Proceedings of the Workshop on Insect Pests, Diseases and Soil Problems in Forest Plantations

July, 2011

Editors

L. Nshubemuki, S.S. Madoffe, S.A.O. Chamshama, S. Bakengesa and C. Balama

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Held at the Kibaha Conference Centre, Kibaha, Tanzania

3rd – 4th February, 2011

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Cover plate: *Pinus patula* infested by pine woolly aphids at Sao Hill forest plantation

FOREWORD

Most of the forest plantations in Tanzania are characterised by few tree species. In this type of plantations there are advantages in management, silvicultural practices and products marketing. However, these plantations have a higher risk of being affected by insect pests and diseases. Trees could also suffer as a consequent of soil problems. For more than five decades now some plantation tree species at different ages and sites have been reported to die, primarily because of forest insect pests, diseases and/or soil problems. Few examples of affected plantations include Sao Hill, Ukaguru, Shume, Rongai and Meru. Infestations in these plantations have been more recurrent and sometimes un-noticed depending on the location of the respective plantations. Infestations of this nature have great implications on the intended goal of supplementing natural forests in terms of wood supply and ecosystem services.

Infestations of these plantation forests have reduced productivity which has led to significant loss of national income and reduced ability to provide ecosystem services. It is anticipated that such loses of revenue may continue if dire efforts are not taken to combat such infestations. For example revenues of about TAS 12.75 and 34.69 billion are estimated to have been lost from Sao Hill forest plantation in 2005 and 2009 respectively. In addition, most of these plantations are in second or third rotation in which the productivity may be declining as well due to poor species-site matching and not adopting appropriate soil and site management practices.

This workshop proceedings present the current situation with regard to insect pests, diseases and soil problems and recommends ways to ensure sustainable forest plantation management. It is my sincere hope that this document will benefit forest plantation managers, researchers, trainers, policy makers, Non Governmental Organisation (NGOs), private forest practitioners and other relevant stakeholders involved in forest plantation management. The workshop was made possible through financial support from the National Forestry and Beekeeping Programme (NFBKP) of the Ministry of Natural Resources and Tourism (MNRT) under the auspices of the Government of Finland. This support is gratefully acknowledged.

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PREFACE

Pionneering attempts to establish forest plantations in Tanzania started in the 1890s with the main aim of supplementing wood supplies from natural forests. This was followed by large scale industrial forest plantations establishment in the 1950s. Success in the establishment of large scale forest plantations was achieved through research conducted by the then Silviculture Research Station of the Ministry of Natural Resources and Tourism and the East African Agriculture and Forestry Research Organisation of the East African Community. Currently, under the Act No. 5 of 1980, the Tanzania Forestry Research Institute (TAFORI) is mandated to carry out and coordinate forestry research in the country.

Currently the total area of public and private sector forest plantations is about 150,000 ha which is equivalent to 0.4% of the total forest cover. These plantations are dominated by softwood tree species particularly *Pinus patula, P. elliottii, P. caribaea, P. kesiya,* and hardwoods like *Eucalyptus* species, *Tectona grandis*, *Acacia mearnsii*, C*edrela odorata, Grevillea robusta* and *Juniperus procera.* Small patches of *Olea capensis* and *Khaya anthotheca* also exist. Forest plantations supply wood and non-wood forest products for industrial and non-industrial uses. The government earns significant income from sale of forest products from these plantations. However, these plantations are currently threatened by insect pests, diseases and soil problems, thus jeopardising the role in the provision of goods and services.

In view of the foregoing, a workshop on forest plantations insect pest, diseases and soil problems was conducted between 3rd and 4th February 2011 at Kibaha with the following objectives:

(i) Get an overview of insect pests, diseases and soil problems in plantation forests in Tanzania;
(ii) Identify affected forest plantations that need immediate attention;
(iii) Develop national insect pests and diseases monitoring and evaluation system (Forest insect pest watch);
(iv) Bring attention to policy makers on the economic implications of forest insect pests, diseases and soil problems;
(v) Establish data base on forest insects and diseases from already published information; and
(vi) Establish a mechanism for sharing information and updates of the same.

This was the first workshop of its kind that brought together Researchers, Academicians, Planners, Plantation Managers, and Policy makers. The workshop was officially opened by the Director of Forestry and Beekeeping Division who was represented by the Assistant Director, Research, Training and Statistics. The workshop was closed by the Acting Chief Executive, Tanzania Forestry Service (TFS). The welcome, opening and closing speeches are in Annexes I, II and III respectively.

The workshop was attended by 30 participants from within the country (Annex V). Participants were drawn from the Forestry and Beekeeping Division (FBD), Regional Administrative Secretary Coast (Regional Forest Officer), Forest Plantation Managers (Sao Hill, Longuza, Shume, Ruvu and Sokoine University of Agriculture (SUA) Training Forest), SUA, Tanzania Forestry Research Institute (TAFORI), Tanzania Tree Seed Agency (TTSA), Forest Training Institute (FTI) and Tropical Pesticides Research Institute (TPRI).

One keynote address and 5 papers were presented. The keynote paper addressed the status of forest insect pests in Tanzania: introduction, spread, damage and management options. The papers presented addressed various issues with regard to forest plantations management in general, insect pests, diseases, its economic implications and soil problems. These papers were presented during day one. In day two in the morning session, participants formed four groups which worked on the following aspects: (i) Resource and capacity building (ii) Research, (iii) Surveillance, monitoring and evaluation and (iv) Knowledge management, information sharing and networking on forest insects, pests and diseases. The group work was followed by a plenary session and deliberations were made (Annex IV).

The workshop was organised by the TAFORI and the Faculty of Forestry and Nature Conservation, SUA. The organising committee consisted of Ms. Siima Bakengesa and Mr. Chelestino Balama (TAFORI) and Prof. Seif S. Madoffe (SUA). The organising committee is thanked for the work well done.

Lastly, we are grateful to the contributors of the historic workshop on insect pests, diseases and soil problems in forest plantations.

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KEYNOTE PAPER

STATUS OF FOREST INSECT PESTS IN TANZANIA: INTRODUCTION, SPREAD, DAMAGE AND MANAGEMENT OPTIONS

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ABSTRACT

In Tanzania, most exotic tree species are attacked by insects. However the intensity of attack varies. Cypress aphid (Cinara cupressivora), Leucaena psyllid (Heteropsylla cubana), Pine woolly aphid (Pineus ?boerneri) and Blue gum chalicid (Leptocybe ivasa) which attack Cypress, Leucaena, Pines and Eucalyptus respectively are the main forest plantation insect pests. Termites also attack both native and exotic trees and the later appears to be more susceptible. Natural forests are generally free from serious insect attack. Conversely, native tree species grown outside their natural habitat are usually susceptible to both native and exotic insect species. Several control measures have been tried to reduce the damage and classical biological control appears to be the most effective option. Forest insect pest management is faced with several management problems amongst them being lack of human and financial resources. In order to manage the insects more effectively the Government (Forest and Beekeeping Division) should develop and implement effective and efficient insect survey (pest watch) and monitoring device together with Integrated Pest Management (IPM) as part of the long-term control strategies. Strong national, regional and international network and cooperation of research scientists and pest management is needed. Furthermore, there is a need to intensify import restrictions and internal quarantine policies.

1. INTRODUCTION

1.1 Forests in Tanzania

Tanzania has a total area covering about 945,000 km^2 of which 33.5 million ha are forests and woodlands (URT, 1998). About 13 million ha have been gazetted as forest reserves. Public and private sectors industrial plantations cover approximately 150,000 ha. The main species planted include: *Pinus patula, P. elliottii, P. caribaea, P. kesiya, Cupressus lusitanica, Eucalyptus* species, *Acacia mearnsii* (wattle trees) *Cedrela mexicana*, *Grevillea robusta*, *Tectona grandis*, *Senna siamea*, *Terminalia ivorensis* and *T. superba*. Most of these plantations were established starting in the 1950s and in spite being free from insect attack at the establishment phase, to date most *Pines* and *Cypress* species are attacked by several exotic insects only at different levels of severity. *Eucalyptus*, *Grevillea* and Teak are attacked by termites and are almost free of alien insect attack.

1.2 Forest entomology in Tanzania

Prior to independence in 1961 most entomological work were limited to termites (Harris, 1940; 1943; 1955; Mc George, 1950). There has never, however been any systematic insect survey in Tanzania after independence. In 1950s J.O. Evans and S.J. Curry of the Kenyan Forest Department, however conducted the first partial systematic survey of forest insects of East Africa and published the results as Annotated list of East African forest insects (Gardner, 1957). Initial survey indicated that the most important pests in the order of priority were: *Oemida gahani* (Cypress stem borer), borers of living *Isoberlinia* and *Syzygium*, *Lepdopterous* and *Coleopterous* shoot borers of *Khaya* and *Cedrela*, *Psyllid* gall makers of *Khaya* and

Milicia, Bosytrychid of sawn timber and ambrosia beetle attacking felled trees and logs (Willan, 1960). Further information on insects injurious to timber in East Africa was obtained from some information obtained from timber firms, architects, private individuals, and forest officers (Gardner, 1957). Most of the wood-destroying insects belonged to orders: Coleoptera and Isoptera, a few from Lepidoptera while in Hymenoptera there was only one genus, *Xylocopa*.

The establishment of East African Agriculture and Forestry Research Organization (EAAFRO) with its headquarters in Muguga, Kenya in the 1950s facilitated entomological work in East Africa. This centre saved as a museum for the East African countries. After the break down of the East African Community (EAC) in 1977 the Kenyan Government inherited the EAAFRO materials and Tanzania was left with very little materials at Silviculture Research Centre Lushoto and Timber Utilization Research Centre, Moshi where most of the entomological work was done. Conversely most identification work was arranged by Commonwealth Institute of Entomology, London due to lack of insect taxonomists in these centres.

In Tanzania, like many developing countries, forest entomology is faced with several problems amongst them being shortage of funds, and lack of experts. There are only three Ph.D., and two MSc. holders specializing in forest entomology and none of these is specializing in taxonomy. On the other hand, there are no field assistants inclined to specific insect group or largely forest entomology. There is also lack of good literature dealing with specific insect problems and poor reference materials.

1.3 Global spread of forest insects

Introduced organisms, including fungi, insects and mammals, are a major cause of damage to trees and in some cases their impact has been almost worldwide (Speight and Wainhouse, 1989). Most introductions of forest pests to foreign countries have been accidental and the process has been going on for over a century. Some of the common examples include, Asian Long-horn beetle and *Lymantria dispar* (gypsy moth) native to Asia and Europe respectively and introduced to USA. Many of the insects now established in different parts of the world originated from Europe. Some of the early introductions into the New World, in the late nineteenth and early twentieth centuries, occurred as a result of the demand for familiar European trees by the large immigrant population to USA and Canada and some of these insects have become serious pests of the native forests.

By contrast there are relatively few documented cases of movement in some other directions for example North America to Asia or Africa. It is likely that, at least in part, this is a result of the limited trade that has taken place between these forest regions in seeds, propagating materials and probably wood products. This situation has, however, changed in the recent years and several pests have been introduced to Africa, Asia and Latin America e.g. *Cypress aphid* and *Leucaena* psyllid.

2. INSECT PESTS PROBLEMS IN TANZANIA

2.1 Factors responsible for insect outbreaks

Since the beginning of this century, exotic trees have been used in East Africa first as ornamental and/or trial plots in the 1900s. Large scale establishment of forest plantations mainly involved exotic tree species. By contrast establishment of plantation using native trees have received low priority mostly due to: their (i) assumed slow and multi - formation growth (ii) prone to insects and diseases (iii) difficulties in seed procurement, (iv) germination and nursery establishment problems. To date, there are tremendous efforts in establishing plantations of native trees. Their importance is based among other things on the fact that they are consistent with the environment and their timber has higher demand at home and abroad. The commonest species used here include: *Khaya anthotheca*, *Milicia excelsa*, *Juniperus procera*, *Maesopsis emini*, *Ocotea usambarensis* and *Olea capensis*.

A few exotic species, which have been grown successfully, are subject to attack firstly, by many non-host-specific indigenous insects, and secondly by a few exotic insects, which have been introduced along with their host plants. Until the recent expansion of forestry, exotic tree plantations were relatively free of insect pest problems. This situation has, however, changed markedly in the last few years (from mid 1960s) with the accidental introduction of several serious insect pests originating from other continents (Ciesla, 1993). These exotic pests, free from natural enemies and other control factors that keep them in tight check in their area of origin, have been able to multiply and disperse rapidly and, in consequence, have caused considerable damage to large areas of forests in different parts of the country.

Many indigenous insects are not well adapted to exotic trees besides being kept in check by a diversity of indigenous predators, parasites and pathogens, and therefore rarely cause serious problems to exotic trees. The process of adaptation of native species to plantations of exotic trees is still very much in process. In spite of this, a few native insects occur on exotic hosts in sporadic, locally severe outbreaks, but that most cause little economic damage.

Establishment of plantations using native tree species is often followed immediately by a simultaneous increase in the associated consumer populations. In the tropics, where many consumers may exist for the same species (v.z. *Khaya anthotheca*), establishment of plantations of indigenous species free of pest and/or pathogen outbreaks may be the exception rather than the rule (Perry and Maghembe, 1989).

The current pest status and management options are examined in this paper and the selected species arranged in approximate order of destructiveness. Their major hosts, the type of damage and other vital information is given briefly.

2.2 Exotic pests

Most forest pest problems of Tanzania like many tropical countries pertain to plantations, although some have been recorded in natural forests (Akambi, 1990).

2.2.1 *Cinara cupressivora*

Cinara cupressivora (Lachnidae: Homoptera), Cypress aphid is the most serious (socially and economically) conifer aphid in Tanzania. The pest is native to Southern Europe however it was accidentally introduced to Malawi and Tanzania in 1986 and 1987 respectively. Infestations have subsequently been reported from Kenya and Uganda (Ciesla, 1991a). It attacks members of the conifer Cupressaceae, including *Juniperus*, *Cupressus*, *Thuja*, *Chamaecyparis*, *Callitris* and *Widdringtonia*. *Cupressus lusitanica*, which is widely, used for timber production, fuelwood, and agroforestry stands, living fences and windbreaks is more susceptible to attack than indigenous species (Ciesla, 1991b). The feeding aphid produces large quantities of honeydew, which cover the foliage and provide an ideal substrate for the growth of sooty mould. The feeding causes desiccation of the needles (shoots) and the progressive dieback of heavily infested trees. Unless infestations are treated promptly, death of trees, which are sensitive to feeding of the cypress aphid is imminent. Threat from this pest compelled the Tanzanian Government to stop planting *C. lusitanica* in the Government plantations while most of the mature plantations were clear felled in 1970s and 1980s. On the contrary, Kenya continued planting and mature plantations were cleared following the management plan of the concerned plantation.

The pest can be controlled by silviculture: e.g. thinning, proper site selection and selection for resistant trees (genetically), classical biological control and chemical control. Chemical control is only feasible on small areas such as hedges. Classical biological control using parasitoid *Pauesia* sp has been implemented in the neighbouring states of Kenya and Uganda under the auspices of FAO (Allard *et al*., 1994). This release was done in early 1990s and records show that in the late 1990s this parasitoid had spread and established in northern Tanzania (Kilimmanjaro and Arusha) where *C. lusitanica* is widely planted. In spite that there has not been a systematic survey to evaluate the status of the pest, general observation shows that the severity of the attack is on the serge and the Government has relaxed its burn on replanting of Cypress while many individuals have continued planting.

2.2.2 *Heteropsylla cubana*

Leucaena (*Leucaena leucocephala*) a multipurpose tree, which is native to Central and South America is widely planted in the tropics. In its natural habitat there is no record of serious insect problems. In 1983, a sap-sucking insect Leucaena psyllid (*Heteropsylla cubana*), which also originates from the leucaena natural range, attacked and caused severe damage to leucaena in Florida (Wheeler and Brewbaker, 1990). Two years later the pest spread across the Pacific and Asia causing severe damage to leucaena (Napompeth, 1994). In 1992 it was recorded in East Africa, (Kenya and Tanzania) the first record of the pest from mainland Africa (Raynolds and Bimbuzi, 1992; FAO, 1994). This pest has caused extensive defoliation and even death of some *Leucaena* species. Although the species is reported to cause substantial losses to *Leucaena* production in Southeast Asia it has not reached serious dimensions in Africa.

In Tanzania, like many other leucaena growing regions, heavy damages have been observed in nearly all infested areas, causing some farmers to abandon the species (Johanssen, 1994; Madoffe and Massawe, 1994; TAFORI, 1995). However, due to its many desirable qualities, the tree may continue to be widely used if the pest is brought under control.

Of the various control strategies, it is generally recognised that only the development of resistant varieties and/or biological control offer potential solutions which are both economically feasible and environmentally desirable (FAO, 1994). Both methods have been used individually with some success in Asia, but little quantitative information has been reported on the biological control, and there is no work in the integration of host plant resistance and biological control (Day *et al.*, 1995). Breeding for resistance using resistant species, for example *L. diversifolia, L. pallida, L. collinsi* and cultural methods using alternative species such as *Gliricidia* and *Calliandra* species has been very successful in Kenya and Tanzania.

Biological control using two hymenopterous parasitoids *Tamarixia cubana,* and *Psyllaephagus yaseeni* introduced from Trinidad and Tobago and released in Tanzania and Kenya and both species are well established in Tanzania, have spread over large areas, and they appear to being effective against their hosts. There is some reduction in pyllid population and Leucaena shoot damage in some areas, which could be attributed to the parasitoids (Madoffe *et al*., 2000). Several potential indigenous natural enemies such as Coccinallidae, dragon flies, lacewings, spiders and ants have been recorded in different parts of the country (Madoffe *et al*., 2000). In spite these arthropods living in association with the psyllid, there is no clear evidence that they are feeding on the psyllid. With the exception of ants, the rest are considered as important predators in South East Asia Pacific region and Central America (Nakahara *et al*., 1987; McClay, 1990; Napompeth, 1994) although there is no quantitative evidence for this (FAO, 1994).

2.2.3 *Pineus ?boerneri*

Pineus ?boerneri (Adelgidae: Homoptera); Pine woolly aphid (formerly *Pineus pini*) is native of Europe, where it may cause serious damage to various pine species (Carter, 1971; Steffan, 1972). Also after being introduced to Iceland, the aphid seriously damaged plantations of the exotic *Pinus sylvestris* and even killed trees that further afforestation with *P. sylvestris* was abandoned (Bakke, 1969).

Pine woolly aphid has accidentally been introduced to other parts of the world (Steffan, 1972). It was introduced to Zimbabwe in 1968 and Kenya in 1969 through *P. taeda* and *P. caribaea* scions imported from Australia in 1962 and 1968 respectively. These are the first known occurrences of the genus *Pineus* in Africa south of the Sahara (Barnes *et al*., 1976). In Tanzania, the pest was first found at Sao Hill and West Kilimanjaro forest plantations in 1968 (Odera, 1974). Being a member of EAAFRO and participated in a seed orchard programme, probably got the pest through *P. radiata* nursery planting stock imported from Australia through Kenya in 1964 (Odera, 1974). Infested trees develop yellowing needles that die and drop from the trees causing defoliation, shoot death and dieback of the growing tips.

