A PLATFORM FOR STAKEHOLDERS IN AFRICAN FORESTRY

THE STATUS AND TRENDS OF FOREST AND TREE PESTS AND DISEASES MANAGEMENT IN AFRICA

African Forest Forum Working Paper Series

VOLUME 3

ISSUE 1, 2017

The status and trends of forest and tree pests and diseases management in Africa

Mercy Gichora

Harrison Kojwang'

Paul Bosu

African Forest Forum (AFF)

P.O. Box 30677-00100, Nairobi, Kenya.
Phone: +254 20 722 4203
Fax: +254 20 722 4001
Email: exec.sec@afforum.org;
Website: www.afforum.org

Citation: Gichora, M., Kojwang', H.,& Bosu, P. (2017). The status and trends of forest and tree pests and diseases management in Africa. AFF Working Paper (3) 3. African Forest Forum,Nairobi.

Cover Photograph: Left: Suspected blue gum chalcid, Leptocybe invasa, galls on young Eucalyptus plants in Niger. Right: Vigorously growing Cedrela odorata pushes stem borer following attack. (Photograph: Bosu, 2016).

Table of Contents

List of figures

List of boxes

List of tables

ACRONYMS/ABBREVIATIONS

AfDB	African Development Bank
AFF	African Forest Forum
AMCEN	African Ministerial Conference on Environment
AMU	Arab Maghreb Union
AU	African Union
AUC	African Union Commission
BGC	Blue Gum Chalcid
CABI	Centre for Agriculture and Bioscience International
CEMAC	Economic and Monetary Union of Central Africa
CEN-SAD	Community of Sahel-Saharan States
CFA	African Financial Community
CFTA	Continental Free Trade Area
CIDA	Canadian International Development Agency
COI	Cytochrome oxidase I (mitochondrial gene)
COMESA	Common Market for Eastern and Southern Africa
COPE	Centre of Phytosanitary Excellence
CPM	Commission on Phytosanitary Measures
DRC	Democratic Republic of Congo
EAC	East African Community
EC	European Commission
ECA	Economic Commission for Africa
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EPPO	European Plant Protection Organization
FABI	Forestry and Agricultural Biotechnology Institute
FAO	Food and Agriculture Organization
FISNA	Forest Invasive Species Network for Africa
FNC	Forests National Corporation
FRA	Forest Resources Assessment
GDP	Gross Domestic Product

GGWSSI	Great Green Wall of the Sahara and Sahel Initiative
IAPSC	Inter African Phytosanitary Council
ICIPE	International Centre of Insect Physiology and Ecology
IDA	International Development Association
IDRC	International Development Research Centre
IGAD	Inter Governmental Authority on Development
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
IPPO	International Plant Protection Organization
ISPM	International Standard on Phytosanitary Measure
IUFRO	International Union of Forestry Research Organizations
MedPO	Mediterranean Programme Office (of WWF)
MLB	Mycosphaerella Leaf Blotch
NEPAD	New Partnership for Africa's Development
NEPPO	Near Eastern Plant Protection Organization
NPPO	National Plant Protection Organization
OAU	Organization of African Unity
ODA	Official Development Assistance
PRA	Pest Risk Analysis
RPPO	Regional Plant Protection Organization
SACU	Southern African Customs Union
SADC	Southern African Development Community
SFE	Subregional Office for Eastern Africa (of FAO)
SPS	Sanitary and Phtyosanitary
TFTA	Tripartite Free Trade Area Agreement
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNSO	The United Nations Sahelian Office
WAEMU	West African Economic and Monetary Union
WTO	World Trade Organization
WWF	World Wildlife Fund

1.0 INTRODUCTION

1.1 Purpose of the report

This synthesis report is based on three recent forest health studies commissioned by the African Forest Forum (AFF) in Eastern, Southern, and West and Central Africa (Bosu, 2016; Gichora, 2016; Kojwang, 2015) as well as literature reviews on the subject of management of forest pests and diseases in the North of the continent. It highlights the following:

a) Inventory of forest and tree pests and diseases in Africa including current trends and drivers;

b) The impact of the identified pests and diseases on forest production and products at all levels (farm, natural and plantation forests, and transboundary forest areas) and their economic implications including gender considerations;

c) Appropriate protocols for the surveillance of pests and diseases and recommend ways for their implementation at national and regional levels; and,

d) Assessment of and propose modalities (including policies, laws and institutional capacity), for facilitating the development of mechanisms and actions for surveillance of forest and trees pest and disease prevalence.

1.1. Short history of modern forest practice and disease-pest problems in Africa

1.2.1 Sub- Saharan Africa

In much of sub-Saharan Africa, the focus on diseases and pests in modern forestry practice originates in the colonial era and particularly in the early part of the 20th Century when the development of industrial forest plantations was initiated to create sustainably managed forestsin response to rapid depletion of natural forests (Kojwang, 2015). It is in this context that industrial plantations using mainly exotic conifer species were established in much of eastern, southern and parts of West Africa. In southern Africa, plantations were established in countries such as Angola, Malawi, South Africa, Swaziland, Zambia and Zimbabwe. In many of these countries planted forest estates were well over 100 000 hectares. South Africa has by far the largest planted forest area, currently standing at 1.35 million hectares (Forestry South Africa, 2014). By their sheer sizes, the plantations represent significant investments of public resources, though in South Africa they are largely privately owned. Any pests and diseases that could impede growth increment and/or lower quality and volumes of wood are of economic importance and thus need to be addressed. In e ffect, the development of forest protection as a sub-discipline of forestry practice in southern Africa was ushered in by the growth of industrial plantations in the 1930's (Kojwang, 2009; Roux et al., 2005).

In natural forests there are also disease and pest problems which are often overlooked but their cumulative effect is timber degradation. Some examples are heart rots and insect damage that reduce harvestable timber volumes and also lower its quality (Nsolomo and Venn, 2000; Ryvarden, 1980). While conventional knowledge has suggested that heart rots and decay fungi of standing trees gain entry at later stages in living trees, recent evidence of the latency of some species in living sapwood is surprising (Parfitt et al., 2010).

Diseases and pests of trees in Africa and other parts of the world have been recognized mainly in situations in which they cause economic losses, whether in commercially exploited natural stands or in plantations such as those in South Africa (Ciesla, 1994; Gibson, 1964; Zwolinski et al., 1990). In addition, trees planted on farm woodlots and urban spaces have also at times succumbed to diseases and pests. In natural forests, decay fungi associated with 'heart rots' andboring insects such as bark beetles which degrade wood are the most common concerns (Nsolomo and Venn, 2000). In eastern and southern Africa, the bulk of diseases are those that affect plantations of exotic species such as pines, cypress and eucalypts. In this regard, historical examples of plantation diseases that were recorded with the advent of plantation forestry using exotic tree species include Dothistroma needle blight and Diplodia die back on pines, cankers of cypress and Armillaria root rot (Gibson, 1972; Heath and Wingfield, 2005; Roux et al., 2005).

With respect to pests, indigenous defoliators at times have switched hosts to attack exotic species. Gonometa podocarpi, a native caterpillar of eastern Africa, is one such example that effectively curtailed the propagation of Eucalyptus globulus as a plantation species in Kenya. In addition, in the 1980s and 1990s, sap-sucking exotic pine woolly and cypress aphids were detected in both eastern and southern Africa (Heath and Wingfield, 2005). In 1994, the Sirex Woodwasp (Sirex noctilio) invaded South Africa, a worrying development because it is associated with a fungus, Amylostereum areolatum, which causes direct tree mortality in pines (Hurley, 2007, Slippers et al., 2015). A biological control programme has been successfully developed for managing it (Slippers et al., 2015).These are examples of pests and diseases of trees, their detection and control, particularly winged pests and vectors and aerially dispersed diseases which often require cross-border cooperation. They also illustrate that pests and diseases can be transmitted or dispersed through movement of traded forest products.

1.2.2 The Sahel

This is a transitional ecoregion of semi-arid grasslands, savannas, and thorn shrub lands lying between the wooded Sudanian savanna to the south and the arid Sahara to the north. The countries of the Sahel today include Senegal, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan and Eritrea (www ref. 1). In this study of forest pests and diseases in Africa, the region received in-depth review by assessing the situation in Sudan in eastern Africa and Niger in West Africa.

The most serious tree pest problem in the Sahel region in recent memory has been the outbreak of the oriental yellow scale insect, Aonidiella orientalis on neem (Azadirachta indica). The outbreak was particularly serious in countries within the so-called Lake Chad Basin, which includes Cameroon, Chad, Niger and Nigeria (Lale, 1988). The emergence of this insect in Africa is a classic example of an introduced invasive pest with serious consequences. It is believed to have originated from India, South East Asia or China, and was first recorded in the northern part of Cameroon in 1985. A few years later, its distribution covered over one million km^2, causing significant damage to neem trees. In Niger and several other countries in the Sahel region where neem is a very important tree species, the impact of the scale insect was quite significant. Attack is followed by premature browning which frequently leads to death of leaves on some or all of the branches of the affected tree (Bosu, 2016).

1.2.3 North Africa

The Mediterranean Woodland and Forest ecoregion includes the lowlands and mid-elevations of the northern half of Morocco, Algeria and Tunisia, and two Spanish sovereign areas, Ceuta and Melilla, located in Morocco. An additional, isolated portion of the ecoregion is located in the Cyrenaic Peninsula of Libya (Jebel al Akhdar). Coastal plains characterize this ecoregion in the northern half of the Atlantic coast of Morocco and on the eastern coast of Tunisia. Hilly land, valleys and plateaus alternate in the hinterland (www ref. 2).

The International Union of Forestry Research Organizations (IUFRO) pays attention to global forest health and management of risks arising from natural hazards in general (www ref. 3). Two IUFRO divisions and several of its working parties supplement efforts by other institutions and bring together experts specialized in forest environment, entomology, pathology, air pollution and forest biodiversity to collaborate in research and report their work at global level. IUFRO Division 7.00.00 on forest health thus covers pathology (7.02.00) and entomology (7.03.00) initiatives. A Working Party exists under this Division to specifically pursue entomological research in Mediterranean forest ecosystems (WP 7.03.14). From proceedings of its meetings, there have been recent updates of the situation regarding forest pests and diseases in North Africa. Research findings suggest that if the current density of alien species arriving on imported plants and wood packaging material will continue, then increasing international trade with Europe is likely lead to more establishments of exotic wood boring beetles with concomitant negative effects on forest health, mainly in Mediterranean countries (www ref. 4).

1.2.4 Forest insect management

FAO (2001) reviewed the pests which occur in plantations and proposed management options. Occurrence and management options for pests of conifer trees in exotic plantations in eastern and southern Africa were specifically addressed by FAO (1991). Pineus pini (Macquart) was the first conifer aphid recorded in 1968 in Kenya on Pinus caribaea grafted material imported from Australia. The pine needle aphid, Eulachnus rileyi (Williams), a less common exotic aphid pest found in pine forests was first recorded in the Mt. Elgon forest in 1988. Cinara cupressivora is a sap-sucking insect that attacks trees in the Cupressaceae family and causes major damage to cypress plantations and hedges. It was first detected on the continent in Malawi in 1986 and subsequently in other parts of Africa, including Tanzania, Burundi, Rwanda, Uganda, Kenya, DRC, Zimbabwe, South Africa, Libya and Morocco. The presence of cypress aphid in Ethiopia was first reported in 2003 and brought under biological control by 2009 (FAO SFE, undated).

Indigenous pests sometimes switch hosts to attack exotic trees. This is the case for Gonometa podocarpi Aur. (Lepidoptera: Lasiocampidae), a well-studied forest pest in eastern Africa (Okelo, 1972). During its larval stage, it causes serious defoliation of conifers, in addition to attacking the leaves of many dicotyledons. Acacia lahai, A. mearnsii, Cupressus benthamii, C. lusitanica, Eucalyptus regnans, Juniperus procera, Pinus halepensis, P. leiophylla, P. montezumae, P. patula, P. radiata, and Podocarpus gracilior are among its various hosts. It was first reported as a pest in 1925 on Podocarpus sp. in the Mt. Kenya region and in later years caused other outbreaks in the Mt. Elgon area on Pinus sp. Fortunately, eggs of G. podocarpi are parasitized by a Hymenopteron of the family Eupelmidae, belonging to the genus Anastus, the only known parasite of G. podocarpi eggs. Adult Anastus parasites usually emerge from the attacked eggs and as such, the eggs do not hatch. The larvae of G. podocarpi are fatally parasitized by a number of insects, the most common of which are the Hymenopterans Meteorus trilineatus Cam (Braconidae) and Pimpla mahalensis Grib (Ichneumonidae), and the Dipteran Sturmia gilvoides Curran (Tachinidae). Most of the parasitized larvae die, and, although a few may go into pupal stage, these too die and do not emerge as moths.

In addition to the parasites, a non-inclusion-type virus is an important disease of G. podocarpi larvae in the fourth and fifth instars. Parasites and viruses offer options for biological control of the pest (Okelo, 1972).

1.3 Types of vegetation found in Africa

This report on the status of tree and forest pests and diseases in Africa examines this situation further and in the context of sustainable forest management. It considers the unique features of different types of forests found on the continent which include montane, plantation, woodland, mangrove forests and trees which are conserved or planted on farmland. See Figure 1.1.

