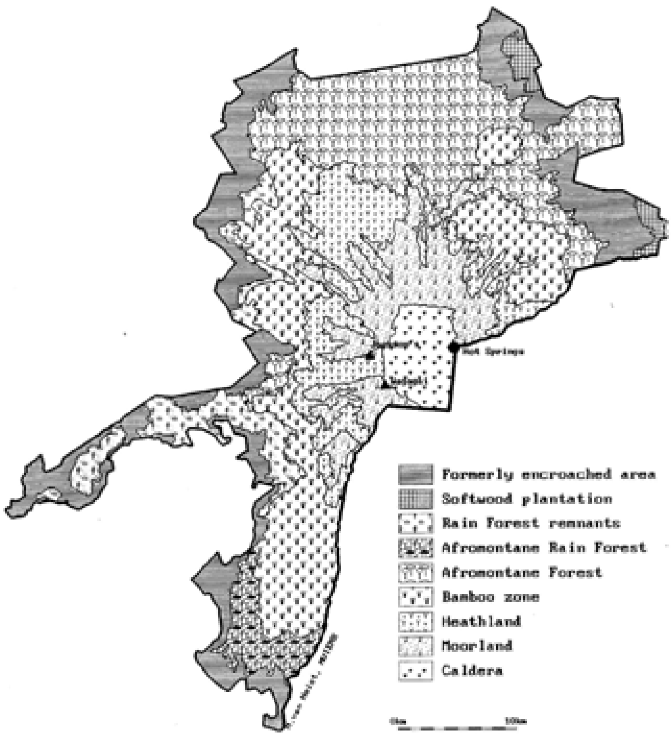

Figure 2: Vegetation classification by van Heist, 1994

Van Heist of Makerere University Institute for Environment and Natural Resources (MUIENR) on behalf of IUCN classified the vegetation in 1994. The classification was very detailed and included 62 different categories of land use. A composite map derived from the classification is reproduced in Figure 2 and shows nine classes of land use.

A previous classification by Dale in 1940 provides a good description of the forests before the agricultural encroachment of the 1970s and 1980s, i.e. those areas that are classified as ‘formerly encroached area’ in the van Heist map and which are the focus of the reforestation project being discussed in this paper.

The vegetation classes in the van Heist map are as follows:

Formerly encroached areas: These are areas that were encroached for agriculture in the 1970s and 1980s and which are now being reforested by the UWA/FACE project. They cover approximately 25,000 ha, which is about 25 percent of the area of the national park.

Softwood plantations: An area of approximately 1,400 ha of plantations of *Cupressus lusitanica* and *Pinus patula* planted originally in the 1950s and 1960s that are managed as commercial plantations by UWA.

Rainforest remnants: These are found mainly in the western area but much of the lower more fertile parts of the formerly encroached area were occupied originally by this type of forest, described by Dale as *Malacantha* (now *Aningeria*) and *Entandophragma* forest. Most of the forest has been cleared for agriculture from the boundary up to the bamboo zone. Remnants of the former forest remain. The forest was similar to the Afromontane rainforest described below but included *Entandophragma excelsum*, which is not found in the zone, described as Afromontane rainforest. The *Entandophragma excelsum* was found in restricted localities mainly in the valleys and on the lower slopes. It is a valuable timber tree that can attain colossal dimensions but no large trees remain today. A small section on the northern side of the ridge extending west from the mountain was dominated by *Podocarpus gracilior* forest, but this has all been removed and is classified in van Heist as 'formerly encroached'.

Afromontane rainforest: This is mainly found in the south and is associated with relatively higher levels of rainfall. It is dominated by *Aningeria adolfi-frederici* but also associated with other trees such as *Syzigium guineense, Neoboutonia macrocalyx, Alangium chinense, Casearia batiscombei, Prunus africana, Allophylus abyssinicus, Croton macrostachys, Polyscias fulva, Albizzia gummifera* and *Schefflera abyssinica*.

Afromontane forest: This is mainly found in the north and the two most common dominant trees are *Prunus africana* and Elgon olive (*Olea welwitschii*). Other common trees are *Albizzia gummifera, Ekebergia capensis (rueppelliana), Allophylus abyssinicus, Syzigium guineense, Dombeya goetzenii, Rapanea melanophloeos, Podocarpus milanjianus, Olinia usambarensis, Teclea nobilis, Euphorbia* spp., *Neoboutonia macrocalyx* and *Polyscias fulva*.

Bamboo zone: Bamboo (*Arundinaria alpine*) grows on the southern and western slopes of Mt Elgon. Maximum development of bamboo occurs at 2,400-2,700 metres, with quite extensive pure stands of up to 15 metres in height. Bamboo is not present on Elgon's northern slopes.

Heathland: The most common plants are *Stoebe kilimandscharica* and *Erica arborea*.

Moorland: Bush and trees are absent. Large plants include *Lobelia* and *Senecio*.

Caldera: Comprises mainly lichens and mosses.

2.6 Socio-economic environment

The soils on farmland that are adjacent to the forest are among the most fertile in Uganda, but population density is high and land holdings are small. Subsistence agriculture is the mainstay of the local economy. The crops include a mixture of perennials like plantain (bananas) and annuals such as maize, beans, peas, root crops like potatoes, yams and cassava, and vegetables such as tomatoes, cabbages and onions. Some fruits such as passion fruit, avocado, mangoes and pawpaw are grown. Livestock is popular in the drier areas on the northern side.

Population density varies from over 375 per km^2 in the south-west to 170 per km^2 in the north-west. The soils have low erosion; however, soil erosion with its associated declining soil productivity occurs because of poor land use practices. The adjacent forest communities rely heavily on the forest for firewood and other forest products such as poles, grass for thatching, medicinal plants, honey and bamboo shoots that are smoked and eaten as a vegetable. The forests are also important as cultural sites.

Agricultural encroachment has been a problem from time to time since the forest was gazetted in 1938. However, serious encroachment did not occur until the 1970s and 1980s due to political and civil unrest. During that period, most of the forest on the lower slopes was cleared and an estimated 25,000 ha were encroached. A number of eviction campaigns were carried out by the authorities in the 1990s that have resulted in the current reduced incidences of encroachment. However, the relationship between the park authorities and the local community is tense and conflict situations frequently arise, but, with the support of IUCN, UWA is trying to mitigate this through a progressive community participation approach to management aimed at involving local communities in the management of the forest. Communities have access to forest resources through collaborative management agreements and resource access agreements that they have signed with UWA.

A small number of forest dwellers (currently 561 families) known as Benet have traditionally lived in the forest and some continue to do so. They cultivate small plots and rear small numbers of domestic animals. In 1983, 6,000 ha of the forest were excised for settlement of the Benet but the attempt was only partially successful as some of the land was wrongly allocated to outsiders and some Benet families sold their plots and moved back to the forest. A second attempt was started in 2000 to move the remaining Benet to the excised land and to redistribute the land, which was wrongly allocated to outsiders, among the Benet. That process is still ongoing.

2.7 Management history of Mt Elgon

The Ugandan side of Mt Elgon was first gazetted in 1938 by the British colonial administration as Mt Elgon Crown Forest and was managed by the Uganda Forest Department until 1993 when it became a national park and management was transferred to UWA. In 1938, the boundary was demarcated and planted with eucalyptus. Exploitation of the timber resources had started under licence in 1921 and continued in a limited way after gazetting. A number of valuable timber species were present in the forest in very large quantities including *Entandophragm excelsum*, *Olea welwitschii* and *Podocarpus* spp. However, the mountainous terrain, lack of roads and low density of valuable species meant that the level of exploitation was low.

The early forest working plans concentrated on (i) protecting and improving the vegetation, especially in the heath and moorlands, to improve the water catchment value, timber stock surveys and inventory, (ii) arranging for the exploitation of the timber by private interests, and (iii) investigating ways of replacing any timber extracted.

In the 1950s, the Forest Department planted two commercial forest plantations with *Pinus patula* and *Cupressus lusitanica* amounting to 1,400 ha in parts of the reserve that were threatened by agricultural encroachment. Management of the forest included protection and marking the boundary with eucalyptus trees. A number of excisions were made in the late 1960s to settle long-running encroachment disputes.

Management was based on standard 10-year working plans. The last such plan was drawn up for the period 1968-78. Before this plan period was completed, Uganda underwent a period of intense political chaos and civil strife, which lasted from 1973 to 1986. During that period, people were encouraged by the government to clear the forest to dislodge rebels. The political situation did not stabilize until 1986. By then, the protected areas of Uganda had suffered serious degradation and Mt Elgon forest was seriously encroached and stripped of valuable trees.

In 1987, the government began a process of rehabilitation with the assistance of NORAD and IUCN. The encroached areas were gradually reclaimed and settlers were evicted. The first general management plan for the forest since the rehabilitation process began was completed in 1998. The plan covered the period 1998-2005.

2.8 Use of computers in forestry in Uganda

The use of computers in forest planning and management in Uganda, either within UWA, NFA or DFS, is a relatively recent practice or currently very limited. Computer literacy is low among most forest technicians since very few staff has access to computers. Within NFA, the use of computers is largely confined to the forest survey section, which benefited from a training programme and a sustained capacity building project in the 1990s. The national biomass study unit of the defunct Forest Department was established and has now become the Biomass Centre of NFA. The Biomass Centre has a cadre of trained staff that uses sophisticated computer systems to provide survey and GIS mapping services to a wide range of clients in Uganda including the UWA/FACE project. Most of its work benefits clients outside NFA but it also provides mapping and inventory services to NFA.

However, UWA staff working at Mt Elgon have benefited from computer systems developed and introduced by FACE. The systems are continually developed and improved. In addition, the project has collaborated with a range of institutions in Uganda in developing computer systems for forest management planning, including MUIENR, the Biomass Centre of NFA and IUCN. The project has also used GIS data generated by IUCN and MUIENR for its activities.

3. THE UWA/FACE PROJECT

3.1 Origins

In 1990 the encroached areas of Mt Elgon National Park amounted to an estimated 25,000 ha. The government evicted encroachers in the early 1990s and carried out a series of eviction campaigns to restore the integrity of the park. At that time, the FACE Foundation was looking for suitable sites for carbon forestry projects and formed a partnership with the Government of Uganda to jointly implement a carbon sequestration forestry project in the formerly encroached areas of Kibale and Mt Elgon National Parks. The Ugandan sites had the advantage that, being inside national parks, they could reasonably be protected in perpetuity and were unlikely to have negative social impacts.

A plan was initially developed to progressively reforest 25,000 ha in Mt Elgon in three phases of three years each. The first phase was implemented from 1993 to 1997 when 3,320 ha were planted; and 2,547 ha were planted in the second phase from 1997 to 2000. The target for the third phase (2000-2002) was 3,000 ha and 1,000 ha had already been planted by 2000.

A three-year operational plan and budget has been developed for each phase and an implementation contract signed by both parties. The details of contractual arrangements and plan are elaborated below.

3.2 UWA/FACE contractual arrangements

The rights and responsibilities of the partners in the project (FACE Foundation and the Government of Uganda) are described in the legal contract signed by both parties at the beginning of each new phase of the project. The contract specifies the areas to be planted, funding details, ownership rights and the agreements between the partners. The basic conditions of the contract (which are influenced by ongoing discussion on UNFCCC operational standards for carbon sink forests) are ecological sustainability, local acceptability and economic feasibility.