In East Africa, about 41 species of pines have been introduced and about 30 species are recorded as furnishing food for the pine woolly aphid (Odera, 1974; Barnes *et al*., 1976; Madoffe, 1989). Towards the end of 1984 nearly all pine plantations in Tanzania had been infested, showing varying degrees of attack (Diwani *et. al*., 1984; Madoffe, 1989, Madoffe and Austarå, 1993). *Pinus patula* and *P. elliottii*, which are the widely planted plantation species, are the most favoured by this pest. In Kenya and Zimbabwe and South Africa studies have been undertaken on the biology, ecology and economic importance of this pest (Mailu, 1972; Odera, 1974; Barnes *et al*., 1976; Zwolinski, 1989). In Tanzania studies are only confined to ecological aspects (Madoffe and Austarå, 1990 and 1993). Pine Woolly Aphid attack is severe where a pine species is under physiological stress and volume production can be reduced if attack is severe (Carter, 1976). In Tanzania surveys at Sao Hill forest plantation revealed that tree mortality and growth loss is associated with heavy attacks, especially in young stands grown at inferior sites (Madoffe and Austarå, 1993). Mortality of young trees has been recorded in Sao Hill forest plantation. Growth loss and mortality has also been recorded in Kenya and Zimbabwe (Odera, 1974).

In any insect control programme, the main concern is with species whose injurious potential is established and whose control is either a social or economical necessity (Clark *et al*., 1982). To avoid or reduce losses, various silvicultural strategies should be evaluated: site amelioration, selection of pine species more resistant to aphid attacks than *P. patula* (Odera, 1974; Barnes *et al*., 1976; Carter and Watson, 1991) or growing other species than pines on the inferior sites. Several chemical insecticides have been tried against *P. ?boeneri* in East Africa (Brown, 1970). Both local and introduced predators have shown some positive effects in controlling *Pineus* in East Africa (Mailu, 1972; Barnes *et al.*, 1976; Mailu *et al.*, 1980). Accordingly, there is clear evidence that *Exochomus* species is the most abundant and effective predator. On the other hand, *Tetraphleps raoi,* which was introduced to Tanzania from Pakistan in 1974 is well established in Sao Hill forest plantation and appear to have reduced the population of the aphid (Madoffe, 1989). *Leucopis* species are important biocontrol agents to *Pineus* and *L. obscura* has regulated pine woolly aphid at its higher densities, to below economically significant levels in Hawaii (Culliney, 1988). *Leucopsis tapeae* has been released in the neighbouring Kenya in 1990 and there is evidence that this predator has now spread to Tanzania. Monitoring and evaluation of the effectiveness of these natural enemies is yet to be done.

2.2.4 *Phoracantha semipunctata* and *P. recurva*

Phoracantha semipunctata and *P. recurva* (Cerambycidae: Coleoptera), *Eucalyptus* bark beetles are important pests of Eucalyptus in Zambia and Malawi (Ivory, 1977; Bubala *et al.*, 1989). They originate from Australia and accidentally introduced in many parts of Southern Africa at the beginning of the century (Tooke, 1935). These pests attack both growing trees and green logs and attack can cause considerable damage to physiologically stressed trees sometimes killing them (Ivory, 1977; Powell, 1982). In a situation when the population density is high, healthy and vigorous trees can become targets of the infestation. These insects were recognised as important pests in Zambia and Malawi in the early 1970s. *Phoracantha semipunctata,* which is the most serious pest in Malawi and Zambia was recorded in the late 1980s in some parts of Southern Tanzania where it attacks both growing trees and green logs. The pests could have spread to other parts of the country; however a survey is needed to quantify this.

The pest management plan for *Phoracantha* is based on the elimination of suitable breeding material in the freshly cut plantations by well planned logging practices, as well as improving forest hygiene by every possible means (Loyttyniemi, 1980). Stand vigour improvement by proper thinning and by other silvicultural means is key to induce tree resistance against beetle attack. There are potentials to control the pest using indigenous natural enemies from this region (Ivory, 1977).

2.2.5 *Eulachnus rileyi*

Eulachnus rileyi (Lachnidae: Homoptera), Pine needle aphid, originates from Europe and North America and was first discovered in Zambia, Zimbabwe and South Africa in the late 1970s but the species has also subsequently spread to Tanzania, Kenya and Malawi in the late 1970s (Odendaal, 1980; Katerere, 1984). In Zambia, Zimbabwe and Malawi this species attacks *P. caribaea, P. chiapensis, P. elliottii, P. kesiya, P. merkusii, P. michoacana, P. oocarpa, P. patula, P. roxburgii and P. taeda* (Katerere, 1984; Mills, 1989). The infested needles turn yellow and are lost prematurely and the aphids produce copious quantities of honeydew, which induce a cover of sooty moulds on heavily infested trees. In Tanzania, the pest is found in most pine growing plantations and Sao Hill forest plantation has the most serious attacks (Madoffe, 1989). Like the pine woolly aphid, *P. patula* and *P. elliottii* seem to be particularly more susceptible. In spite that there is no available information about the quantitative effect of the pine needle aphid on its pine host in Tanzania, the actual damage to pines is slight than that caused by the pine woolly aphid. In Europe related European Lachnid, *Schizolachnus pineti* (Fabricius) causes a marked reduction of growth in young pines due to the loss of photosynthetic area (Thompson, 1977). Combined attack of *P. ?boerneri* and *E. rileyi* especially towards the end of dry season could have much more serious consequences.

Tetraphleps raoi, which was specifically introduced to Tanzania to control pine woolly aphid appear also to be effective against pine needle aphid (Madoffe, 1989). Chacko (1973) described *Tetraphleps raoi* as the most important predator of *Pineus* species. *Leucopis tapeae* could also have some prospects for this pest. Proper site selection and silvicultural practices and use of resistant pine species could also reduce ravages from this pest.

2.2.6 *Leptocybe ivasa*

Leptocybe ivasa (Chalcidae: Hymenoptera) Blue Gum Chalcid is a gall forming wasp. For several years, Eucalyptus trees have been pest free all over the world, until the year 2000 when the Blue Gum Chalcid was discovered for the first time in history (Nyeko *et al*., 2009). The insect is of Australian origin and has recently been found as a pest of the same species of *Eucalyptus* in Morocco, Iran, Israel, Italy, Ethiopia and Uganda and recently (2002) in Kenya (Nyeko *et al*., 2009; Nyeko *et al*., 2010). The insect has been reported in Shinyanga and

Tabora, Tanzania in 2004 attacking *E. camaldulensis*, *E. saligna* and *E. grandis*. In 2005, it was recorded in Kibaha, Tanzania attacking Eucalyptus clonal experiment. The attack appears to be spreading very fast and to date it is found in most Eucalyptus growing areas.

The pest attack induces gall formation on the *Eucalyptus* leaves, which later attracts nutrients denying them to the shooting tips of the host tree, leading to stunting of the young foliage and severe attack leads to seedling/tree mortality (Nyeko *et al*., 2010). Though the damage is more devastating on seedlings, older trees are also attacked. In nurseries, Confidor and Acephate chemicals have been used in Tabora and they appeared to be effective. Cultural techniques i.e. the use of alternative tree species such as *Senna siamea, Azadirachta indica* or any fast growing drought resistant species are recommended. Similarly for a long-term management, the use of resistant *Eucalyptus* species, biological control and/or Integrated Pest Management (IPM) could be considered.

2.3 Native pests

2.3.1 Termites

Termites (Isoptera) are the most important damaging native insects to forest trees in Tanzania and the tropics at large. There are six families in the order Isoptera and in Tanzania most species belong to termitidae (Browne, 1968). Exotic hardwood plantation tree species are more susceptible to termite attacks. *Eucalyptus* species are the most susceptible followed by teak and *Grevillea.* Other hard woods species attacked include *Senna*, *Acacia*, *Gmelina*, *Leucaena* and *Terminalia.* There are also some attacks from plantations/stands of indigenous tree species. At the initial stage of plantation, termites attack the root system of the young trees causing tree mortality. Stem of drought stressed trees could also be attacked causing even more tree mortality.

In spite of the threats posed by the termites in Tanzanian forests there has been very little work on this pest especially on taxonomy, economic valuation and protection. Conversely there has been considerable work on taxonomic, control, and ecology of termites in the neighbouring country of Zambia (e.g. Coaton, 1972; Nkunika, 1982, Selander *et al*., 1989).

Protection of seedlings and young plantation trees is usually made by application of insecticides to the potting mixture or applying the insecticides to the planting holes respectively. Aldrin and dieldrin have been the most widely chemical used in both tree nurseries and plantations (TAFORI, 1989). These chemicals (chlorinated hydrocarbons) are now burnt in many countries (May, 1986) and carbonsulfan in conventional and controlled release is used as an alternative. This insecticide is an effective and environmentally sound and safe alternative to aldrin for termite control (Mitchell, 1986). Other control measures include cultural practices (planting of resistant trees), intensive plantation/nursery watering and forest hygiene.

2.3.2 Other native pests

2.3.2.1 Coleoptera

Attack on green timber by ambrosia beetles and other wood-boring beetles are very common in African forestry (Gray, 1972; Beaver and Loyttyniemi, 1991). These beetles are however, rarely major forest pests in the tropics but are an ever-present nuisance (Madoffe, 1993). In Tanzania there is no record of this group of insects attacking exotic pines except a long horn beetle *Oemedia gahani* which attacks Cypress. *Oemedia gahani* has also caused diversified effects on *Milicia excelsa* grown out of its natural niche. Sporadic and minor attacks are likely in some localities but these cannot be quantified due to lack of regular surveys. Some minor attacks on indigenous hardwoods have been recorded from the following genus: Polygraphus, Platypus and Dolygraphus (Platyponinae) and Xyleborus (Scolytinae) (Madoffe, 1993). In Zambia, records show that most pine trees are only sporadically attacked by this group of insects (Loyttyniemi, 1980; 1990). In spite of actual damage being unimportant, the risk of introduction of specified pine borers exists. Some indigenous wood-living beetles may transfer to pine as evidenced elsewhere in the tropics (Roberts, 1977).

2.3.2.2 Lepidoptera

Hypsipyla species (Pyralidae: Lepidoptera), mahogany shoot borer was the only serious pest to *Khaya anthotheca* until in the recent years (Schabel *et al.*, 1988). *Heteronygmia dissimilis* (Lymantridae: Lepidoptera) defoliator and more recently a phacopteronid leaf gall *Pseudophacopteron* (=*Phacosema*?) *zimmamanii* have made establishment of this species very difficult in some parts of Tanzania (Schabel *et al.*, 1988).

Sporadic attack of *Gonometa podocarpi* (Lesiocampidae: Lepidoptera) has been recorded on genus *Pines*, *Cypress*, *Acacia*, *Podocarpus* and *Eucalyptus* (Austara, 1971). Other important native defoliators of conifers include: *Orgyia mixta*, *O. basilis*, *Buzura edwardsi* and *Lechriolepsis basirufa*.

2.3.2.3 Homoptera

In Tanzania, there is no record of seriuos attack of native Homoptera to either natural or exotic tree species. The most well known example, is perhaps, the destruction of plantation of *Milicia excelsa* by gall insect *Phytolama lata* (Psyllidae: Homoptera) (White and Eastrop, 1964). These attacks could be reduced if the trees are grown under light shade.

2.4 Some potential exotic pests to our alien plantations

2.4.1 *Sirex noctilio*

Sirex noctilio (Siricidae: Hymenoptera: Wood Wasp) is a native to southern Europe, the Near East and North Africa, where it attacks and breeds in the holes of weakened and dying pines. This pest has been listed by the Invasive Species Specialist Group (ISSG) of the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN) as one of the 157 species that negatively impact forests and the forest sector (www.issg.org/database [Accessed January 2011). This pest is generally not considered a pest in its natural habitat (Ciesla, 1993). *Sirex noctilio* is the vector of the fungus *Amylostereum serolatum*, which together with the toxic mucus injected to a tree by an ovipostering female could kill a tree.

The species was introduced to New Zealand in 1900s, Tasmania 1950s, Australia 1960s and recently in South America and South Africa (Ciesla, 1993). By the end of the Second World War, *Sirex noctilio* was causing extensive mortality in New Zealand's exotic conifer plantations (Rawlings and Wilson, 1949). To date this pest is not a threat in Australia due to improved stand management and biological control programme involving the release of nematodes into dead pine trees, which act as trap trees for the *Sirex* wasp. The nematodes destroy the *Sirex* eggs. There is concern about the potential for its spread in other parts of Africa including Tanzania where pine is the main plantation species.

2.4.2 *Blastopsylla occidentalis* and *B. ctenarytainini*

Blastopsylla occidentalis and *B.* c*tenarytainini* (Homoptera: Psylloidea) Eucalyptus psyllid have been noted attacking seedlings of *Eucalyptus* nurseries in Kisumu, Kenya (Mutitu, 2007). The insect is of Australian origin and was introduced to New Zealand, Hong Kong, USA (California and Hawaii) in mid 1980s. These are free-living sap sucking insects attacking *E. camaldulensis* and a number of other *Eucalyptus* species. According to the Kenyan taxonomist's testimony, this is the first record of these insects for sub-saharan Africa (Mutitu, 2007). There are no records of this insect in Tanzania, probably due to lack of survey.

3. CONCLUSION AND RECOMMENDATIONS

Several forest insect pests have been recorded in Tanzania on both exotic and indigenous forest plantation species since 1950s. Exotic tree species appear to suffer more yet natural forests are almost free of forest insect pests. Some of the exotic pests have caused serious impact to exotic plantations and to the economy of the country. Similarly, some native tree species growing outside their natural niche have also suffered some attack by native insect species. Several control measures have been tried and classical biological control has good prospects in Tanzania. Development of effective and efficient monitoring device together with IPM could form part of the long-term control strategies. More strict quarantine and inspection at port of entry is proposed to reduce possible future insect pest importation. These measures have to be taken on regional basis since insects don't obey political/geographical boundaries. The culture of establishing extensive monocultural plantations, which favours insect attack, should be re-considered.

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PAPERS

STATUS AND IMPACT OF CONIFER APHIDS IN FOREST PLANTATIONS IN TANZANIA

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ABSTRACT
A review of the background and current status of conifer aphids in forest plantations in Tanzania is presented in this paper. Outbreaks, some impacts, symptoms and possible controls of Pineus ?boerneri (Pine woolly aphid), Eulachnus rileyi and Cinara cupressivora, the introduced sap sucking insects which are posing a great threat to our forests, particularly the exotic conifers are addressed. It is concluded that little information on current status of conifer aphids is available and therefore further research is necessary to reveal the full extent of the conifer aphids in Tanzanian forest plantations.

1. INTRODUCTION

Trees in plantation forests, like many other plants, their health can be affected by biological factors (insects, diseases, wildlife), environmental factors (weather, soil) and cultural factors (pruning, watering, fertilization). The effects of these three factors can cause serious damage, thus resulting in poor tree growth, poor pole and timber quality and in some cases, complete destruction and reduction of forest cover. This has both economic and environmental implications. Thus, trees and forests need to be protected from these agents of destruction (NAFORRI, 2005).

Although aphids have a world-wide distribution there are fewer species in the tropics than in temperate regions. It is difficult to understand why aphids have not flourished as a group on the rich tropical and subtropical floras (Aloo, 1996); however, this could be due to the harsh environment of the tropics and subtropics. Primack (2006) reported that in the tropics and subtropics where floral diversity is very high, few species of plants are apparent enough to sustain an aphid species and that is why more aphids are polyphagous in the tropics than in the temperate regions. The greater number of aphids in the temperate regions can be due to the fact that in the temperate regions there are fewer plant species than in the tropics and the commonest ones are, apparently enough to sustain one or more species of aphids. This is combined with the greater niche diversity produced by seasonal changes in habitat quality in temperate regions (Aloo, 1996).

Conifer aphids have been the major problem in Africa for several decades particularly in countries where planted conifer forests are common. While Kenya, Malawi and Mauritius reported the cypress aphid, *Cinara cupressivora,* as a pest of cypress and cedar trees, it is also known to be or has been a major problem in other African countries including Burundi, Democratic Republic of Congo (DRC), Ethiopia, Rwanda, South Africa, Uganda, Tanzania, Zambia and Zimbabwe (Ciesla, 1991; Ciesla, 2003). Kenya and Malawi also reported pine needle aphid, *Eulachnus rileyi*, which has become a major pest of planted pines throughout eastern and southern Africa since its initial introduction into the region (South Africa, , Zambia and Zimbabwe) in the late 1970s (Murphy *et al*., 1991). The Pine Woolly Aphid, *Pineus ?boerneri*, has attained pest status worldwide. While it has been reported from Kenya, Malawi, Zambia, Tanzania and South Africa, information on this pest's occurrence in other African countries is lacking. The European woodwasp, *S. noctilio*, now established in South Africa, is a significant pest of conifer forests in many other countries outside Africa as well, causing considerable damage and cost to local economies. Efforts are being made to address the severe threat of this pest to the African continent, knowledge and increasing the understanding of *S. noctilio* and its worldwide threat to forestry (FAO, 2009). Nothing has been reported on the occurrence of the pest in East African countries.

Pineus ?boerneri, Eulachnus rileyi and *Cinara cupressivora* are introduced sap sucking insects and are posing a great threat to Tanzanian forests, particularly the exotic conifers (Madoffe, 1989). Following the global movement of insects and plant materials and the conditions of our forests, there is no reason to believe that other pests may not adapt to the exotics. Limited studies have been done on conifer aphids especially population dynamics, the impact on tree growth and biological control. However in most of Tanzanian forest plantations, no study has been done in the last twenty years to determine the status (population abundance, density and distribution) and effects of conifer aphids except for the pine woolly aphid (Madofe, 1989).

For more than two decades now some plantation species at different ages and site classes have been reported to die and the deaths have been dominantly associated with forest insect pests, diseases and/or soil problems (Nshubemuki, 1998). Few examples are highlighted in 2005 in Itimbo West (Sao Hill) where 288.8 ha of *P. patula* with the estimated volume of 98,411 m^3 were affected. The project incurred more than US$ 54,072.48 for buying chemicals (Sumithion 96% ULV) for spraying, cost for hiring aircraft for spraying, ground application costs and transport, etc (SHFP, 2009). In 2009, 700 ha planted with *Cypress* and 40 ha with *Pines* species in Shume Forest Plantation were affected in patches. However, some trees recovered after rain (Masunga, pers. commun. 2010). In Rongai, 1.5 ha of *P. patula* at the age of ten years were totally affected and the management decided to clear fell the whole plot and were sold as poles. In Oldonyo Sambu Range (Meru Forest Plantation), about 40% of the 14.4 ha planted with *Acacia melanoxylon* and *P. patula* planted between 1999 and 2000 were seriously hit by dieback (Matunda *et al*., 2010). Such infestation has implications on the intended goal of supplementing natural forests and the overall wood industry.

Studies have identified some of the forest insect pests affecting different tree species which include *Cinara cupressivora, Pineus ?boeneri, Heteropsylla cubana, Eulachnus rileyi, Eucalyptus chalcids* and *Phoracantha semipunctata and P. recurva* (Nshubemuki, 1998). Despite knowing the insects pests of the tree species, little research has been done to establish the exact cause of death of the trees and determine the best management practice(s) to reduce or eliminate the problem. This paper reviews some selected conifer aphids affecting trees (Pine and Cypress) in Tanzania of which their major hosts, type of damage and other vital information are given. While the identification of the pests and the nature of the damage are well known, little is known on the extent of damage and its impact.