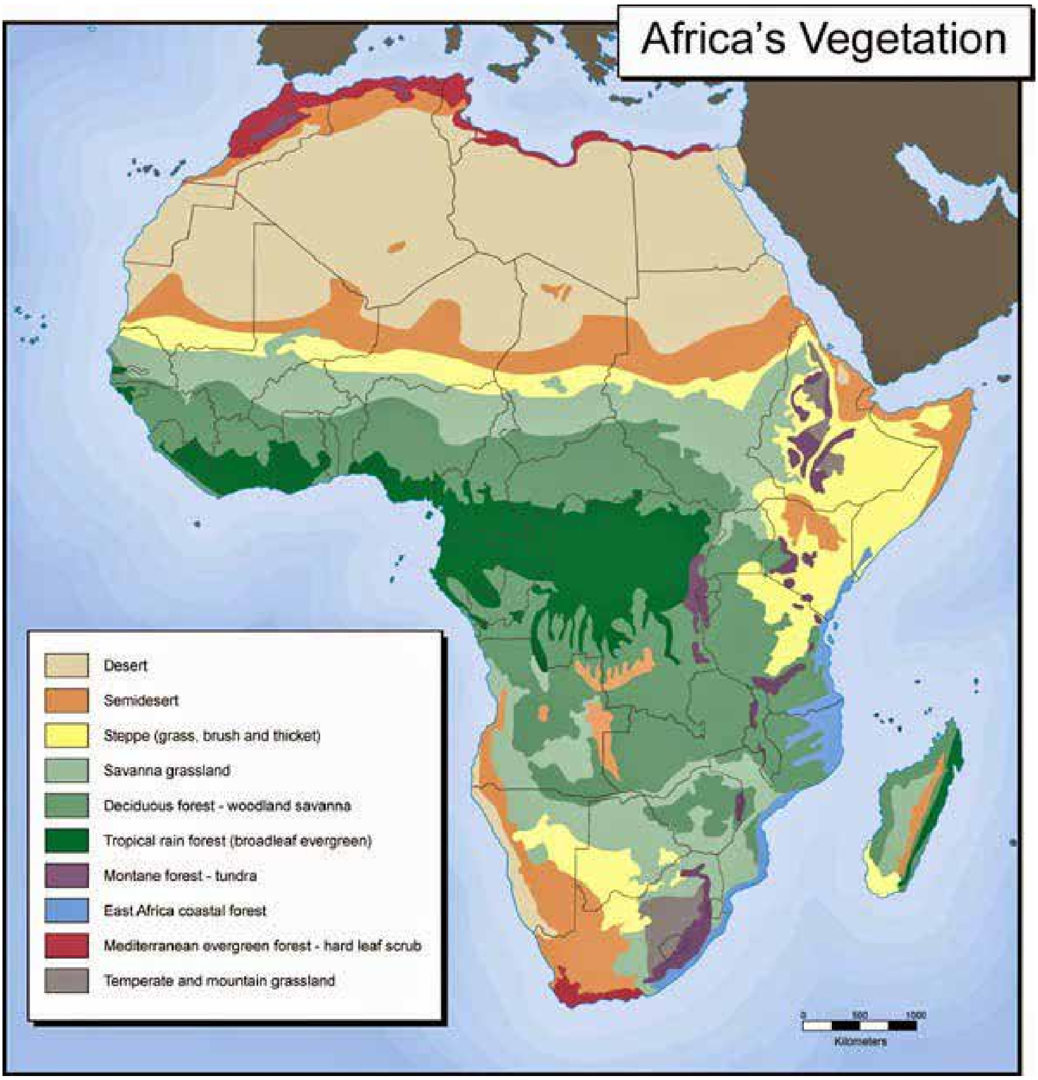

Figure 1.1 Vegetation map of Africa.

Miombo woodlands, which span wide areas of western, central and southeastern Tanzania as well as parts of Zambia, Zimbabwe, Mozambique and Malawi, are prone to fires. In East and Central Africa, the woodlands can be divided into dry and wet types (Abdallah and Monela, 2007). The dry miombo woodlands occur in areas receiving less than 1000 mm rainfall annually. They occur in Zimbabwe, central Tanzania, and the southern areas of Mozambique, Malawi and Zambia. Canopy height is less than 15 m and the vegetation is floristically impoverished.

The wet miombo woodlands occur in areas receiving more than 1000 mm rainfall per year and these are found in eastern Angola, northern Zambia, south western Tanzania and central Malawi. Canopy height is usually greater than 15 m reflecting generally deeper and moister soils, which create favorable conditions for growth. The vegetation is floristically rich. The present day distribution of miombo reflects its history, particularly past climatic changes and past and present human activities. Vegetation is dominated by trees belonging to the family Caesalpiniaceae, characterized by Brachystegia and Julbernardia species and change in form can vary from woodland savannas to savanna woodlands depending on land drainage. More than 50% of woodlands have been converted into agricultural use. The woodlands are thus under increasing human population pressure and are managed by using fires to remove the woody vegetation. A summary of the regions covered, and forest types of interest, is provided in Table 1.1.

Table 1.1 A summary of the regions covered and forest types of interest to this study

Region	Countries	Forest types of interest
North Africa	Algeria, Libya, Mauritania, Morocco, Egypt and Tunisia	The Mediterranean woodland and forest ecoregion: vegetation comprises of holm oak forests, cork oak forests, wild olive and carob woodlands, as well as extensive Berber thuya forest.
West and Central Africa	Ghana, Nigeria, Niger, Senegal, Gabon, DRC, Burundi, Cameroon, Central African Republic, Chad, Eq. Guinea, Rwanda, Sao Tome and Principe, Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, the Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Sierra Leone and Togo	Humid-zone forests and other wooded lands in many Sahelian countries, Plantations of exotic and indigenous trees
Southern Africa	Mozambique, South Africa, Zambia, Zimbabwe. Malawi, Swaziland, Angola, Botswana, Lesotho and Namibia	Forest plantations of exotic trees, miombo woodlands
Eastern Africa	The Comoros, Djibouti, Eritrea, Ethiopia, Rwanda, Burundi, Madagascar, Mauritius, Seychelles, Somalia, Kenya, Tanzania, Uganda, Sudan and South Sudan	(i) highlands/montane forest belt, (ii) mid-elevation Lake Victoria basin, (iii) Miombo woodlands of Tanzania, (iv) mangrove forests along the Indian Ocean coast, (v) extensive arid and semi-arid lands which cover the bulk of Djibouti, Eritrea, Somalia and Kenya, and (vi) tropical forests on the islands of Madagascar and, to a lesser extent, the Comoros

2.0 OCCURRENCE, DISTRIBUTION AND MANAGEMENT OF FOREST PESTS IN AFRICA

The situation regarding occurrence, distribution and management of forest insect pests on the African continent was described in detail by FAO (2009). Defoliators were mentioned as the most common problem in the belt of natural forest running across northern and central Africa. Research on forest pests was limited but the main problems encountered in West Africa, which remain unsolved to date, are the mahogany shoot borer, Hypsipyla robusta, and the iroko gall louse, Phytolyma lata, as well as ambrosia beetles. They are managed mainly using silvicultural methods, but action soon becomes limited owing to economic considerations. In eastern Africa, the review covered Kenya, Uganda and Tanzania, and, to a lesser extent, Zambia and Malawi. As in West Africa, a major problem of shoot borers of indigenous hardwoods caused by Hypsipyla spp. was reported but, more importantly, Lamiid beetles of the subfamily Tragocephalini were of significant concern. A cerambycid, Oemida gahani, was a major pest of exotic cypress plantations. Ambrosia beetles were also important pests. Despite large areas of exotic plantations of conifers and Eucalyptus spp., only minor outbreaks of defoliators had been observed by then. Surveys were directed mainly against borers and defoliators of plantations, while research was concentrated on Oemida, termites and ambrosia beetles.

The situation in southern Africa was slightly different in that the principal insect pests were associated with exotic forests, consisting mainly of conifers, but also eucalypts, black wattles, and poplars. It was noted that the many forest districts were widely separated and, with the exception of black wattles and some eucalypts, insect attack was not continuous and rarely severe. The indigenous bagworm was the most serious pest of black wattle and it was sometimes necessary to resort to aerial spraying to prevent severe defoliation. An introduced curculionid had been brought under control on eucalypts by the introduction of a parasite from southern Australia. There were records of Sirex wood wasp having been intercepted in South Africa, but it was by then not found in living forests.

Except for a few introduced species, forest insects attacking exotic plantations in southern Africa at the time were indigenous (FAO, 2009). Some foreign species of insects had been found in plantations of exotics. The danger of introducing foreign pests into South Africa was appreciated and a policy of prohibiting entry of trees was rigidly enforced to prevent it. Continuing surveys of plantations to locate new introductions or outbreaks was considered to be most important approach. On the international scene, exchange of information on problems of a similar nature was encouraged.

An invasive insect reported on Eucalyptus is Thaumastocoris peregrinus (Hemiptera: Thaumastocoridae), the winter bronze bug. It is a serious sap-sucking insect pest infesting non- native Eucalyptus plantations in Southern Africa, South America and Europe (www ref. 5). Severe infestations of this sap sucking pest result in leaf senescence, leaf loss, thinning tree canopies and, during severe infestations, branch dieback. A current host range of over 30 Eucalyptus species and hybrids, and its ability to survive in a variety of climatic regions, has aided the invasive success of this small insect pest. T. peregrinus is native to Australia, where very little was known about it before 2002, when very high infestation levels occurred on street and garden-planted eucalypt trees in the Sydney region. Since its initial discovery in South Africa in 2003 and Argentina in 2005, this pest has both established itself and rapidly spread into neighboring countries in southern Africa, South America and southern Europe, where the most recent outbreak and pest establishment have been found. The current situation in different regions of Africa has been reviewed based on recent studies by Gichora (2016), Bosu (2016) and Kojwang (2015) and literature available on North Africa.

2.1 Pests of Southern Africa sub region

A comprehensive list of all types of pests that occur in southern Africa are listed and described by Roux et al. (2012) and in many other scientific publications which concentrate on the biology and management of specific types (Kojwang, 2015). Complex patterns in spreading of invasive species have also been reported by Garnas et al. (2015) who advocate for understanding this in a global context. They present, for example, the case of Gonipterus scutellantus (the Eucalyptus Weevil) whose management for many years was based on the assumption that only one species was involved. When further investigated, at least three distinct species have been found with two species co-occurring in some regions without the knowledge of the practitioners managing the pest.

Table 2.1 contains a list of eleven pests which are prioritized as the most economically important in the southern African region. The table also provides brief descriptions on the type of damage caused by each pest and the countries in Southern Africa in which occurrence has been recorded.

Table 2.1 Priority pests of commercial tree species in southern Africa (Kojwang, 2015).

Pest	Host Species	Nature of Damage	Distribution (Reported)
Deodar Weevil	*Pinus* spp.	Feeds on tips, kills shoots, causes	
Pissodes nemorensis		forking and branching, tree mortality	
Sirex Woodwasp	*Pinus* spp.	Wilting and mortality	South Africa,
Sirex noctilio			Swaziland
Bronze Bug	*Eucalyptus*	Canopy reddening, yellowing and	Mozambique,
Thaumastocoris	spp. &	browning	South Africa,
peregrinus	hybrids	Canopy thinning and branch dieback	Swaziland
			Zimbabwe
Blue gum chalcid	*Eucalyptus*	Galls on leaf mid-ribs, petioles and	South Africa,
(wasp)	spp. &	stems, leaf curling, stems	Swaziland
Leptocybe invasa	hybrids	deformations, stunting and occasional	Mozambique,
		mortality in small trees	Zimbabwe
Red gum lerp psyllid –	*Eucalyptus*	Waxy secretions and honey dew,	South Africa
sap sucking insect	spp. &	drooping leaves and drying of leading	Swaziland

Pest	Host Species	Nature of Damage	Distribution (Reported)
Glycaspis	hybrids	shoots, defoliation and even mortality	Malawi
brimblecombei			Mozambique
			Zimbabwe
Eucalyptus weevil /	*Eucalyptus*	Feeds on foliage and young shoots –	Mauritius
Snout beetle	*dunnii, E.*	causing stunting and mortality in	Mozambique
Gonipterus species	*smithii*, and	severe cases	Malawi
	hybrids		South Africa
			Swaziland
			Zimbabwe
Shell lerp psyllid	*Eucalyptus*	Brown sea shell-like lerp and reddish	South Africa
Spondyliaspsis c.f.	spp.	brown foliage lesions	
pliocatuloides			
Eucalyptus gall wasp	*Eucalyptus*	Small green to reddish blister like	South Africa,
Ophelimus maskelelli	spp.	galls on leaves, premature leaf fall	Zimbabwe
		with heavy galling	

Reports of pests occurring on trees that are popular in several countries are an indication that prompt action is necessary to monitor and contain spread on individual country basis. One of the most expensive and successful introduced pest management programmes in South African forestry history involved the Sirex Wood Wasp. In general, improving tree vigour through silvicultural thinning to reduce competition and availability of suppressed trees is recommended together with the application of biological control agents (Slippers et al., 2015).The main biological control agents are Deladenus siridicola and Ibalia leucospoides.

2.2. Pests of West and Central Africa sub-region

2 .2.1 Endemic Pests of Trees and Forests in the Humid Zone

Indigenous tree species with endemic pest problems in the humid forest zone include Iroko(Milicia excelsa and M. regia), African mahogany (Khaya and Entandrophragma spp), Afrormosia (Pericopsis elata), Obeche (Triplochiton scleroxylon), Opepe (Nauclea diderrichii), and Terminalia ivorensis (see Appendix 1). Endemic pest problems of these high- value indigenous timber species generally account for the persistent failure in their performance in plantations in the sub region.