Under the terms of the contract, the FACE Foundation funds the project and in return receives exclusive rights to the sequestration and offset value of the entire amount of CO_2 sequestered in the contract area. This enables FACE to offset such carbon against the carbon dioxide produced by its clients in the Netherlands or elsewhere and thus assists them to reach their greenhouse gas emission reduction targets, which were agreed to in the Kyoto Protocol. FACE is also entitled to trade in those carbon credits should a market develop for such trading. The contract prohibits UWA from disposing of the CO_2 offsets to a third party; it also requires UWA to register, in the appropriate registry in Uganda, the exclusive entitlement of FACE to any and all CO_2 sequestration and offset in the contract area for the duration of the contract (99 years). This does not mean that FACE owns the trees and biomass, or that it has any right to use the forest resource in any way other than as carbon offsets.

The responsibilities of UWA under the agreement are to implement the project in the field and to manage and protect the forest for the duration of the contract. In return, it gets funding for initiating the reforestation and all the benefits of the resulting forest except the right to trade the carbon offsets. UWA and the Government of Uganda retain ownership of the land and forest. Apart from the requirement not to log, UWA retains all the privileges and benefits of ownership, e.g. the water catchment value, conservation and biodiversity values, and tourist values. The agreement not to log for 99 years cannot be regarded as a cost (or a benefit foregone) to UWA as Mt Elgon forest is already protected as a national park and logging is prohibited. In principle, selective logging is not necessarily incompatible with carbon sequestration projects although the logging activity does somewhat reduce the store of carbon and consequently the value of the forest as a carbon sink.

3.3 Project organization

The project manager is a senior warden in UWA. Until recently, the project staff was employed on contract by the project but now are employees of UWA on contract for the duration of the current phase. The project office staff consists of a project manager, field supervisor, a secretary, an accountant and two computer/information and communication technology staff. The number of field staff varies as the work is seasonal. On average, approximately 240 field staff from the local communities are employed on nursery and reforestation work and there are about 12 field supervisors who are trained forest technicians.

3.4 Development of the management plan

3.4.1 Planning hierarchy

The planning hierarchy in UWA currently includes a five-year strategic plan for the institution as a whole, five-year management plans for the individual national parks, and one-year operational plans. The current five-year (1999-2004) management plan for Mt Elgon National Park was developed over a period of two years. It involved data collection and consultation with the full range of stakeholders before finalization and adoption by the Board of Directors of UWA. The plan provides a framework for management of all aspects of the national park including the UWA/FACE reforestation project. However, the management plan was not approved by the Board of UWA until late 2000 and the level of coordination between the plan and the UWA/FACE operational plan has been weak.

Since the inception of the project in 1994, the UWA/FACE project areas have been managed under a series of three-year operational plans that correspond to each phase of the project. The scope of the plans is limited to forest establishment and protection of the park and does not include provision for harvesting as the areas will not be logged or subjected to any silvicultural treatments once they are established for the agreed period of 99 years.

3.4.2 Planning activities

Generally, the development of the plans takes place in two major stages: (i) office work and (ii) field work. Office work involves pre-planning activities such as holding planning meetings to discuss and agree upon a work plan, securing the tools, equipment and consumables required for the exercise, engaging the desired personnel and determination of the data required in order to develop the management plans. Types of data required include areas to be planted and their stratification, site and terrain classification, labour productivity and activities and costs. Maps, aerial photographs, satellite images and the old management plan to be revised are also put together at this stage.

Field work is often carried out in order to collect data required for developing or revising the forest management plan. Activities involve the use of GPS to map the reforestation areas, inventory of stocking density, survival and growth rates of the trees and site suitability assessment in order to determine the right species. Labour requirements are estimated in order to compute the costs of forest management operations such as planting, weeding, pruning, thinning, climber cutting, forest road maintenance, boundary maintenance and fire control.

3.4.3 Participation of stakeholders in forest management planning

The concept of community forest management (CFM) is relatively new in Uganda and Mt Elgon National Park is one of the protected areas where the concept has been piloted. CFM provides an opportunity for local stakeholder involvement in forest management including development of management plans. In Mt Elgon National Park, the level of consultation during the development of the project's three-year operational plans was initially limited to the two project partners with little or no involvement of other stakeholders. However, stakeholder involvement has increased with management adopting a more inclusive approach to project planning. This move is due partly to a more community centred approach to protected area management adopted by UWA and partly to the social impact requirements of CDM. In addition, the requirements for certification under the principles and criteria for forest stewardship of the Forest Stewardship Council require consultations with people affected by forest management operations.

Given the history of conflict between the park authorities and local communities, a much more inclusive approach to planning was considered to be desirable. As a result, consultations were held by UWA/FACE staff with various stakeholders in order to obtain information on the management of the forests in the park. One of the key stakeholders is the local community surrounding the park whose views have to be sought and their demands for forest products accommodated in the management plan. Although Mt Elgon is a national park without extractive activities, the forest within its boundaries needs to be managed in a systematic manner as outlined in the Uganda National Forestry Policy of 2001. Community participation mainly involves engaging the local people in forest management operations and supporting community-based forest activities. The local people also enter into collaborative resource management agreements with UWA to regulate access to certain forest products for local use. The agreement aims at reducing resource use conflicts.

3.5 Planning activities prior to field data collection

3.5.1 Stakeholder analysis

Stakeholder analysis should be conducted prior to field inventory. The analysis can help to identify macro- and micro-level key individuals and organizations that have an interest and stake in the forest resource whose management plan is to be developed. The analysis also involves the types of relationship between major stakeholders, major secondary stakeholders and direct users of the forest resources, and key stakeholders and the forest. There is also a need to produce area specific analyses that identify stakeholders to be included in discussions and the process of developing workable forest management plans, as well as possible implications of not including certain stakeholders in the discussion process.

3.5.2 Identification and development of management objectives

The first step in developing a forest management plan prior to resource inventory is to identify resource management objectives including products and amenities that the stakeholders wish to obtain from the resource. It is imperative that these objectives be identified at the beginning because they determine the field inventory process and define the goal of the management plan.

Some stakeholders may be interested in only one management objective e.g. maximizing the net financial return on investment through timber yield or developing the forest primarily as wildlife habitat or for biodiversity conservation. This is referred to as dominant-use management. The forest can also provide more than one product or amenity referred to as multiple-use management.

3.5.3 Preparing a resource map

Before embarking on forest inventory, it is important to know the resources with the help of a map. A resource map shows clearings, forest boundaries, physical features such as hills, ridges, swamps and many others. It might also include roads, trails and developed areas such as houses or recreation sites; unique and sensitive areas such as waterfalls and the location of areas such as nature reserves, buffer zones and community use and research zones. Fitting all of this information manually onto a single map can be difficult and the use of computer is essential in this respect.

3.5.4 Logistical arrangements

Logistical arrangements should be planned prior to the inventory exercise. It should consider nearby accommodation, arrangements for lunch for fieldwork days, sufficient vehicles, portable computers, funds to purchase refreshments for community consultative meetings and supplies such as flip chart paper and markers.

3.5.5 Training of field team members

Training of field team members may be required in order to collect reliable and valid data for forest management planning.

3.6 Post-field data collection activities

3.6.1 Data analysis

Inventory data should be analyzed to determine what the forest site is capable of producing. The use of computer is again essential at this stage. The computer files of raw data should be prepared and checked before undertaking subsequent analysis.

3.6.2 Development and implementation of the management strategy

Based on the inventory analysis, a management plan is then developed to achieve the management objectives. These forest management strategies should be based on and limited by what is biologically/ecologically possible in the area, what is economically and organizationally feasible, and what is socially and politically desirable.

The biological/ecological characteristics of the forest (e.g. tree species, soil type, topography, etc.) determine what is possible in the area, including which tree species will grow, how fast they will grow, what biodiversity will live on the area and so on. Based on the biological/ecological characteristics of the site, silvicultural practices may be prescribed to achieve management objectives. Silvicultural prescriptions are treatments designed to manipulate forested land such as timber cutting, tree planting, thinning, pruning, prescribed burning and the use of specific chemicals such as herbicides and fertilizers where necessary.

Economic/financial considerations may determine which activities are feasible. If economic/financial objectives are important to management, then silvicultural activities to be undertaken must not only be biologically/ecologically possible, but must also contribute positively to the appropriate economic/financial analysis. Management activities may also be constrained by what is socially and politically desirable. Activities that violate the law or interfere with the social security of local communities adjacent to the forest are obviously unacceptable and generally not prudent.

3.7 Pre-planning activities leading to improvement of the degraded forest

3.7.1 Site preparation

Site preparation is undertaken to make land ready for forest establishment. Methods used may include chemical vegetation control, mechanical cultivation or burning. Best management practices (BMPs) to protect water and soil quality should be followed during site preparation.

a) Mechanical site preparation
Grass competition in a planting site may be reduced with a heavy sod by ploughing. Minimizing the amount of soil disturbance helps to reduce the threat of water erosion and weed seed invasion. Dry season ploughing should be discouraged as it will introduce air into the soil which can lead to desiccation (drying) of the roots of newly planted stock.

b) Chemical site preparation
Weedy or grassy competition can be controlled with selective herbicide use. Effective control depends on four factors: timing of application, herbicide selected, weather conditions and application rate. Heavy sod can be controlled by application of herbicide in the year prior to planting. Alternatively, a pre-emergent herbicide can be applied in the season just after the trees are planted and the existing grass cover has not "greened up" yet. Herbicides should not be allowed to come in contact with the tree roots. Very dry conditions will limit the effectiveness of most herbicides.

c) Prescribed burning site preparation
Prescribed burning site preparation is a very effective tool in re-establishing forest stands, particularly pines. It is by far the simplest and least expensive method of preparing planting sites. Prescribed burning helps to remove dense logging debris and expose more plantable area; controls competing underbrush and other biological agents, thus improving planting bed conditions and opportunities for survival, early growth and development; and provides heat sufficient to kill the overstorey competition, thus reducing overhead shade and competition for moisture and sunlight.

Prescribed burning is a highly technical job that requires knowledge of fire behaviour, suppression techniques and the environmental effects of fire. Prior to its use, a prescribed burning plan should be prepared.

3.7.2 Species selection

This is done to meet management goals and suitable sites. Factors that should be considered when selecting species are growth rate, site requirements, climatic suitability, genetic variability, wood and fibre properties, aesthetics, wildlife value, biological diversity, erosion control and potential insect and disease problems.

3.7.3 Spacing

Initial spacing affects both the biological and operational factors of the forest. Height growth may be reduced at extremely high and low densities. Diameter growth is usually unaffected by spacing until competition begins. The period of fast, early diameter growth is often longer at wider spacing. Wide spacing may also result in branch retention leading to knotty woods. Spacing may also be affected by species selected for natural regeneration or planting. Relative shade tolerance, species growth patterns and anticipated maintenance operations such as thinning and pruning also influence initial spacing.

3.7.4 Planting methods

The choice of planting method will depend on whether the degraded area will be afforested or re-afforested. Re-afforestation tends to rely mostly on natural regeneration, as it is the cheapest method to reproduce a stand. Success of natural regeneration depends on whether there is adequate seed, seedling or sprout supply, ample soil moisture, a well-prepared seedbed (in the case of pines), adequate sunlight on the forest floor and control of competing vegetation. Careful planning is required to ensure success.

Artificial seeding can apply in both cases (afforestation or re-afforestation). Seed may be sown by either spreading from ground level or by broadcasting from the air over the site or in spots. This is most common with cone-bearing trees (pines, etc.). For hardwoods, direct seeding usually gives successful result. Success is determined by many of the same factors that affect natural regeneration. Rodents and birds can consume large quantities of seed, leading to poor survival.

3.7.5 Post re-planting activities

1. Fertilization

If necessary, fertilizer is applied where a soil test indicates a critical shortage of one or more nutrients. The best time to adjust fertility is at the time of the stand's establishment. Best management practices dictate that only the needed amount of fertilizer be applied and that care is taken to prevent water pollution from fertilizer.