2. STATUS OF CONIFER APHIDS IN TANZANIA

During the expansion of forest plantations, exotic tree were relatively free of insect pest problems. This situation has, however, changed markedly from mid 1960s with the accidental introduction of several serious insect pests originating from other continents (Ciesla, 1991).

2.1 *Cinara cupressivora*

2.1.1 Distribution and its impact

Cinara cupressivora is native in Eastern Greece to just south of the Caspian Sea and it was introduced in Africa: Burundi (1988), DRC and Ethiopia (2004), Kenya (1990), Malawi

(1986), Mauritius (1990), Morocco and Rwanda (1989), South Africa (1983), Uganda (1989), Tanzania (1988), Zambia (1985) and Zimbabwe (1989). It attacks members of the family Cuppressaceae, including, *Callitris*, *Chamaecyparis*, *Cuppressus, Juniperus*, *Thuja* and *Widdringtonia nodiflora*. *Cupressus lusitanica* is the most susceptible host (Odera, 1991; Ciesla, 2003). In East Africa the pest was estimated to cause losses in annual growth of *C. lusitanica* of US $ 17.5 million, not counting the widespread death of trees which it has caused (Ciesla, 1991). In Meru Forest Plantations in Tanzania, it was found that about 30% of trees died through infestation, representing a loss in volume of 350 000 m^3 valued at TAS 289.5 million based on 1992 prices (O'Kting'ati and Nangawe, 1996). Threat from this pest forced the Tanzanian Government to stop planting *C. lusitanica* in the Government plantations while most of the mature plantations were clearfelled in 1970s and 1980s (Madoffe, 2006). Currently, the pest is still being reported in some of the forest plantations, though the intensity of attack and current economic loss has not yet been established.

2.1.2 Symptoms and damage

Adults and nymph suck the plant sap on terminal growth of young and old trees (Ciesla, 1991). Feeding retards new growth and causes desiccation of the stems and progressive die back on heavily infested trees. Damage to host trees includes browning and defoliation which in some cases, causes die back and death of trees. A secondary problem caused by aphid feeding is the copious quantities of honeydew which encourages the growth of sooty moulds (Ciesla, 1991). These moulds cause foliage discoloration and interfere with photosynthesis and gas exchange. The occurrence of ladybird beetle adults and larvae (Coleoptera: Coccinelidae) is often an indicator of aphid infestation as is the presence of ants, which tend the aphids and feed on the honey dew.

2.1.3 Control measures

Cultural and biological control tactics are available for management of damaging populations of *C. cupressivora.* Short term protection of Cypress hedges and small ornamental trees has been achieved with ground applications of chemical pesticides but this is not recommended. In Africa, observations indicate that Cypress plantations established on good soil are more tolerant of aphid infestations than those established on shallow, and rocky soils while young, fast-growing plantations are less susceptible to damage than mature plantations (Ciesla, 2003). Based on these observations, silviculture methods, proper site selection and timely harvesting of plantations should reduce losses**.** Biological control agents have been used successfully against several species of *Cinara*. The introduction of a parasitoid, *Pauesea sp* in Kenya and Malawi has significantly reduced the impact and spread of *C. cupressivora* (Day *et al.*, 2003). The release of the parasitoid was done in the early 1990s and records show that in the late 1990s it had spread and established in northern Tanzania (Kilimanjaro and Arusha) where *C. lusitanica* is widely planted. In spite of lack of a systematic survey to evaluate the status of the pest, a general observation is that the severity of the attack is diminishing and the Government has relaxed its ban on replanting of Cypress, while many individuals have continued planting the species (Madoffe, 2006).

2.2 Pineus ?*boerneri*

2.2.1 Status and impact of Pine woolly Aphids

The pine woolly aphid, *Pineus ?boerneri* (Homoptera: Adelgidae) was originally identified as *Pineus pini* (Macquart) which is indigenous to Europe and possibly some parts of Pakistan and India (Murphy *et al*., 1991). It has a number of host species of exotic *Pinus* in Africa and feeds on the bark, shoots and bases of pine needles, producing tufts of white woolly wax (Zwolinski, 1989; 1990). It has about 50 hosts of pine species in Africa of which 41 species have been introduced in Eastern and Southern Africa and nearly 30 species are recorded as furnishing food for the pine woolly aphid (Madoffe, 1989). Towards the end of 1984 nearly all pine plantations in Tanzania had been infested, showing varying degrees of attack (Madoffe and Day, 1995).

A number of studies have been conducted to determine the impact of the pine woolly aphid on wood production in Africa. In Kenya, Mailu *et al.* (1980) showed that 6% of the plantations of medium-aged *P. patula*, one of the major species grown for industrial purposes, were infested with the aphid and trees were losing approximately 5% of their volume over a six year period. The study conducted by Kisaka (1990) at Sao Hill in Tanzania showed that increment in basal area of the attacked tree was 1.14% less than that of unaffected trees. It was also shown that uninfested trees grow faster in height by 1.14% than that of infested trees. Moreover, Madoffe and Austarå (1990) showed for studies in Tanzania, that the shoots and stems of seedlings of *P. patula* lost 20.9% of their dry weight after 24 weeks.

Petro (2009) pointed out that the intensity of attack of aphid at Sao Hill was lower than that reported by different authors in the late 1980s and early 1990s. This was probably due to the effect caused by *Tetraphleps raoi*, an exotic predator which was released in the forest in the 1970s, local natural enemies and resistance of pines as a result of being well adapted at Sao Hill. Also Petro (2009) reported that among the two tree species studied within the plantation, *P. elliottii* was seen to be more affected by Pine woolly aphid than *P. patula* but not statistically different. This finding is different from that reported by Madoffe (1989). The middle age class (11 – 25 years) was seen to be more damaged, followed by old age class (above 25 years) and young age class (0 – 10 years) was seen to be the least damaged. The middle part of the tree crown was more damaged by aphids, followed by lower crown part and upper crown was the least damaged. This indicates that the distribution of aphids on the tree is mainly affected by light, temperature and wind. However, nothing has been reported from other forest plantations for more than 10 years on the current status of Pine Woolly Aphid.

2.2.2 Control measures

The commonest control method of Pine Woolly Aphid is by practicing proper silviculture e.g. sites amelioration and use of resistant pines. Biological control has also been used successfully for example in Tanzania, native predators such as the Coccinellids, Chaelemens, Chilocorus and Rodolia species have been found to keep down the aphid population in some pine plantations in the Sao Hill, West Kilimanjaro and Meru forest plantations (Kisaka, 1990). Kisaka (1990) also reported that *T. raoi* predator was not very effective as it did not reduce the population sufficiently to prevent tree growth reduction and occasional tree mortality. Conversely, Madoffe (2006) considered the predator to contribute to the reduced numbers and damage of the pine woolly aphid in Sao Hill forest plantation. Similarly some chemicals have been reported to suppress the pest though they are expensive and not environmentally friendly. Some of chemicals which were tried against Pine woolly aphid in East Africa were spraying of thiodan and teepol 1% solution and propoxur (Baygon E.C) at Sao Hill and was found to be effective (Kisaka, 1990).

2.3 *Eulachnus rileyi*

Eulachnus rileyi (Homoptera: Lachnidae) is a pine needle aphid of European and North America origin and was for the first time discovered in Zambia, Zimbabwe and South Africa in the late 1970s but the species has subsequently spread to Tanzania, Kenya and Malawi where pines are grown (Katerere, 1984). Like the pine woolly aphids, *P. patula* and *P. elliottii* seem to be particularly more susceptible. The infested needles turn yellow and could be lost prematurely and the aphids produce copious quantities of honeydew, which induce a cover of sooty moulds on heavily infested trees (Madoffe, 2006). In Tanzania, the pest is found in most pine growing plantations and Sao Hill forest plantation has the most serious attacks (Madoffe, 1989).

However, there is no available information about the quantitative effect of the pine needle aphid on its pine host in Tanzania, Kenya, South Africa and the actual damage to pines is slight than that caused by the pine woolly aphid (Murphy *et al.,* 1991). Mazodze *et al.* (1990) reported in Zimbabwe that the pine plantations were very safe from serious damage of *E. rileyi* and no economic loss was reported. Combined attack of *P. ?boerneri* and *E. rileyi* especially towards the end of the dry season could have much more serious consequents. *Tetraphleps raoi*, which was specifically introduced to Tanzania to control pine woolly aphid, appear also to be effective against pine needle aphid. Massawe (1991) described *T. raoi* as the most important predator of *Pineus* species. *Leucopis tapeae* could also have some prospects for management of this pest. Proper site selection, proper silvicultural practices and use of resistant pine species could also reduce ravages from this pest.

3. CONCLUSION AND RECOMMENDATIONS

The review made is based on old information which can not reflect the existing condition. Therefore research is needed to get the current information on status and impact of conifer aphids in Tanzania**.**

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FOREST SOILS AND THEIR RELATIONSHIP TO FOREST PRODUCTIVITY

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ABSTRACT

There is a growing concern about declining forest soil productivity in Tanzania as elsewhere in tropical Africa further compounded by the impacts of climate change. Review of forest soils and their relationship to forest productivity is essential for harnessing existing knowledge on the forest soils and forest productivity to enhance sustainable forest management. Based on the analysis made from published and unpublished literature, various soil parameters including physical, chemical and biological attributes were noted to be fundamental in understanding the relationship of forest soils and forest productivity. The review has shown that the productivity of most forest soils depends largely upon soil organic matter (SOM), both qualitatively and quantitatively. Moreover, clay soils contain predominantly stable highly mineralized particles with little contribution to short-term plant nutrition, while fine loamy soils constituted the labile and short-time plant nutrition. It further revealed the existing forest soils physico-chemical and biological changes following forest harvesting practices and subsequent land cultivation. However, very few studies have dealt with declining forest productivity from conversion of natural forests into exotic plantations, agroforests and cultivated land systems particularly in Tanzania and similar forests in tropical Africa. Most of forest plantations in Tanzania are being established using existing general information on soil quality and practical experiences of productivity and little research has been carried out on the status of forest soils and their relationship to forest productivity before and after different rotation periods. However, it is obvious that the expanding forest plantation area of short rotation exotic species represents intensification of land use and that will increase the demand on soil nutrients. This review recommends that the actual status of forest soils in Tanzania and their productivity be examined. Evaluation of the impacts of soils and site management practices on the productivity of successive rotations and developing management options for maintaining or increasing soil productivity is important.

1. INTRODUCTION

Plantation forestry in many tropical countries is relatively new, having started about 60 years ago. Reported yields vary considerably across tropical ecosystems. In most tropical African countries little is known about the potential capabilities for increasing productivity as well as potential problems that may limit productivity (Brown *et al*., 1997). Declining forest soil productivity in these countries including Tanzania has become a major concern as a result of continued land degradation, climate change and rapid population growth (FAO, 1981; Swaminathan, 1983; United Nations, 1989). Tanzania with an area of approximately 33.5 million ha occupied by forests, of which 150,000 ha comprises plantation forests (FAO, 2006). The plantations of exotic tree species were established around the 1950s when *Pinus patula, P. elliottii, Cupressus lusitanica, Tectona grandis* and some Eucalyptus species were planted in areas cleared of natural forests. These stands of exotic trees have been found to be ecologically different from indigenous forests in terms of organic matter production, soil conditions and type of vegetation growing on the forest floor (Lundgren, 1978 in Maro *et al.,* 1991).

Changes in soil properties due to the introduction of forest plantations may either favour an increase in the nutrient status of a soil (Chijioke, 1980) or result in decline of nutrients (Will, 1968) or have no significant changes on soils (Adejuwon and Ekanade, 1988). However, the productive potentials of forest plantations in Tanzania as elsewhere in tropical Africa are decreasing at alarming rate (Hanson, 1992) and the question inevitably arises from silvicultural practices and knowledge of and management on forest soils. According to Hanson (1992) of the three billion hectares of arable land in tropical Africa only 14.7% is considered to be free of physical or chemical constraints. One third (32.2%) has physical constraints, 13.2% has limited nutrient retention capacity, 16.9% has high soil acidity and 6.8% has high phosphorus (P) fixation.

Furthermore, it is already known that biological, physical and chemical properties of soil in plantations are greatly influenced by management practices during establishment, tending and harvesting (Lundgren, 1978; Evans, 1982; Raison *et al*., 1982; Maganga and Chamshama, 1984; Shepherd, 1986). Throughout the tropical regions slash and burn is practiced in different areas as a means of land preparation. Burning means that most of the Nitrogen (N), Sulphur (S), P and Carbon (C) associated with organic matter are lost to the atmosphere (Van de Watt and Valentin, 1992). Prescribed fire is used to reduce slash for ease of planting, setting back or killing competing vegetation, or exposing mineral soil for seeding. Hot-slash burns on dry sandy soils have the potential to reduce soil productivity by consuming the forest floor, which reduces the water-holding capacity of these sites, volatilizes some nutrients and makes nutrients rapidly available to plant uptake, runoff or leaching.

The productivity of plantation forestry depends on variables such as ecological capabilities of the site which differs in different countries (Table 1), intensity of management, impact on soil, water and other environmental values (Brown *et al.,* 1997). According to Nambiar and Brown (1997) ecological capability of a site depends on:

(i) The inherent soil and biophysical constraints;
(ii) The responsiveness of the soil to management inputs; and
(iii) The genetic potential of the species and their interaction with the environment of the site

Table 1: **Example of productivity profile of some plantation genera in selected Tropical African Countries**

Species	Country	Rotation length (yr)	MAI ($m^3ha^{-1}yr^{-1}$)
	Tanzania	8 - 10	8.5
	Burundi	8	1 - 2
Eucalypts	Congo	7	30
	Rwanda	8	8.5
	South Africa	8 - 10	18 - 20
Pines	Tanzania	20 - 25	15
	Malawi	20 - 25	17
	Madagascar	15 - 18	6 - 10
	Mozambique	18 - 25	11

Source: Brown *et al*. (1997)

Forest soil productivity decline may begin during the conversion of the natural forests into plantation monocultures (Maro *et al*., 1991). In Tanzania research on the extent of forest soil productivity changes are limited although soil conditions differ from one plantation site to another (Maro *et al*., 1991). This implies the importance of tracking soil productivity changes in all locations where forest plantations are established. Such information could be necessary in understanding forest site productivity under various rotations.

Soil productivity is reflected in the growth of forest vegetation or the volume of organic matter produced on a site (Skovsgaard and Vanclay, 2008). In forest management, soil productivity is often measured by volume or biomass produced. Decrease in forest soil productivity could affect the volume of wood the forest can sustain as well as other forest values, such as biodiversity and ecosystem services (Renard *et al*., 1997). Maintaining and enhancing forest soil productivity should be an essential part of any strategy to achieve sustainable forest management (Burger, 2004).

2. APPROACHES TO ASSESSING FOREST SOILS PRODUCTIVITY

The majority of the soils in tropical Africa are classified as Acrisols, Ferralsols, Plinthisols, Alisols, Nitisols and Lixisols in the World Reference Base for Soil Resources (Kauffman *et al*., 1998). The major soil groups available for plantation forestry are characterized by low amount of weatherable minerals, low cation exchange capacity, low to very low base saturation, and high levels of exchangeable aluminium (Lal, 1997; Goncalves *et al*., 1997). The Acrisols and Ferralsols are well or moderately well drained and organic carbon contents range from 1% to 2% in the surface 20 cm and 0.5% at 100 cm (Kauffman *et al*., 1998). The most critical accumulations of organic matter are in the litter layer which is crucial for maintaining nutrient supply, water retention ad structural stability.

Pre-planning and on-site soil investigations are good tools for enhancing forest productivity. Soil conditions should be evaluated to determine suitable tree species, preferred season of operations and preferred site preparation and regeneration techniques. Forest soil productivity may be assessed in several ways, usually classified as either geocentric (earth-based) or phytocentric (plant based) (Leary, 1985; Vanclay, 1994; Skovsgaard and Vanclay, 2008) (Table 2). Geocentric are based on site properties, including physical characteristics of climate, soil conditions/topography. Phytocentric are based on characteristics of vegetation such as forest stand, components of individual trees response to diseases and pests (Burger, 2004, Skovsgaard and Vanclay, 2008).

Table 2: **Methods for assessing forest site productivity**

Assessment methods	Geo-centric	Phyto-centric
Assessment attributes	Soil texture	Rooting depth
	Soil moisture and nutrient analysis	Plant community characteristics
	Soil parent materials	Volume measurement
	Humus form/Soil Organic Matter	Site index by stand height
	Climate	Ground vegetation
	Topography	Photosynthetic issues

Source: Skovsgaard and Vanclay (2008) modified

In Tanzania, forests grow on a wide variety of soils and site conditions, and this is very important when making forest management decisions to evaluate the soil conditions on the site. Specific soil conditions will allow managers to develop specific prescriptions for a given site that will ensure that the productive capacity of a site is not reduced due to forest management. Practices that impose stress to forest soils such as soil compaction affect the site quality and tree growth through its effect on the rooting environment, reduced aeration which significantly decreases the respiratory activity of plant roots and their capacity to supply the plant with adequate moisture and nutrients. Such practices further increase the loss of nutrients and organic matter which is very important factor for preventing soil chemical degradation (Folster and Khanna, 1997). Loss of nutrient varies with management practices and can have dramatic effect on the growth of the next rotation.

Physical degradation such as soil compaction reduces the amount of water available for plant growth and also reduces infiltration capacity of forest soils, resulting in increased amount of over-land flow, which can lead to increased erosion rates. Perhaps, the greatest factor controlling surface erosion in forests is the amount of vegetation cover and forest litter protecting the soil surface. Soil erosion impacts the long term productivity of a soil by removing surface soils rich in organic matter and nutrients, and influences water-holding capacity of soil. Accelerated erosion is caused by forest management activities such as removal of vegetation and litter or disturbance of surface soil, which exposes mineral soil to rain and water. Large scale clearing accelerates soil erosion, surface sealing and crusting (Lal *et al.*, 1986; Kooistra *et al*., 1990; Van de Watt and Valentin, 1992).

Subsequent cultivation may result in rapid deterioration of the biological, chemical and physical properties of the soil (Lavelle *et al*., 1997). For example, continuous cropping on Alfisols, Ultisols and Oxisols in the tropics has resulted in a rapid decline in soil organic matter in the surface soil during the first few years following land clearing (Juo *et al*., 1995). Continuous cultivation also causes a significant decline in soil pH and exchangeable Calcium (Ca) and Magnesium (Mg) levels.

3. FOREST SOIL PARAMETERS IMPORTANT FOR FOREST PRODUCTIVITY

The soil physical, chemical and biological aspects determine the site productivity for a given forest crop. These three characteristics are closely interrelated and impacts on one aspect may influence others. Physical properties include such factors as soil texture, structure, porosity, soil density, drainage and surface hydrology.

In a study assessing effect of soil characteristics on teak growth at Kilombero Valley Teak Company, Katety (2006) reported that soil mottling, top soil colour, percent silt content, sub soil Organic Carbon were singled out in discriminant analysis and multiple regression as factors that best discriminate site quality classes for teak plantations.