Iroko suffers severe attacks from the Iroko gall maker Phytolyma spp. (Homoptera: Psyllidae) throughout the region and beyond, as far away as Tanzania and parts of East Africa (Wagner et. al., 2008). This pest attacks Milicia in Ghana and westward through Cote d'Ivoire to Senegal. Other species of Phytolyma namely P. fusca and P. tuberculata attack M. regia in Ghana, and eastward through Togo, Nigeria and Cameroon, and all the way to Tanzania.

All life stages of the tree are attacked but seedlings and actively growing saplings in young plantations are most preferred, often resulting in total failure.

Another serious pest of regional and global significance is the mahogany shoot borer, Hypsypyla robusta (Lepidoptera: Pyralidae). It attacks species of the Meliaceae family in Africa, especially African mahogany (Khaya and Entandrophragma). Planting of mahogany faces major challenges in Ghana, Nigeria, Cameroon, Togo and Cote d'Ivoire. Shoot borer attack on mahogany often results in damage and deformation and sometimes death of plants at the nursery stage and in young plantations. Other important endemic pests include Lamprosema lateritialis (Lepidoptera: Pyralidae) on Pericopsis elata (Afrormosia), Orygmophora mediofoveata (Lepidoptera: Noctuidae) on Nauclea diderrichii (Opepe/Kusia) and Anafe venata (Lepidoptera: Notodontidae) on Triplochiton scleroxylon (Obeche/Wawa).The insects described above usually occur on host trees in natural forest stands where their presence is hardly noticeable and impact on tree survival and growth is almost insignificant. As a result, insect pest outbreaks are rare in natural forest stands in the humid/closed forest zone. From related literature at least one major pest outbreak has been recorded in a natural forest stand in the humid forest zone (Sidibe, 2009). In late 2009 to 2010, an outbreak of Achaea catacoloides (Lepidoptera: Erebidae) occurred in Liberia, Sierra Leone and Guinea, with devastating environmental and socioeconomic effects on forests and agriculture (Bosu, 2016).

2 .2.2 Major Insect Pests of Exotic Species in the Humid Forest Zone

In addition to the problems encountered on indigenous species, introduced or exotic species such as Gmelina arborea, Cedrela odorata, Tectona grandis and various Eucalyptus species which are widely planted in the sub region often succumb to insect pest attacks. In the humid forest zone, G. arborea suffers from severe attack by Achaea and Apophylia species. Records show that this resulted in significant damage in Nigeria in the past (Louppe, 2008).Teak (Tectona grandis) and Cedrela (Cedrela odorata) are perhaps the most commonly planted species in the humid zone of West Africa and occur in Ghana, Togo, Nigeria and Cote d'Ivoire. The two species do not have serious problems with insect pests, except for sporadic attacks by some generalist insects. In Ghana, outbreaks of the wood borer Apate terebrans during the dry season are of some concern to tree growers. Several such outbreaks were reported in 2004 and 2005. However, no significant economic damage was recorded. The attack is characterized by multiple boring of the stem, reducing the quality of poles or wood. In heavy infestations, trees may die.

In young plantations, defoliation by the variegated grasshopper Zonocerus variegatus is visible in plantations in the forest zone but attacks appear to have very little impact on plant growth as the trees usually recover over time. Cedrela also suffers attacks from another species of Apate (A. monachus) and other bark borers, especially when the trees are under stress. Unlike teak, however, Cedrela often responds to borer attack by exuding sap which pushes out the invading insects often killing them (see Figure 2.1). This has been observed in various plantations in Ghana, including the Afram Headwaters, Anhwiaso South and Worobong South forest reserves.

2.2.3 Major Insect Pests of the Savanna and Sahel Zones

As in the humid forest zone, incidences of pests in the woodlands are uncommon, except perhaps the routine outbreak of the desert locust (Shistocerca gregaria) in the Sahel zone that is a major problem on agricultural crops. It also affects tree species in the savannah region such as neem (Azadirachta indica), Terminalia mantaly, T. catappa and Eucalyptus spp. Nearly all of these are commonly planted in towns and cities in the humid zone. Terminalia mentalis grows very vigorously and is the tree of choice in most cities for shade and avenue planting. Terminalia species rarely suffer attacks from pests and diseases except for occasional infestation by generalist stem and bark borers. Damage inflicted by borers becomes conspicuous and makes the trees unattractive which may necessitate prompt pest control intervention or outright removal.

The most serious tree pest problem in the Sahel region is of the yellow oriental scale insect Aonidiella orientalis (Hemiptera: Diaspididae) on neem, an introduced invasive pest believed to have originated from India, South East Asia or China, and was first recorded in the northern part of Cameroon in 1985. Within a few years, its distribution covered over one million km^2, causing significant damage to neem trees. In Niger and several other countries in the Sahel region where neem is a very important tree species, the impact of the scale insect was quite significant. Attack is followed by premature browning which frequently leads to death of leaves on some or all of the branches of the affected tree. Trees 10-15 years or older are more susceptible to attack than younger trees. Vigorous management efforts made in the 1990s brought the neem scale insect problem under control.

Various species of Eucalyptus are widely planted in the sub-region, among which are E. camaldulensis, E. territicornis and E. alba. They are grown for pulp, poles, amenity or wood fuel. Worldwide, eucalypts are highly susceptible to pests and diseases, and the blue gum chalcid (BGC) Leptocybe invasa has caused significant losses in Eastern and Southern Africa. During the field survey in Niger and Senegal, leaf galls characteristic of BGC attacks were observed on saplings of Eucalyptus in plantations (see Figure 2). In Senegal, the observation was made in a small plot of Eucalyptus located within the city of Dakar. In Niger, the observation was made on saplings in an 80 ha plantation established in a town north of Niamey. In Ghana, BGC attack has been reported in a plantation at Kwame Danso, in the Forest- Savannah Transition zone.

Figure 2 . Left: Suspected blue gum chalcid, Leptocybe invasa, galls on young Eucalyptus plants in Niger. Right: Vigorously growing Cedrela odorata pushes stem borer following attack. (Bosu, 2016).

2.3 Forest disturbance in Eastern Africa sub-region

2.3.1 Fires

Threats to African woodlands can be attributed to a number of factors and processes including policies that fail to take into account impacts on forests, conversion of forest to cropland arising from both population growth and structural adjustment policies, urbanization, over-dependence on wood-based energy sources, unsustainable harvesting of wood products, fire and climate change and variability (Chidumayo, 2011). While fire is used as a tool for land preparation for cultivation in savanna woodlands, it predisposes trees to stress and secondary attack by pests and pathogens. It is a serious problem in nearly all forest areas in the Sudan where it has led to abandonment of the establishment of exotic tree plantations after the failures associated with it (FNC, 2011). See Box 1.

Traditional honey gatherers make use of smokers which contain live embers that start fires in forests in Eastern Africa. Such is the cause of fire in Nyungwe National Park, a montane forest ecosystem in Rwanda that continues across the border into Burundi to become known as Kibira National Park. Managing this threat has trans-boundary implications over which the two countries have reached a memorandum of understanding.

Box 1 Fire occurrence and its impacts on Forest Plantations in Jebel Marra in The Sudan.

After establishing 500 ha of Cupressus lusitanica plantations in the Golod area in 1957, fire swept through them in 1974. They were replanted in 1980 but again fire wiped them out in 1984. Another attempt to re-establish the plantations was made in 1989 but when they burned down again in 1994, the efforts to establish them were shifted elsewhere. Massive planting of trees was undertaken with assistance of FAO and the Government of Netherlands to create Sudan's Gum Belt in the early 1990s. It consisted of massive Acacia senegalensis tree seedling production and distribution. Food was provided as a part of the project strategy but the results were not entirely satisfactory because the survival rate of planted trees was often low. Community participation in forestry projects picked up in 1990s, mostly with eucalypts, because they interested local people more and the trees were more fire resistant. El I Ain Community Forestry Project is an example of one such successful venture which continued to flourish after the project had long concluded. (UNEP-FNC, 2011).

Fire seems to be a major problem in Tanzania's forest plantations (Ngaga, 2011). In the period 2005-2009, for example, close to 6 000 ha were destroyed by fire, most of it in Sao Hill (2 160 ha) and in Kilombero valley (3 300 ha). During the year 2009/10, information provided by some plantation managers showed that a total of approximately 3 900 ha were affected by forest fires. The strategies recommended to ensure that future losses due to forest fires are minimized in Tanzania equally apply to other affected countries in the region. Measures required to prevent fire occurrences, and/or put off forest fires, include cleaning fire breaks before the fire season, purchasing and maintaining fire-fighting equipment in good working condition ready for use in case of fire occurrence, as well as keeping standby firefighting crews and vehicles during the fire season. In addition to these precautionary measures, forest patrols are essential for reporting any fire incidences when they occur.

2.3.2 Insect Pests of Forests in Eastern Africa

Pests that attack indigenous trees and forests in the Sudan include, among others, tree locusts, termites and several beetles (see Appendix 2). They cause damage to the bark, seeds, leaves and roots (El Tahir et al., 2010; FAO, 2007b; El Atta, 2000). The most serious pest of trees and forests is Sphenoptera chalcichroa arenosa, a cambium and wood boring beetle that is wide- spread on Sunt (Acacia nilotica), the most valuable timber-producing species in northern Sudan. Sunt contributes an estimated 40-50 % to the total sawn timber production in northern Sudan and 10-15 % to fuel wood production. Dieback was reported as early as the 1930s and was attributed to infestation by this beetle whose larvae tunnel into the cambium layer of branches and stems causing dieback and gradual tree mortality. By the early 1950s, the condition had affected most of the forests between Khartoum and Sennar and it was estimated to have caused losses of up to 60 % in the plantations along the Dinder River. The outbreak spread to the south and appeared on both banks of the Blue Nile in 1989 when it suddenly erupted, reaching huge proportions. Fourteen reserves were affected with a total area of 500 ha and 15 % of the A. nilotica area in the reserves had died by 1995 (FAO, 2007b).

In Rwanda, indigenous caterpillar defoliator outbreaks are known to occur at irregular intervals in Nyungwe Forest where they first attack the pine buffer forest along its periphery and then spread to Newtonia buchananii (Baker) G.C.C. Gilbert & Boutique, an indigenous species thatis dominant in the park as well as Alchornea hirtella Benth., an undergrowth shrub. The attacks subside afterwards but the contributing factors have not yet been well documented.

A comprehensive book on forest entomology in East Africa with a special focus on forest insects of Tanzania was published by Schabel (2006). Considering the multiple pressures, including insects, that Eastern Africa forests are subjected to, this is the first work to focus exclusively on East African forest insects. The monograph distils 135 years of scientific and historical literature extending from before the colonial era to the year of publication into an authoritative survey of the region's major pests of trees and wood, as well as their antagonists. The comprehensive treatise also addresses insects of social and economic importance, such as endemics, edible and collectible insects, wild bees and silk producers. It describes defoliating insects - shoot, bark and wood borers, flower, fruit and seed feeders, root and root collar feeders, as well as sap feeding insects.

Eucalyptus species and their hybrids are found on farms and in plantations in eastern Africa. These popular trees are attacked by several insect pests, mostly of exotic origin. Leptocybe invasa Fisher & LaSalle (Hymenoptera: Eulophidae), for example, was reported in Ethiopia in 2002. This gall forming wasp has a relatively narrow host range, attacking only eucalypt species, clones and hybrids. Adult wasps can spread very quickly by flight and wind currents. They can also be introduced into new areas through the movement of nursery stock and international flight traffic. The eggs are laid in young shoots where they hatch into larvae protected by galls. Severe attack can lead to deformed appearance, loss of vigor, stunted growth and eventually death of the affected trees. The insect pest commonly referred to as the blue gum chalcid, was first found in Bahardar region of North Ethiopia. By 2007 it was already reported elsewhere in Africa, in Algeria, Kenya, Morocco, Mozambique, South Africa, Tanzania, Tunisia, Uganda and Zimbabwe (FAO, 2012).

Sporadic outbreaks of a shoot borer in mangrove forests affecting Sonneratia alba were reported in Kwale and Mombasa in Kenya in the mid-1990s and re-occurred in Gazi Bay as recently as 2013. Damage is caused by the caterpillar stage of Salagena discata Gaede, a wood moth, which tunnels into the bark and wood and causes defoliation (FAO, 2007a). Repeated attacks can cause tree mortality and recently a massive insect infestation event occurred in Pemba, Tanzania where infested trees experienced massive defoliation of such wide scale that it caused concern in the region (Jenoh, undated). The residents of Gazi Bay who were interviewed for this study, however, regarded it as a minor pest and expressed little concern about it. This was confirmed by a site visit in 2015 whereby only a low population was observed. It is possible that natural control agents keep it in check when it reaches outbreak populations but more comprehensive studies should be done on its population dynamics.

Schmutterer (1998) reported on anthropod pests and semi-parasitic plant pests of neem trees in Kenya. Gall and spider mites were recorded alongside numerous insect pests (thrips, psyllids, scales and caterpillars). In Africa and Asia, neem trees are attacked by a number of mistletoes, for instance Dendrophthoe spp. and Tapinanthus spp. In case of heavy infestation, such as by T. globifera in Africa, the growth of the affected trees is retarded and dieback of branches may also occur (Boa, 1995). The same applies if neem trees are attacked by C. filiformis, a parasitic plant. Crows and bats which feed on neem fruits were confirmed to be seed dispersal agents as they only utilize the pulp and leave seeds unharmed.