2. Weed control

Weed and grass control is considered essential to the survival and initial growth of young seedlings. Weeds and grasses compete with seedlings for moisture and sunlight. Control can be manual, mechanical or through herbicide application (if deemed necessary). The latter is the most common and generally the most cost effective.

3. Crop tree release

Crop tree release (CTR) is also a form of weeding. Normally, it is applied to hardwood stands that have not reached commercial size classes. It is the practice of deadening selected trees in younger forests for the benefit of releasing desirable crop trees. CTR may be used to alter species composition within a forest, and to concentrate diameter growth on desirable, potentially valuable crop trees. CTR leaves the forest with well-spaced trees whose crowns are capable of rapidly responding to increased growing space. The goal is to shorten the rotation length, allowing desirable trees to survive and mature sooner. A variety of tools such as chainsaws, hatchets, axes, hypo-hatchets and tree stump injectors have been used to conduct CTR, sometimes in combination with a herbicide applied to the cut surface.

4. Commercial thinning

Thinning is tree removal in a forest stand that reduces tree density and tree-to-tree competition. Thinning is very similar to CTR, except it is normally a commercial venture producing moderate income. It can be more systematic, removing straight rows of trees (as with pine). Thinning seeks to control stocking and crown competition. It is usually done in even-aged stands when the tree crowns become so dense that they shade each other and suppress growth. Thinning enhances forest health. Often stands that are not thinned are more vulnerable to disease and insect infestations, and take longer to mature.

5. Pruning

Removing persistent low branches improves wood quality and increases the percentage of valuable, clear (knot free) wood production. Pruning is best done when branches are less than 5 cm in diameter. Pruning is labour intensive, and normally limited to trees that have potential for high monetary value.

6. Controlled or prescribed burning

These are intentional fires set to accomplish a management objective, such as silvicultural, wildlife or fire hazard reduction. A prescribed burn can be used to remove debris and create a seedbed, or to retard the understorey growth of woody species to favour herbs for wildlife. Conditions such as weather, soil moisture and wind must be favourable prior to ignition.

7. Protection from livestock

Grazing of forested areas by livestock negatively impacts both forest and wildlife values. Livestock severely limit or eliminate the presence of grassy cover, forbs and shrubs that provide both food and cover for a wide variety of wildlife species. Long-term grazing in more open forests causes soil compaction and tree root damage. In forests adjacent to or drained by streams, livestock can develop paths along the stream bank that contribute to erosion, degrade water quality through excrement and disturb aquatic habitat.

4. COMPUTERIZED AND ELECTRONIC EQUIPMENT AND SOFTWARE USED IN MANAGEMENT OF THE FOREST

4.1 Staff capacity to use computer systems

The FACE Foundation uses common systems and procedures in all its carbon forestry projects including the UWA/FACE project in Uganda. The central component is MONIS, a database developed by FACE to store all types of project data and produce a range of pre-defined reports. The system is managed by the project MONIS officer who has database management and GIS skills and is responsible for database maintenance, updating and generation of GIS maps and other reports for project managers. Several other staff at the project are skilled in standard computer applications such as MS Office. When specialist input is required, such as satellite image interpretation, the project capacity is supplemented by specialists commissioned from other institutions in Uganda or abroad.

4.2 Computer hardware and software

Several computer hardware and software are in place for use by the UWA/FACE project. The computer hardware at the project office consists of:

- Four desktop personal computers (PCs) that are not networked. The PCs have standard specifications and peripheral equipment such as a printer, uninterruptible power supply (UPS) and voltage regulator. The regulator is needed to guard against surges in power supply and UPS to enable the computer to be shut down when occasional power cuts occur. The project has a generator for emergency power supply during power cuts.

- Zip drive for backing up computer files. Back-up zip disks are stored safely in a separate location and are retrieved in case hard disk problems occur or PC data are lost.

- Eight GPS (Trimble GeoExplorer II model) units for field mapping and data capture (ref. section 4.7.3 below).

- A base station consisting of laptop computer for differentially correcting GPS readings (ref. section 4.7.1 below).

- Equipment shared with other FACE projects for use in measuring biomass in sample plots using the Field-Map software application. The equipment consists of a field computer, electronic callipers and laser range finder (ref. section 4.9 below).

The software used by the project consists of:

- MONIS*:* The FACE Foundation's monitoring and information system (ref. section 4.5 below).

- ArcView 3.2a: This is a Geographic Information System (GIS) software mainly used for data storage, analysis, display and retrieval. Some of the outputs of the software include compartment and other thematic and viewing maps (ref. sections 4.3 and 4.7.7).

- ILWIS: This software is used for correcting area data for slope, getting the true area on the ground and calculating slope and aspect of compartments (ref. sections 4.7.9 and 4.7.10).

- Pathfinder Office: This software is used for designing a data dictionary for the GeoExplorer II GPS and downloading files from GPS to the PC.

- Field-Map: This software is shared with other FACE projects and is used for storing and managing data from sample plot measurements (ref. section 4.9 below).

- Dbase. This database programme is only used as a file format for attribute tables in ArcView 3.2a thematic maps.

- MS Office: This software package is mainly used for word processing and general data processing functions. MS Word and MS Excel are the most commonly used packages.

- Accounts View software. This is used by the project accountant along with MS Excel for management of accounts and financial reporting.

4.3 Using GIS in planning reforestation areas

4.3.1 Strategic planning

Potential reforestation areas on Mt Elgon were determined initially using the detailed vegetation classification carried out by IUCN in 1994 (Van Heist, 1994). Figure 2 shows a composite of the survey as well as the scale of agricultural encroachment in the 1970s and 1980s. Using GIS maps produced during the survey and taking into account logistical issues and the need to plant in a number of locations simultaneously, a long-term strategic reforestation plan was developed to plant 25,000 ha over a period of 18 years in six phases of three years each (Figure 3).

4.3.2 Operational planning

The proposed reforestation sites for each phase are broadly outlined in the strategic plan map (Figure 3). At the operational level, the specific planting sites are selected about one year before planting. Before making a final decision on areas to be planted, sketch maps based on the vegetation maps are produced using ArcView 3.2a software. The sketch maps are used to locate the potential planting areas in the field with the help of a GPS that provides the coordinates corresponding to the planting areas identified on the sketch map. A field reconnaissance of the sites is then carried out and a decision made on the sites or sections of sites to be planted. Subsequently, sketch maps are modified on site to reflect the areas to be planted.

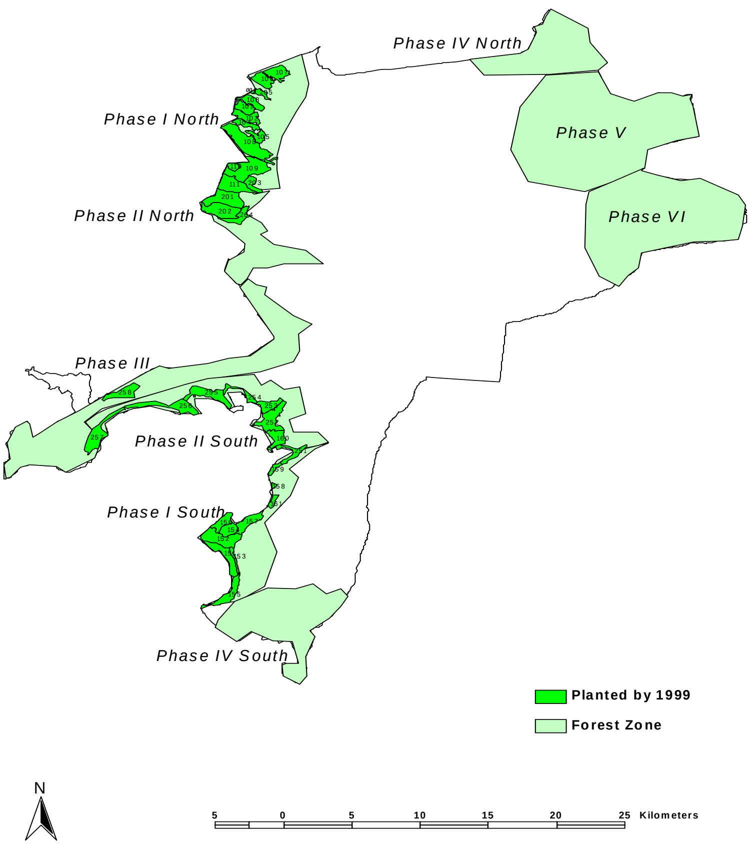

Figure 3: Map showing the proposed reforestation plan for Mt Elgon. The plan is divided into six three-year phases. Areas planted by 1999 are highlighted

4.4 Planning and locating nurseries

When a final decision is made on the sites to be planted, nursery planning begins. Despite the fact that GIS modelling, using parameters such as proximity to water, moderate slope and minimum walking distance to the planting site, would be used to identify suitable locations for tree nurseries, the approach is not yet used probably due to insufficient expertise. Instead, nursery sites are identified based on three criteria: (i) proximity to permanent water supply; (ii) existence of moderate and preferred slope; and (iii) proximity to the planting site.

Sketch maps of the planting sites are used in conjunction with vegetation classification maps in ArcView 3.2a to determine the number of seedlings required for the reforestation programme.

The vegetation classification map is important because it enables elimination of areas that are not to be planted such as sections of remnant forests.

4.5 Monitoring and Information System (MONIS)

MONIS is a software application developed by the Face Foundation to monitor activities supported by the Foundation and store basic data on its forestry projects in a logical order. The data are used for management and planning purposes at project sites and for monitoring at FACE Foundation headquarters in the Netherlands. The MONIS unit at the project is responsible for database development and maintaining MONIS information on the Mt Elgon project up to date. MONIS contains a range of information such as maps of areas planted, site conditions, inventory data on the status of forests and trees, silvicultural operations undertaken and costs. It also contains background documents and agreements between FACE and its partners, site photos, manuals on procedures and methods for mapping, parameters to be measured, etc. The system contains data entry forms for inputting field and financial data at the projects on a monthly basis, from which status reports can be generated. At the Mt Elgon site, the database is not fully operational yet.

The system is periodically updated and improved. The current version of MONIS (Version 3.0) was installed on the project computers in December 1999 and was due to be updated with a new version in 2001 to overcome software bugs that were preventing data entry in some categories. The system is explained below with some sample views of the user interface. The opening screen allows the operator to select a project or to export, import, edit project names and add coordinates. If the Mt Elgon project is selected, the data for Mt Elgon are retrieved instantly.

In the sample screen below (Figure 4), information on the Mt Elgon project is shown. The "Compartment" tab is selected in the example. Data for compartment 101 are shown, which is 116 ha planted in 1994. The "Physiography" sub-tab is selected and shows the physiography of the selected compartment, i.e. average altitude, percentage of compartment area according to exposition and percentage of compartment area according to slope. The other tabs under "Compartment" if selected would show soil, vegetation, planted forest, inventory or remarks. Some of these elements have not been activated yet and there are no data on soil or forest inventory.

The table on the lower left-hand side is designed to show the measures or activities undertaken in the selected Compartment 101, i.e. silvicultural operations and associated costs. This element has not been activated yet at the project and to date no activities or costs have been entered for any of the compartments. This is due to a problem with the software, which is currently being corrected. However, in the example below, silvicultural operations undertaken in compartment 101 and associated costs have been entered for illustration purposes. In the example shown, the maintenance costs for 1999 are highlighted and the associated labour, goods and materials costs are shown in the lower right-hand side of the table. The total cost to date for the compartment is shown as UShs. 6,872,350 (equivalent to USD 3,972 or $33.86 per ha)[1].

[1] Note that the termination date is shown as 31/5/93, which stands for 2093, that is 99 years after the start date of 1994.