The chemical properties of soil include nutrient status (inputs and outputs) and pH, while biological properties include the multitude of organism that thrive in the soil, such as mycorrhizae, other fungi, bacteria and worms. Most forest plantations in Tanzania are located on strongly acidic soils and tend to be deficient in N and P (Lundgren, 1978; Maro *et al*., 1991) and are likely to respond to fertilization. For example, Tairo *et al.* (2007) reported that the strongly acidic soil (pH $CaCl_2$ 4.4 to 4.8) of Sao Hill forest plantation were severely P deficient (<10 mg P kg^{-1}). In a pot trial, N fertiliser significantly increased *Eucalyptus saligna* seedling height measured at 12 weeks from 25.4 cm in the control, to 31.0 cm at 80 kg ha^{-1} (Tairo *et al.*, 2007). Application of P fertilisers significantly ($P<0.05$) increased seedling height at 12 weeks which ranged from 16.2 cm in the control, to 38.0 cm at 100 kg P ha^{-1}. Increasing P from 0 to 100 kg ha^{-1} doubled root collar diameter (1.6 - 3.7 mm), and increased seedling dry weight fourfold (422 to 1690 mg).

Agricultural practices influence these characteristics especially soil organic matter status, which in turn has beneficial effects on soil structural stability (Feller and Beare, 1997; Barthes *et al*., 1999). Organic matter is known to reduce the impact of rain drops on soil surface, improves soil porosity and water infiltration; fauna activity can also be improved significantly when soils are amended with organic matter (Lavelle *et al*., 1997). Organic matter in soil exists as partially decomposed plant and animal residues, living and dead microorganisms and humified organic matter or humus. Stable humus constitutes 50 to 75% of the total soil carbon and is little affected by management (Barthes *et al*., 1999).

According to Maro *et al*. (1991), forest soils have more organic matter in the organic layer, followed by 0 - 10 and 10 - 50 cm depths in both natural forests and plantations forests of *Cupressus lusitanica* comparatively (Table 3). The occurrence of more organic matter in natural forests is attributed to number of factors including vegetation cover (Maro *et al*., 1991) and rapid mineralization compared to cypress plantation (Lundgren, 1978).

Table 3: **Mean standard deviation and range of organic matter content at different soil depths in natural forests and adjacent *Cupressus lusitanica* plantation at west Kilimanjaro, Tanzania**

Type of forest	Organic matter content (%)		
	Organic layer	0-10cm	10-50cm
Natural forest	29.09 ± 8.45	16.06 ± 3.62	(10.50 ± 3.65)
	(9.2 - 44.8)	(7.6 - 23.0)	(1.2 - 20.2)
C. lusitanica	23.51 ± 7.92	15.26 ± 4.49	10.84 ± 6.47
	(12.0-46.8)	(5.8-24.6)	(4.0-37.8)
Level of significance	**	NS	NS

**=Significant at $p<0.01$, pared test;
Ns=Not significant
Source: Maro *et al.* (1991)

In addition, soil chemical characteristics are influenced by many factors, including soil origin, soil texture and drainage, degree of soil weathering and development (Walker and Desanker, 2004), and qualitative and quantitative properties of organic matter (Agboola and Corey, 1973; Woomer and Ingram, 1990). Forest management affects site productivity through removal of nutrients in forest products or disturbance of surface soils through harvesting and site preparation activities and through soil leaching and surface runoff. Nutrients that are of primary concern for forest soil and forest site productivity are N, P, K, Ca and Mg. Understanding of nutrient use and sustainability requires not only knowledge of the amount of nutrients removed during the harvesting (or through poor site preparation techniques), but also knowledge of the nutrient capital of the soil and the rates of natural additions and losses.

Normally, N deficiencies are often limiting the productivity of many forest ecosystems (Weetman and Webber, 1972; Weetman and Algar, 1983). The availability of N is associated with the rate and type of humus decomposition (Weetman and Webber, 1972). Canopy removal greatly accelerates the decomposition process and results in increased levels of available N and other nutrients (Weetman and Webber, 1972, Gordon, 1983). However, available forms of nutrients such as nitrate ions (NO_3^-) are often more soluble in water and therefore may be more easily lost from the site through leaching.

Other forest management practices such as timber harvesting and some site preparation practices remove nutrients and have the potential to create deficiencies if the removal of nutrients through harvesting practices is greater than the replenishment through natural processes (Juo *et al*., 1995). For example, full tree harvesting removes more nutrients from the site than tree length harvesting methods due to higher nutrient concentration in the branches and foliage (Maliondo *et al*., 1990). Among the possible effects are decline in soil fertility, loss of organic matter and potential increase in soil acidification (Maliondo *et al*., 1990). However, the quantity and proportion of nutrients removed from the forest site varies with species, stand age and the inherent fertility of the site. There is little quantitative information regarding the effects of full tree harvesting on long-term site productivity (Maliondo *et al*., 1990). More recently, Egnel (2011) reported that whole-tree harvesting reduced stand growth in Norway spruce during the first 31 years after planting, largely due to a temporary reduction in site productivity 8 – 12 years after planting. Results from foliar analysis indicated that reduction in site productivity, assessed as stand growth, was primarily due to increased N loss associated with whole-tree harvesting.

Nevertheless, the initial nutrient capital of a forest sites varies widely by soil type (Stoorvogel *et al*., 1993). For example, a fine loamy soil may contain four times the amount of Ca in the rooting zone than a well-drained sandy soil. Most macronutrients that are removed from a site through timber harvest are replaced over the rotation period by nutrient inputs through such processes as precipitation, dust deposition and N fixation (Stoorvogel *et al*., 1993). Other nutrient-retention strategies include, retaining or redistributing slash on the site, avoiding full-tree harvesting or full tree skidding that piles slash without redistributing it, addition of nutrients to the site and avoiding shortened rotations.

4. CONCLUSIONS AND RECOMMENDATIONS

The following are the main conclusions and recommendations:

(i) Soil is the fundamental resource of the forests, maintaining soil productivity sustains forest in a condition that favours regeneration, survival and long term growth of desired forest vegetation, and it is the key to boost sustainable forest management. Productive forest soils influence what plants can grow on a site and how well they grow. Thus maintaining the productivity of forest soil is the key to meeting society's need for forest products and other amenities of the forest;

(ii) Some of plantation forests operations do impact on the forest soil productivity, good harvesting operations, conservation of organic matter and management of slash and litters may reduce the threat of declining forest soil productivity;

(iii) Specific soil conditions will allow the manager to develop specific prescriptions for a given site that will ensure that the productive capacity of a site is not reduced due to forest management;

(iv) The actual status of Tanzanian forest soils and their productivity issues need to be examined; and

(v) Evaluation of the impacts of soils and site management practices on the productivity of successive rotations and developing management options for maintaining or increasing soil productivity is important.

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FOREST PLANTATION DISEASES IN TANZANIA

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ABSTRACT
The importance of forest plantations to the economy and livelihoods of people of Tanzania cannot be overemphasized. Productivity of the plantations does not meet the current demand for wood and wood products. The main setbacks are reported to dwell on insect pests, diseases and soil problems. Tropical diseases decimating forest plantation in Tanzania include: stem canker in Cypress and Eucalyptus, diplodia dieback in pines, root rot disease in pines and Grevillea robusta, damping off in tree nurseries, foliage diseases and the red band needle blight of pines. Forest diseases can have catastrophic effects on some tree species, and in some cases it could lead to the complete destruction of large areas of forest plantations. In this paper an overview of some diseases affecting forest plantations is presented as well as topical approaches to their management. Lastly, long term strategies for curbing forest disease problems in Tanzania are proposed.

1. INTRODUCTION
Tanzania has about 33.5 million ha of forests and woodlands, out of which about 13 million ha have been gazetted as forest reserves of which about 90,000 ha are under public sector forest plantations. The area under private sector plantations is about 60,000 ha. About 50% of the public sector plantations area is located in the Sao Hill Forest Project in Iringa (Tairo, 2008). At least 12 exotic tree species have been planted in industrial plantations, among which five dominate. *Pinus* is the most widely planted genus in Tanzania and it accounts for 56% of the planted area (VCS, 2009). *Pinus patula* is the most widely planted species accounting for 85% of the area under pines. *P. caribaea* accounts for about 14% while other pines notably *P. elliottii* and to a lesser extent *P. kesiya* account for about 1% of the planted area. Meanwhile, *Cupressus lusitanica* accounts for 13% of the area under plantations, *Eucalyptus maidenii, E. saligna* and *Tectona grandis* occupy 4.3% and 3.3%, respectively. Thus, the most important plantation tree species planted in Tanzania are: *P. patula, P. caribaea, P. elliottii, P. kesiya, C. lusitanica, Eucalyptus maidenii, E. saligna* and *Tectona grandis.*

Since commencement of forest plantation establishment in the 1950s, some plantation species in the nursery and/or field have been reported to die due to various diseases. Some of the important forest diseases affecting different tree species include: Cypress and *Eucalyptus* canker, *Diplodia* dieback of pines, root and butt disease of *Tectona grandis,* heart rot disease of *Ocotea usambarensis* and the red band needle blight *(Mycosphaerella pini)* of pines. . Despite knowing some diseases of the tree species, little research has been done to establish the exact cause of death of the trees and determine the best management practice(s) to reduce or eliminate the problem.

The purpose of this paper is to complement current efforts by providing baseline information that could be used to develop and disseminate management strategies for diseases succumbing commercial forest plantations in Tanzania. Within this broad goal, an overview of some diseases described and found to be associated with forest plantations in Tanzania is given as well as topical approaches to their management. Finally proposals for long term solution for curbing forest disease problems in Tanzania are given.

2. OVERVIEW OF DISEASES IN FOREST PLANTATIONS IN TANZANIA

The following are some of the diseases decimating forest plantations in Tanzania: stem canker in Cypress and *Eucalyptus*, diplodia dieback in pines, Root rot disease in pines and *Grevillea robusta,* damping off in tree nurseries, foliage diseases and the red band needle blight of pines.

2.1 Stem canker

Stem canker disease is mostly common in Tanzania which was reported in 1940s attacking *Cupressus macrocarpa* (Cypress canker) in Shume-Magamba plantations. The young trees in forest plantation were severely affected by this canker and some trees died while the survivors had poor quality stems. Due to the massive deaths of *C. macrocarpa* in East Africa, planting was abandoned in 1952 and replaced by less susceptible species *C. lusitanica* (Nsolomo and Venn, 1994).

Botryosphaeria stem canker has been observed to attack *Eucalyptus* species. It is the most common disease of eucalypts in East Africa. It mainly attacks *E. grandis* and *E. camaldulensis.* The affected tree results in to the production of gum and cracking of stems. Mwangi (2010) reported that, in Kenya some *Eucalyptus grands* × E. *camaldulensis* (GC) clones are being affected e.g. GC 540, GC 522, and GC 14 among others. In Tanzania, the information is still lacking whether the GC clones are affected by *Botryosphaeria* stem canker or not. In Ethiopia, the disease was recorded on *E. globulus, E. saligna, E. grandis* and *E. citrodora* and the fungi involved in causing stem canker on *Eucalyptus* species was identified as *Botryosphaeria parva* (Alemu *et al*., 2004).

2.2 Diplodia dieback of pines

Diplodia dieback of pines is caused by *Diplodia pinea* (Syn: *Spharopsis sapinea*). Stresses from environmental condition as well as mechanical damage predispose trees to the disease. In Tanzania, diplodia dieback was reported for first time at Sao Hill forest plantation in 1980s where it caused some losses. The disease occurs on trees from 5 years and above (Mwangi, 2010). The cankers exude copious amount of resin from stems and branches. The fungus also causes blue stain on timber.

2.3 Root rot disease

Root rot disease (*Armillaria* root disease) is caused by a fungus '*Armillaria* species'. The fungi are found throughout the temperate and tropical regions of the world. *Armillaria mellea* has been reported from Kenya, Malawi and Sudan (FAO, 2009). *A. mellea* has been observed to infest pines and *Grevillea robusta* trees at Usa River in Meru forest project (Diwani *et al*., 1984). In the last two decades *Armillaria* was the most widely reported disease found on all the tree species reported to have one or more diseases (Nsolomo and Venn, 1994). However, currently, the extent of attack and economic loss of the disease to different tree species is not known.

2.4 Damping off

Damping off is a disease that occurs on young seedlings before or after germination. It is caused by several fungi but the most common are: *Pythium* spp., *Cylindrocladium* spp. and *Rhizoctonia* spp. etc. Fungi are mostly found in soil and they grow rapidly when conditions are favourable and eventually attack the seedlings. The predisposing factors include: high nitrogen levels, high humidity, high pH, low light, extreme temperatures, over-compacted growing media, dirty seed, heavy and frequent irrigation. The disease spreads through seed, soil, water, growth media etc. Pre- and post emergence diseases result into death of seed before germination and death of hypocotyl respectively.

The symptoms of the disease include the failure of germination when pre-emergence damping off is involved; post emergence damping off attacks at the root or below the soil line; or below cotyledons. Control is by chemicals e.g. chemical composition of Benlate, avoiding over watering, use of soil with good drainage and low sowing density offer cultural control.

2.5 Foliage diseases

Foliage diseases occur in tree nurseries and forest plantations. They are caused by group of fungi called *Mycosphaerella* species. There are three types of the disease; leaf spots which results in to dead necrotic areas, blights which results to extensive necrosis and mildews resulting to white coating on leaves. The leaf spots are the most common on seedlings in the nurseries and trees in the field. The leaf spotting fungus, *M. molleriana* was first observed in Tanzania in 1991 attacking *E. maidenii* countrywide causing severe necrotic spots leading to foliage drying and defoliation (Nsolomo and Venn, 1994). Mature foliage is also attacked in some trees but the damage is mild compared to juvenile foliage and no defoliation occurs. Shoot dieback and leaf blotch are the common symptoms of *Mycosphaerella* leaf diseases. It causes premature defoliation, retarded growth and in severe case it may cause total abandonment of planting susceptible species. Three species of this fungal genus namely *M. molleriana*, *M. nubilosa* and *M. heimii* have been reported to attack foliage of the eucalypts in Africa. In South Africa the *Mycosphaerella* leaf disease has been found on 10 eucalyptus species and pathogens were identified as being *M. molleriana* and, *M. nubilosa* (Lundquist, 1987).

2.6 Red band needle blight

Red band needle blight disease is a fungal disease previously referred as the *Dothistroma* blight. It was first observed in northern Tanzania in 1958 at Shume forest plantations, spread vigorously and virtually wiped out the young plantations of *P. radiata* in East Africa and Malawi within 20 years (Nsolomo and Venn, 1994). The disease again led East Africa to abandon further planting of *P. radiata* in 1964 (Diwani *et al*., 1984). In some other African countries, the severe defoliation caused by *Dothistroma* needle blight also led to abandonment or restriction of planting the fast growing *P. radiata* and in most cases it has been substituted with a slightly slow growing *P. patula* (Ciesla *et al.,* 1995; Lundquist and Roux, 1984). *P. radiata* was a superior conifer tree in terms of wood quality and was comparable to the most durable timber trees growing in the region. The disease is caused by *Mycosphaerella pini* (*Dothistroma pini).* It is characterized by the formation of red bands on needles and the affected needles turn brown and fall. No current survey has been done to document its current status on Tanzanian forest plantations.

3. EFFECTS OF THE DISEASES

The diseases have caused enormous losses to forest plantation trees. Each has causative agent, known host range, transmission methods and predisposing factors. From this disease scenario, there is a need to have a comprehensive knowledge of the environment in which the disease develops. Knowledge on the occurrence and progression of forest diseases is necessary to ensure appropriate control of the disease. Disease management aspects are discussed in the following sections.

The lack of effective prevention and control measures including quarantine, increased in international trade of forest products, exchange of plant materials has resulted in the introduction of pathogens and insects in Tanzania. Most of the commercial tree species are exotic (Palanisamy *et al*., 2009) and the worst forest tree diseases in the country are accordingly most exotic (Nsolomo and Venn, undated). These introductions have led to the destruction of introduced tree species especially cypress in the 1990s. It is likely that a newly introduced pest is more likely to continue to increase until food is limiting, and then disperse, extending the outbreak to new areas.

4. PROPOSED APPROACH TO THE MANAGEMENT OF FOREST DISEASES

The following procedures need to be considered in forest disease management:

(i) Assessment of incidence and severity of disease at nursery and plantation stage;
(ii) Collection of tree samples from diseased trees for isolation and identification of the pathogens;
(iii) Determine the predisposing factors (for each pathogen), i.e. which circumstances make it easy for the pathogen to germinate and proliferate; and
(iv) Economic importance of the affected forest trees determines the choice for the method of control (biological, chemical, cultural).

5. LONG TERM STRATEGIES TO FOREST DISEASE PROBLEMS IN TANZANIA

The following are the long term strategies to ensure a healthy forest:

(i) Deployment of disease resistant germplasm. This embraces such aspects as screening and selection of genotypically resistant trees as well as matching species to site;
(ii) Emphasizing on species diversification as well as use of mixed species in plantations.
(iii) Use of Integrated Pest Management (IPM) in disease control;
(iv) Enhance surveillance system (i.e. readiness or preparedness for handling disease outbreaks);
(v) Managing the impact of human activities by doing away with the traditional disease triangle and view pathosystems as a quartet rather than a triangle in which human activities make a new component;
(vi) Strengthening quarantine to reduce new entry of pathogens and spread to new areas; and
(vii) Capacity building in forest disease management.

6. CONCLUSION AND RECOMMENDATION

Currently there are no regular disease surveys and monitoring in the country, thus some diseases may go unnoticed and sometimes the impact can be detrimental. It is therefore important to deploy long term strategies including preparedness for handling disease outbreaks and applying well known techniques for forest disease control.

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PLANTATION FORESTRY MANAGEMENT IN TANZANIA: CURRENT SITUATION AND FUTURE FOCUS

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ABSTRACT

Large scale establishment of forest plantations dates back to the 1950s after some years of species and provenance trials. The area under public industrial forest plantations in Tanzania is estimated at 90,000 ha while that under private sector is about 60,000 ha. Large scale establishment of forest plantations by the private sector is more recent. The main species are Pinus patula, P. elliottii, P. caribaea, Cupressus lusitanica, Tectona grandis and some Eucalyptus species. Forest plantations supply wood and non-wood forest products for industrial and non-industrial uses. In addition, forest plantations if sustainably managed also contribute positively towards provision of environmental services.

A review of management practices shows that most public sector forest plantations are characterised by replanting backlogs, low intensity site preparation techniques, poor quality trees due to use of un-improved seed and low survival due to poor species-site matching and delayed or low intensity weeding. It is also noted that they are generally neglected or have irregular pruning and thinning. On the other hand, private sector plantations are relatively better managed due to use of best practices.

The quality and productivity of forest plantations will be enhanced by: using improved germplasm, site and species/provenance matching, high quality planting stock, appropriate silviculture (site preparation, establishment, weeding, fertilization, pruning, thinning and protection). Further, site productivity must be maintained by adapting appropriate soil and site management practices namely nutrient retention (e.g. by leaving foliar mass on site, retaining post-harvest slash rather than burning it) and use of planned low impact logging techniques.

Due to knowledge gaps, research is needed in the following areas: management trials (spacing, pruning and thinning) for new species currently being used in plantations; fertilisers and nitrogen fixing legume trials in sites found to have nutrient deficiencies; species mixture trials; effects of forest plantations on water resources, biodiversity and soil health; search for new plantation tree species with emphasis on indigenous species; and monitoring and evaluating forest health with respect to insect pests, pathogens, invasive species and fire.