Among the most widely studied insect pests in the region are those attacking Eucalyptus species in Kenya. A recent study by Mutitu et al. (2013) outlines the methods followed in studying the biology and rearing of Cleruchoides noackae Lin and Huber (Hymenoptera: Mymaridae), a solitary egg parasitoid and biological control agent under consideration for management of Thaumastocoris peregrinus, a relatively new pest of Eucalyptus in plantations. Mutitu et al., (2008) had earlier produced a leaflet on associated insect pests and diseases of Eucalyptus in Kenya. Other scientific publications by Mutitu et al. on the subject matter in the eastern Africa region are listed in www ref. 6. FAO (2007b) also provides an in-depth review of introduced forest pests and their management in Kenya. In addition, it covers pests of indigenous origin such as Gonometa podocarpi Aur (Lepidoptera: Lasiocampidae) and Oemida gahani Dist (Coleoptera: Cerambacydae) which occur on conifers.

2.3.4 Pests of trees and forests in North Africa

Literature on the situation of forest pests in North Africa is scanty. A workshop organized by IUFRO Working Party 7.03.14 on pests of the Mediterranean region in 2014 sheds some light on the pest situation on indigenous forests (www ref. 7) and a summary is presented in Appendix 3. In brief, Thaumetopoea pityocampa, the pine processionary moth is a Mediterranean forest pest endangering pine and cedar plantations. Its larvae cause allergies in mammals and are serious defoliators. Significant damage caused by defoliating Lepidoptera pests was observed in 2009 on Quercus afares Pomel, an endemic species that grows as a small relict population in the northwest of Tunisia. Elsewhere in Tunisia, healthy trees of Eucalyptus astringens and E. sideroxylon demonstrated the ability to inhibit tunneling by young Phoracantha recurva larvae by means of kino exudation while young larvae could penetrate through the bark of E. camaldulensis and E. gomphocephala and dig their feeding tunnels. In Algeria, attacks by pest insects affecting primarily the leaves, the acorns and the trunk of cork oak have been reported. A survey was conducted in two cork forests in North-Eastern Algeria (El Kala and Souk

Ahras) from which 59 species of Coleoptera belonging to 17 different families were identified - with diversified feeding types and associations (coprophagous, saproxylic, predatory, herbivorous or decomposers) (www ref. 7).

The outcomes of the interactions within IUFRO Working Party 7.03.14 have been captured in a book edited by Paine and Lieutier (2016). The Mediterranean Basin, the largest of all regions with such similar climate, experiences no cold ocean current influence. North Africa is warmer and drier than the European side. The book documents defoliators in native insect systems of the Basin and other regions which fall under the Mediterranean climate regime. The editors focus on native fruit, cone and seed feeders; native sap sucker insects; bark beetles of Mediterranean conifers; native Buprestid and longhorn beetles; foliage feeding invasive insects; invasive fruit, cone and seed insects; invasive sap sucker insects and alien wood-boring beetles.

2.4 Regional collaboration in forest insect pest management in Africa

FAO (2009) lists common insect pest species reported across the continent. The occurrence of similar insect pests in different countries of Africa is an opportunity to explore possible collaboration in managing them at regional level. They include the longicorn borers Phoracantha recurva and P. semipunctata and the leaf-feeding curculionid Gonipterus scutellatus, which are significant pests of eucalypts. Heteropsylla cubana is a pest of the fast- growing Central American tree, Leucaena leucocephala, which has been widely planted in the tropics since the 1970s for agroforestry, wood production and fodder. The shoot borer, Hypsipyla robusta, is a major pest of several high quality timber species including African mahogany (Khaya spp.), mahogany (Swietenia macrophylla, S. mahagoni) and teak (Tectona spp.). The blue gum chalcid, Leptocybe invasa, is a relatively new threat to planted eucalypt forests in Africa, reported first from Kenya in 2002 and from South Africa in 2007. This pest is also known to occur in Morocco although the date of introduction is unknown.

When the eastern and southern regions of the continent were battling with rapid invasions of exotic aphids in the mid-1990s, FAO organized a workshop that was held in Kenya in 1991 and participants recommended that the countries concerned should establish a network to address the following activities:

i. Training.
ii. Information exchange, through a newsletter, etc.
iii. Collaborative research, detection and monitoring, screening of insecticides, ecological and socio-economic impact studies, integrated pest management and other development activities.
iv. Quarantine services.
v. Exchange of expertise.
vi. Public awareness and education.

Collaboration in pest management programmes was proposed between national institutions and relevant regional and international organizations, such as FAO, IIBC, ICIPE and the PTA. The network was expected to stimulate synergy, an essential ingredient for overcoming constraints to integrated management of the exotic aphids and related pernicious forest pests in the region. It was proposed that a regional biological control programme would be funded by CIDA and implemented by IIBC and national institutions. Projects in Kenya and Malawi would form part of the network. KEFRI was endorsed to host a secretariat to coordinate the network. Representatives of collaborating countries were expected to develop a regional programme embracing identified activities and approach funding institutions such as ODA, CIDA, IDA and IDRC for appropriate follow-up activities. FAO, IDRC and/or PTA would be approached to fund a meeting of the committee in not less than six months from the date of the workshop, to develop a modus operandi for this network. The secretariat was expected to liaise with existing networks in Africa and elsewhere, such as ICIPE's PESTNET and FAO's Forestry Commissions for guidance. It was unfortunate that this concept of a regional network, however elaborate, failed to materialize.

Another similar proposal by FAO (2009) elaborated how a Forest Invasive Species Network for Africa (FISNA), created by a group of African scientists with the support of FAO and the United States Forest Service, could coordinate the collation and dissemination of information relating to forest invasive species in sub-Saharan Africa. The network was expected to raise regional awareness on forest invasive species, encourage the publication and sharing of research results, management and monitoring strategies, and act as a link among experts, institutions, networks and other stakeholders concerned with forest invasive species in the region. Up-to-date information on new invasions was supposed to be disseminated through various FAO websites (www ref. 8 and www ref. 9). The network encourages subscription by request and one can find historical information and enroll for an e-learning course on good practices for forest health protection. The network exists today but lacks vibrancy and is dormant.

On the African continent, plant protection and phytosanitary issues are addressed by the Inter- African Phytosanitary Council (IAPSC) which is a Regional Plant Protection Organization (RPPO) of the International Plant Protection Convention (IPPC). It is structured to bring together expertise from different regional economic communities in the continent to work on pests of economic importance but it does not pay sufficient attention to forest insect management.

3.0 OCCURRENCE, DISTRIBUTION AND MANAGEMENT OF FOREST DISEASES IN AFRICA

Depending on the parts and organs of the host plant that they attack at any stage of growth, diseases can be described as foliar, stem, root and branch diseases. In addition, there are decay fungi which may be described as heart and butt roots. In the natural forests in Africa, abiotic diseases, also known as physiological diseases, are associated with harsh physical environments and are attributed to mineral deficiencies and toxicities. Additionally, high temperatures, droughts and flooding can also cause diseases (Kojwang, 2015). These different types of diseases occur in all regions of Africa as globally classified by Gonthier and Nicolotti (2013) to fall in the following broad categories:

Non-Fungal Infectious Forest Diseases

- Forest Diseases Caused by Viruses
- Forest Diseases Caused by Prokaryotes: Phytoplasmal and Bacterial Diseases
- Forest Diseases Caused by Higher Parasitic Plants: Mistletoes
- Pine Wilt Disease and Other Nematode Diseases

Forest Diseases Caused by Fungi and Fungal-like Organisms

- *Root and Butt Rots*
  - ◊ Annosus Root and Butt Rots
  - ◊ Armillaria Root Rots
  - ◊ Laminated and Tomentosus Root Rots
- *Stem Rots*
  - ◊ Heart Rots, Sap Rots and Canker Rots
- *Vascular Diseases*
  - ◊ Ceratocystis Diseases
  - ◊ Dutch Elm Disease and Other Ophiostoma Diseases
  - ◊ Blackstain Root Disease and Other Leptographium Diseases
- *Canker Diseases*
  - ◊ Cankers and Other Diseases Caused by the Botryosphaeriaceae
  - ◊ Chestnut Blight
  - ◊ Other Cankers Caused by Cryphonectria and Sibling Species
  - ◊ Cypress Canker
  - ◊ Pitch Canker
  - ◊ Larch Canker
  - ◊ Hypoxylon Canker
- *Branch and Tip Blights*
- *Foliar Diseases*
  - ◊ Dothistroma Needle Blight
  - ◊ Other Foliar Diseases of Coniferous Trees
  - ◊ Foliar Diseases of Broadleaved Trees
- *Oomycete Diseases*
- *Rust Diseases*
- *Nursery Diseases*
  - ◊ Seed, Seedling and Nursery Diseases
- *Introduced Pathogens*
  - ◊ Diseases Caused by Exotic Tree Pathogens

3.2 Diseases of Southern Africa sub region

In southern Africa, recorded disease problems appeared in the first half of the twentieth century when forest plantations were established. Since then, the research programmes of South Africa have given tree provenance site matching, growth and yield and resistance to pests and diseases priority (Louw, 2012; Roux et al., 2005).

3.2.1 Diseases of Eucalyptus

In addition to the growing of exotic softwoods in Southern Africa, the increasing popularity of Eucalyptus species as an exotic hardwood has been accompanied by reports of a number of disease problems in its many species and hybrids (Chungu et al., 2010; Roux et al., 2005; Mausse-Sitoe et al., 2016).

Root diseases

Phytophthora root and collar rot is a serious disease associated with die-back and collar rot of eucalypts. This disease is caused by P. cinnamomi and P. nicotianea and others in Southern Africa. Hosts include Acacia mearnsii and several species of cold tolerant eucalyptus, namely, E. smithii, E. nitens, E. fraxinoides and E. fastigata, and, occasionally E. grandis.

Canker diseases

The fungus Chrysoporthe austroafrica (Cryphonectria eucalypi) occurs in all areas in East and Southern Africa where eucalypts is grown. It causes canker disease, and its key hosts are E. grandis, E. camaldulensis, E. saligna and hybrids, especially those of E. grandis x camadulensis (GC) and E. grandis x urophylla (GU). In addition, species related to Eucalyptus such as Syzygium and Tibouchina are also susceptible to the fungus. Cryphonectria cubensis is a related fungus that infects eucalyptus trees through wounds. Infection of the bases of young trees is the most common and infection sites are presumed to be natural growth cracks at the root collar. The spores are dispersed by rain splash.

Botryosphaeria canker is especially common on trees that are planted off-site, resulting in the development of stem cankers. These first become visible as small cracks, with the exudation of kino, and may develop into larger, girdling cankers which seriously affect wood quality and growth, and may result in stem breakages. The fungus is an opportunistic pathogen that manifests itself under conditions of environmental stress. These stress triggers include drought, frosts, cold and hot winds, branch pruning, insect damage and off-site planting. Species of Botryosphaeria spread via airborne spores that can also be spread through rain splash. According to Cortinas et al. (2006), another serious canker of eucalyptus species and their hybrid clones, particularly clones and hybrids of E. grandis, is caused by a fungus which was first named Coniothyrium zuluense (and later as Teratosphaeria zuluense) and another species known as T. gauchensi. Thought at first restricted to Southern Africa, particularly South Africa,T. zuluense has since been reported in Central, South America and Asia.

Leaf diseases

Mycosphaerella leaf blotch is serious on eucalypts and is present in all countries in Southern Africa where they are grown. It is present in all East African countries as well. In South Africa, for example, it is a disease of cold tolerant Eucalyptus spp., e.g. E.

nitens, E.globulus, E. grandis and E. smithii. The rust Puccinia psidii causes leaf spots and death of young new shoots that are often covered by a bright yellow spore masse - uredinia/uredospores - and it requires high humidity and periods of low light, such as cloudy overcast conditions, for its germination and infection. It is mostly a problem in sub-tropical areas of the world where eucalypts are grown. In southern Africa, the disease has been recorded in Mozambique, South Africa and Zimbabwe.

3.2.2 Diseases of pines

Pitch canker is caused by the fungus Fusarium circinatum and is currently a serious problem in South Africa. Since its introduction to the country in 1990, it was a largely a nursery pathogen but recently young plantations of 3 to 5 years have been attacked. It affects especially P. patula and P. radiate, but also infects P. elliottii and P. taeda. Diplodia pinea is one of the most important pathogens of pine, particularly in South Africa where P. radiata, its key host, is grown. The host range of Diplodia canker and die-back includes all Pinus spp., but is especially common and most severe on P. patula, P. pinaster and P. radiata. A root disease of P. elliottii and P. taeda, caused by D. pinea has been described (Wingfield and Knox-Davies, 1980).

Armillaria root rot is a well-known root pathogen throughout much of Sub-Saharan Africa. The rot is caused by Armillaria fuscipes in South Africa. Conclusive evidence of Armillaria is usually the presence of white mycelial fans between the bark and the sapwood and, under favorable conditions, a proliferation of yellowish brown mushrooms develops at the base of the tree. Infection starts with a single tree then radiates through root contact to neighboring trees. It affects plantations, mainly of pines which have been established on areas previously cleared of indigenous forests. All pines are susceptible and incidences of attack on Eucalyptus species and Acacia mearnsii have been recorded in South Africa.