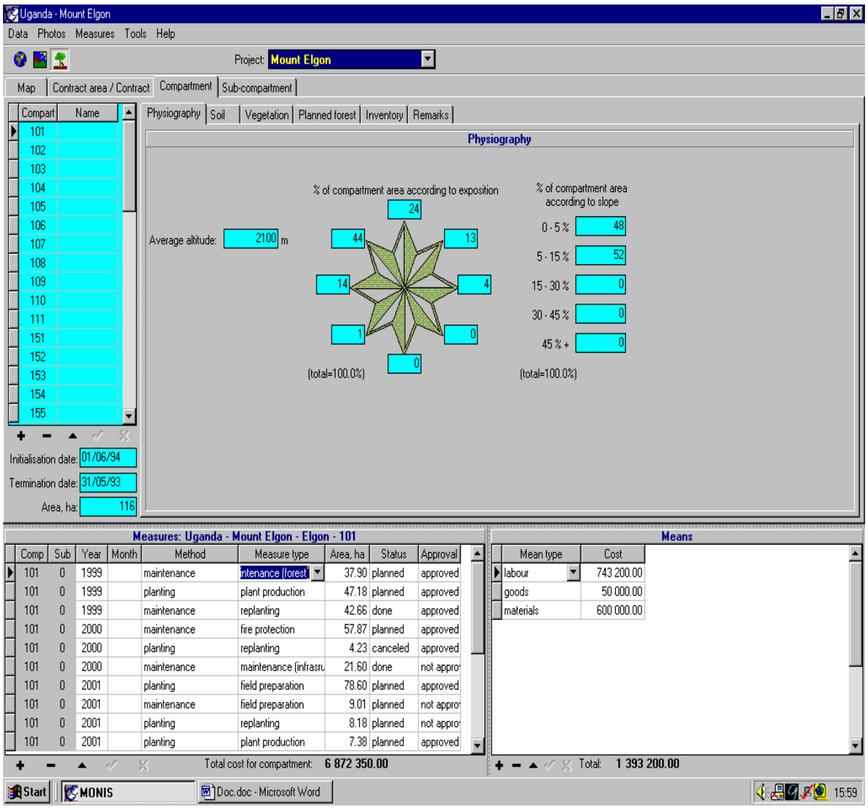

Figure 4: An example of compartment data stored in MONIS

The programme map and database elements are fully integrated. For example, if the operator is looking at a map of an area, he/she may request information from the database on the forest types and activities carried out in that area. On the other hand, when dealing with the data on vegetation type, activities, etc., a map of that area can be directly requested to see its location using the MONIS maps application option.

Figure 5 shows the map tab selected. The screen shows the Mt Elgon gazetted area (elggaz_polyg) map as a base map, which is overlaid with a compartment map (elgcpts) showing compartments planted in the first two phases of the project. The maps are developed in ArcView 3.2a software and exported to MONIS as shapefiles.

If the "Contract area" tab is selected, information on the contracts (one for each phase) is shown. The sub-compartment tab is not used at Mt Elgon, as compartments are not subdivided.

The database contains photographs of the reforestation sites, which may be viewed by selecting the Photos tab. Figure 6 shows the condition of compartment 205 prior to planting.

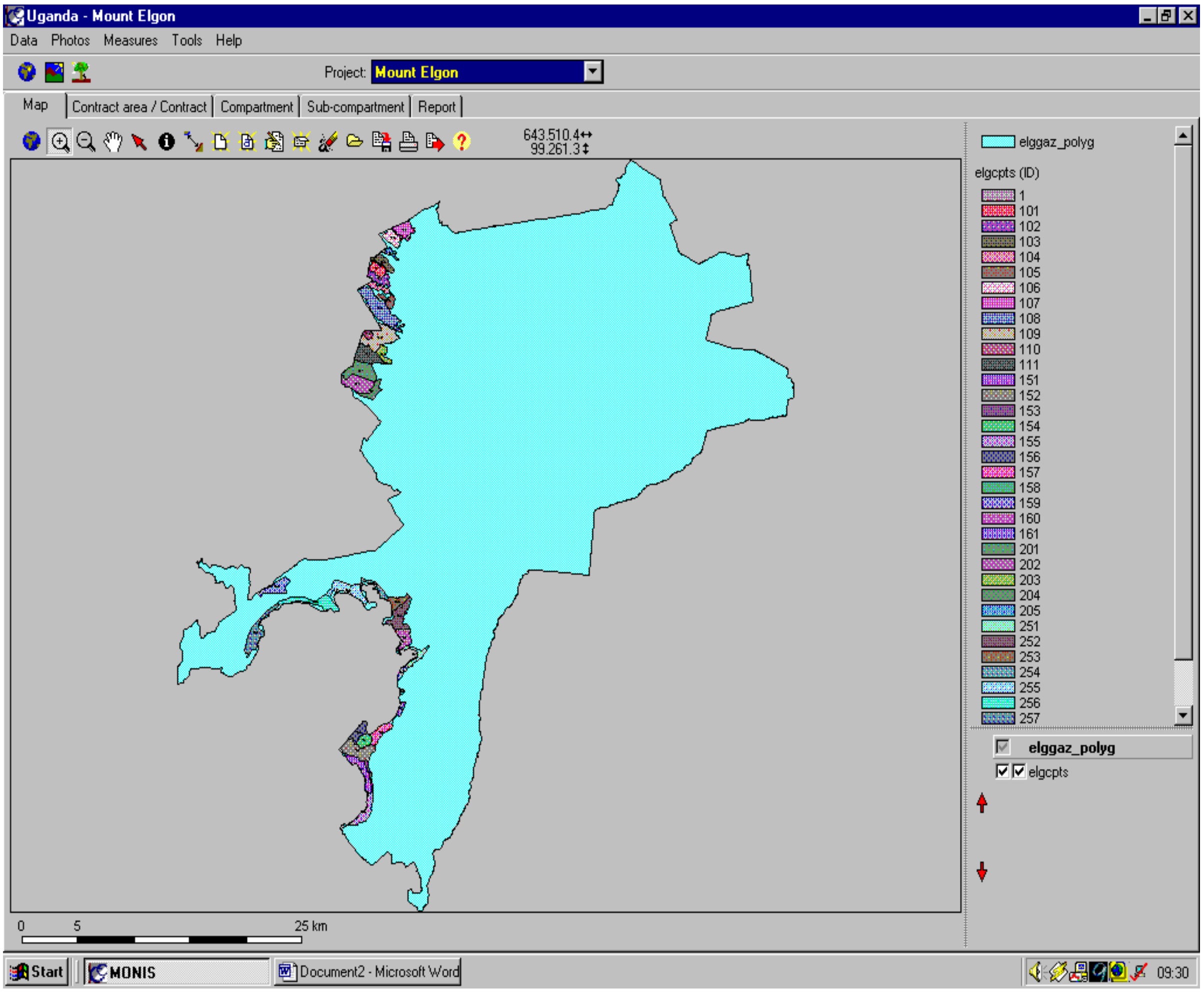

Figure 5: MONIS map functions

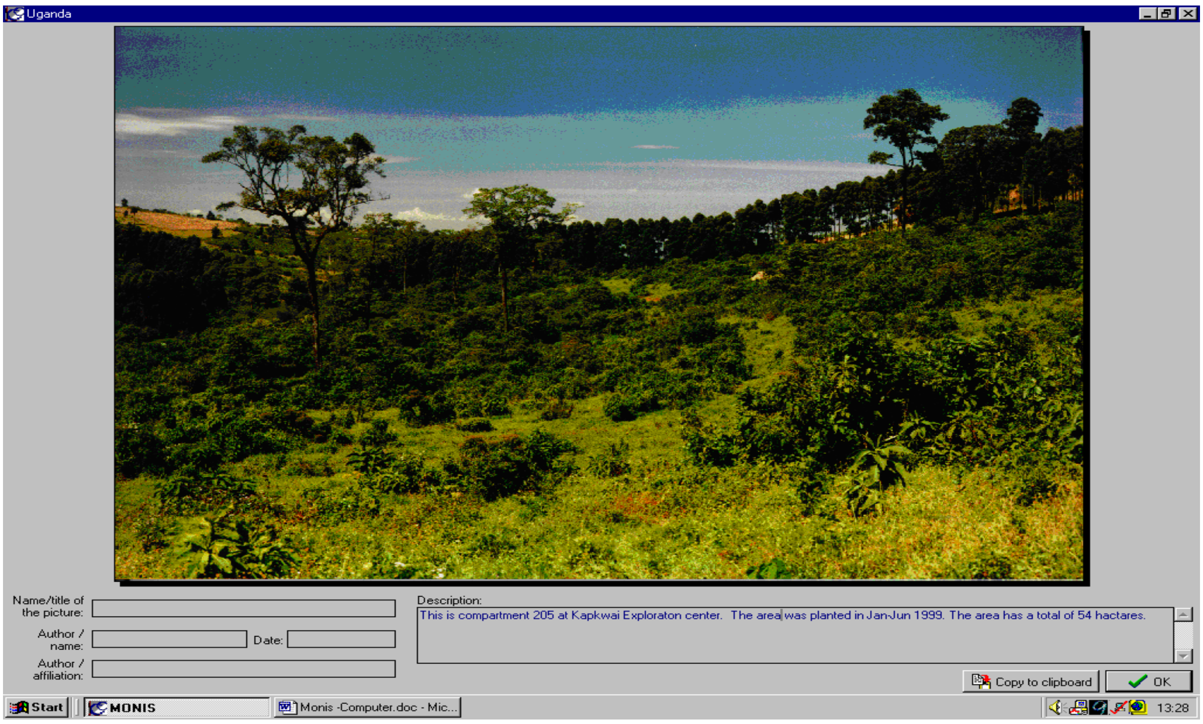

Figure 6: MONIS photo storage functions

A menu of reports is available by selecting the Reports tab. The user is restricted to the predefined report options. Figure 7 shows a sample report generated for Compartment 101. It should be noted that soil data fields are blank, as MONIS does not contain any soil data for Mt Elgon, as is the case for the inventory fields.