1. INTRODUCTION

The history of plantation forestry in Tanzania dates back to 1893 when the Germans established an experimental nursery near Dar es Salaam and raised various species of tropical trees both ornamental and exotic. Other early developments included the establishment of a Biological-Agricultural Station at Amani in 1902 where field tests involving Australian *Acacias*, several species of pines, teak, cypress and Mexican cedar among others, were conducted (Schabel, 1990), and Kigogo Arboretum in Sao Hill established in 1935, where trials of exotic tree species were conducted. The Amani Station was in 1948 transferred to Muguga (Kenya) leading to the establishment of Lushoto Silviculture Research Station in 1951. Species and provenance testing continued at this station and other sites in the country.

Successful results from these trials led to large scale planting from the early 1950s mainly using exotic tree species.

The justifications for plantation development in Tanzania and other Sub Saharan Africa (SSA) countries have been growth superiority and product uniformity attributes of plantations over those of useful, but normally slow growing, but ecologically superior indigenous tree species in natural forests. Plantations also have the ability to provide affordable wood for industry and wood-based products for consumers. In addition, tree plantations are often the most rational way of producing some non-wood forest products, for rehabilitation of degraded areas and improvement of watersheds, and for meeting environmental quality objectives such as windbreaks, shelterbelts and more recently, carbon sequestration.

Initial large scale planting consisted mainly of *Pinus patula*, *P. radiata* and *Cupressus lusitanica*. Later, several *Eucalyptus* species were also planted. The planting of *P. radiata* was discontinued in the early 1960s due to attacks by the fungus *Dothistroma pini*. The public sector plantations are situated in 19 locations with a total area of about 90,000 ha. There has since never been efforts to significantly expand the government forest plantations areas. Plantation establishment by private companies started in the 1990s. There are now about 60,000 ha of privately owned plantations and the area is increasing. Overall however, the total area of forest plantations which is about 150,000 ha is low given high domestic and export demand of forest products and the fact that Tanzania is one of the few African countries with potential areas for expansion of forest plantations (FAO, 2003a).

Plantation programmes especially the public sector plantations in Tanzania and many other countries of SSA face various challenges and have been on the decline, particularly in the last two decades. Land use conflicts, concern about the negative ecological impacts of plantations, weakening public forest services as a result of diminishing priority given to them in the face of economic reforms such as structural adjustment programmes, and declining donor interest in funding forestry activities are among the many factors that have contributed to this situation (Chamshama *et al.,* 2009).

In the light of this, it is important to reassess the forestry plantation programme in the country with a view to map out the way forward in improving the performance of the plantations to achieve sustainable forest management (SFM). In this paper an overview of the current situation of forest plantations in Tanzania and recommendations on the way forward are given.

2. TREE IMPROVEMENT AND SILVICULTURAL CONSIDERATIONS: EFFECT ON PRODUCTIVITY AND QUALITY OF INDUSTRIAL PLANTATIONS

The success of any plantation depends largely on adoption of appropriate tree improvement and silvicultural practices, which consist of various treatments applied to forest plantations to maintain and enhance their utility for any purpose. These practices include: choice of species including seed source and genetic improvement, species-site matching, method of regeneration, site preparation, initial spacing, planting, fertilisation, tending (i.e. weeding, pruning and thinning), protection and harvesting practises (FAO, 2000; FAO, 2001a). Appropriate and timely silvicultural practices also called *good forestry practice* determine the pattern and quality of crop development thereby modifying both the quality and the quantity of end products. It is this effect on quality and quantity of the end products that makes silvicultural practices important in forest management. The following review focuses on silvicultural practises used in Tanzania and their effects on the productivity and quality of industrial plantations.

2.1 Tree improvement related aspects

2.1.1 Seed supply

When large-scale establishment of plantations started in Tanzania, seed requirements were initially met by importation from the donor countries i.e. countries from which the various species are indigenous (e.g. Central America, Mexico and Australia) or from South Africa, which had a longer experience with forestry plantations. In the 1970s, local seed sources i.e. seed stands (essentially an interim seed source) and seed orchards were established for the major tree species (Forest Division, 1982; Madoffe and Chamshama, 1989). Local seed sources continued to be supplemented by importation to meet domestic demand. For example, seed of the following species were imported by the Tanzania Tree Seed Agency (TTSA) between 2005 - 2010 *Eucalyptus grandis*, *E. tereticornis*, *E. saligna*, *Pinus caribaea*, *P. elliottii*, *P. kesiya*, *P. oocarpa*, *P. patula*, *P. tecunumanii* and *P. taeda* (TTSA, 2010).

The tree improvement efforts started in the 1960s to produce advanced generation seed orchards or clonal material were not continued and even the established seed stands and unrogued first generation seed orchards were neglected. As a consequence, most forest plantations constitute a significant proportion of trees of low productivity and quality (Chamshama *et al.*, 1996a; Nshubemuki *et al.*, 2001). Table 1 shows seed sources for some forest plantations. Although there is some seed importation from second and third generation seed orchards, most of Forest Plantation Managers source their seed from older stands or TTSA unimproved seed source classes as there are only four improved seed orchards of *C. lusitanica*, *Tectona grandis*, *Eucalyptus tereticornis* and *Grevillea robusta* (TTSA, 2010). The former three already produce seed.

Table 1: Seed sources for planting in some public and private sector forest plantations

Ownership and name of forest plantation	Source of seed for planting	Level of genetic improvement
Public sector		
Sao Hill	Older clear felled trees	None
	Local sources & Importation through TTSA	(1) Not indicated for local sources (2) Second or third generation for imported seed
Meru	Local sources & Importation through TTSA	(1)Not indicated for local sources (2) Second or third generation for imported seed
SUA Training Forest	Local sources & Importation through TTSA	(1)Not indicated for local sources (2) Second or third generation for imported seed
	Older clear felled trees for Eucalyptus	None
Ukaguru	Local sources & Importation through TTSA	(1)Not indicated for local sources (2) Second or third generation for imported seed
Private sector		
Tanga Forest Ltd	TTSA	Not stated
	TTBP	Highly improved clones
	Importation through TTSA	Second or third generation
Idete, Kitete, Mapanda, Taweta and Uchindile	Seed stands	Not stated
		Improved clones
	Importation through TTSA	Second or third generation
Kilombero Valley Teak Company (KVTC)	TTSA	Not stated

Source: Angyelile (2010), Maro (2010), Mrecha (2010), Mnangwone (2010), Mussami (2010) and TTSA (2010)

There have been efforts started in the 1990s towards production of improved seed and clones. TTSA has established a number of seed stands and seed orchards. Those that have not yet started to produce seed are shown in Table 2a while those that are already producing seed are shown in Table 2b (TTSA, 2010). There are also unimproved seed sources of various species in form of seed collection zones (21), identified stands (149) and selected stands (6) (TTSA, 2010).

The Tanzania Tree Biotechnology Project (TTBP) of the Tanzania Forestry Research Institute (TAFORI) is testing improved *Eucalyptus* clones in several locations of the country. These clones have started being used in forest plantations as indicated by Tanga Forests Limited (Mnangwone, 2010).

Table 2a: TTSA provenance seed stands and seed orchards which are yet to produce seed

Type of seed source and tree species	Sites and areas (ha)
Provenance Seed Stands*	
Azadirachta indica	Mkundi Forest Reserve (two sites 7.6 and 3.8), Chamwino Forest Reserve (2.8)
Grevillea robusta	Pangawe Forest Reserve (0.5)
Khaya anthotheca	Mkundi Forest Reserve (5.5)
Milicia excelsa	Pangawe Forest Reserve (5)
Pterocarpus angolensis	Kising'a Forest Reserve (3)
Pinus patula	Magamba Forest Project (54)
Eucalyptus grandis	Magamba Forest Project (12)
Calliandra callothyrsus	Magamba Forest Project (0.5)
Acrocarpus fraxinifolius	Magamba Forest Project (0.5)
Gmelina arborea	Mkundi Forest Reserve (1)
Seed Orchard**	
Grevillea robusta	Pangawe Forest Reserve (2)

Source: TTSA (2010)

*A plus stand that has been generally upgraded and opened by removal of undesirable trees and then cultured for easily and abundant seed production (TTSA 2010).

**A plantation of selected clones or progenies which have been isolated or managed to avoid or reduce pollination from outside sources and managed to produce frequent, abundant and easily harvested crops(TTSA 2010).

Table 2b: TTSA seed production areas, provenance seed stands and seed orchards currently producing seed

Type of seed source and tree species	Stage of improvement
Seed production areas*	
Acacia polyacantha	Nil
Grevillea robusta	Nil
Polyalthia longifolia	Nil
Terminalia catapa	Nil
Pinus patula	Poor phenotypes removed
Tectona grandis Longuza	Poor phenotypes removed
Tectona grandis Mtibwa	Poor phenotypes removed
Provenance Seed stands	First generation
Acacia mangium	Second generation
Eucalyptus camaldulensis	Second generation
Eucalyptus citriodora (Corymbia citriodora)	Second generation
Eucalyptus tereticornis	Second generation
Gliricidia sepium	Second generation
Seed orchards	
Cupressus lusitanica	First generation
Tectona grandis	First generation
Eucalyptus tereticornis	First generation

Source: TTSA (2010)

*A selected stand where poor phenotypes have been rouged and then cultured for easily and abundant seed production (TTSA, 2010).

2.1.2 Species/provenance-site matching

Due to their evolutionary development, most tree species are generally site specific and careful consideration must be given to matching species to overall site characteristics (Zobel *et al.*, 1987). This entails adequate knowledge of the climate, edaphic and topographic factors both in the natural habitat of the species (for an exotic) and in the proposed country of introduction. The low productivity of various tree species has in some cases been attributed to "off-site" planting (Jackson, 1984; Zobel *et al.,* 1987; Evans, 1992; FAO, 2002). This arises from starting large scale planting without species/provenance trials and where the trials were carried out; they were of very short duration i.e. less than the recommended half rotation period. Of all the factors considered in various reviews, species/provenance-site matching is considered to have the greatest and often longest effect on differences in productivity of various plantation forests (Vichnevetskaia, 1997; FAO, 2002). Off-site planted trees grow under stress, and this may increase their susceptibility to pests and diseases (Zobel *et al.,* 1987; FAO, 2001a). Other than the failures observed in the 1970s at the proposed Ruvu Pulpwood Plantation Project in Pwani Region, the impact of off-site planting on productivity of forest plantations in Tanzania is not much documented.

2.1.3 Tree species diversification in forest plantations

When Tanzania commenced industrial forest plantations, fewer species/provenances were initially used and species/provenance tests continued with the objective of broadening the genetic base and increasing species diversity. It is generally acknowledged that this may serve as an insurance against pests, diseases and climatic fluctuations. Additionally, this may result in increased market security through species and product diversification. However, only limited information is available on species diversification in forest plantations. Table 3 shows tree species diversification in some public and private sector forest plantations. Except for the mainly teak growing plantations (KVTC and Lindi), there is limited diversification in most of the other plantations. With very low tree species diversification, pests/pathogens may have devastating impacts.

A recent Technical Order issued by the Forestry and Beekeeping Division (FBD) (FBD, 2003) has given additional tree species for planting in public sector forest plantations mainly based on species/provenance trials conducted in various parts of the country (Table 4). The area so far planted with the new species is not yet known. Improved seed sources of these tree species is an area requiring urgent action as well as appropriate establishment and tending techniques.

Studies are also needed to evaluate the biological and economic feasibility of mixed stands, as studies elsewhere have shown that mixed species plantations yield more diverse products than monospecific stands, helping to diminish managers'/farmers' risks in unstable markets, have greater biological diversity, aesthetic benefits, may have lower risk against pests and diseases and may be less demanding on site nutrients than pure stands (Khanna, 1997; Montagnini, 2000).

Table 3: Tree species in some Tanzanian forest plantations

Plantation / Company	Tree species	End product(s)	Extent of species diversification (%)
Private Sector			
Kilombero Valley Teak Company (KVTC)	*Tectona grandis, Swietenia macrophylla*	Saw logs	Almost all area is teak
Tanga Forests Ltd	*Casuarina equesetifolia, Eucalyptus camaldulensis, E. tereticornis, A. mangium, Markamia lutea, Tectona grandis, E. grandis, E. europhylla*	Saw logs, pulp wood, energy, Co_2 sequestration	*Casuarina* 37, *Eucalyptus* 37, and *A. mangium* 12
Lindi Forests Ltd	*Tectona grandis, E. camaldulensis, E. tereticornis, Dalbergia retusa, Gmelina arborea, Dovialis cafra, Dovilis retusa, S. humilis,* and *Pinus caribaea*	Saw logs, pulp wood, energy	*T. grandis* 95, Rest 5
Idete	*E. grandis, E. saligna, E. camadulensis, Pinus patula, P. elliottii*	Saw logs, pulp wood, poles, Co_2 sequestration	*P. patula* 40, *E. grandis, E. camaldulensis* and *E. saligna* 59
Mapanda	*P. patula, E. grandis and saligna*	Saw logs, transmission poles, energy, Co_2 sequestration	*P. patula* and *P. elliottii* 72, *Eucalyptus* 27
Uchindile	*Pinus patula* and *Eucalyptus saligna*	Co_2 sequestration, saw logs, transmission poles and renewable energy	*Pinus patula* 44, *E. saligna* 55
Public Sector			
Sao Hill	*P. patula, P. elliottii, P. kesiya, P. caribaea,P. radiata, C. lusitanica, E. grandis, E. maidenii, E. saligna*	Saw logs, pulp wood, poles	*P. patula* 74, *P. elliottii 9, C. lusitanica* 9, *Rest* 10
Ukaguru	*P. patula, C. lusitanica*	Saw logs	*P. patula* 92, *C. lusitanica* 8,
Meru	*P. patula, C. lusitanica, G. robusta, E. maidenii, A. melanoxylon, Casuariana junghuniana, Olea capensis, Eucalyptus maidenii*	Saw logs, poles	*P. patula* 42, *C. lusitanica* 10, *G. robusta* 14, *E. maidenii* 8, *A. melanoxylon* 4, *Casuariana* 4, *Olea + Grevillea* 8, *Mixed hardwood* 10
SUA Training Forest	*P. patula, C. lusitanica, Eucalyptus spp, Grevillea robusta, Acacia melanoxylon,Casuarina species*	Saw logs, poles	*P. patula* 57, *C. lusitanica* 15, *G. robusta* 14, *A. melanoxylon* 7, *Eucalyptus spp.* 7

Source: Bekker *et al.* (2004), Angyelile (2010), Green Resources (2010), Kiangi (2010a), Maro (2010), Mrecha (2010)

Table 4: Tree species for planting in public sector forest plantations

Zone & Major Species	Alternative Exotic	Species Indigenous	Remarks
Lake Victoria *P. caribaea*	*P. patula* *P. patula var tecunumanii* *P. kesiya* *E. camaldulensis* *E. citriodora (Corymbia citriodora)* *E. saligna, C. odorata* *A. fraxinifolius* *M. azedarach, G. robusta*	*Antiaris toxicaria* *Maesopsis eminii* *Markhamia platycalyx Syn. M. lutea* *Milicia excelsa* *Hallea rubrostipulata* *Trichilia emetica* *Podocarpus usambarensis* *Khaya nyasica*	Suitable for areas receiving more than 1600 mm mean annual rainfall
	Albizia lebbeck *Azadirachta indica, E. alba, E. crebra, E. cloeziana* *E. melonophlora* *E. microtheca*	*Faidherbia albida* *Acacia nilotica* *A. polyacantha* Miombo species (see Inland plateau)	Suitable for areas receiving less than 700 mm mean annual rainfall
Inland Plateau (None)	As for the lake Victoria zone receiving less than 700 mm mean annual rainfall *C. equisetifolia* *T. grandis* (dry area prov)	*Afzelia quanzensis* *Dalbergia melanoxylon* *Julbernadia globiflora* *Pterocarpus angolensis* *Vitex keniensis*	Miombo covers 40% of the country. Thus future forestry development depends on this area
Highland Areas *P. patula* *C. lusitanica* *E. grandis* *E. regnans* *E. saligna*	*Casuarina junghuniana* *Pinus elliottii* *P. kesiya* *P. taeda* *C. odorata* *C. japonica* *C. camphora* *Grevillea robusta* *P. radiata* (resistant strains) *E. botryoides* *E. citriodora* *E. globulus* *E. maculata* *E. maidenii* *E. microcorys* *E. paniculata*	*Beilschmedia kweo* *Cordia africana* *Cephalosphaera usambarensis* *Fagaropsis angolensis* *Newtonia buchananii* *Olea capensis* *P.usambarensis* *Vitex keniensis* *Ocotea usambarensis* *Olea capensis* *Juniperus procera* *Podocarpus usambarensis* *Acacia sieberiana var. sieberiana,* *A. seyal* *Vitex keniensis*	
Eastern Arc Mt. foothills *T. grandis*	*Cedrella odorata* *Gmelina arborea* *Grevillea robusta* *Terminalia superba* *T. ivorensis* *C. japonica*	*Brachylaena huillensis* *Entandrophragma stolzii* *Khaya nyasica* *Milicia excelsa* *Steculia spp* *Trichilia emetica* *Sterculia apendiculata* *Pterocarpus angolensis* *Dalbergia melanoxylon*	
Coast *Pinus caribaea* *P. elliottii* *P. patula ssp tecunumanii*	*Dalbergia sissoo* *Eucalyptus camaldulensis* *E. tereticornis* *C. equisetifolia*	*Dalbergia melanoxylon* *Rhizophora spp* *Pterocarpus angolensis* *Sterculia apendiculata*	Other mangrove species also suitable

Source: FBD (2003)

2.2 Nursery, establishment and weeding techniques

2.2.1 Production of planting stock

Early nursery cultural techniques were tailored to producing large, healthy and robust seedlings (Procter, 1967). Such seedlings survived and grew well as they were planted mainly in highland areas with comparatively fertile soils and less frequent water stress problems.

In the 1970s and 1980s there was introduction of plantations into much drier areas such as Ruvu and as small village woodlots. Nursery studies were carried out on techniques to increase seedling survival and growth in such areas. The studies showed that adoption of right and timely dosages of fertilisers especially nitrogen (N) and potassium (K), also root/top pruning and decreasing watering regimes towards planting out result in increased field survival and early growth (Solberg, 1978, 1981, 1983; Chamshama and Hall, 1987a; Chamshama *et al.*, 1996b, c). These cultural techniques result in reduced plant dry weight, increased root-shoot ratio, decreased transpiration rates and high root growth capacity (Chamshama and Hall, 1987a; Chamshama *et al.,* 1996b, c). In addition, such attributes reduce the planting stock period and enable a fast establishment of root contact with soil moisture and nutrient reserves thus improving survival potential.

In view of the current climate change effects which make tropical climate more variable and extreme events more severe, drought hardening techniques should be used even in areas formally considered humid and thus not requiring drought hardy seedlings, so as to improve survival and early growth.

2.2.2 Plantation establishment

2.2.2.1 Spacing

Tree spacing plays an important role in tree growth as it influences the quantity and quality of wood produced (Zobel *et al*., 1987; Evans, 1992). Also it influences costs of various operations such as planting, beating up and weeding, timing of thinning, selection of final crop, and rotation age. The choice of initial spacing depends on the following factors: the site, the species, and the objectives of the management such as the number of trees desired at the time of thinning and at the end of rotational age, and the expected size of trees to be harvested (Iddi *et al*., 1996).