3.2.3 Diseases of Wattle (Acacia mearnsii)

The rust fungus, Uromycladium acaciae, has multiple life stages typical of a macro-cyclic life cycle, hence produces spermagonia, telia and uredinia. The foliage rust affects A. mearnsii and *A.*decurrens, which occur throughout South Africa and, since 2013, seems to be spreading. It has also been documented that A. mearnsii is attacked by Armillaria root rot. Ceratocystis wattle wilt, mainly on A. mearnsii, was first described in South Africa in 1989 in Kwa Zulu Natal. The fungal pathogen belongs to a family of highly destructive tree pathogens, the Ceratocystis, of which C. ulmi of the 'Dutch Elm Disease' is one of the most famous pathogens in the history of plant pathology. Ceratocystis albofundus can kill one-year old wattle trees within six weeks and affects trees of all ages. It is known only in Africa and affects both A. decurrens and A. mearnsii. Its symptoms are rapid wilting of infected trees and in some cases stem cankers, black red mottled lesions, cankers and gummosis occur. Blisters which are swollen gum pockets are observed and internally uneven brown streaks appear in the xylem. Infection by C. albofundus requires wounds, which can be caused by insect damage, wind, hail and silvicultural practices, such as pruning. Severe disease outbreaks have especially been found after hail and silvicultural damage and the spores of Ceratocystis can only infect over a short period of time after wounding, especially during warm, humid/wet summer months.

Acacia mearnsii also suffers from Phytophthora root and collar rot caused by P. cinnamomi and P. nicotianea. The latter causes the disease known as Black butt, which, even though it does not necessarily kill trees, reduces the yield and quality of the bark and affects trees of all ages. The black butt symptom is only visible on older trees and refers to the black discoloration of the bark on the butt log of the tree. This discoloration is accompanied by cracking of the bark and the exudation of gum from active cankers and tends to affect the thickest, most valuable bark at the base of trees (Kojwang, 2015).

3.3 Diseases of West and Central Africa sub-region

Most disease reports from this region occur in plantations rather than in natural forests or woodlands (Bosu, 2015). From available literature, root diseases, decline and dieback are the major tree and forest diseases in the sub-region. Damping-off in the nursery is common throughout the sub-region whenever the conditions permit.

3.3.1 Root diseases

In 2006, Armillaria root rot was observed on exotic teak and cedrela plantations located within the Kwamisa, Tano Nimiri and Mamiri reserves in the Moist Forest zone of Ghana, while in Côte d'Ivoire and Nigeria. Armillaria mellea, Chaetophoma sp., Polyporus sp. and Thanatephorus cucumeris have been reported as fungal pathogens (Gbadegesin, et. al., 1999).

3.3.2 Canker diseases

Stem canker of Cedrela odorata was first reported in a 16-hectare plantation in Anwhiaso Forest Reserve and thereafter in Worobong South and Afram Headwaters forest reserves.

3.3.3 Tree decline and dieback diseases

Dieback has been reported on Ceiba pentandra, Terminalia ivorensis, Gmelina arborea, and Casuarina equisetifolia and other trees in planted forests in West Africa (Apetorgbor and Roux, 2015; Agyeman and Safo, 1997; FAO, 1994). Of the major tree diseases, dieback of T. ivorensis, G. arborea and decline of Azadirachta indica were recorded between 1970 and 1990. The occurrence of dieback on T. ivorensis in Ghana and Côte d'Ivoire during the early 1970s was a major setback to the progress of forest plantation development in the sub-region. Dieback was observed at the time when T. ivorensis was gaining popularity as a candidate for the establishment of indigenous species plantations. Plantations aged 10-20 years were mostly affected with very high mortalities. Symptoms of attack included branch dieback beginning at the crown apex, chlorotic and wilting foliage, crown thinning and sapwood staining. In Ghana, the imperfect stage of Endothia sp. was associated with the high mortality recorded (Ofosu-Asiedu and Canon, 1976). However, no biotic agents were clearly linked to the disease and the infection was generally associated with environmental and nutritional stresses. Fortunately, the other Terminalia species, T. superba, was not affected and is currently planted widely in West Africa (Bosu, 2016).

Dieback of C. pentandra has a major impact on the regeneration of the affected species. It was first observed in Ghana in experimental trials at the Bobiri Forest Reserve in 1996 but is not yet reported in other countries of the sub-region. Unlike the T. ivorensis dieback, Ceiba dieback affects hosts at the nursery stage, can cause significant damage to seedlings and can persist throughout the growing stage. Without proper care and maintenance the likelihood of recording a 100% mortality of the seedlings at the nursery stage is quite high.

However, infected plants two years old and above often recover from the attack, which occurs during the wet season. Fusarium sp. and Lasiodiplodia theobromae have been associated with the disease (Apetorgbor et al., 2003).

Gmelina arborea is a fast growing tree species introduced to some West African countries with the aim of producing wood for pulp and paper. Over time, many of the plantations established in Ghana, Nigeria, and Sierra Leone suffered from dieback. In Ghana, dieback was prevalent in the 15 000 ha Subri Industrial Plantation at Daboase in the Western Region. The cause was not determined but it was believed that regional droughts and changes in water tables were possible causes, with the disease condition complicated in some cases by the activity of weak pathogens. In Sierra Leone, dieback incidence was very high with infection rates up to 40% in plantations.

Symptoms of decline have also been reported, first in Niger and subsequently in other countries of the Lake Chad Basin. The symptoms of the decline were initially confused with a scale insect outbreak. According to Boa (1992), the most conspicuous symptom of Azadirachta indica decline is the loss of older foliage. The foliage loss gives the normally dense crowns an open appearance with clumps of foliage occurring at the branch apices. In advanced cases, only a small tuft of foliage remains at the branch tip, a condition described as 'giraffe neck'. Similar to the Terminalia and Gmelina dieback described above, neem decline has also not been clearly associated with any biotic agents.

Although several fungi, such as Nigrospora sphaerica and Curvularia eragrostidis, have been recovered from affected trees, they have been shown to be secondary pathogens (Bosu, 2016).Major diseases of trees and forests in West and Central Africa are summarized in Table 3.1. They occur on introduced and indigenous hosts and comprise of diebacks, stem canker and root diseases.

Table 3.1 Major diseases of trees and forests in West and Central Africa (Bosu, 2016).

Host tree	Disease type	Causal pathogen (s) or Predisposing factors	Countries of occurrence	Host species Indigenous or Introduced
Azadirachta indica	Decline	No pathogen associated with decline. Caused by environmental/ nutritional stresses	Cameroon, Chad, Mali, Niger, Nigeria	Introduced
Casuarina equisetifolia	Dieback	Associated with soil nutrition limitations	Benin	Introduced
Cedrela odorata	Stem canker	*Armillaria* sp.	Ghana	Introduced
Ceiba pentandra	Dieback	*Fusarium solani, Lasiodiplodia theobromae, Colletotrichum capsici*	Ghana	Indigenous
Gmelina arborea	Dieback and root diseases	*Gibberella fujikuroi Sclerotium rolfsii Armillaria mellea, Chaetophoma* spp., *Polyporus* sp. *and Thanatephorus cucumeris*.	Ghana, Côte d'Ivoire, Nigeria	Introduced
Terminalia ivorensis	Dieback	No pathogen associated with dieback. Caused by environmental/ nutritional stresses	Ghana, Côte d'Ivoire	Indigenous
Tectona grandis	Root disease	*Armillaria* spp., *Phellinus noxius, Phaeolus manihotis, Ganoderma* spp. and *Rigidoporus lignosus*.	Ghana, Nigeria, Côte d'Ivoire, Benin	Introduced

3.4 Diseases of forests in Eastern Africa

The first report of Lasiodiplodia theobromae infecting Boswellia papyrifera in Ethiopia, which represents a new constraint to the sustainable management of this commercial tree species and incense production in the country, was made by Alemu et al. (2014). Incense is extracted by frequent, intensive and repeated wounding made at different directions and positions on the bole of the tree. Depending on the size of the tree, there could be between 6 and 16 tapping spots that are refreshed and widened 8-12 times each year at an interval of 15 to 20 days (Gebrehiwot, 2003). Tapping for incense has a negative impact on the survival rate, growth and reproduction of the tree (Rijkers et al., 2006) and wounding predisposes trees to microbial infection.

Disease symptoms and death of Boswellia trees have been commonly observed in all areas where tapping has been practiced. Specific symptoms include canker formation, exudation of gum, wilting, dieback, vascular browning and death of the tree.

On exotic species, a comprehensive study of diseases of eucalypts and pines in Ethiopia was conducted and reported by Alemu et al. (2003a). Armillaria root rot, which was endemic on indigenous tree species such as Cordia alliodora, Cedrella odorata and Acacia abyssinica was reported as the main course of death of Pinus patula in plantations around Wondo Genet. It caused wilting and yellowing of crowns and death of trees in groups. Historically, Pinus radiata D. Don. was abandoned as a plantation species in Ethiopia after a disease outbreak caused by Diplodia pinea occurred. No practical management programme was developed (Roux et al., 2005).

Botryosphaeria cankers are also found on Eucalyptus grandis, E. saligna, E. citriodora and E. globulus in Ethiopia. The disease is characterized by black discoloration and cracking of stems, from ground level up to a height of about one metre. When the bark is removed, the cambium beneath was completely discolored and soaked with kino. At Menagesha, symptoms of stem canker were frequently observed on coppices of E. globulus, resulting in death or wilting. A species of Botryosphaeria was isolated from diseased material collected from all sites. The occurrence of this disease is favored by environmental stress, especially drought and frost.

A follow up survey of diseases that was carried out in Ethiopia on Eucalyptus documented a serious stem canker disease on E. camaldulensis trees at several localities in the south and south-western parts of the country (Alemu et al., 2005). The disease was characterized by the presence of discrete necrotic lesions, stem cankers, cracking of stems, production of kino pockets in the wood, as well as malformation of stems. These symptoms are similar to those caused by Coniothyrium zuluense in South Africa. This study identified the causal agent of the disease in Ethiopia and it represents the first confirmed report of C. zuluense and the disease caused by it in Ethiopia and Uganda. It also showed that C. zuluense is closely related to species of Mycosphaerella and not to other Coniothyrium spp. and that it will require a name change in future. The disease is considered to be one of the biggest threats to eucalypts as it not only complicates debarking but also affects tree growth, timber quality and, in serious cases, kills the trees (Alemu et al., 2003a).

Pink Disease caused by Erythricium salmonicolor on E. camaldulensis is also of concern in Ethiopia (Alemu et al., 2003b). Characteristic symptoms of the Pink Disease include branch die-back, stem cankers, branch and stem girdling, production of epicormic shoots on stems, death of trees as well as production of pink mycelial growth on symptomatic plant parts. Reports have also been made of the presence of Mycosparella Leaf Blotch (MLB) in Ethiopia on E. globulus. Several Mycosphaerella species are involved in causing the blotch observed on leaves and subsequent defoliation of young trees. Alemu et al. (2006) later characterized the causal agents and identified more than one species of Mycosphaerella as responsible for MLB on E. globulus in Ethiopia. Analysis of sequence data showed that three Mycosphaerella spp.- M. marksii, M. nubilosa and M. parva - were present. This was the first report of these three species from Ethiopia. Elsewhere in Africa, MLB has been reported in Malawi, South Africa, Kenya, Uganda and Zimbabwe. A summary of the diseases reported on trees and forests in Ethiopia is given in Appendix 4.

Grevillea robusta is one of the most important trees for agroforestry in the tropical highlands of Eastern and Central Africa. According to a quick guide to multipurpose trees from around the world (Fact Net, 1998), the tree is commonly planted to mark boundaries along the perimeter of small farms, in a single row at 2–2.5 m spacing. It is also planted in rows between small fields, and as scattered individuals over crops such as coffee and maize (Spiers and Stewart, 1992). Akyeampong et al. (1995) found that G. robusta produced the highest wood volume (18 m3/ha at 3.5 years) of 9 tree species tested in agroforestry trials in Burundi when planted at 312 stems/ha, intercropped with banana and beans. Yield of bananas was not affected to age 3.5 years, while bean yields were reduced by 29% in the 7th harvest at age 3.5 years.

In addition to their use as soil mulch, the leaves of G. robusta are used by some farmers in the Embu district of Kenya as a fodder supplement for cattle in the dry season when other fodder sources are scarce (Spiers and Stewart, 1992). They are also used as bedding in livestock stalls. From the late nineteenth century onwards, G. robusta has been planted extensively as high shade for tea and coffee plantations, and this use continues in many countries. The trees are often pollarded to produce a spreading crown, and have a typical working life of 40–50 years before they become senescent and must be replaced (Rao, 1961). Although relatively free of pests and diseases in native Australia, use of the tree as tea shade has been largely discontinued in Kenya and Rwanda because of the risk of Armillaria and other root pathogens spreading from dead G. robusta roots to those of tea plants (Tea Research Institute of East Africa, 1969; Rural Industries Research and Development Corporation, 2008). A comprehensive study of stem canker and dieback disease on G. robusta in Kenya was undertaken by Njuguna (2011) during which distribution, causes and implications of the disease in agroforestry were examined in detail. She concluded that the canker and die back disease are associated with Botryosphaeriaceae species complex with Neofusicoccum parvum as the most important pathogen.

With respect to threat of plantation diseases in Tanzania, Ngaga (2011) reports historical incidences of Dothistroma and Cercospora needle blights on pines in the 1950s and considers the growing of few related tree species to be the greatest concern. As a control measure, the planting of P. radiata was banned and P. elliottii was introduced as an alternative species. Cupressus macrocarpa and its hybrids were also found to be more susceptible to canker attack than other cypress species when the disease was first reported in Tanzania in the 1960s. The spread of the disease was minimized by the elimination of C. macrocarpa from planting programmes, replacing the areas with C. lusitanica.