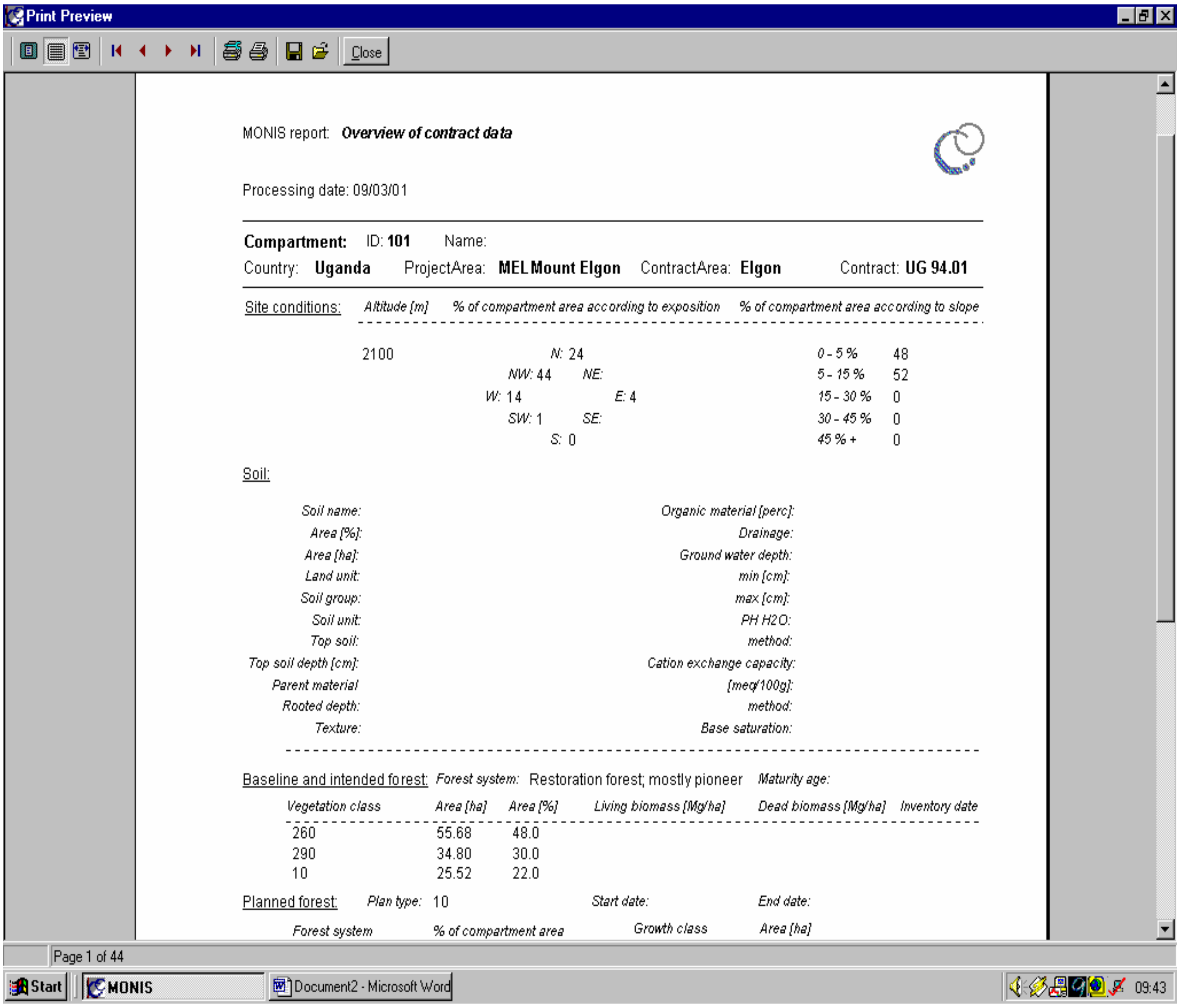

Figure 7: MONIS reporting functions

4.6 Compiling feature attribute data for MONIS

Feature attribute data are collected in the field using the hand-held Trimble GeoExplorer II GPS unit and downloaded direct into the office desktop computer using the Pathfinder software before storing in MONIS as described below.

Designing the data dictionary and loading into the GeoExplorer II GPS

The first step is to decide which items of data are required and list them in a "data dictionary" that shows the features together with their types and attributes, among other things. Table 1 shows the data dictionary currently in use at Mt Elgon that contains 14 types of geographical feature and a number of types of attribute data to be collected for each of the features. The data dictionary is designed on the office PC using the Pathfinder Office software and is downloaded into the hand-held GPS unit that is used as both a geo-referencing and data capture device in the field. The data capture facility allows the user to record, review, rename and delete base files and to review or delete the data dictionary. Once the data dictionary has been loaded into the GPS, the user may store position data in addition to other feature and attribute data in a "rover" file. Up to 99 rover files may be stored on the GeoExplorer II receiver. If a data dictionary has not been loaded into the GPS, it can only be used for storing position data.

Table 1: Data dictionary used in the GeoExplorer

N^{o}	Feature	Feature type	Attributes	Choices
1	River	Line	Type	Seasonal Permanent
			Name	Enter a name
2	Path	Line	Type	Tour/vill Work/vill Tourists Workers Villagers Work/tour Tour/work/vill
			Location	Inside park Outside park
3	Rock outcrop	Area	Name	Enter a name
			Area of outcrop	Give area and units
4	Road	Line	Grade	Tarmac Murram Seasonal (no murram)
			Type	Park road Local govt road Highway
5	Building	Area	Type	Permanent Semi-permanent Grass thatched
			Size	0 - 15 m^2 15 - 25 m^2 25 - 50 m^2 >50 m^2
			Ownership	Park Government Private
6	Tree	Point	Species	Enter name
			Location	Inside park On boundary On public land
7	Junction	Point	Type	River/river River/path River/road Path/path Path/road Road/road
8	Park boundary	Line	Type	Eucalyptus planted No eucalyptus planted
9	Compartment	Area	Compartment N^{o}	Enter number
10	Sub-compartment	Area	Sub-compartment N^{o}	Enter number
11	Survey point	Point	ID number	Enter number
12	Fireline	Line	Type	External Internal
13	Compartment Point	Point	ID number	Enter number
14	Hill top	Point	Name	Enter name

Entering the data

Data are input direct to the hand-held GeoExplorer II unit. The user selects a feature and is prompted to enter data using drop down lists of attributes described in the data dictionary. This system of data collection saves time as data are subsequently downloaded direct into the PC and minimizes errors as the operator is restricted to predefined selection options.

The data dictionary is comprehensive but the data currently being collected are limited to compartments, roads, fire lines, buildings, paths and boundary of the park. The data are stored in the programme under "planned forest".

4.7 Compiling compartment maps

Compartments are mapped shortly after planting. They are a basic necessity for forest management and are one of the most useful elements of the MONIS database at the UWA/FACE project. The mapping is done by a crew of four skilled in the use of GPS equipment.

The field equipment needed for mapping includes: GeoExplorer II GPS receiver, shoulder carrying pouch, AA batteries, external rechargeable battery plus battery cable, GeoExplorer II quick reference, and sketch maps of the area in which the crew will be working in addition to pens, papers and pencils for drawing sketch maps in the field.

The mapping process is rather complex and involves a number of software applications. The steps in the process are as follows:

- Setting up a differential base station for correcting GPS readings.
- Navigating to the site using pre-drawn sketch maps.
- Mapping the compartment boundaries with GPS.
- Download data from GPS to PC.
- Differential correction of GPS errors.
- Conversion of GPS data to local coordinate system.
- Export the maps to ArcView.
- Consolidating compartment theme map in ArcView.
- Area calculation in ILWIS.
- Calculation of slope and aspect percentages for compartments.

The above steps are described in detail below.

4.7.1 Setting up the differential GPS base-station

Position data collected using GPS in the field have to be corrected to eliminate errors caused by a number of technical sources. The principal source of error is usually the distortion of GPS signals introduced by the US Department of Defence known as selective availability effect. However, this was removed in May 2000 and, as a result, the precision of the hand-held units has increased making differential correction less necessary. The remaining sources of errors include atmospheric conditions, cloud/tree cover interference and poor position dilution of precision (PDOP) values that are known to have a limited effect on the hand-held units. GPS units can now give an acceptable level of precision for compartment mapping but as the staff are used to the system of differential correction, they continue to use this system.

Differential correction involves taking position fixes simultaneously in the field and on a fixed point referred to as a base station using the same satellites simultaneously. The difference between the GPS reading at the base station at a given time, and the known coordinates of the base station location, is the error at that particular time. The error at any particular time may be used to correct a GPS reading in the field taken at that time. This technique is called differential GPS and is used when mapping in Mt Elgon National Park. To facilitate this, a base station has been set up at the project offices in Mbale. The base station consists of a laptop computer to which a GPS is attached.

A timetable is made for switching on the base station and running the base station programme when the crew is taking GPS readings in the field. This is done daily at given time intervals and is switched off when the personnel collecting data in the field informs the office that the day's work is over. The reason for not leaving the base station turned on permanently is simply to limit the size of files generated. The GPS Pathfinder Base Station automatically collects base files and outputs real time corrections, with which users may differentially correct GPS files later in the office. After differential correction, the level of accuracy is 1-3 meters, which is adequate for forestry compartment mapping.

4.7.2 Navigating to the site using pre-drawn compartment sketch maps

The sketch maps that were produced before planting, and which were used by the planting crews to locate the planting sites, are used again by the mapping crew to navigate back to the site to do the detailed mapping after planting (ref. 4.3 above).

4.7.3 Mapping the compartment boundaries with GPS

When a compartment has been planted, a detailed map of the compartment is produced. The crew navigates to the site to be mapped using GPS and the pre-drawn compartment sketch maps. A reconnaissance of the compartment or plot to be mapped is made, determining where to start and which features need to be mapped. The crew discusses the locations of the boundaries before commencing work.

A separate file is used for mapping each compartment. The operator takes coordinate readings at each corner on the compartment boundary until the compartment is completed. Polygons are formed by a series of straight lines with nested points at each corner. The points are numbered. When the compartment is completed the file is closed and a new one opened for the next compartment. In mapping the roads, paths and fire-lines, each feature is followed to its conclusion before closing it.

4.7.4 Download data from GPS to PC

GPS is connected by cable to the COM 2 port of the computer. Pathfinder Office software is used to download the data. When starting, the user selects a project folder into which the data are downloaded. The downloaded files have the extension .ssf. The user can check the attribute data and view the position points on a map that displays the raw GPS positions used to create the features.

4.7.5 Differential correction of GPS errors

The second step is to correct errors in GPS position readings by using data from the base station. The base station data are found in the directory previously specified. The names of the base files have the following convention: *AYMMDDHH*.ssf, where *Y* stands for the last year digit, *MM* for month, *DD* for day and *HH* for hour. The base station should have been active while the field readings were being taken. The file names are checked to ensure that the base station files cover the time the crew was in the field taking measurements.

The differential correction is executed using the Pathfinder software. The programme checks whether the base files span the time period during which the GPS files were created. If everything is all right, the differential correction programme is executed. The programme writes the corrected files to the folder with the extension "*.cor*". The coordinate data are then free from GPS errors. The corrected files may be opened and viewed.

4.7.6 Conversion of GPS data to local coordinate system

The GeoExplorer receiver always computes and stores positions in the WGS-84 datum. The coordinate system that the project uses is the UTM with the ARC-1960 (Kenya/Tanzania) projection. Therefore, the data must be converted to the new coordinate system using options\coordinate system in the Pathfinder.

4.7.7 Exporting maps to ArcView GIS

The map coordinates are then exported to ArcView GIS so that they may be viewed and used with other GIS maps. This requires converting them to a format that can be read by ArcView, usually Dbase IV. The Pathfinder software through its Utilities\Export command aids in this. The input files are the corrected GPS files with extension "*.cor*" and they are output to a specified directory as ArcView shapefiles. The maps may then be viewed with the other existing maps in ArcView.

4.7.8 Consolidating the compartment theme map in ArcView

The map files exported from Pathfinder as ArcView shapefiles generally need to be combined with pre-existing theme maps or joined together to form a new theme using ArcView. For example, if compartment boundaries have been mapped, there may be several shapefiles each consisting of one compartment. These should be combined in one theme or combined with an existing compartment theme map to form a single compartment map showing all the compartments.

4.7.9 Area calculation using ILWIS

Compartment area is not measured in the field. It is calculated from the map data. However, when area features have been mapped with GPS the areas calculated in Pathfinder and ArcView assume that the site is flat. If the area is sloping then the surface area on the ground will be greater than the area shown in the ArcView or GPS map. In the mountainous forests of Mt Elgon the actual area on the ground is greater than the area shown on the maps and the area data must be corrected for slope to obtain the true areas of the mapped compartments. This is done using the software programme ILWIS that creates a digital elevation model using existing digitized contour maps of the area. The resulting compartment areas are the true areas for each compartment. ArcView automatically shows the area (i.e. the flat area) of each polygon (or compartment) in the compartment theme attribute table but the true area data may be exported to a database file and joined to the attribute table of the compartment theme map in ArcView.