Before Technical Order 1 was issued in 2003, initial spacings used for different tree species being planted in public sector plantations varied (Nshubemuki *et al.,* 2001). For example, *C. lusitanica* and *P. patula* grown for saw logs were planted at spacing ranging from 2.5 x 2.5 m to 3.0 x 3.0 m, while teak was planted at a spacing of 2.0 x 2.0 m or 2.5 x 2.5 m. Currently spacing in public sector forest plantations is according to Technical Order 1 (Table 5). It is not known to what extent Plantation Managers adhere to these specifications. Table 6 shows spacings used in some private sector plantations.

Table 5: Initial spacing used in public sector industrial forest plantations in Tanzania

Tree species	Type of end product	Initial spacing (m)
P. patula, P. patula ssp. tecunumanii,	Saw logs	3.0 x 3.0
P. elliottii, P. caribaea &	Pulp wood logs	2.0 x 2.0
C. lusitanica		
T. grandis & *Grevillea robusta*	Saw logs	2.5 x 2.5
Eucalyptus species	Saw logs	3.0 x 3.0
	Pulp wood logs & Poles	2.0 x 2.0
Acacia melanoxylon & *Olea capensis*	Poles & saw logs	2.0 x 2.0

Source: FBD (2003)

Table 6: Initial spacing used in private sector industrial forest plantations in Tanzania

Company and Tree species	Type of end product	Initial spacing (m)
KVTC		
Tectona grandis	Saw logs	2 x 2 (1993-1999) 3 x 3 (2000+)
Tanga Forests Ltd		
A. mangium, Several *Eucalyptus spp, Casuariana, Tectona grandis*	Saw logs, pulp wood, energy, Co_2 sequestration	3 x 2 4 x 2
Idete, Kitete, Mapanda, Taweta and Uchindile		
Pinus patula, *P. elliottii*	Saw logs, pulp wood, energy, Co_2 sequestration	3 x 3
Eucalyptus camaldulensis, *E. saligna, E. grandis*	Saw logs, pulp wood, energy, Co_2 sequestration, poles	2.5 x 2.5

Source: Bekker *et al.* (2004), Mnangwone (2010) and Mussami (2010)

2.2.2.2 Site preparation techniques and planting

Site preparation is carried out with the objective of securing both high survival and rapid early growth because of improved soil moisture relations caused by reduced weed competition and increased water infiltration and storage. A number of studies on the effects of different site preparation techniques on early survival and growth have been carried out in Tanzania. Results show that rigorous site preparation such as complete cultivation (ploughing and harrowing) result in improved survival and early growth of planted seedlings (Chamshama and Hall, 1987b; Kalaghe and Mansy, 1989; Mhando *et al.*, 1993). For example at Sao Hill, 6 year *P. patula* was found to yield 106 - 121 m^3ha^{-1} with complete ploughing, 63 m^3 ha^{-1} with strip cultivation and 30 m^3 ha^{-1} in the control treatment (Kalaghe and Mansy, 1989).

Land preparation in all public sector forest plantations except Sao Hill (in the 1980s) was through manual labour using hand tools such as axes and bush knives to fell trees, followed by piling and burning of the slash (Abeli and Maliondo, 1992). Many plantations were established though the 'taungya' system where farmers or squatters were given temporary rights to clear, cultivate and grow agricultural crops in the forest land, and in return plant and tend tree seedlings until canopy closure (Abeli and Maliondo, 1992; Chamshama *et al.*, 1992). After canopy closure, farmers would move to other areas requiring planting. In the past, mechanical site preparation was carried out at Sao Hill where tractors were used for strip and complete cultivation (ploughing and harrowing). Sub-soilers were also used to break compact soil layers.

Currently, all public sector plantations are in the second or third rotation and site preparation mainly involves burning of logging slash before re-planting or food crop planting by taungya farmers. The resulting ash from burning is rich in base nutrients (which may be lost by leaching or surface movement). Further hot burns (>300°C) result in volatilisation of N and sulphur (S), loss in organic matter, degradation in soil structure, reduction in macropores, erosion by wind and raindrops and decreased infiltration rates due to fire induced water repellence (SAIF, 1994). Slash disposal by burning results in reduced site productivity as shown in a recent study at Shume, North Eastern Tanzania (Mugasha *et al*., 2006).

Site preparation at KVTC involves vegetation clearing and burning, and pre planting herbicide application (Glyphosate roundup 3l/ha) (Bekker *et al.*, 2004). At Tanga Forests Ltd, site preparation is done by strip or complete ploughing (Mnangwone, 2010). In Idete, Kitete, Mapanda, Taweta and Uchindile Forest Plantations, chemical site preparation is used and involves application of roundup (3 l/ha) to the grass followed by screefing before pitting and planting (Mussami, 2010).

Proper pitting and planting is necessary to ensure high initial survival and growth. The following general rules apply. Pits should be large: 30 cm deep x 30 cm diameter. Roots are inserted into the pit up to the root collar, avoiding breaking, bending or crushing them. The soil is gently firmed around the roots to eliminate air pockets and bring the earth into intimate contact with the roots. While planting techniques are followed, the main problem in public sector plantations has been low planting rates leading to backlogs. Ukaguru forest plantation for example has a replanting backlog of 1,100 ha (Angyelile, 2010). Other replanting backlogs have been observed in Kiwira, Buhindi and Kawetire (Balama, 2010). Information on replanting backlogs was not available for most forest plantations.

2.2.2.3 Forest fertilisation

Fertilisation at planting is carried out on nutrient deficient sites to improve early survival and growth of seedlings through provision of readily available nutrients which accelerate tree recovery thus survival and growth after field planting. Forest fertilisation is gaining prominence with the extension of plantations into more marginal sites and the need to enhance tree growth and maintain productivity of second and subsequent rotations.

A number of reports have indicated nutrient deficiencies in first rotation stands in Tanzania (Procter, 1968; Cannon, 1985; Tangwa *et al.*, 1988). Results from a few fertiliser trials and soil analysis suggest nutrient deficiencies especially in latosols at Sao Hill (Procter, 1968; Nykvist, 1976; Mhando *et al.*, 1993; Chamshama and Hall, 1987b). Apart from Sao Hill, these problems are likely to be serious in Shume (Lundgren, 1978). The limiting nutrients include N, phosphorus (P) and boron (B) (Maliondo and Chamshama, 1996). However, so far fertilizers have not been used forest plantations in Tanzania.

Other than use of inorganic fertilizers, experience from Australia, New Zealand and Hawaii (Will and Manley, 1983; Waring and Snowdon, 1984; Debell *et al.*, 1989; Binkley *et al.*, 1992) suggest that soil fertility can also be increased by annual and perennial nitrogen fixing legumes planted as companion crops (mixed species) or during fallow periods. Preliminary results from a trial involving *P. Patula* interplanted with *L. diversifolia* established at Shume, Tanzania in 1998 and assessed for 4 years showed that the cumulative growth performance of the second rotation pine plantations in their pure stands were generally superior to those recorded in the mixtures with *Leucaena* trees - mainly resulting from the underground competition for limited nutrient resources (Maliondo *et al.,* 2007). These results were considered preliminary as further monitoring is going on.

2.2.2.4 Weeding

Weeding of planted seedlings is necessary in order to reduce or eliminate competition for light, soil moisture and nutrients from undesirable species. Weeding is usually manual using hand tools. Table 7 shows weeding techniques currently used in some forest plantations. Weeding ranges from intensive (chemicals or clean weeding by taungya farmers) to low intensity (spot, strip or slashing) with definite impacts on seedling survival and growth (Forest Division, 1982; Isango and Nshubemuki, 1998).

Table 7: Weeding techniques used in some forest plantations

Ownership and name of forest plantation	Type of weeding techniques used
Public sector	
Sao Hill	Taungya during first year, Spot weeding thereafter
Meru	Taungya and slashing thereafter
Ukaguru	Taungya and spot weeding
Matogoro	Spot weeding and slashing
Mtibwa	Spot weeding and slashing
Private sector	
KVTC	Chemical and manual (spot/complete- not indicated)
Tanga Forests Ltd	Strip weeding, spot weeding and chemical weeding
Idete, Kitete, Mapanda, Taweta and Uchindile	Spot weeding using hand hoe 1 m diameter

Source: Angyelile (2010), Balama (2010), Kiangi (2010a), Maro (2010), Mnangwone (2010) and Mussami (2010)

Several studies have been carried out on the effects of weeding types/intensities on seedling survival and growth (Sangster, 1956; Willan, 1963; Bryant, 1968; Raunio, 1975; Maghembe, 1979; Maghembe *et al.,* 1986; Sabas and Kalaghe, 1986; Ahimana and Maghembe, 1987). Overall, clean weeding (manual or chemical) has been shown to result in high survival and initial growth. Often, spot and strip weedings are used depending on the site, species and financial availability (Abeli and Maliondo, 1992). Even though less intensive weeding techniques are used, weeding backlogs have been reported in several public sector forest plantations (Balama, 2010).

A recent study at Sao Hill showed that survival of *P. patula* and *P. elliottii* aged 1 - 5 years ranged between 61 - 77% (Kiangi, 2010b). Height growth was also found to be low when compared with the yield table. The generally low survival and growth were attributed to low intensity weeding (slashing) resulting in severe competition for nutrients and moisture between seedlings and weeds.

A study evaluating the taungya system showed that the system is beneficial in terms of tree survival, food crop production, financial income to the peasant farmers and reduction of forest plantation establishment costs (Chamshama *et al.,* 1992). The other benefit is reduction of conflicts between plantation authorities and surrounding communities. The system however requires close supervision, so that roots and stems are not injured. The system may also encourage soil erosion due to cultivation, burning and clean weeding of steep lands and results in removal of nutrients in harvested crops and slash burning (Abeli and Maliondo, 1992). In this taungya system there is excessive pruning to allow more light for the food crops and this reduces tree vigour and thus close supervision is necessary.

2.2.3 Tending

2.2.3.1 Pruning

Pruning is a deliberate removal, preferably while still live of some of the branches from the lower trunk (bole) of a tree, with an objective of reducing knots in sawn timber and similar finished products. Branches form knots, which are the most common defects of timber, especially those formed by dead branches. The lateral grain distortion around knots leads to reduced timber strength. Low pruning (1.5 - 2.0 m above ground) is carried out to provide free access into the plantation and reduce fire risk while high pruning is done to produce knot free timber.

Pruning is generally due when crowns touch and the pruning schedules vary according to management objectives. The decision to prune or not to prune must almost be entirely based on the consideration of economic factors. High pruning must be associated with price differentiation between pruned and unpruned timber which currently is not the case.

Tanzania pruning schedules were adapted with modifications from South Africa which has a longer experience in growing the various species. Table 8 shows the current pruning schedule for *P. patula* and *C. lusitanica*. Despite the presence of the pruning schedules, there are pruning backlogs mainly in public plantations and this is often attributed to budgetary constraints (Nshubemuki *et. al.,* 2001; Balama, 2010). At Sao Hill, only 3,156 ha of Pines (7% of total plantation area) have received access pruning and high pruning is not being practised (Kiangi, 2010a). Similarly, pruning backlogs have been reported at Buhindi, Kiwira, Matogoro and Ukaguru, (Angyelile, 2010; Balama, 2010).

For the private sector plantations, a pruning schedule for teak at KVTC is shown in Table 9. No pruning backlogs were reported for the private sector forest plantations which provided information.

Craib (1939) has shown that clear timber must be at least 10 cm thick for pruning to be economically justifiable. To obtain this for pruning as high as 7 m, the mean breast height diameter overbark would need to be at least 45 cm for most pines (Marsh, 1978). Other than regular thinning, rotation length must be adjusted to allow for such diameter growth (Zobel *et al.,* 1987).

Pruning trials must be developed for the new species being planted in forest plantations, as a basis for developing pruning schedules.

Table 8: Current pruning schedules for *Pinus patula* and *Cupressus lusitanica* (spacing 3 x 3 m), Tanzania

Type of pruning	Site class									
	I			II			III			
	Age (yrs)	Height (m)		Age (yrs)	Height (m)		Age (yrs)	Height (m)		
		Mean	Pruning		Mean	Pruning		Mean	Pruning	
P. patula										
First	3.0	5.5	2.7	3.5	4.9	2.4	Omitted			W.C
Second	5.0	9.8	5.8	5.5	7.3	4.6	7.0	6.1	3.7	S
Third	7.0	13.7	8.2	7.5	10.4	6.1	9.0	7.9	4.9	S
C. lusitanica										
First	1.0	2.4	1.2	2.0	2.4	1.2	Omitted			W.C
Second	3.0	6.7	3.4	4.0	5.5	2.7	5.0	4.0	2.0	S
Third	5.0	10.1	6.7	6.0	7.3	4.9	7.0	5.2	3.4	S
Fourth	7.0	12.8	8.5	8.0	9.1	6.1	9.0	6.4	4.3	S

Notes

- W.C: Whole Crop pruned
- S: Selective pruning
- Pines for pulpwood are normally pruned once for access at the height of 1.5 – 2.0 m or even at 3.0 – 5.0 m.
- High quality sawlog require pruning height of 7.0 – 9.0 m.

Source: FBD (2003)

Table 9: Current pruning schedule for *Tectona grandis* at KVTC (spacing 3 x 3 m)

Age, years	Stem diameter, cm	Prune to, m
4	8	2.5
6	8	5.0
8	8	7.5

Source: Bekker *et al.* (2004)

2.2.3.2 Thinning

Artificial thinning is the removal of a proportion of individual living trees from a stand before clear felling (SAIF, 2000). It is generally understood to take place after the onset of competition. The major objectives of thinning are (Evans, 1992; SAIF, 2000): to reduce the number of trees in a stand so that the remaining ones have more space for crown and root development to encourage stem diameter increment and so reach a utilizable size sooner; to remove trees of poor form; prevent severe stress which may induce pests, diseases and stand instability; and to provide an intermediate financial return from sale of thinnings. More trees are initially established than the required final crop mainly to ensure sufficient trees from which the final crop can be selected, enhance early canopy closure to suppress weed growth and to utilise the site better (SAIF, 2000).

Tanzania's public sector plantations earlier thinning schedules, with modifications where necessary were based mainly on South African experience. This was necessary initially as thinning experiments were just starting. The current thinning schedules are shown in Table 10 (FBD, 2003). For private sector plantations, thinning schedules for some tree species are shown in Tables 11 and 12 (Bekker *et al*., 2004; Mussami, 2010). Overall, the teak thinning schedules for KVTC and public sector plantations are very different. The dimensions and quality of the final crop trees arising from these schedules have not yet been evaluated.

While thinning is an important silvicultural operation, which must be done at the right time, right way and right intensity, various reports and the authors personal observations show that thinning operations in many public plantations in Tanzania do not follow the prescribed schedules (Munishi and Chamshama, 1994, Nshubemuki *et al.*, 2001; Balama, 2010; Kiangi, 2010a). At Sao Hill and Ukaguru for example, thinning is never carried out (Angyelile, 2010, Kiangi, 2010a). Where thinnings have been carried out, they have been fewer and lighter than recommended, resulting in the standing volume being distributed to too many small trees rather than fewer ones of greater value per cubic metre. The main reasons given for the neglect of thinnings are shortage of funds, lack of markets for unsawn thinnings, lack of plantation management skills and experience, foresters' traditional attitude against waste and lack of processing plants (Ahlback, 1988). No thinning backlogs were reported for the private sector forest plantations which provided information.

Table 10: Thinning regimes for different tree species in industrial forest plantations, Tanzania

Species	Age (years)	Stems per Hectare (SPH)
P. caribaea	0	1111 (3.0 x 3.0 m spacing)
P. elliottii	10	650
P. patula	15	400
P. tecunumanii	25 - 30	0
C. lusitanica		
T. grandis	0	1600 (2.5 x 2.5 m spacing)
	5	800
	10	400
	15	300
	30 - 40	0

Source: FBD (2003)

Table 11: Thinning schedule for *Tectona grandis* at KVTC

Age (years)	SPH remaining
2	Remove multiple stems
8	650
13	400
20	250-280
30-32	0

Source: Bekker *et al.* (2004)

Table 12: Thinning schedule for *Pinus patula* at Idete, Kitete, Mapanda, Taweta and Uchindile

Age (years)	SPH remaining
0	1600
10	800
14	500
18	300
25	0

Source: Mussami (2010)

Thinning trials should be established for the new tree species being planted in forest plantations. Meanwhile, research results or experiences from countries with similar ecological conditions should be used to prepare the schedules.

2.2.4 Forest fires, pests and diseases

Some aspects of this topic have received detailed treatment in the preceding papers. Only a brief overview is presented in this section.

Fire seems to be a major problem in Tanzania's forest plantations. During the year 2009/10, information provided by some Plantation Managers showed that a total of 3898 ha were affected by forest fires (Kiangi, 2010; Mussami, 2010). Strategies need to be in place to ensure that future losses due to forest fires are minimised.

With regard to diseases and pests, it is generally believed that outstanding initial performance of exotic species in the areas of introduction is attributed to the absence of pests or diseases. However, with time, diseases and or pests tend to follow (sometimes through accidental introductions) those species in their areas of introduction and hence assume economic importance. *Pinus insignis (P. radiata)* is believed to be one of the first pine species to be introduced to Tanzania (Anon, 1902 In: Lundgren 1978; Schabel, 1990). For about 60 years no pests or diseases were reported. In the 1960s all areas planted with *P. radiata* had to be clear felled following incidences of *Dothistroma* needle blight at Shume Forest Project in 1958; and *Cercospora* needle blight at Sao Hill (Etheridge, 1965). As a control measure the planting of *P. radiata* was banned and *P. elliottii* was introduced as an alternative species. The species soon proved to be susceptible to pine woolly aphid, *Pineus pini* infestations which also attacks *P.*

patula. Biological control of the aphid relying on *Tetraphleps raoi*, and native predators has minimised the spread of infestation (Odera, 1974). Outbreaks of canker diseases caused by *Monochaetia unicornis* were first observed in Machakos, Kenya in 1937 and at Shume, Tanzania in 1943. In Geita (near Buhindi) the disease was observed in 1963 in trial plots of *Cupressus arizonica*, and in Ukerewe Island in a *C. lusitanica* plot. It was later found that *C. macrocarpa* and its hybrids were more susceptible to canker attack than other Cypress species. The spread of the disease was minimised by the elimination of *C. macrocarpa* from planting programmes replacing it by *C. lusitanica* (Forest Division, 1982). Recent infestation of *C. lusitanica* by *Cinara cupressi* has threatened future planting programmes (FAO, 1991).

Some environmentalists and other members of the society claim that growing trees in plantations, and especially exotics is dangerous because they are inherently vulnerable to diseases and pests. Partly as a consequence of this, the topic has received wide review (see e.g. Zobel *et al.,* 1987; Evans, 1992; FAO, 2001b; Cossalter and Pye-Smith, 2003; Nair, 2003). Nair (2003) in a detailed review on pest outbreaks in tropical forest plantations posed the question "Is there a greater risk for exotic species than for indigenous tree species?" The author looked at the experience of nine species and genera widely used as exotics. Nair found out that no generalisation is possible for exotics as a group although more species seem to be at a lesser risk. The empirical data also showed that pest outbreaks do occur in plantations of indigenous tree species and sometimes even in natural forest stands. The conclusion by Nair for pests, which may as well apply to diseases, is that while plantations are at greater risk of pest outbreaks, plantations of exotics are at no greater risk than plantations of indigenous tree species because the exotic status is only one among the many determinants of pest outbreak. In a review of pest and disease problems of forest plantations, FAO (2001b) noted that there are several major examples where plantations have faced major disease or insect problems that have stopped the use of a particular species or clones, overall, diseases and pests have not caused such widespread damage as to seriously question plantation silviculture as a practice.