In Kenya, Eucalyptus species suffer from diseases mentioned by the Kenya Forest Service (2009). Mwangi (2014) produced an updated leaflet on pests and diseases of Eucalyptus and their management in Kenya. Diseases listed by FAO (2007a) include Armillaria root rots on indigenous and exotic hosts, twig canker caused by Lepteutypa cupressi on native and introduced conifers, wattle wilt caused by Cerastocystis species on Eucalyptus grandis and Acacia mearnsii as well as powdery mildew caused by Oidium species and found on fruit trees in farms and on Eucalyptus species and hybrid clones found in forests. Leaf spots caused by Mycosphaerella pini also occur on Eucalyptus species and hybrid clones and on Pinus radiata.

Forest diseases which occur in natural and planted forests in the Sudan were reviewed by FAO (2007b). There were no introduced diseases in natural forests or indigenous diseases found on planted forests. The challenges present were in introduced diseases occurring in planted forests. A concern was expressed about Armillaria mellea as a common pathogen of trees, woody shrubs and some herbaceous plants, causing root, root-collar and butt rot. The pathogen invades trees through the bark of major roots, progressively destroying the living root tissues and leading to serious decline and ultimate death of hosts. Symptoms of infestation are premature autumn coloration and leaf drop, stunting of growth, yellowing or browning of the foliage, a general decline in the vigour of the plant, and twig, branch and main stem dieback. Such a decline usually occurs over several years but may appear to progress very quickly as the tree shows advanced symptoms of decline and death. As decline progresses, decay of the buttress roots and the lower trunk is evident. Small plants die quickly after the first symptoms appear with large trees surviving for a number of years. A severely infected tree also exudes resin, gum or a fermenting watery liquid from the lower trunk. In the Sudan, this disease affects plantations of Tectona grandis.

Another notable tree disease in the Sudan is caused by Nattrassia mangifera and manifests itself through stem and branch dieback and blossom blight. It has a wide host range, occurring on many tropical plants and orchard trees including fig (Ficus carica), walnut (Juglans regia), apple (Malus domestica), Citrus spp., mulberry (Morus alba), Prunus spp., mango (Mangifera spp.), Arbutus spp. and Eucalyptus spp. Symptoms differ depending on the part of the tree affected.

Nsolomo and Venn (1984) undertook a comprehensive background review and updated the status of forest diseases in Tanzania. In the form of a checklist, they addressed outbreaks of the most destructive exotic and indigenous diseases on indigenous and exotic trees, including ornamental and agroforestry trees. Among important diseases described was the camphor heart rot attributed to a Basidiomycete fungi that hampers coppice and root sucker regeneration of Ocotea usambarensis in the Uluguru Mts. Die-back of leading branches and stem decay symptoms were also reported in the same species in the Usambara and Mt. Kilimanjaro regions. Armillaria root rot was also reported on Grevillea robusta and on pine trees. It was noted that growing exotic and indigenous trees in the same ecosystem harbored a possibility of passing the disease from the more tolerant indigenous hosts to the highly susceptible exotic species, especially as a result of changes in climate and food characteristics. The occurrence of key diseases of major forest types and tree species in Kenya as representative of eastern Africa are provided in Appendix 5.

3.5 Forest diseases of North Africa

The information available on the situation regarding occurrence of forest diseases in North Africa is very limited. Gonthier and Nicolotti (2013) made brief mention of the occurrence of cypress canker caused by Seiridium cardinale and rated its severity as low in North Africa when compared with other regions of the Mediterranean Basin. It has been reported in Algeria, Morocco, Tunisia and South Africa as an introduced invasive pathogen (www ref. 10).

4.0 THE ECONOMIC IMPACTS OF FOREST DISEASES AND PESTS IN AFRICA

4.2 Data requirements

Much remains to be done to quantify economic impacts and implications of pests and diseases but economic data can be used to secure resources needed to carry out control measures. In east and southern Africa, for example, it was estimated that the introduced cypress aphid Cinara cupressivora killed trees to an estimated value of USD 41 million and was causing a loss in annual growth increment (including that from dead trees) of a further USD 14 million per year. In addition, the two pine aphids, Pineus boerneri and Eulachnus rileyi caused a further loss of USD 2.25 million per year in the region. 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 were alarming enough to secure financing for a biological control programme, which led to substantial reductions of the cypress aphid (Murphy, 1996).

To determine the extent of economic loss attributed to poor forest health, it is necessary to have data about disease and pest incidences and their effects on forests and forest products. Insect and disease outbreaks in developing countries are primarily surveyed and reported for plantations and planted trees only, and corresponding surveys of forest declines and diebacks in these countries are rare. Allard et al. (2003) thus lauded a FAO global information sharing initiative whose aim was to facilitate access to such information in order to improve the reliability of risk assessments and the design and application of effective cost-efficient forest protection strategies. The cases of pest and disease outbreaks reviewed and presented in this report on the African situation are sufficient to illustrate that few countries report on related economic losses. Estimates of the full costs of biological invasions are rare because of the difficulty in estimating costs of a problem with so many components, many of which are difficult if not impossible to quantify such as the impacts of alien invasive species on biodiversity, ecosystem functions, human health and other indirect costs such as the impacts of control measures (Moore, 2005). Yet alien invasive species generate substantial costs to the forest sector in lost revenues, in expenses for their control and in lost conservation values and ecosystem services. Alien invasive species, in particular insect pests and diseases, can damage trees in all stages of development and affect the ability of both natural and planted forests to meet their management objectives (FAO, 2001). In addition to these direct production and trade costs, the associated control costs, including the costs of inspections, monitoring, prevention and response, of even just a few species, can be enormous (Moore, 2005). Among the most serious pests of trees and forests in Sudan is Sphenoptera chalcichroa arenosa, a cambium and wood boring beetle that is wide spread in the country (see Box 2).

The impact of pests and diseases is felt more directly in an economy like the Sudan's which is predominantly based on natural resources including agricultural production, livestock, forestry and fisheries, which together contribute about 48% of GDP. Forests play a significant role in integrated land use systems in Sudan for socio-economic development and environmental protection functions in addition to provision of the needs of the various stakeholders and in livelihood support. The government earns money from direct sales of wood products such as fuel wood, construction timber and sawn timber. The majority of Sudanese households in the rural areas are highly dependent on forest products for livelihood support and income generation. The sector employs 15% of the local population in rural areas especially in the collection, processing and marketing of non-wood forest products thus providing an income for the elderly, women and children. Sudan exports about 60-80 thousand tons of gum arabic annually.

Box 2. Spread of wood boring beetles in Sudan.

> Sunt, Acacia nilotica, is the most valuable timber-producing species in northern Sudan. It contributes an estimated 40-50 % to the total sawn timber production and 10-15 % to fuel wood production. Dieback of A. nilotica was reported in the Sudan as early as the 1930s and was attributed to infestation by Sphenoptera chalcichroa arenosa, a cambium and wood boring beetle. The larvae of this beetle tunnel into the cambium layer of branches and stems causing dieback and gradual tree mortality. By the early 1950s, the condition had affected most of the forests between Khartoum and Sennar and was estimated to have caused losses of up to 60 % in the plantations along the Dinder River. It spread to the south and appeared on both banks of the Blue Nile in 1989 when it suddenly erupted reaching plague proportions. Fourteen reserves had been affected with a total area of 500 ha affected and 15 % of the A. nilotica area in the reserves being killed by 1995. (Source: FAO, 2007b).

In all of sub-Saharan Africa, pest problems of ecological and economic significance are few and of limited concern in naturally occurring forest stands. Pest impact therefore becomes significant mainly in plantations (Bosu, 2016). In the humid forest zones of West and Central Africa, plantations of high- value timber species such as iroko (Milicia excelsa and M. regia) are attacked by the iroko gall bug Phytolyma spp., and mahogany (Khaya and Entandrophragma spp.) are susceptible to the shoot borer Hypsipyla robusta. Plantations of these species have been largely avoided for these reasons, even though they appear to do better than expected when piloted. On the other extreme are plantations of exotic species which grow and thrive in the earlier years only to succumb to invasive alien pests and diseases once well established. The Blue Gum Chalcid which attacks eucalypts in eastern and southern Africa, for example, has now reached West and Central Africa placing at risk plantations of the susceptible species planted there.

4.3 Way forward

Mitigating the impact of pests and pathogens requires an integrated approach which is based on decisions reached and action taken before an outbreak is detected. Many countries in Africa have not embraced the decision-making step adequately and should consider completing it even though it is often the most time consuming and complex aspect of integrated pest management (IPM). It requires careful consideration of the pest, its host, resource management objectives and the ecological, economic and social consequences of the various available tactics (FAO, 2001). Population levels of pests are estimated and anticipated resource losses are projected, as are the costs of treatment and its anticipated benefits. If treatment costs exceed losses, a rational decision may be to not treat and accept the losses. Other questions to address include whether natural controls will take over within a short enough time so that artificial controls will be unnecessary; or whether the effects of proposed treatments could be so adverse that they would outweigh the benefits of treatment. Quick fixes are thus not an option in resolving forest health issues.

Monitoring of forest pests and diseases and their resultant damage is a critical input to the IPM decision process. Pest monitoring is becoming a sophisticated process that makes use of many technologies. Pheromones and other chemical regulators are often used to monitor insect population levels. Remote sensing technologies like aerial sketch-mapping, aerial photography and airborne video are used to map and assess forest damage. Geographic information systems (GIS) can be used to relate the location of affected areas to key resource values, terrain features, land ownerships and environmentally sensitive areas. Mathematical models can predict resultant damage caused by certain levels of pest numbers and their consequences. In some cases, pest, growth and yield and economic models are linked to make projections of pest and disease impacts.

Prevention consists of tactics designed to either reduce the probability of the occurrence of a pest or disease or to create environmental conditions inhospitable for its buildup into damaging numbers. Regulatory, cultural or genetic tactics are examples of prevention strategies. Tactics directed against pests or diseases, once detected, are referred to as direct control or suppression tactics. Examples include various types of biological, mechanical or chemical methods. Room should be made to accommodate more effective technologies of pest management as they are developed. They include more accurate pest monitoring, prediction of new pest management tactics, and more effective treatments with fewer undesirable side effects. If such a wholesome approach to forest pest and disease management was to be taken by more countries in Africa, the impact of devastating pest and disease losses as currently reported in forests could be greatly reduced and the economic development blue prints in which forests are sustainably managed to meet rising demands for goods and services would become a reality.

5.0 REGIONAL COOPERATION IN MANAGEMENT OF FOREST PESTS AND DISEASES

A major impediment to effective monitoring and early detection of outbreaks is the shortage of highly trained and skilled people capable of identifying insects and diseases as causal agents of damage to forests. This is compounded by a lack of infrastructure and transport in most countries as a result of low levels of public investment in forests when compared to other productive sectors of the economy. It is a problem which countries can tackle by cooperation within existing regional economic blocks and at the apex, as an African union.

Managing pests and diseases for the sake of forest health and optimal production is a popular concept for which FAO (2001) defined the healthy state as “a forest in which pests and diseases remain at low levels and do not interfere with management objectives.” In ecological terms, a healthy forest is “a fully functional ecosystem; one in which all of its parts can interact in a mutually beneficial way.” The healthy forest concept directs forest managers to focus on the forest rather than its pests and diseases and takes into account the natural role of insects, fungi, fire and other so called “damaging agents” and their interactions in forest dynamics. Under an overall policy of forest health protection, pests and diseases are looked upon as a symptom of an unhealthy forest rather than as the problem. This directs forest managers and forest protection specialists to address the underlying causes of the pest or disease – factors such as overstocking, over-maturity, poor site/species matching, excessive fuels and single species forests with little diversity. Striving for healthy forests also involves anticipating pests and diseases based on historical records of their occurrence and the knowledge of forest and climatic conditions that favour their abundance. This allows time to implement management practices that will make these forests inhospitable for build-up of damaging pests and disease (Ciesla, 1998).

5.1 Developments in Africa’s regional integration

A brief overview of regional integration processes on the African continent reveals that a number of colonial cross-border arrangements have continued to exist also after independence and to serve the regional integration agenda thus far (www ref. 11). Various pan-African organizations are, through different mechanisms, promoting sustainable economic growth and development, where the key component of regional integration is present in their workings. The Economic Commission for Africa (ECA) was thus established by the Economic and Social Council of the United Nations in 1958 as one of the five regional commissions of the United Nations that, together with partners and member States, consecutively work towards sustainable development. ECA focuses on providing technical assistance by undertaking research and policy analysis to strengthen the capacity of institutions driving the regional integration agenda, including the African Union (AU), regional economic communities and member states. Moreover, a key priority of ECA has been to target Africa’s development challenges, particularly in the context of poverty eradication, to ensure sustainable growth and good governance on the continent and thus promote international cooperation for Africa’s development.

Apart from the political liberalization efforts to free Africa from the yokes of colonization and apartheid, the Organization of African Unity (OAU) was formed in order to: promote unity and solidarity among African States; organize and strengthen cooperation for development on the continent; protect the sovereignty and territorial integrity of its member States; and, encourage international cooperation as outlined by the UN. Parallel to the creation of OAU was the establishment of the African Development Bank (AfDB) Group. The Group includes two other entities, with AfDB as the parent institution – the African Development Fund, which was established in 1972 by AfDB and 13 non-African countries, and the Nigeria Trust Fund, which was set up in 1976 by the Federal Government of Nigeria.