4.7.10 Calculation of slope and aspect percentages for compartments

Slope and aspect are calculated for each compartment and derived from GPS data. Each compartment is classified according to a number of categories of slope and aspect. The software applications used for this purpose are ILWIS, MS Access and MS Excel and Dbase. The input data were already prepared in the last step, i.e. the elevation gradient (dx, dy) calculated from the elevation model in the ILWIS shapefile (polygons) of compartment boundaries. The slope and aspect classes calculated for each compartment are entered in MONIS as attributes of the compartment.

Slope and aspect data are not used for management purposes at present but are easy to calculate in ILWIS and are seen as a by-product of the area calculation process in ILWIS. The data are stored in MONIS as they may be useful in future.

4.8 Other data for MONIS

The data on “measures”, i.e. silvicultural operations and associated costs, are not entered in the system at present because of software problems. The data are being stored manually and awaiting the new version of the programme.

A small number of site photos are currently stored in MONIS. The existing photos were entered on a trial basis. The project lacks a digital camera, which would facilitate the collection of photos. The photos help in visualizing the planting sites and progress to date especially for the head office staff. In addition, MONIS has the capacity to store text documents such as manuals and other project documents. However, these aspects of the system are not used at present.

4.9 Inventory/biomass measurement

No inventory data have been entered yet into the MONIS database. However, as some of the reforestation areas are already seven years old, the project has started to develop techniques for measuring total biomass production as an index of carbon sequestration. Two measurement exercises have already been carried out using stratified sampling techniques to measure total biomass in sample plots. Part of the motivation for these early assessment exercises was to develop appropriate sequestration measurement tools and techniques for use in these forests in the future. The first measurement exercise was undertaken in 1998 when the national biomass study at the defunct Forest Department was commissioned to develop a methodology for assessing and monitoring biomass accumulation and carbon assimilation at UWA/FACE reforestation areas (Begumana, 1998). A stratified sampling system was used to assess biomass accumulation, and traditional methods of measurement were used throughout the exercise. Use of computers was limited to data compilation and processing. The second biomass measurement exercise was carried out in 2000 primarily to test a new computer-aided field data collection system. The system is called Field-Map and was developed for forest inventory applications by the Institute of Forest Ecosystem Research Ltd (IFER) in the Czech Republic. Biomass was measured in a number of sample plots and provided a valuable field test for the new system, which has been used successfully in European forests and is currently being developed and adapted to suit the conditions in Mt Elgon. The experience with using Field-Map in Mt Elgon is described below.

4.9.1 Use of Field-Map in sample plot measurement

The system consists of a software application called Field-Map, which runs on a field computer to which a number of peripheral devices can be attached and parameters such as tree height and diameter measured and fed direct into the computer. The programme runs in an MS Windows environment and can be used for development of field measurement designs and related database structures. It is user-friendly and facilitates easy database design and data input. Field-Map also has GIS mapping functionality which allows the operator to visualize data as they are being input, e.g. tree diameter or crown dimensions can be visualized as polygons on the field computer screen and viewed from a range of perspectives. The system allows for detailed description of stand structure and is downloaded direct from the field computer into a PC in the office.

At Mt Elgon National Park, a number of sample plots in the reforestation sites (all under eight years old) were measured to test the suitability of the system and equipment for biomass measurement and to help in the design of a suitable database for data storage and management.

The equipment used in the exercise consisted of:
- A desktop PC with Field-Map application running in a windows environment.
- A Pen-PC field computer running MS windows 98 operating system.
- Laser equipment for distance measurement that incorporated an electronic inclinometer for measuring vertical angles and a compass for measuring horizontal angles.

These three features allow for three-dimensional descriptions of objects in the field.
- A cable connecting the device direct into the computer.
- An electronic calliper for use in measuring tree diameters, which is connected by cable to the computer.
- A GPS that is connected to the computer and is required for geo-referencing the data.

However, the system can generate its own local coordinates so it is not essential to use GPS.

4.9.2 Project design/database design

Before moving to the field, a field measurement and related database structure were designed on the PC or the field computer using Field-Map's project manager. The Field-Map database uses the "plot" as the basic unit to which several data layers may be connected. Multiple layers can be defined, e.g. points, lines, polygons, trees, features such as horizontal crown projections, slanted trees, deadwood, etc. The database structure is easily built up using visual tools. Once the database is designed according to the project's needs, it is ready for use in field data collection.

4.9.3 Field trials

Field trials with the system were carried out in Mt Elgon in October 2000. Two staff from IFER, the software development company, accompanied the field crew during the tests. Plots were measured in a variety of conditions such as steep slopes, dense shrubby areas and tall forest with dense undergrowth. A number of plots were chosen to represent the range of conditions on Mt Elgon. The crew were equipped with a field computer mounted on a monopod with peripheral devices attached (Figure 8). A range of parameters was measured including tree height, dbh, crown width and crown height using the devices attached to the computer. Data such as tree height, dbh, or location coordinates were entered direct from the attached devices (laser range finder, electronic callipers and GPS). Other attribute data such as species were entered via edit boxes or combo boxes with drop down lookup lists, which help to reduce errors in data input (e.g. species, dbh categories, etc.).

Maps are generated, as data are entered. Points and lines are created based on the coordinates coming direct from external devices (laser measurement device, GPS or callipers). Multiple layers can be created, visualized and edited. The poly-shape tool in the Field-Map builds polygons with full topology. Areas and perimeters of polygons are then calculated. Trees are located as points. Dbh can be entered direct using an electronic calliper attached to the field computer and visualized as polygons of tree basal area on the map in the computer. Tree heights and height of crown bases may be measured using the laser equipment attached to the computer. Tree crowns may be measured and visualized as polygons on a separate layer.

Existing maps (vectors and images) may be used as background maps. They can be very helpful in building or editing maps when combined with Field-Map's electronic field mapping and pen mapping utilities.

Figure 8: The Field-Map system in use for measurement of biomass in sample plots. The operator is using a field computer mounted on a monopod, on top of which is a laser range finder. The operator is entering data with an electronic pen into the Field-Map database. It will be downloaded later to a PC in the office

4.9.4 Further data processing

Upon return to the office, data are downloaded to the PC. Data may also be exported to other applications for further processing. The internal structure of the Field-Map database is based on Paradox. Therefore, tables may be exported to Access or Dbase for further processing or used with other applications. The Field-Map maps are based on ArcView shape files and may be exported for use with other GIS software such as ArcView.

4.9.5 Evaluation of the Field-Map test

The navigation features provided by Field-Map were particularly useful in allowing navigation back to unmarked permanent sample plots and efficient navigation within plots. A number of minor problems were experienced, but the flexibility of Field-Map generally allowed creative solutions, e.g. there are four alternative methods of height measurement, which helped to overcome height measurement problems in a dense forest. The project design features were generally good. The software development specialists accompanying the team noted a number of improvements required in the application software. A new version of the software was prepared following the trials in Uganda. Overall, the system was judged to be promising and performed better than expected in tropical forest conditions. No major problems were experienced with the hardware or software. A list of improvements was noted for the hardware, mainly relating to robustness, portability and protection.

4.10 Forest management plan structure

Computerized and electronic equipment play a major role in the preparation of forest management plans, as described in the preceding section, for use by all stakeholders in forestry like UWA/FACE. The UWA/FACE 2000-2002 operational plan begins with a strategic planning section, which describes the long- and short-term objectives. The long-term targets for each of the phases in terms of planting rates and locations are also described.

The other sections of the plan are:

- Goal and management objectives.
- Description of the area including size, physical features, location, geology and soils, socio-economic aspects, legal aspects, the proposed forest and current vegetation.
- Description of expected benefits including environmental, socio-economic and cultural benefits in consultation with local forest communities.
- Description of general aspects of forest management including work organization, implementation of work programmes, staff administration and details of links with other institutions.

Achievements to date in the previous phases include areas planted by compartment, planting dates, survival rates and vegetation changes resulting from planting and production performance.

Management recommendations including operational targets for the current three-year phase, give a detailed description of work to be carried out during the phase including:

- Lists of compartments to be planted, plantable areas in those compartments, current vegetation status of each compartment.
- Tree nursery details including number and location of nurseries, number of seedlings to be produced, species to be raised, guidelines on nursery site selection, a list of nursery operations.
- Tree planting details including site preparation schedule, species site matching, appropriate mix of climax and pioneer species, spacing and a time schedule for planting activities.
- Tending and maintenance operations and a tentative three-year schedule of tending activities for each compartment.
- Protection measures against pests, diseases and fires including a schedule of fire line maintenance, patrols, public awareness campaigns and fire-fighting arrangements.
- Environmental impact assessment of the plan, dealing with mitigation of possible adverse environmental impacts and with measures to assess possible socio-economic impacts (a proposed socio-economic survey) and possible mitigating measures for any adverse impact.
- Research and monitoring proposals including a list of potential research activities needed to provide information on technical aspects of the programme, a list of collaborating research institutions and their roles and details of planned monitoring activities.
- Training requirements during the plan period and proposed staff capacity building activities.
- Activity-based budget for the phase.

The appendices in the plan are:

- A map of the planted and proposed planting areas.
- A map of the intended forest.
- A map of current vegetation type.
- A map showing the proposed reforestation areas in each phase.
- A map of compartments planted.
- A map of proposed current phase (2000-2003) compartments,
- A list of species and proposed planting locations.
- Terms of reference for management staff.

5. SILVICULTURE AND FUTURE MANAGEMENT

The management goals of the Mt Elgon National Park forest are conservation for water catchment, biodiversity and subsistence forest products for local communities. Its new role as a carbon sink does not impose any new conditions or burdens on management. The requirement that the forest not be logged but protected for 99 years is entirely consistent with the original management goals. Moreover, extractive activities are prohibited in the park. Management of the park's forest will largely consist of protection, periodic CO_2 sequestration measurement and managing the neighbouring community's subsistence use of forest resources. Other silvicultural operations will not be carried out.

5.1 Silvicultural aspects of forest establishment

The reforestation plan aims to restore the original forest, which consisted of a mosaic of species varying from site to site according to the terrain, rainfall, altitude and other factors. The type of forest that had previously existed on the site was known from surveys undertaken by earlier scientists such as Dale in 1941 and from old management plans. Tree nurseries were established near the planting sites and planting stock was produced consisting of a mixture of wildlings and seedlings.

Climax species such as *Prunus africana, Olea welwitschii, Aningeria adolfi-frederici* and *Entandophragma excelsum* were initially planted exclusively but after experiencing poor growth rates the policy was changed to include a mixture of pioneer species such as *Veronia* and *Neoboutonia macrocalyx.* The pioneer species provides temporary shade for the climax species in the early years and has resulted in better survival rates.

Lines are slashed in the undergrowth at five-meter intervals to allow access to the planting site. Seedlings are planted in pits at 5 m x 5 m spacing (400 seedling/ha). Most planting sites are covered with grass or naturally regenerating bush, but some sites are totally fallow where encroachers had recently been evicted

The use of chemicals and fertilizers was explicitly prohibited by the contract. Manual spot weeding and creeper cutting is carried out twice a year for three years and thereafter the forest is allowed to grow naturally. Beating-up is done if the survival rate is below 50 percent and if the number of naturally regenerating seedlings is inadequate. Grass-dominated sites are more difficult to establish and require a higher proportion of pioneer species for successful reforestation. It is important to note that the natural regeneration capacity of the forest is inherently very good and would be adequate to restore the original forest through natural succession if it were protected from encroachment, grazing and fire. However, a climax forest is established more quickly by planting.

The establishment phase may last up to five years especially on grass-dominated sites where repeated beating-up is sometimes necessary. Once the forest is established and well-stocked, no further silvicultural operations are envisaged.

At present, there is no intention of manipulating the forest to increase its carbon sequestration or other values, though this cannot be ruled out in the future as long as the management goals are not compromised.