Susceptibility to pests and diseases has been shown to occur under the following situations (FAO, 2001a):

(i) Failure to give proper attention to species/site matching "offsite planting", resulting in trees growing under stress;
(ii) Use of planting stock from a narrow genetic base;
(iii) Failure to maintain optimum stocking levels and tree vigour through intermediate cuttings; and
(iv) Dependency on one or two species in plantation programme.

Perhaps the greatest concern with regard to susceptibility to pests and diseases is the number of species used in a country's plantation programme (FAO, 2001a). Some SSA countries rely on one or two closely related species, and should a pest/disease appear, the results could be devastating (FAO, 2001a).

2.2.5 Plantation forest long-term site productivity

While in some instances new areas will be opened up for plantations, future wood needs will, in most situations, have to be obtained from existing sites, i.e. through second and subsequent rotations. The productivity of these will have to be maintained or increased to meet the increasing domestic and international demands for wood and non - wood products.
Maintaining or increasing plantation productivity can be achieved by:

(i) Confining harvesting of forest products to stem wood, which generally represents a small export of nutrients from a site (Zobel *et al*., 1987; Evans, 1992, 1996; FAO, 2001a);
(ii) Proper harvesting planning, which, among others, includes careful re-use of extraction routes to minimise compaction and erosion (FAO, 2001a);
(iii) Slash retention on site after harvesting (i.e. avoiding slash burning or raking) (FAO, 2001b; Mugasha *et al.*, 2006); and
(iv) Appropriate soil conservation measures to reduce nutrient losses due to erosion (Evans, 1982; Vichnevetskaia, 1997; FAO, 2001a).

One of the few studies on productivity of second and subsequent rotations of forest plantations is that by Evans (1996) in Usutu, Swaziland. Evans found that there is no evidence of yield decline in three rotations *P. patula* as a consequence of plantation forestry practices.

In Tanzania, only stem wood is harvested, resulting in small export of nutrients. However, harvesting planning is often poor, and slash burning after harvesting is common. These practices jeopardise long-term site productivity. For example, in a recent trial at Shume, northern eastern Tanzania, the effect of post-harvest *C. lusitanica* slash on early growth of *P. patula* was investigated (Mugasha *et al*., 2006). Where slash was removed or burned, seedling volume growth (3 yrs) was found to be significantly poor compared to where slash was retained.

3. ECOLOGICAL SUSTAINABILITY OF FOREST PLANTATIONS

Planted forests serve numerous ecological stabilization and protective roles such as climate amelioration, soil and water protection and conservation of biodiversity. Planted forests help with moderating of temperature and humidity as well as in balancing atmospheric compounds by acting as carbon sink and helping with carbon dioxide (CO_2) sequestration. Plantations contribute to rain seeding; precipitation by assisting in fog condensation; and serve as windbreaks. In addition, planted forests refine the air by absorbing and recycling pollutants; control water supply sources and reduce sedimentations that affect water quality; and minimises risks of ecological disasters like land slides, falling rocks and surface runoff. The role of forest plantations with regard to biodiversity conservation, water use and invasiveness in discussed in the following sections.

3.1 Biodiversity in forest plantations

The ability of plantations to improve biodiversity is important for plantation sustainability. Recently a number of studies in SSA forest plantations have shown the catalytic effect of forest plantations on the regeneration of native woody species under their canopy and their subsequent succession as well as increased flora and fauna diversity in the plantations (Evans, 1992; Bernhard-Reversat, 2001; Cossalter and Pye-Smith, 2003). There is however species differences on this, as well as the contiguity i.e. the establishment of the plantation in relation to any existing natural forest (Evans, 1992; Cossalter and Pye-Smith, 2003). Also, delayed or omitted silvicultural operations like pruning and thinning may result in reduced biodiversity of shade intolerant species.

Forest plantation designs that retain individual natural forest trees or patches within the plantation ensure availability of seed and seed dispersers (birds and animals) for natural regeneration thus increasing biodiversity (Montaginini *et al.,* 2005). Other ways of increasing biodiversity under forest plantations include: maintaining a mosaic of plantation age classes with a potential value in providing a range of habitat (Gerrand *et al*., 2003), using a mixture of species within the plantation to increase structural and functional diversity and potentially increase overall production (Gerrand *et al*., 2003, Montaginini *et al.*, 2005), and retaining native vegetation in watercourses, ridges or steep areas (Gerrand *et al.*, 2003).

3.2 Plantations and water resources

The hydrological effects of trees, and particularly the effects of plantations (especially Eucalypts) on water yields and flooding, have been of much controversy. The understanding of the relationship between forests and water resources is a complex matter since the real contribution of forests and plantations to water regimes will vary with topography, soil type, local climate, the type of tree involved and a variety of other factors which exert their own particular influence (Cossalter and Pye-Smith, 2003). Environmentalists often criticise large-scale plantations on the grounds that they reduce the amount of water that flows through the water catchment.

A recent global synthesis of the effect of afforestation on water yield which analysed 26 catchment data with 504 observations (Farley *et al.,* 2005) showed that runoff decreased consistently and substantially with afforestation across the entire data. Both the type of original vegetation and plantation species and age influenced proportional changes in stream flow. Annual runoff reductions were greater in grasslands than in shrub lands, and Eucalypts had greater impact than Pines. Run off reduction increased with plantation age. With regard to policy implications, on average a tree was found to use approximately 15% more precipitation than grasses or shrubs, and this value can serve as a useful indicator for land managers and policy makers in guiding the location of plantations with respect to the demand for water resources.

3.3 Invasive exotic species

Most exotics are economically very important and enhance the production of various forest commodities, while a few species introduced intentionally have become established in the wild and have spread at the expense of native species thus affecting the entire ecosystem (FAO, 2003b). There are no records of serious invasions by alien woody species in forest plantations in Tanzania but there are cases of exotic species becoming invasive in natural forest ecosystems (e.g. *Cedrella ordorata* at Kimboza Forest Reserve).

In South Africa, a notorious example of such invasions include *Acacia mearnsii.* Substantial costs have been incurred in South Africa to remove invasive species along water courses. Great care is required to ensure that such species serve the economic purposes for which they were introduced and do not escape and cause unanticipated negative effects on native ecosystems (FAO, 2003b).

4. CONCLUSION AND RECOMMENDATIONS

The main conclusion is that most of public sector forest plantations are in poor condition because of having trees of poor form, and lack proper tending. This state of affairs is due to use of seed of inferior genetic quality and low budgetary allocations resulting in the skipping of some silvicultural operations. On the other hand, the private sector plantations are better managed and have high productivity due to careful site selection, intensive cultural practices, selection of best species/provenances and genetic improvement through research.

The following recommendations are put forward to ensure high productivity and quality of forest plantations as well as long term site productivity:

4.1 Tree seed and nursery techniques

(i) Test seed from advanced generation seed orchards from neighbouring countries (with similar ecological conditions) in pilot plantations followed by use large scale planting;
(ii) Seed importation should continue for species not currently producing seed and for the establishment of seed orchards;
(iii) Vegetative propagation should be used for species which root easily as cuttings like most *Eucalyptus* species; and
(iv) The on-going climate change will make tropical climate more variable and extreme events more severe. There is a need to emphasize seedling drought hardening techniques in the nursery so as to ensure high early survival and growth under such situations.

4.2 Establishment and tending

(i) Undertake elaborate site preparation and weeding to increase initial survival and growth. During harvesting, planning vehicular traffic is necessary to minimise compaction, and retain slash (i.e. avoid burning) so as to maintain productivity of subsequent rotation; and
(ii) Pruning and thinning schedules should be adhered to and there should be price differentiation between pruned and unpruned timber both for the local and export market.

4.3 Biodiversity conservation

Use forest plantation designs that retain individual natural forest trees or patches within the plantation to ensure availability of seed and seed dispersers (birds and animals) for natural regeneration thus increasing biodiversity as well as retaining native vegetation in watercourses, ridges or steep areas.

4.4 Research

(i) Establish management trials (spacing, pruning and thinning) of new species currently being used in plantations;
(ii) Establish inorganic fertilisers and nitrogen fixing legume trials in sites found to have nutrient deficiencies;
(iii) Establish species mixtures trials;
(iv) Assess effects of forest plantations on water resources, biodiversity and soil health;
(v) Search for new plantation tree species with emphasis on indigenous species; and
(vi) Monitor and evaluate forest health with respect to insect pests, pathogens, invasives and fire.

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ECONOMIC IMPLICATIONS OF INSECT PESTS AND DISEASES IN FOREST PLANTATIONS IN TANZANIA

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ABSTRACT

Forests contribute significantly to the national economy and welfare of the people. Economic contribution of plantation forests is in terms of biomass, building materials, industrial materials, income and revenue and linkages to related activities. Currently, government and private forest plantations in Tanzania cover an estimated area of about 150,000 ha. The Government is generating revenue from fees, royalties, licenses upon use of forest resources in both local and export markets. Moreover, forests are a significant sink for carbon dioxide emissions. The potential of forest plantations to sequester carbon is an emerging opportunity which depends on forest health. Reports show incidences of forest pests and diseases in different age and site classes of forest plantation species in Tanzania. Economic impacts and implications of insect pests and diseases to forest plantations has not been done apart from a detailed study on impacts of aphid destruction of Cupressus lusitanica in Meru Forest Plantations in 1996 which indicated losses of TAS 290 million. Another study on the infestation of C. lusitanica by Cypress aphid in Tanzania showed a loss USD 0.103 billion (TAS 1.5 billion 1986 values). There has also been a study on the cost of protecting forest plantations after infections. A total of USD 73,315.81 (TAS 95.31 million) was used in Itimbo West, Sao Hill forest plantation after insect pest outbreak in which 500 ha of P. patula with the estimated volume of about 98,411 m^3 were affected. Other than these studies, there is only information of areas affected by insect pests and diseases in various forest plantations in Tanzania. This information could not allow making an economic analysis of the loss. The following are the main recommendations from this paper: a separate budget for forest protection be set aside; regular record keeping on insect pests and diseases outbreak in forest plantations be mounted; development of a national insect pests and disease monitoring and evaluation system; and nation wide economic valuation of insect pests and diseases be instituted.

1. INTRODUCTION

Industrial forest plantations in Tanzania cover about 150,000 ha out of which about 90,000 ha is under public ownership and about 60,000 ha is under the private sector (Table 1). The main tree species being planted are *Pinus patula, P. caribaea, P. elliottii, P. radiata, Tectona grandis, Grevillea robusta* and some *Eucalyptus* species such *E. camaldulensis, E. tereticornis, E. saligna and E. grandis* (Nshubemuki, 1998). Most of these plantations are threatened by insect pests, diseases and soil problems.

Table 1: Coverage of forest plantations in Tanzania

Name	Location / Region	Plantation area (ha)		% of each sub-total industrial planted area
		Total land area	Planted	
Public Sector				
Sao Hill	Iringa	135,000	45,000	49.59
Ruvu	Coast	*67,000	8,355	9.21
Meru	Arusha	6,900	6,600	7.27
Rongai	Kilimanjaro	6,254	6,054	6.67
West Kilimanjaro	Kilimanjaro	6,019	4,500	4.96
Shume	Tanga	4,360	4,250	4.68
Buhindi	Mwanza	11,000	3,420	3.77
Kiwira	Mbeya	2,784	2,739	3.02
Kawetire	Mbeya	3,245	2,080	2.29
Longuza	Tanga	2,200	1,750	1.93
Mtibwa	Morogoro	3,115	1,640	1.81
Rubya	Mwanza	1926	1,623	1.79
Rondo	Lindi	2,550	1,100	1.21
Ukaguru	Morogoro	1,701	760	0.84
Rubare	Kagera	2,450	520	0.57
Matogoro/Wino	Ruvuma	5,550	352	0.39
Sub – total		262,054	90,743	100
Private Sector				
TANWAT	Iringa/Njoluma	15,560	14,300	24.13
Green Resources Company Ltd (GRs)	Iringa, Lindi, Morogoro and Tanga	56,395	9,643	16.27
Kilombero Valley Teak Company (KVTC)	Iringa	28,000	8,000	13.50
Others	Scattered		27,314	46.09
Sub – total		99,955	59,257	100
Total		362,009	150,000	

Sources: Mandalo Salum (FBD), Mbaga (TANWAT), Haule (KVTC), Ngegba (GRs) (pers. commun., 2011)
*Includes natural forest

The government has been receiving revenues from timber from forest plantations. For example, Sao Hill forest plantation (SHFP) alone collected a total of about TAS 69 billion between 2000 and 2010. This amount constitutes royalty, logging miscellaneous deposit account (LMDA), *CESS* (Local Government tax) and value added tax (VAT). However, this value can also be sustained or increased if forest health is maintained. Forest sector is also estimated to employ about 3% of paid labour and even a bigger proportion of people in the informal forestry related sector (FOSA, 2000). Moreover, forests are a significant sink for carbon dioxide emissions, the potential of forest plantations to sequester carbon which is an emerging opportunity (Thomas and Baltzer, 2002.) depends mainly on forest health. For example the Green Resources Company Limited has managed to sell carbon (139,358 tCO_2e) from a healthy forest (4,000 ha) through voluntary carbon units, which fetched about US$ 830,000 (Ngegba, pers. commun., 2011).

Insect pests and diseases may cause some damage to trees and stands. These damages are eventually expressed as economic loss, i.e. a loss of income to a farmer or loss of revenue to a community or country. When the damage reaches an economic damage level, then the insect pest/pathogen requires control measures (Hill, 1997). Economic insect pests/pathogens may have adverse effects on many aspects of forests like tree growth and survival, yield and quality of wood and non – wood forest products, wildlife habitat, recreation, aesthetics, and cultural value. The impact of pests and diseases may result in the curtailment of plantation programmes, the abandonment of a given tree species, or the necessity to clear - cut large areas dominated by infested trees (Ciesla, 1993; Schabel, 2006).

In East and Southern Africa it was estimated that the introduced cypress aphid, *Cinara cupressivora* has killed trees to an estimated value of US$ 41 million and was causing a loss in annual growth increment (including that from dead trees) of a further US$ 14 million per year (Schabel, 2006). In addition, the two pine aphids, *Pineus ?boerneri* and *Eulachnus rileyi* caused a further loss of US$ 2.25 million per year in the region (Schabel, 2006). Information for the analysis included area, growth and monetary values of softwood timber, aphid distribution, feeding ecology, associated tree growth loss and tree mortality. While conservative, these figures enabled availability of finance for a biological control programme, which led to substantial reductions of the cypress aphid (Murphy, 1996).

In Tanzania, some economic incidences of forest insect pests and diseases in forest plantations have been observed. In 1993 the Government partly lost 350,000 m^3 of timber due to infestation by aphid pest in Meru Forest Plantation (O'Kting'ati and Nangawe, 1996). This amount of timber was equivalent to TAS 290 million in lost revenues (Table 2).

Table 2: Volume and value loss caused by Aphid attack at the end of 1992 (In 1992 prices)

Product	Volume '000' m^3	Value mill. TAS
Sawlogs	192.85	212.13
Chiplogs	102.20	75.63
Fuelwood/poles	17.50	1.75
Waste	37.45	-
Total	350.00	289.51

Source: O'Kting'ati and Nangawe (1996)

Overall little has been done in Tanzania to quantify the economic implications of insect pests and diseases on forest plantations. Economic data can be used to secure resources needed to carry out control measures.

2. ECONOMIC IMPLICATIONS

Impacts of attacks/infestations have been observed in the following aspects: death of trees, poor product growth and quality, unplanned harvesting schedule and compensation to consumers.

2.1 Death of trees due to attacks/infestations

For over 50 years now, some forest plantation species at different ages and site classes have been reported to die and the deaths have been dominantly associated with forest insect pests and diseases (Nshubemuki, 1998). In 1986 about 30% of *C. lusitanica* at Meru forest plantations were found to be infested with aphids. When extrapolated to national level the loss of Cypress was estimated to be US$ 0.103 billion (TAS 1.5 billion 1986 values). There after planting of *C. lusitanica* has remained in patches.

2.2 Reduced quality of the product

According to Chamshama *et al.* (2009) most of the forest plantations in the sub-Saharan Africa are characterised by illegal felling, low quality and productivity of the products due to abandonment, poor seed quality and infestations/attacks from pests and diseases. These characteristics lead to reduced quality of the products, and hence their value. Table 3 shows areas affected by insect pests and diseases in various forest plantations. However, information provided by the plantation managers could not allow making an economic analysis of the loss.

Table 3: Areas affected by insect pests and pathogens in some forest plantations in Tanzania

Plantation	Area affected (Ha)	Causal agent/disease	Tree species affected
Ukaguru	4.8	Grasshopper (*Zonocerus variegatus)*	*P. patula*
Shume	700	Cypress aphid	*C. lusitanica*
	40	Pine wooly aphids	*P. patula*
Meru	6	Die back	*Acacia melanoxylon* and *P. patula*
Rongai			
SHFP	575.84	Unidentified	*P. patula*

Sources: SHFP (2010), Masunga (pers. commun. 2010), Angyelile (pers. commun. 2011), FBD (2011), Matunda *et al*. (2010).

2.3 Unplanned harvesting schedule

Unplanned harvesting (accelerated harvesting) refers to harvesting before rotation or after rotation due to economic damage resulting from insects and or diseases. This results into lower quality and value of products. A case in point is the harvesting of 500 ha of *P. patula* at SHFP estimated at 98,411 m^3 due to infestation by Pine woolly aphids in 2005. The lost value of this activity ranged between TAS 12,753,037,500 and 34,688,262,000 (Tables 3 and 4). In addition to these loses, more than US$ 73,315.81 (TAS 95.31 million) was spent for buying chemicals to protect some of the plantation species (SHFP, 2009). The protection was however not timely due to late release of funds for the work.