The main objectives of the Group have been to mobilize and allocate resources for investments in member states, and provide policy advice and technical assistance that supports the development efforts on the continent. The work of the above mentioned pan-African organizations are founded on treaties, protocols, conventions and other formal agreements entered into by sovereign States and international organizations (pan-African organizations and regional economic communities included) and are thus binding under international law.

At the fourth Extraordinary Summit of OAU held in Sirté, Libya in 1999, the Heads of State and Government called for the establishment of an African Union (the Sirté Declaration) in conformity with the ultimate objectives of the OAU Charter and the provisions of the Abuja Treaty. The establishment of an African Economic Community in the foreseeable future, the strengthening of existing regional economic communities and the creation of others to cover the continent as a whole were decisions intended to further nurture continental social-economic integration. The Abuja Treaty is arguably the most important agreement with regard to economic, social and political collaboration, coordination and convergence in Africa as it lays out the future of the continent with the establishment of an African Economic Community. The integration process is set to cover a period of 34 years from 1994 to 2028.

The regional economic communities that will form the building blocks of the continental community include the Economic Community of West African States (ECOWAS) which already exists among the West African countries. Southern Africa also had a socioeconomic cooperation arrangement, the Southern African Development Coordination Conference created in the 1980s, which was later replaced by the Southern African Development Community (SADC) in 1992. Similarly, Southern and Eastern Africa had established a Preferential Trade Area in 1981, which eventually became the Common Market for Eastern and Southern Africa (COMESA) in 1993. Conversely, in Central Africa, an Economic Community of Central African States (ECCAS) was created in 1983 by the leaders of the pre-existing Customs and Economic Union of Central Africa. The remaining regional economic communities – the Inter- Governmental Authority on Development (IGAD, 1986), the Arab Maghreb Union (AMU, 1989), the Community of Sahel-Saharan States (CEN-SAD, 1998), and the East African Community (EAC, 1999) – were all recognized as regional economic communities after the Abuja Treaty. See Figure 5.1.

Member states of CEN-SAD are: Benin, Burkina Faso, Central African Republic, Chad, the Comoros, Côte d'Ivoire, Djibouti, Egypt, Eritrea, the Gambia, Ghana, Guinea-Bissau, Libya, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Sierra Leone, Somalia, the Sudan, Togo and Tunisia.

A different group of member states that forms ECCAS comprises of Angola, Burundi, Cameroon, Central African Republic, Chad, Congo, DRC, Equatorial Guinea, Gabon, Rwanda and Sao Tome and Principe.

The member states of COMESA are Burundi, the Comoros, DRC, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Sudan, Swaziland, Seychelles, Uganda, Zambia and Zimbabwe.

EAC membership comprises of Burundi, Kenya, Rwanda, South Sudan, Uganda and United Republic of Tanzania.

The member states of SADC are Angola, Botswana, DRC, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

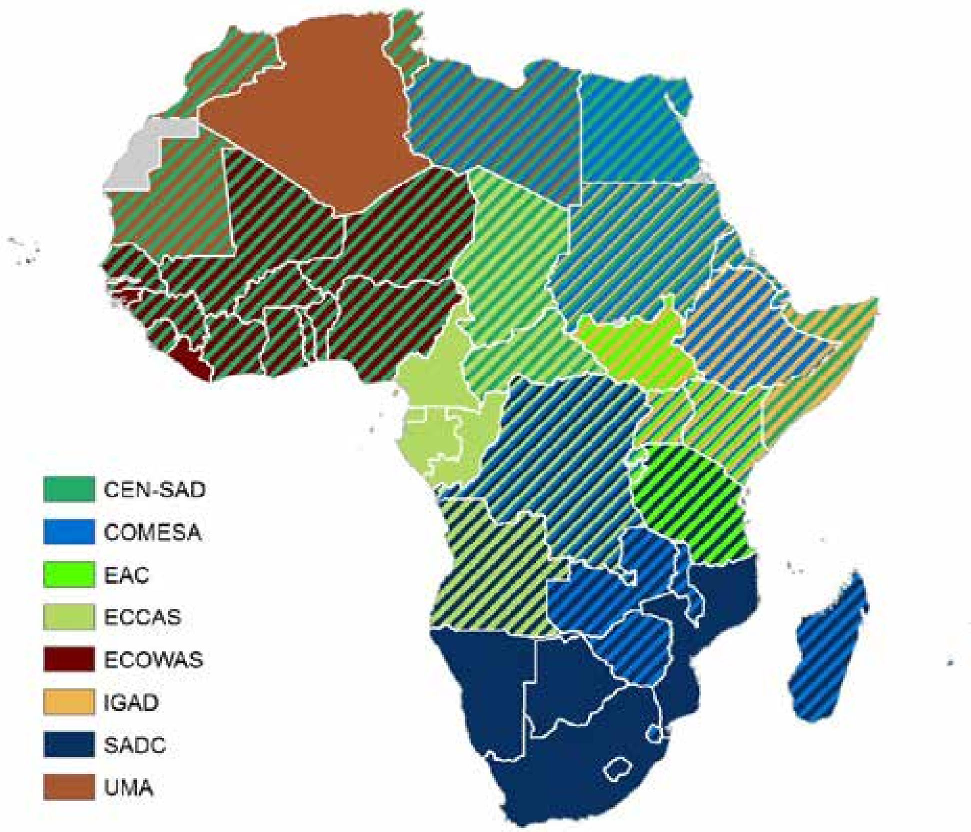

Figure 3. Regional Economic Communities of Africa. Source: www ref. 11.

Given that countries of Africa share indigenous and introduced vegetation types which spread across borders, implications for the communities for forest pest and diseases management are that countries need not act in isolation when faced with biological forest health challenges. Avenues can be explored with ease under the higher framework of the regional communities to collaborate and implement integrated pest management of the concerned organisms.

6.0 INSTITUTIONS AND INSTITUTIONAL CAPACITIES FOR FOREST PEST AND DISEASE CONTROL AND MANAGEMENT IN AFRICA

6.1 Status of Regional Sanitary and Phytosanitary protocols

6.2.1 Eastern Africa

EAC has already developed and adopted a common phytosanitary protocol which is based on the requirements of IPPC and whose benefits are many-fold (EAC, undated). The EAC protocol on Sanitary and Phytosanitary measures is based on the provisions of Chapter XVIII of the treaty for the establishment of EAC.

- Article 105 to 110 of Chapter 18 of the Treaty provide for Partner States to cooperate in agriculture and food security.
- Article 108 provides for cooperation in the control of plant and animal diseases.

In order to facilitate trade within the community and other trading partners,

- Article 38 of the protocol on the Establishment of the EAC Custom Union requires the Partner states to take cognizance of cooperation in Sanitary and Phytosanitary measures.

It is expected that the protocol will, among other things.

- Harmonize inspections and certification procedures of plant and plant products.
- Regulate the importation, research on, development and use of living modified organisms and products of modern biotechnology and biological control agents.
- Provide framework for the management of pests
- Ensure the safe movement of plants and plant products.

It is too early to tell if all the perceived benefits will be realized and emerging issues resolved. These include dealing with the loophole of repackaging of materials while in transit and plant import permits being considered as non-tariff barriers to trade. The enforcement of the protocol also relies on formal trade in plant products whereby it is hoped to intercept infested cargo. In reality, there is also informal trade between countries and winged pests are usually dispersed by natural means such as air currents over which ports of entry have no control.

6.2.2 Southern Africa

SADC has a phytosanitary protocol which member countries adopted in 2008 (Kojwang, 2015). Key objectives of the protocol are:

- To promote the development, conservation, sustainable management and utilization of all types of forests and trees.

- Promote trade in forest products from sustainable sources.
- Achieve effective protection of the environment and safeguard the interests of both present and future generations.

The protocol goes further to provide suggested actions which are quite instructive. The regional study for southern Africa on forest pests and diseases, however, discloses that the protocol has been inactive despite the necessary technical committee has been constituted. The remaining linkages between practitioners and specialists would also have to be established for it to become fully operational. The need to activate this protocol is considered all the more urgent given that commercial plantations in this region sometimes rely on importation of large numbers of seedlings from neighboring countries and other regions of the world for their forestry programmes. Existing quarantine services are only equipped for agricultural imports.

6.2.3 On-going collaborative initiatives in southern Africa

For regulation of trade, there is a tri-partite agreement that is under negotiation between EAC, SADC and COMESA, which covers seed exchange. It addresses seed trade policy harmonization and was launched in 2014. It recognizes that differences in seed policies and standards across countries (and between different regions), as well as that differing levels of technical capacity can create challenges that ultimately impact the availability and access of seeds (Kuhlmann and Zhou, 2015). In every case, a country's rules on variety release and registration, seed certification, SPS measures and PVP laws need to be assessed within the context of regional harmonization in order to understand future market potential and how implementation of rules will work in practice. The architects of the process are encouraged to develop innovative approaches that draw upon successful experiences from other regions.

6.2.4 West and Central Africa

ECOWAS does not have a regional phytosanitary protocol. However, a draft ECOWAS Regulation has been developed (Magalhães, 2010). Through specific projects, ECOWAS in collaboration with AU organizes training workshops for "SPS focal persons" in its Member States (Magalhães, 2010). However, inability of ECOWAS to regularly monitor and also assist member countries to implement new regional regulation is a major challenge. On the other hand, ECCAS currently does not have a common phytosanitary policy for the region. Inadequate human and financial resources and a lack of political awareness about SPS issues are serious constraints hampering ECCAS to develop common phytosanitary regulations (Magalhães, 2010). In the past, SPS regulation on food safety, animal and plant health was developed with FAO through the Food Security Regional Programme. A common phytosanitary certificate which follows the IPPC model has been recommended for the region.

7.0 MODALITIES OF DEVELOPING SURVEILLANCE MECHANISMS

The countries of Africa have signed agreements for forest pest and disease surveillance as independent parties to the International Plant Protection Convention (IPPC). This individual action allows National Plant Protection Organizations (NPPOs) to become members of Regional Plant Protection Organizations (RPPOs),, thereby aligning them to cooperate to tackle problems of entry, establishment and spread of forest pests and diseases at continental level. IPPC parties play a major role in the process of making International Standards on Phytosanitary Measure (ISPMs) as they can initiate action by proposing development of new ones or revising existing ones to deal with a particular issue. Alternatively, RPPOs gather and disseminate information and may identify priorities for regional standards which may become the basis for new ISPMs. All African countries, with the exception of Morocco, are members of the Inter African Phytosanitary Council (IAPSC), making it the regional body of choice to coordinate and galvanize action in protection of trees and forests on the continent under the Convention. IAPSC could therefore play a key role in the future of forest pest and disease management in Africa. The Council needs to review its current arrangements to give more prominence to forestry issues on the continental scale. In so doing, it will better fulfill its mandate and core functions as follows:

- Development and management of information to serve Africa and International Plant Protection Organizations (IPPOs).
- Harmonization of Phytosanitary regulations in Africa.
- To prevent the introduction and spread of pests which attack and damage crops and forests in Africa.
- To develop a common strategy against the introduction and spread of pests, particularly through the harmonization of phytosanitary legislation.
- To ensure co-operation and a harmonized approach in all areas of plant protection where governments take official measures (registration of pesticides, certification of plant materials, accreditation of people who apply pesticides, etc.).
- To provide a documentation service for provision and exchange of information in all areas of its activities.

Activities of the Council are outlined in the Maputo Declaration by AU in 2003 and are as follows (www ref. 12):

- Plant protection information management.
- Promotion of safe and sustainable plant protection techniques.
- Enlightenment of member states on the implications of the WTO-SPS Agreement on international agricultural trade.
- Capacity building among member states in phytosanitary and plant protection activities.

- Development of regional strategies against the introduction and spread of plant pests (insects, plant pathogens, weeds etc.).
- Training of various cadres of NPPOs in Pest Risk Analysis (PRA), phytosanitary inspections and treatment, field inspection and certification, laboratory diagnoses, pest surveillance and monitoring, etc.

In addition to other guidelines, FAO (2011) assists those charged with management of forest pests and diseases to interpret phytosanitary standards, equipping them with knowledge for meeting the objectives of sustainable forest management. Specifically, the guide explains:

- how the ISPMs and NPPO regulations affect the import and export of forest commodities,
- how people in the forest sector can reduce the risks of spreading pests through effective management approaches,
- how ISPMs can be used to prevent forest pest introduction and spread, and,
- how forest sector personnel can work together with NPPOs to contribute to the development and implementation of ISPMs and national phytosanitary regulations that help reduce pest movement while being as least restrictive to trade as possible.

Implementing these guidelines can lead a party to adopt best practices in managing pests and diseases in an integrated way. Good practices begin before trees are planted, are followed during growing seasons, at harvest, in post-harvest treatment and handling imports and exports of forest commodities. Any country with such a sound forest pest and disease management regime will fulfill its obligations under the IPPC.

Another approach to take in the war against invasive species is building technical capacity and equipping research facilities to address the challenges faced at present. An overview by Garnas et al. (2015) of invasive species management not only clearly illustrates how genetic tools can inform management but also highlights the urgent need for adequate taxonomic systems to describe this diversity. In many cases, expertise to identify and describe cryptic species or distinct lineages using traditional tools simply does not exist. New ways to systematically characterize and/or name biological diversity that go beyond traditional taxonomic approaches will additionally have to be explored, particularly with respect to microbes and also for insects. The increased recognition of the complexity of invasion patterns in insects (and other organisms) has been driven in a large part by advances in the availability of more powerful molecular markers and analysis tools. In insects, mitochondrial COI sequence data have long been used to trace the origin of invasive populations. While useful and often very informative, this tool is also plagued by problems, such as poor amplification in some groups or the presence of nuclear mitochondrial pseudogenes (numts) that can cause an overestimation of diversity and otherwise confound phylogenetic relationships if not detected.