5.2 Forest protection

The young forest is susceptible to fire until the canopy closes at about three to five years under the conditions of the region. Fire protection is provided by fire-lines that are maintained free of combustible material as long as the forest is vulnerable.

The main threat to the forest is the risk of agricultural encroachment in the future. The high population density and subsistence agriculture economy around Mt Elgon means that land is scarce and people value agricultural land above forest products. The future security of the forest can only be assured when local people value the forest above its potential for agriculture. Currently the economic incentives for local people are weighted against protection and conservation because people can potentially gain more from using the forest for agriculture than for its products. The existence of such perverse economic incentives that encourage encroachment poses a long-term challenge to management and protection of Mt Elgon forest as it does to protected areas in many parts of the world. The challenge can begin to be met by maximizing resource use benefits of the forest to local people and trying to devise systems which allow local people to benefit economically in other ways from the existence of the forest.

The funding for the project, which is provided by the FACE Foundation, concentrates on the establishment phase. Subsequent protection is the responsibility of UWA. Long-term protection may prove to be a serious challenge in the future given the current perverse economic incentives referred to above as well as the high level of poverty.

The contract period is 99 years and this means that the forest must remain in place as a “permanent” carbon sink for 99 years, after which UWA would be entitled, if it wishes, to log the area. It will fall upon UWA to revisit its management goals of the national park to determine the appropriate course of action. The activities that will be carried out after the first carbon sequestration cycle will therefore be in line with the management goals at that time. However, logging activities are not likely as the forest is viewed as a water catchment and nature conservation site.

It is not clear whether computerized and electronic equipment will continue to be used by management given that the termination date of the contract is still far ahead. Moreover, high investment costs in computerized management technologies tend to discourage many resource-poor institutions from using the technologies. However, the advantages associated with using such computerized tools like GPS and computers in mapping, data collection and analysis and presentation of management results to aid decision-making should override the above fear. Instead, more tools should be procured and used in developing and implementing forest management plans.

5.3 Managing the forest community interface

Resource extraction from national parks is permitted in Uganda if the resource users have signed an agreement with UWA permitting them to do so. The resources are limited to dead firewood, grasses, wild vegetables and fruits, honey, bamboo shoots and medicinal plants. Timber harvesting or cutting live trees for poles is prohibited. At Mt Elgon, a number of agreements have been signed with parish communities as part of a pilot scheme led by IUCN to develop models for community involvement in park management. The approach is still evolving but results to date are promising and it is likely that the approach will be expanded to include all parishes around the park, as well as those bordering the UWA/FACE forests. Only those communities that have signed agreements are legally allowed to harvest resources. However, in the absence of signed agreements, illegal harvesting is widespread, as the forest is often the only source of firewood and other products. The current management objective is to bring this illegal harvesting under control by negotiating resource access agreements with all communities neighbouring the park.

There is no reference to community use of the forest in the UWA/FACE contract agreements although the reforestation areas are along the forest boundary on the interface between the park and the neighbouring communities. During the first phase (1994-97) UWA/FACE adopted a strict security approach and prevented local people from collecting resources from the forest in an over-zealous attempt to maximize carbon accumulation on site. This created resentment, resulted in conflicts and had negative social impacts, which were contrary to the requirement under the Kyoto Protocol that such projects be locally acceptable and have positive socio-economic impacts. Since then, the project has modified its approach to allow resource access if agreements have been signed with UWA and now aims to *optimize* rather than *maximize* on site carbon. The current approach is likely to improve relations with adjacent communities, reduce the requirement for law enforcement and improve long-term protection, although resource use will need to be monitored and managed to ensure that it not exceed sustainable levels. Collaborative forest management guidelines developed by the Forest Department (now National Forestry Authority) will be of great help in this respect.

Resource use monitoring is an important aspect of the agreements between the park and communities. Monitoring systems are being developed and are likely to involve a combination of approaches including community-based monitoring, use of sample plot measurements and use of remote sensing to monitor vegetation changes. The sample plot-based systems of CO_2 sequestration measurement discussed below are likely to be expanded in future to include parameters for monitoring the impact of community resource use despite the fact that no progress has been made in this area to date.

6. MEASURING THE RATE OF CARBON SEQUESTRATION

The quantity of carbon sequestered and the rate of accumulation are important questions for management. Carbon accumulates in stems, branches, leaves, roots, undergrowth, leaf litter and soil. Techniques for measuring the quantity of carbon accumulation have developed rapidly over the last 10 years as interest in the use of forests as carbon sinks has grown. Traditional methods of forest assessment and inventory that are geared towards measuring volumes of merchantable logs are not very suitable for measurement of carbon accumulation. Some growth models developed for various tree species are also geared towards merchantable log measurement and are of limited value. The techniques that have been developed for assessment of carbon accumulation in forests involve measurement of total biomass as an indicator of carbon content. Soil carbon accumulation can be measured by comparing soil carbon content under agriculture, degraded forest with soil carbon content under climax forest and interpolating results for the site in question. However, this method would have to carefully document comparability of sites and would require knowledge of area history; any equation needs to be validated by independent test.

The UWA/FACE reforestation areas in Mt Elgon are all under seven years old. The measurement of biomass accumulation in such young forests at this stage can provide, at best, a tentative indication of potential carbon accumulation. However, when used with measurements of biomass in mature high forests nearby, they can provide a good indication of potential rate of carbon accumulation. The interpolation of results from measurement of very young and mature forests must account for varying growth rates as the forest matures. The rate of vegetation growth is slow initially, then reaches a stage of rapid accumulation and gradually slows down as the forest reaches maturity. Eventually, equilibrium is reached where carbon gain through new growth is more or less balanced by carbon loss through decomposition, although it is likely that the carbon stock continues to increase marginally in the soil through litter fall.

6.1 Measurement of CO_2 sequestration carried out in 1998

In 1998, Begumana assessed actual and potential carbon accumulation resulting from the first phase of the project (1994-97). It was assumed that not only was biomass (and carbon) accumulating in reforestation sites, it was also increasing in the existing forest outside the reforestation sites that were now protected from grazing, illegal pit-sawing and other destructive activities. It was assumed also that the additional carbon sequestered in those forests was a direct result of the existence of the project and that FACE could claim credits equivalent to that amount in the future.[2]

To estimate biomass in reforestation sites, tree height, dbh and crown width were measured in a series of sample plots using a stratified sampling system and converted to biomass using a tree biomass equation. In the existing forest, the increase in biomass since the project started was estimated by measuring current biomass and discounting to the base year (1995) using known growth rates of trees in farmland. Carbon content in wood was calculated using a conversion factor. Carbon dioxide assimilated was calculated by multiplying carbon value by 44/12, which is the molecular weight ratio of CO_2 to carbon. The results are shown in Table 2.

Table 2: **Carbon dioxide assimilation per annum**

Vegetation type	Tree carbon accumulation in tonnes per ha	Area (ha)	Annual carbon fixed	Soils	Total carbon fixed	Annual CO_2 assimilated
Forest (outside the reforestation site)	1.1	14,791	15,766	4,437	20,203	74,147
Forest remnants (in the refor. site)	0.8	1,610	1,309	483	1,792	6,576
Shrubby area (in the refor. Site)	0.9	1,883	1,653	565	2,218	8,138
Short grass (in the refor. site)	0.3	1,826	599	548	1,146	4,207

Source: Begumana, 1998.

The mature forest (at 50 years old) is estimated to have a potential biomass of 430 tons per ha including root biomass, which is equivalent to 215 tons of carbon. At this rate, the 5,600 ha

[2] This provision is provided for in the contract agreement. Although the exercise in Mt Elgon National Park involved measuring CO_2 sequestered in reforestation sites and surrounding forests, this is not consistent with the provisions of Kyoto Protocol on carbon trading because carbon credits can only be traded if they accumulate through afforestation on non-forest land after 1990 and where there is no leakage.

reforested by 1998 (in both Kibale and Mt Elgon National Parks) would have sequestered 988,000 tons of carbon when mature in 2050 plus about 12,000 tons of additional soil carbon. The project plans to plant 25,000 ha of forest. Assuming the whole 25,000 ha are reforested and that the whole of the existing forest outside of the reforestation area reached a biomass of 430 tons per ha, and adding soil carbon, the total carbon accumulation due to the project is estimated at 4.6 million tons which is equivalent to about 17 million tons of carbon dioxide.

Most of this carbon (79 percent) can accumulate in existing forest outside the reforestation areas. The assessment contained large error margins for biomass in the existing forest. The relevance of the conversion factors or the discount rate (growth rates) to trees in Mt Elgon is not known. Therefore, the results can be regarded as indicative only. Another question is the validity of the claim that the increase in tree biomass in the forest outside the reforestation area is due solely to the protection of the project. To answer these questions a new assessment was planned for 2001 to establish baseline data for carbon content of forest outside the reforestation in the base year 1995 and to identify which sections of forest were being protected by the activities of the project.

7. COSTS AND BENEFITS

7.1 Planting versus natural regeneration

The project has decided to restore the forest by actively planting rather than waiting for natural regeneration to take its course. Evidence on the ground shows that, in many areas, once the site is protected from agricultural encroachment, fire and grazing, the natural forest quickly re-establishes itself. Pioneer species such as *Veronia* first take over the site and provide shade, which enables intermediate and climax species to become established. The pioneers die off after a few years. The advantage in planting is that the forest is established faster and more uniformly. Natural regeneration is patchy especially in grassy sites where planting speeds up establishment by several years. At Mt Elgon, a further justification for planting is that the act of planting, and the physical presence of project staff planting trees, helps to protect the area from encroachment by sending out a clear message that the forest is now being re-established and that further encroachment is not allowed. In addition, by employing local people as nursery workers and in tree planting, the project benefits the local community by providing employment. No studies have been made to compare natural regeneration with planting but the view at the project, based on site observations, is that planting speeds up the process by 5-10 years.

Foresters normally plant trees when they want to control the species and quality of forest produced. These justifications do not apply in the case of carbon forests where the objective is to produce biomass and sequester carbon. The species and quality do not matter. Planting can only be justified if natural regeneration is not feasible or the rate of regeneration is slow, or if there are other social considerations as is the case at Mt Elgon. A cost benefit analysis is required to establish if the cost of planting is justified by the saving of 5-10 years in reaching maturity, social considerations notwithstanding.

It is difficult to estimate the cost efficiency achieved by using the computer systems, but overall establishment costs in Mt Elgon are approximately USD$500 per ha. NFA records indicate that the cost of establishment and management of pine plantation currently varies from USD700-800 per ha using the traditional methods. It is not clear how much it would cost when using computer-aided techniques, although the estimate varies from USD800-1,200 per ha. This amount includes all operational and overhead costs but does not include the FACE

Foundation overhead costs in the Netherlands. The amount also compares favourably with forest establishment costs in other similar tropical sites.

7.2 Cost benefit of the computer systems

In Uganda, labour costs are low and labour intensive work practices do not have a major impact on cost efficiency. Any efficiency achieved in labour costs by using computers, GPS units or other computerized systems or equipment is likely to have a minimal impact on overall costs although investment costs in computing equipment are generally regarded as high. The cost of computers and equipment is likely to far outweigh any labour cost savings. Therefore, the justification for using computer systems comes not from labour cost savings, but rather from the capacity of those systems to provide the type of accurate and verifiable data that would otherwise not be possible or easy to collect manually. The FACE head office in the Netherlands requires ready access to detailed and accurate data on its projects and a computerized monitoring and information system such as MONIS is the only feasible way of achieving this. As the intention is to trade in the carbon credits accruing from the project, good quality, verifiable and reliable data on the quantities of carbon assimilated are required. Moreover, forest certification requires that the project can prove that precise levels of carbon additionality are due to the project's activities.