Table 3: Estimated minimum revenue (TAS) lost since 2005 – 2009 at Sao Hill Forest Plantation due to recurring insect pest infestations

Year	2005	2006	2007	2008	2009	Total collections
Location	Itimbo West (240,000) *600	Matanana and Itimbo West (443,528) *1108.82	Itimbo West and Ilasa (123,768) *309.42	Itimbo West (114,536) *286.34	Itimbo West (98,411) *288.8	
Royalty	480,000,000	887,056,000	247,536,000	229,072,000	196,822,000	2,040,486,000
LMDA	2,400,000,000	4,435,280,000	1,237,680,000	1,145,360,000	984,110,000	10,202,430,000
CESS (5% of royalty)`	24,000,000	44,352,800	12,376,800	11,453,600	9,841,100	102,024,300
VAT (18% of royalty)	86,400,000	159,670,080	44,556,480	41,232,960	35,427,960	367,287,480
Education (2% of royalty)	9,600,000	17,741,120	4,950,720	4,581,440	3,936,440	40,809,720
Total	3,000,000,000	5,544,100,000	1,547,100,000	1,431,700,000	1,230,137,500	12,753,037,500

Note:
- Numbers in parentheses are volumes of wood lost (m^3)
- *Area affected by insect pest (ha)
- Assumed that wood lost came from trees with DBH Class 1 – 21 cm
- Price is 2,000 TAS/m^3 (Financial year 2010/2011)
- LMDA calculated based on 10,000/= TAS/m^3 (rate for soft wood species except *Juniperus procera*)

Table 4: Estimated maximum revenue (TAS) lost since 2005 – 2009 at Sao Hill Forest Plantation due to recurring insect pest infestations

Year Location	2005	2006	2007	2008	2009	Total collections
	Itimbo West (240,000) *600	Matanana and Itimbo West (443,528) *1108.82	Itimbo West and Ilasa (123,768) *309.42	Itimbo West (114,536) *286.34	Itimbo West (98,411) *288.8	
Royalty	4,608,000,000	8,515,737,600	2,376,345,600	2,199,091,200	1,889,491,200	19,588,665,600
LMDA	2,400,000,000	4,435,280,000	1,237,680,000	1,145,360,000	984,110,000	10,202,430,000
CESS (5% of royalty)`	230,400,000	425,786,880	118,817,280	109,954,560	94,474,560	979,433,280
VAT (18% of royalty)	829,440,000	1,532,832,768	427,742,208	395,836,416	340,108,416	3,525,959,808
Education (2% of royalty)	92,160,000	170,314,752	47,526,912	43,981,824	37,789,824	391,773,312
Total	8,160,000,000	15,079,952,000	4,208,112,000	3,894,224,000	3,345,974,000	34,688,262,000

Note: - Numbers in parentheses are volumes of wood lost (m^3)
- *Area affected by insect pest (ha)
- Assumed that wood lost came from trees with DBH Class >35 cm
- Price is 19,200 TAS/m^3 (Financial year 2010/2011)
- LMDA calculated based on 10,000/= TAS/m^3 (rate for soft wood species except *Juniperus procera*)

The economic sustainability of forest plantations depends on fulfillment of a set of conditions; reduced cost of production through achieving economies of scale from improved technical efficiency to lower production prices and increased output; creating effective demand and obtaining attractive prices for plantation - grown wood. The costs incurred to destroy the pests were at the expense of other plantation development activities that were left behind unattended. For example at SHFP there were backlogs of some silvicultural activities that were in the 2010 plan (Table 5).

Table 5: Some of the silvicultural activities carried out in 2010 at Sao Hill Forestry Plantation, Mafinga Iringa

Activities	Target (Ha)	Achievements	Backlog (Ha)
		July – September	
Land preparation	1,329	508.6	820
Weeding	3,431.89	1,013.67	2,418.22
Coppice reduction	207	93.17	113.83
Singling	480.69	50	430.69
Access pruning	584.8	236.5	348.3
Second pruning	222.27	57.5	164.77
		March - April	
Slashing	300	70.5	229.5
Pitting	300	227	73
Replanting	300	227	73
Beating up	30	15	15
Weeding	2,814	70.5	2,744
Pruning	207	70.5	500

Source: SHFP (2010)

2.4 Compensation to consumers due to forest diseases

Heart rot is a disease that affects trees of different ages in the plantation forests. For example it was noted that some of the trees aged 40 years and above in teak plantations have been affected by heart rot. This has been noticed at Mtibwa and Longuza forest plantations. There has been some compensation to buyers of the trees but the economic values were not available (Mchomvu and Katety pers. commun., 2011).

3. CONCLUSION AND RECOMMENDATIONS

Incidences of insects and diseases in forest plantations are increasingly recurring. There is a pronounced amount of revenues loss from the affected trees by the insect pests and diseases in Tanzania. The Government of Tanzania has put some efforts to restrain the destructive insect pests and diseases after occurrence. The money used in this process in most cases comes from other budget lines which make relevant activities unattended. In most of the forest plantations there have been some backlogs of different activities such as silvicultural activities. It is now recommended that:

(i) a separate budget for forest protection be set aside;
(ii) regular record keeping on insect pests and diseases outbreak in forest plantations be mounted;
(iii) development of a national insect pests and disease monitoring and evaluation system; and
(iv) nation wide economic valuation of insect pests and diseases be instituted.

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ANNEXES

ANNEX I: WELCOMING ADDRESS BY MR. EVARIST SABAS, ACTING DIRECTOR GENERAL, TANZANIA FORESTRY RESEARCH INSTITUTE (TAFORI)

The Guest of Honour,

On behalf of TAFORI and SUA, the two organizing institutions of this workshop on forest plantations: insect pests, diseases and soil problems, I wish to welcome you to officiate the event.

The Guest of Honour, We thank you for rescheduling your activities so that you can have time to officiate this occasion. It is also an indication of your commitment to sustainable forestry development in Tanzania.

The Guest of Honour, We also wish to thank FBD for almost totally financing this workshop. In this regard we also thank M. Kagya, for her personal efforts in ensuring that this workshop materialises.

The Guest of Honour, Participants in this workshop are: Forest and Beekeeping Division (FBD) and Forest Plantation Managers, TAFORI, SUA, Tropical Pesticides Research Institute (TPRI) and Tanzania Tree Seed Agency (TTSA). The private sectors involved in Forestry Plantations were invited but have not made it. The organizers have also invited Develoment Link Partiners to facilitate the workshop.

The Guest of Honour, I do not remember when such kind of workshop was convened. This, I think, marks a great opportunity to start up a sustainable monitoring and control of forest pests and diseases, not only in forest plantations but also in natural forests.

The Guest of Honour, Karibu sana ili ufungue warsha hii.
Asante Sana.

ANNEX II: OPENING SPEECH FOR THE FOREST PLANTATIONS INSECT PESTS, DISEASES AND SOIL PROBLEMS WORKSHOP BY DR. FELICIAN KILAHAMA, THE DIRECTOR, FORESTRY AND BEEKEEPING DIVISION (FBD), MNRT.

Invited Guests,

Ladies and Gentlemen,

I have the honour to welcome you all to Kibaha Township at Kibaha Conference Centre. I am sure during these two days you will be busy deliberating on forest plantation insect pests, diseases and soil problems in Tanzania.

I wish to thank the organizers of the workshop (Tanzania Forestry Research Institute and the Faculty of Forestry and Nature Conservation, Sokoine University of Agriculture) for good preparations. This workshop, I understand got its major support from the National Forestry and Beekeeping Programme (NFBKP) under FBD which is financed by the Governemnt of Finland. Further, I wish to thank all other institutions and individuals who in one way or another have given us support.

Ladies and Gentlemen,
The country has long history in forestry plantations dating back to 1890s, with experimental nurseries of various tropical tree species. Industrial forest plantations establishment in the country started between 1920 and 1961, after some years of species and provenance trials. This was so in order to supplement wood supplies from natural forests.

Currently, it is estimated that about 90,000 ha of industrial forest plantations is under public ownership. Meanwhile the area under private sectors is about 60,000 ha. The main species being planted are *Pinus patula, P. caribaea, P. elliottii, Tectona grandis,* and some *Eucalyptus* species such *E. camadulensis, E. tereticornis, E. saligna and E. grandis*. However Technical Order No. 1 of 2003 has widened tree species range and these are now being planted in forest plantations.

Ladies and Gentlemen,
Based on the saw-log rotation age of 25 – 40 years, most of the forest plantations are now in second and third rotation. While planting might be extended to new areas in a few plantations, most of them are replanting in harvested areas. Plantation yield during the first rotation varied from 25 to 35 m^3/ha/yr for pines and cypress and 30 m^3/ha/yr for eucalyptus and 10 m^3/ha/yr for teak The productivity of the second and subsequent rotations will have to be increased many folds to meet the ever increasing demand for wood. This can be achieved by adopting strategies that will increase yield per unit area through adoption of more intensive silvicultural techniques than those adopted in the first rotation.

Ladies and gentlemen,
Just to highlight on the extent of the problem, for more than six decades now, some plantation species at different age and sites have been reported to die and the deaths have been dominantly associated with forest insect pests, diseases and/or soil problems Few examples are highlighted in 2005 in Itimbo West (Sao Hill) where 288.8 ha of *P. patula* with the estimated volume of 98,411 m^3 were affected. In 2009 in Shume Forest Plantation, 700 ha planted with *Cypress* and 40 ha with *Pines* species were affected in patches. In Rongai, 1.5 ha of *P. patula* at the age of ten years were totally affected. In Oldonyo Sambu Range (Meru forest plantation), about 40% of the 14.4 ha planted with *Acacia melanoxylon* and *P. patula* planted between 1999 and 2000 were seriously hit by dieback. Thus, this workshop has come at the right time with an ultimate goal of proposing measures to reduce or eliminate this problem.

Ladies and Gentlemen,
Many stakeholders are involved in one way or another in researching on forest insect pests, diseases and soil problems. These include Government Ministries, Research and Training Institutions, NGOs, Farmers, etc. Just to mention a few, TAFORI, SUA, and Tropical Pesticides Research Institute (TPRI). These institutions need to collaborate and network in combating forest insect pests, diseases and soil problems.

Ladies and Gentlemen,
I am informed that this workshop is comprised of distinguished participants; who have gathered here to:

(i) Get an overview of insect pests, diseases and soil problems in forest plantations in Tanzania;
(ii) Identify affected forest plantations that need immediate attention;
(iii) Develop national insect pests and diseases monitoring and evaluation system (Forest insect pest watch);

(iv) Bring attention to policy makers on the economic implication of forest insect pests, diseases and soil problems;

(v) Establish data base on forest insect pests, diseases and soil problems from already published information; and

(vi) Establish a mechanism for sharing information and updates of the same.

Ladies and Gentlemen,
I am confident that every one of us in this workshop has good, constructive and workable ideas in his/her mind which are important in the development of the subject ahead of us. In the light of the above, we urge you to speak out your constructive ideas openly and transparently. If we all speak out our open and constructive ideas, suggestions and opinions, we shall have a good conclusion on how to control and monitor forest plantation insect pests, diseases and soil challenges in plantations and chart out the way forward.

Invited guests, workshop participants, Ladies and Gentlemen, I wish you all fruitful deliberations, and at this juncture, I declare the forest plantation insect-pests, diseases and soil problems workshop officially opened.

THANK YOU FOR YOUR TIME AND ATTENTION

ANNEX III: CLOSING ADDRESS BY MS. MONICA KAGYA, THE ACTING CHIEF EXECUTIVE, TANZANIA FORESTRY SERVICE (TFS)

Dear colleagues,
Ladies and Gentlemen,

Our two days workshop is drawing to a close. Our great minds have come together here at Kibaha Conference Centre to deliberate on forest plantations insect pests, diseases and soil problems. Definitely, it has been a constructive and historic event which has brought together researchers, academicians, planners, plantation managers, and policy makers in the forestry field.

Ladies and Gentlemen,
In this regard, let me specifically direct my thanks to the following: Workshop organizers, TAFORI and SUA. I extend my sincere gratitudes to participants from: FBD, TAFORI, SUA, Regional Administrative Secretary Coast (Regional Forest Officer), Forest Plantation Managers (Sao Hill, Longuza, Shume, Ruvu and SUATF), TTSA, FTI and TPRI for devoting your valuable time to participate in this historical event.

Ladies and Gentlemen,
In this workshop, one keynote paper and other five technical papers have been presented. We thank paper presenters for devoting their time to develop these presentations. From these papers, it is evident that we have a number of challenges which need to be addressed. Some participants have expressed their views that this should have come earlier. However, better late than never.

Ladies and Gentlemen,
Let me recapitulate the workshop objectives,

(i) Get an overview of insect pests, diseases and soil problems in forest plantations in Tanzania;
(ii) Identify affected forest plantations that need immediate attention;
(iii) Develop national insect pests and diseases monitoring and evaluation system (Forest insect pest watch);
(iv) Bring attention to policy makers on the economic implication of forest insect pests, diseases and soil problems;
(v) Establish data base on forest insect pests, diseases and soil problems from already published information; and
(vi) Establish a mechanism for sharing information and updates of the same.

Ladies and Gentlemen,
To realize workshop objectives, distinguished participants, I am told you had four working groups which were working on priority areas which you jointly developed. These groups were (i) Resource and capacity building, (ii) Research, (iii) Surveillance, monitoring and evaluation and (iv) Knowledge management, information sharing and networking, on forest insects pests, diseases and soil problems. Your deliberation in these groups is the key inputs to overall workshop objectives.

Although we have come to an end of this workshop, we are convinced that the process is continuous and that we shall continue to work hand in hand with you all.

Ladies and Gentlemen,
We need to ensure that the outputs from this workshop are pursued to their logical conclusion. In this regard, I ask TAFORI, SUA and FBD – perhaps a few representatives from these institutions to see to it that the recommendations from this workshop are implemented. My commitment to see this happen is as strong as ever.

Ladies and Gentlemen,
I wish at this juncture to thank the major support from the National Forestry and Beekeeping Programme (NFBKP) under FBD which is financed by the Governemnt of Finland. Further, I wish to thank TAFORI and SUA for commiting their resources to this workshop. Last but not least I thank all individuals who in one way or another have given us support to this workshop.

Ladies and Gentlemen,
The venue of our workshop has been the Kibaha Conference Centre. It is now opportune to thank the management and staff of this facility for logistical and other forms of support. Our stay has been trouble free and to this we say thank you very much**.** Soon after this session workshop delegates will travel to their respective work stations. I wish you safe travel.

Ladies and Gentlemen,
Having said that it is now my duty to declare that: the first historic forest plantations insect pests, diseases and soil problems workshop is officially closed.

I THANK YOU ALL FOR YOUR TIME

ANNEX IV: WORKSHOP DELIBERATIONS

The following are the workshop deliberations with regard to forest plantation insect pests, diseases and soil problems in Tanzania.

1. Resources and capacity building

(a) Priority training needs

Institute	Current strength			Proposed requirements			
SUA	PhD	MSc	BSc	PhD	MSc	BSc	Dip./Cert.
Entomologists	1**	0	0	1			
Pathologist	0	0	0	1			
Soil scientists	1**	0	0	1			
Soil Technicians	1	1	1				
Entomology technicians	0	0	0			1	
Pathology technicians	0	0	0			1	
TAFORI							
Entomologists	0	1	0	8			
Pathologists	0	1	0	8			
Soil scientists	0	0	0	8			
Soil technicians	0	0	0			8	
Entomology technicians	0	0	0			8	
Pathology technicians	0	0	0			8	
OLMOTONYI							
Entomologist	0	0	0		1		
Pathologist	0	0	0		1		
Soil scientists	0	1	0		1		
Soil technicians							1
Entomology technician							1
Pathology technician							1
FBD							
Entomologist	1	0	0				
Pathologist	0	0	0		(1)		
Soil scientist	0	0	0				
Soil Technicians	0	0	0				

Note: * The group felt that as for now we did not look at the district and regional levels.
** They are about to retire.
( ) Forest Protection Officer. He/she can be of any profession.

(b) Key resources

(i) Infrastructure requirement

Institute	Available facilities	Requirement	Number	Cost TAS (mil.)
SUA	Soil laboratory	Pathology laboratory	1	168
		Entomology laboratory	1	168
TAFORI		Soil laboratory	1	168
		Pathology laboratory	1	168
		Entomology laboratory	1	168
		Total costs		**840**

Note Construction of 200 m^2 lab. Cost = 600,000/m^2, equipments 25% and furniture 15% of construction cost.

(ii) Training

Level of training	Number	Unit cost (mil. TAS)	Total (mil.TAS)	
PhD	27	50	1350	
MSc	4	20	80	
BSc/Dip/Cert	29	10	290	(Short courses)
	Total		**1720**	

(iii) Potential funding sources

i. Central Government through Ministry of Natural Resources and Tourism and Commission for Science and Technology (COSTECH);
ii. Tanzania Forest Fund (TFF);
iii. Tanzania Forest Services (TFS); and
iv. Development partners.

2. Research

A lot of researches have been done:

(i) But most of them are for academic use which does not solve the problem;
(ii) They are fragmented/scant;
(iii) They are also donor driven; and
(iv) They cannot assist to make any sound decision.

Category	Research Areas	Responsible Institutions
Short term	1. Determine factors which trigger insect pests and diseases outbreak for specific insects, diseases and locality 2. Determination of status and effectiveness of natural enemies 3. Carrying out periodic assessment to determine tolerable economic threshold 4. Use of indigenous knowledge on the control of forest insect pests, diseases and soil problems.	TAFORI, SUA TPRI, OTHER UNIVERSITIES
Medium term	1. Develop prediction models for forest pests, diseases and soil problems 2. Assess the effects/impact of climate change on insects and diseases outbreak 3. Assessment of economic and ecological effect/impact of insect pests, diseases in forest plantations	
Long term	1. Determine insects pests and diseases incidences in relation to soil conditions in subsequent rotations 2. Identify and breed insect pests and diseases resistant trees 3. Develop database on insects pests and diseases in the country 4. Develop IPM programmes	

3. Surveillance, monitoring and evaluation of forest insect pests and diseases

(a) Key issues in the state of art:

(i) Surveillance and monitoring are not regularly done (i.e. not linked directly to causative factors);
(ii) Evaluation is not timely conducted; and
(iii) Lack of geo-referenced information on occurrence of forest insect pests and diseases.

(b) Strategies on effective and efficient forest insect pests and diseases surveillance

(i) Basic knowledge should be developed to support surveillance of forest insect pests and diseases (sampling, detection and identification);
(ii) Site specific orientation of new staff is important;
(iii) Surveillance should be synchronized with other forest activities;
(iv) Use of information from other specialized agents e.g. Tanzania Meteorological Agency (TMA) and other related establishments including use of internet; and
(v) Develop surveillance protocols (like tools, digitisation, adapting of existing tools).

(c) Strategies on effective and efficient forest insect pests and diseases monitoring and evaluation:

(i) Information of past insect pests/diseases incidences and instituted control measures should be amalgamated;
(ii) Following the detection of forest maladies, information (standardized) should be shared among stakeholders through appropriate network; and
(iii) Control effectiveness:
  - To account for costs incurred in combating insect pests, diseases and soil problems; and
  - To account for the extent of damages if no action was taken.

4. Knowledge management, information sharing and networking

(a) State of art:

(i) At FBD there is no unit to coordinate issues regarding insect pests, diseases and soil problems and their control;
(ii) Available information regarding the above is fragmented;
(iii) Weak collaboration between research institutions, plantation managers and practitioners;

(iv) No structured template for collecting and reporting information regarding insect pests, diseases and soil problems;
(v) Weak networking mechanism between research and academic institutions regarding information sharing; and
(vi) Existence of NAFOBEDA at FBD is an opportunity.

(b) Strategies:
(i) At FBD, establish a Schedule Office under ADRTS to deal with forest health issues (invasive plant species, insect pests, diseases, soil problems and forest fire and their control);
(ii) To strengthen NAFOBEDA at FBD in order to capture information regarding invasive plant species, insect pests, diseases and soil problems;
(iii) To encourage proactive cooperation between all stakeholders in sustainable forest management;
(iv) Develop a format for collecting and reporting information regarding insect pest, diseases and soil problems;
(v) To establish a National Forest Health Forum (NFHF) to be coordinated electronically; and
(vi) FBD and TAFORI to revive annual scientific meetings where forest health issues will be discussed.

ANNEX V: LIST OF WORKSHOP PARTICIPANTS

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