The costs involved in using computer technology at the project include the cost of the hardware, software licences, staff training and specialist computer staff costs. It would be difficult to justify these costs on the basis of management efficiencies achieved at the project. It may also be argued that the reforestation programme could be implemented effectively and efficiently using traditional systems. But the requirements for ready access to accurate and verifiable data mean that these systems are necessary.

7.3 Carbon costs

Begumana (1998) reported that within 30 years the forest would have attained a stock of air-dry biomass of about 430 tonnes per ha, including root biomass. The total carbon accumulation due to the project was estimated at 4.6 million tonnes assuming (a) the whole 25,000 ha are reforested, (b) the whole of the existing forest outside of the reforestation area reached a biomass of 430 tonnes per ha due to protection afforded by the project, and (c) soil carbon is included. It is not clear at present how much of this will be allowed as certifiable carbon credits. Measurement of the quantities of carbon assimilation will need to be done to certifiable standards.

The tradable value, if any, of carbon credits in the future will depend on the rules yet to be agreed upon by the Conference of Parties to UNFCCC. It is not known yet if carbon sinks will be allowed or what limits will be put on the amount of permissible credits. If international agreement is reached to allow offsetting carbon credits against carbon emissions, the value of the credits traded internationally could rise dramatically. On the other hand, if carbon credits are not allowed, investment in carbon forestry will cease and the carbon credits will have no intrinsic value.

The current value of carbon credits is difficult to determine, as they are not yet freely traded. One way of measuring the value of carbon credits is to use the "willingness to pay" or "willingness to invest" method. Organizations such as FACE are willing to invest in carbon credits and the amount invested per tonne of expected carbon is a measure of the perceived value of carbon credits. The amount of funds invested in new carbon sequestration projects worldwide is a measure of what the market thinks the carbon is worth at that time. Using this method of valuation, the value of carbon credits has risen steadily since the first transactions for CO_2 emissions in the early 1990s (Costa, 1999). The binding commitments entered into at COP-3 in Kyoto resulted in a greater demand for carbon offsets and the level of investment (or willingness to pay) for carbon sequestration rose as high as USD$20-25 per ton (Costa, 1999). The impact on investment in carbon sequestration of the failure to agree on operational rules for forestry projects at COP-6 (The Hague, Netherlands, 2000) is yet to be seen.

Investment in the UWA/FACE project in Phase 1 (1993-97) amounted to NLG 2,465,000 total for an expected area of 3,000 ha. (FACE Foundation annual reports). The investment in the current phase of the UWA/FACE project in Uganda is equivalent to USD$10-$15 per ton of carbon.

8. ASSESSMENT OF THE ADVANTAGES AND DISADVANTAGES OF THE SYSTEMS USED

Some aspects of the computer-based systems used at the project have been found to be of limited value and others are regarded as very useful and greatly increase efficiency. These aspects are discussed below along with recommendations on potential future areas of development.

8.1 MONIS

A standardized monitoring and information system that provides similar types of information for projects has obvious advantages for an organization such as the Face Foundation that has projects in several countries. At Mt Elgon, the fact that large parts of the system have not yet been populated with data limits its usefulness. The most useful aspects of the MONIS system are the compartment map data and associated attribute data that are regarded as extremely useful by project management staff. However, the attribute data are limited, a major weakness being the absence of silvicultural and cost data for each compartment, which is not entered at present because of problems with the software. This is being addressed and a new version of MONIS is expected to be installed at the project shortly.

Whereas some important data such as silvicultural and other operational costs are missing, some other data, which are not used, such as detailed slope and aspect, are included. However, these data are generated as a by-product of the ILWIS area conversion analysis and may be of use in the future. The project documents and agreements between FACE and its partners have not been entered into the system, very few site photos have been entered, and manuals on procedures and methods for mapping, parameters to be measured, etc. have not been entered into the system.

Because of the data gaps, the reports produced have many blank fields (e.g. Figure 7). The range of reports is limited and the user does not have the flexibility to generate user specified report specifications. There is an advantage in having a predefined report menu in that minimal skills are required to generate reports, but it does limit the usefulness of the system for management.

8.2 Use of GPS for mapping and data capture

The use of GPS units for mapping compartments proved to be very efficient and they are regarded as one of the most useful tools for field staff. The alternative traditional survey methods would involve surveying from park boundary markers with known coordinates, or drawing sketch maps using measuring tapes and compass. The GPS method has enabled staff to produce accurate maps very cheaply and quickly.

The process of differential correction is no longer justified now that the selective availability effect has been removed. It is likely that it will be omitted in the near future as the level of precision is acceptable for compartment mapping.

The data capture functions of GPS have been useful but the potential has not been fully realized as relatively small amounts of data are input. At Mt Elgon the field staff has adapted well to using GPS units for navigation and data input, and the level of training required is moderate.

8.3 ArcView GIS

The use of GIS is not essential as coordinates can be read from GPS and plotted manually on OS maps to draw the compartment boundaries. However, the use of ArcView makes this much easier and the ArcView GIS application is regarded as one of the most useful tools at the project for storing data and for producing maps for management purposes. The project is fortunate in that there is a large body of pre-existing ArcView theme maps available for the Mt Elgon area such as contours, rivers, roads, administration boundaries, gazetted areas, vegetation classification, etc. In addition there are geo-referenced population census data available that are potentially useful in managing the interface with the local communities. Even without these additional theme maps and data, ArcView would be regarded by the project as a very useful tool.

However, the use of ArcView at the project is largely confined to mapping and little or no use is made of its data analysis functions. There is scope for greater use of these functions to help management improve cost effectiveness, e.g. in choosing optimal sites for tree nurseries in relation to planting sites, yet it holds much potential in improving the planning process.

A disadvantage of using ArcView is that it requires a highly trained staff. In Uganda, it is difficult to recruit and retain skilled GIS staff as they are in high demand. At Mt Elgon, there is one GIS specialist working in the MONIS unit who manages the data and produces maps. Because the level of understanding of GIS as a management tool is quite low among the management staff, it is likely that GIS will continue to be used primarily as a mapping tool.

8.4 Calculation of surface area, slope and aspect using ILWIS

In a mountainous site such as Mt Elgon, the surface area of a compartment may be considerably larger than the area of the polygon mapped using GPS. In flat sites, it would be unnecessary as the map and the surface areas are similar. ILWIS is used to calculate the surface area. The process requires a skilled operator but as the skills are available in the MONIS unit the analysis can be done relatively easily. The slope and aspect of the compartments can also be readily calculated.

These data have limited value at present. Slope and aspect are stored in MONIS but are not used in management of the forest at present. The area data are produced for each compartment and are only used at the project to verify field reports on numbers of seedlings planted and area planted.

8.5 Potential of Field-Map for sample plot measurement and inventory

The suitability of the Field-Map system for biomass measurement in sample plots was tested in 2000. The system’s database development functions and associated field data entry functions are very good and easy to use. It has good potential for use not only for sample plot data entry but for collection of a range of other data that are likely to be required in the near future such as data for monitoring community use of the forest, degradation or ecological changes.

During field data collection, the peripheral devices may be used if desired or, if preferred, manual measurements may be made. Manual callipers may be much more practical than electronic callipers that currently have to be connected to the field computer by cable, which can restrict the movement of the user.

The cost of the equipment and the high level of skills required to use the system are a limiting factor at present. The amount of measurement work at Mt Elgon project would not justify the cost of the equipment. It would be better to share the equipment among a number of projects and use it periodically at Mt Elgon.

Since no harvesting activities are envisaged in the park, the Field-Map system will not be used in this respect. In the Uganda context, all national parks are protected areas and extractive activities are prohibited.

8.6 Socio-economic impacts of using computers and computerized systems and software in forest management planning

The use of computers and computerized systems and software in development and preparation of forest management plans will help to expedite the process and production of management plans based on accurate and reliable data. No negative socio-economic consequences are envisaged such as reduced employment opportunities with UWA. Instead, UWA may recruit staff with knowledge and skills in applying computer techniques in forest or park management planning or equip staff involved in management planning with skills and knowledge to use the computer systems in order to improve their efficiency and output. Local people are not usually involved in data collection, analysis and processing in forest management planning except at the consultative stages when their views and inputs are solicited on certain matters. As such, no negative impacts on the local communities are anticipated.

Environmental impact of managing the forest with computers and software

The use of computers and software in generating, analyzing, storing and retrieving data for forest management planning has positive environmental attributes. For example, data on forest loss or degradation due to encroachment, over-exploitation of forest products or natural calamities such as landslides would help in developing appropriate restoration interventions, mitigation measures and monitoring tools. Use of computers and software in environmental monitoring in Mt Elgon National Park would be particularly essential because of the frequent landslides causing land degradation and soil erosion during the rainy season. Environmental monitoring should be a key aspect of forest management planning in the park.

9. CONCLUSIONS AND RECOMMENDATIONS

The MONIS system has the potential to provide far better information to management both in Uganda and at the FACE headquarters (HQ) in the Netherlands but this potential is not being realized because of the many data gaps. The lack of “measures” data (activities and costs by compartment) is the major weakness.

The use of GPS units for mapping, and to a lesser extent for data collection, is efficient, accurate and provides valuable data for forest management. The potential of the units for data collection in the compartments at the time of mapping is not being fully exploited. A comprehensive data dictionary has been designed but few data items are being collected at present.

ArcView GIS is being used to produce compartment maps which are an essential part of MONIS for both HQ and local management. However, there is scope for more innovative use of the analysis functions of the software and for improving efficiency in management decision-making in a variety of areas such as tree nursery establishment and management.
The MONIS system is designed to provide information on the project sites only, whereas the national park in which the project operates also needs an information system. At Mt Elgon the area reforested to date amounts to approximately 6 percent of the park area. There is relatively good but narrowly focused information on that area and a lack of information on other areas in the park. UWA requires a good and broader based information system on the park as a whole and the MONIS data will need to be expanded to other data relevant to UWA or integrated with a more comprehensive park information system. The database functions of Field-Map provide opportunities for developing a flexible and easy-to-use database for the broader needs of the national park. The data of particular interest to UWA/FACE can be entered and the system expanded to accommodate other data as required. Indeed, measurement of biomass parameters can be combined with measurement of other parameters for monitoring ecological aspects or monitoring community use of the forest.

The focus initially was on the reforestation sites but this has now broadened to include areas of existing forest, which are benefiting in terms of biomass accumulation from the protection of the newly reforested areas. Much of the carbon sequestered as a result of the project is likely to be in existing forest. Any increase in biomass must be certifiable if it is to be traded. The lack of basic research data on forest dynamics and tree growth rates in Mt Elgon poses a challenge to measurement of baseline (1995) biomass data.

A further challenge in successful management of the reforestation area in the future is the improvement of relations between the community and national park authorities. As long as the relationship is poor, the risk of encroachment or degradation will remain high. The UWA/FACE programme presents opportunities to improve relations as the employment provided by the project is highly valued by the communities. The restored forests will provide opportunities for communities to benefit from forest resources including firewood and wild foods as long as the level of off-take remains sustainable and does not compromise the goals of the park or the project.

The UWA/FACE establishment phase on a given site lasts five years. Thereafter, the protection of the forest is the responsibility of UWA for the remaining 94 years (the contract period is 99 years). The FACE funding is for the establishment phase only. Given the history of conflict, which is largely due to high population pressure, the protection of the sites is likely to require considerable input through community conservation in maintaining good relations with surrounding communities in the future.

Community attitudes to the project are generally very favourable because of the benefits of employment provided by the project. However, failure to involve communities in planning previous phases was a serious oversight given the potential for conflict. The level of local community involvement in planning future phases should be much greater.

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