The ease with which modern sequencing platforms allow the development of SSR markers as well as their power and repeatability for population genetic analysis has led to a dramatic increase in the use of such approaches over the past decade (Santana et al., 2009). These same advances in sequencing technology are now also driving the increased use of single nucleotide polymorphisms (SNPs) as preferred markers, particularly at a whole genome or transcriptome level. These genomic approaches to population genetics not only vastly increase the power of the markers available to describe patterns of diversity, but also enable the study of the causes and consequences of invasion at a population genetic level. These tools have not yet been widely applied to invasive insects (Garnas et al., 2015). Expertise in these new fields requires to be developed in Africa for molecular research on the continent to keep up with international trends.

Managing forest pests and diseases in Africa must also be informed by the fact that apart from the complications arising from the existence of different lineages in distinct parts of an invader's range (for example, if management must be customized), the uniting or reuniting of previously isolated populations or species can result in unique combinations of alleles via hybridization or admixture, which can further complicate management approaches. Garnas et al. (2015) give an example of the emergence of new genetic combinations resulting from uniting or reuniting separately evolving lineages has been shown for the Pine Processionary Moth, Thaumethopea pityocampa. While the moth was considered to have expanded naturally from southern Europe with global warming, its northward spread now appears to have been driven at least in part by long-distance transport by humans of potted pine trees. As a result, the northern front of the advancing distribution is characterized by genetic admixture combining genes of populations from different parts of Europe having different primary phenologies. Large imports of seedlings for plantation establishment which Kojwang (2015) observed in southern Africa therefore might have serious implications on forest health on the continent.

Noting that the existence of globally distributed species is not new and in some cases appears to be largely independent of modern trade (that is, in highly dispersive species with wide environmental tolerances, though cryptic species also commonly occur in these groups), Garnas et al. (2015) focused on the role of human movement in spread of pests and diseases of trees. They found global spread to be very strongly influenced by the movement of our own species based on a recent spate of invasions of pests of agriculture, including forest plantations of pine and eucalypts (particularly the latter). It appears that many invasive insects are reaching global status much more rapidly than before. Species such as S. noctilio, Gonipterus spp. and Ctenarytaina eucalypti (among others) that escaped their respective native ranges in the late 1800s/early 1900s generally took between 50 and 100 years to reach truly global distributions (that is, presence on all or most continents where hosts occur). Among more recently emerging invasive insects, several have achieved such distributions in little more than a decade or less. For example, Leptocybe invasa, a gall wasp on eucalypts, was first reported in Israel in 2000. At that time, this wasp was completely unknown, but by 2008 it had spread throughout the North and South America, southern and southeast Asia, the Mediterranean and Africa in what appeared to be a more or less stepwise fashion. The spread has been exceptionally rapid, but several other pests of Eucalyptus (e.g. Glycaspis brimblecombei, Ophelimus maskelli and Thaumastocoris peregrinus) are currently spreading globally at similar pace.

This phenomenon has been seen in a number of insects from diverse taxonomic lineages, as well as across hosts, herbivorous feeding guild, and life histories. While some recently emerging pests that exhibit rapid spread could be specifically and idiosyncratically linked to pathways that permit it, it has been shown that this faster spread constitutes a general phenomenon for invasive insects since the mid-1990s, for Europe at least (Garnas et al., 2015). There is widespread agreement that increasing global connectivity, in particular the growing volumes and rates of movement of goods and people, is the most important factor influencing the increase in the number of invasive insects and micro-organisms.

There further appears to be complex interplay between factors that influence the global movement of pests, leading to the rapid attainment of global distributions and 'pest homogenization' on crop and forestry hosts. Apart from trade and the movement of people, these include: (1) the global homogenization of host species (e.g. Eucalyptus) which is increasingly becoming a global fiber crop; and, (2) the positive feedback between global introduction and spread and subsequent invasion. This latter phenomenon, where invasive populations act as the source of further introductions, has been termed the ''bridgehead effect'' and is increasingly seen as an important driver of increasing rates of global invasive species. This effect was first described by Lombaert et al. (2010) in the context of the invasion of the Harlequin ladybird beetle (H. axyridis), where a highly fit invasive population in North America appears to have acted as a source from which further invasions into Europe, South America and Africa originated. This phenomenon - where one or more invasive populations serve as a source or hub for further global introduction - has also subsequently been described for many other insects and is evident in invasions of S. noctilio, L. invasa and other insects given to global spread.

A particularly successful original invasion that serves as the source of subsequent invasions could be the result of an evolutionary shift in this population that increases its invasive ability. Alternatively, such patterns could be ascribed to a geographic or other advantage with respect to human movement and trade (Garnas et al., 2012). Understanding the processes that influence some populations to serve as sources of invasion while not others is an important objective of future studies of invasive insects. Regional cooperation will continue to play an important role for managing invasive pests and diseases through consultation and taking joint and timely action.

8.0 CONCLUSIONS

The report presents sustainable forest management as the approach that will ensure trees and forests to remain healthy and that they enrich the ecosystem with goods and services to support meaningful livelihoods for people and nature-based sectors of the economy that depend on them. The current situation is marked by a shortage of technical skills in undertaking surveillance for tree pests and diseases as well as inadequate infrastructure to match the field and subsequent laboratory investigations that are often necessary. It is proposed that management of pests and diseases can be made more cost effective by recognizing centers of excellence that offer support services and serve to build capacity of experts at regional and continental level.

The most recent advances have been reviewed in the fight against pests and diseases of trees and forests in Africa. Tremendous strides have been made in understanding pests and diseases of introduced trees and FABI continues to play a crucial role for Southern Africa, the entire continent and globally in training and equipping scientists to tackle related challenges. The current approach to phytosanitary measures is one whereby countries prefer to come together as parties to an international convention. Organization of trade through economic communities further justifies adoption of regional protocols which cover all member countries.

With regard to the above, the following points are worth noting:

- Historically, the eastern and southern Africa regions have shared similar disease and pest problems of exotic tree species grown in industrial plantations. Findings of this study also confirmed that sub-regions of central, western, southern and eastern Africa share some disease and pest problems, particularly those that affect species of Eucalyptus.
- Regarding some valuable, indigenous timber species, the Iroko gall fly (Phytolyma sp.} and Mahogany shoot borer are widespread in west, central, eastern and some parts of southern Africa. This suggests that much cooperation on research to manage these pests is needed. In essence, these pest problems have effectively inhibited the commercial growing of the two species but it is not clear if sufficient efforts have been put in their control and management.
- The rates at which pests and diseases of Eucalyptus have spread in Africa over the last 5 years is a cause for alarm and the situation calls for research and management action to develop or reactivate dormant protocols for regional and bilateral surveillance.
- Tree disease and pest problems in Africa have implications on selection, breeding and the silvicultural practices to be adopted for plantations such as mixed species planting, provenance-site matching and sanitation programmes, to name but a few.
- Based on what we know about interactions between hosts, pests and the environment, the phenomenon of climate change could favor their faster spread and, as a result, may exacerbate economic damage. This is clearly an issue for the attention of policy makers who will be required to allocate resources for both research and integrated disease and pest management.

9.0 RECOMMENDATIONS

The situation of forest pests and diseases in Africa calls for a concerted management effort integrating several approaches at national, regional and continental levels. It is recommended that:

1. At national level, strengthen research by investing in human resource and infrastructural development so as to equip local institutions with knowledge and skills to combat forest health threats.

2. At regional level, adopt harmonized surveillance approaches for monitoring the health of trees and forests. Regional economic communities can adopt common SPS protocols.

3. Regional Economic Communities supported by scientists in member states should generate data to demonstrate urgency with which countries need to reactivate dormant protocols for regional implementation. This activity must be given top priority.

4. Scientists and forest managers should gather data on the economic impacts of disease and pest infestations as it is a critical input to influence policies. The data can be analysed to illustrate the dynamic situation within and between countries so that concerted efforts can be made to manage shared pest and disease problems.

5. Tertiary training and research institutions should undertake strategic programmes since there is evidence to demonstrate that spread of some pests is taking place at astonishing rates and can cause significant economic damage. Centers of excellence in biological control of forest pests and diseases, such as FABI and COPE, should be facilitated to interact more widely with other institutions in sub-Saharan Africa that are responsible for forest pest and disease management.

6. To create good will amongst stakeholders, regional tree and forest disease and pest alerts should be shared widely so as to help raise awareness of the need to take common action.

7. In virtually all African countries, plant quarantine services fall under departments of Agriculture whose technical personnel have little or no experience in handling forest pests and diseases. Forest departments in all countries therefore need to proactively engage with national plant quarantine authorities to ensure that materials infested with forest pests and diseases of concern are recognized and intercepted.

8. At continental level, it will be necessary to take advantage of the existence of internationally recognized regional plant protection organizations under the IPPC to develop adequate programmes for management of pests and diseases of trees and forests. The African Union is at the highest level of economic cooperation on the continent and is affiliated with the IAPSC to which a majority of its members are parties. The Council is well placed to regulate pest and disease movement, especially entry into new territories.

10.0 : ACKNOWLEDGEMENTS

We appreciate the kind financial support received from the Government of Sweden through the Swedish International Development Cooperation Agency (Sida) to implement an AFF project on "Strengthening sustainable forest management in Africa" that generated much of the information that formed the basis for writing this Working Paper. AFF is also indebted to the Swiss Agency for Development and Cooperation (SDC) for its support of another AFF project on "African forests, people and climate change" that also provided inputs into this document.

11.0 REFERENCES

Abdallah, J.M. and G.G. Monela, 2007. An Overview of Miombo Woodlands in Tanzania. Working

Papers of the Finnish Forest Research Institute 50: 9–23.

Akyeampong, E., L. Hitimana, S. Franzel, and P.C. Munyemana, 1995. The agronomic and economic performance of banana, bean and tree intercropping in the highlands of Burundi: an interim assessment. Agroforestry Systems 31(3):199-210.

Alemu, G., J. Roux and M.J. Wingfield, 2003a. Diseases of Exotic Eucalyptus and Pinus species in Ethiopian Plantations. South African Journal of Science 99:29-33.

Alemu, G., J. Roux and M.J. Wingfield, 2003b. First report of pink disease on Eucalyptus camaldulensis

in Ethiopia. Plant Pathology 52, 402.

Alemu, G., M-N. Cortinas, M.J. Wingfield and J. Roux, 2005. Characterizaton of the coniothyrium stem canker pathogen on Eucalyptus camaldulensis in Ethiopia. Australasian Plant Pathology 34:85-90.

Alemu G., 2006. Mycosphaerella species associated with leaf disease of Eucalyptus globulus in Ethiopia.

Alemu, G., A. Yirgu and Habtemaria Kassa, 2014. First report of Lasiodiplodia theobromae causing canker on tapped Boswellia papyrifera trees in Ethiopia. New Disease Reports 29, 11.

Allard, G.B., S. Fortuna, Lee Su See, J. Novotny, A. Baldini and T. Courtinho, 2003. Global Information on Outbreaks and Impact of Major Forest Insect Pests and Diseases. WFC XII. Quebec, Canada.

Agyeman, V.K. and E.Y. Safo, 1997. Mineral nutrition and dieback in Terminalia ivorensis A. Chev. in Ghana. J. Trop. Ecol. 13:317-335.

Apetorgbor, M.M., D.E.K.A. Siaw and A. Gyimah, 2003. Decline of Ceiba pentandra seedlings, a tropical timber species, in nurseries and plantations. Ghana Journal of Forestry 11(2): 51-62.

Apetorgbor, M.M., J. Roux and E. Nkrumah, 2013. Cedrela odorata and Tectona grandis mortality on Quarm Farms. Report submitted to Quarm Farms. 10pp. CSIR-FORIG, Kumasi.

Apetorgbor, M.M. and J. Roux, 2015. Diseases of plantation forestry trees in Southern Ghana.

International Journal of Phytopathology 4(1):5-13.

Boa, E.R., 1992. Neem Disorder and Neem Scale in Nigeria. Project TO 361. Natural Resources Institute, Overseas Development Administration. 41 pp

Boa, E.R., 1995. A guide to the identification of diseases and pests of neem (Azadirachta indica). RAP Publ. No. 41, FAO Bangkok, 71 pp.

Bosu, P., 2016. Status and Trends of Forest and Tree Pests and Diseases in West and Central Africa. Technical Report, African Forest Forum.

Browning, J.A., M.D. Simons, and E. Torres, 1977. In: Plant Disease, an Advanced Treatise, Vol. 1.J.G. Horsfall and E.B. Cowling (eds). 191-192. Academic Press, NY.

Chidumayo, E., 2011. Climate Change and the Woodlands of Africa, In: Chidumayo, E., D. Okali, G. Kowero and M. Larwanou (eds.), 2011. Climate change and African forest and wildlife resources. African Forest Forum 85-101.

Chungu, D., A. Muimba-Kankolongo, M.J. Wingfield and J. Roux, 2010b. Identification of fungal pathogens occurring in eucalypt and pine plantations in Zambia by comparing DNA sequences. Forestry 83(5):507-515.

Ciesla, W.M., 1994. Ensuring sustainability of forest through protection from fire, insects and diseases.In FAO Forestry Paper 122. Readings in sustainable forest management. ISSN 0256-6150.

Cortinas M. N., P.W. Crous, B.D. Wingfield and M.J. Wingfield, 2006. Multigene phylogenies and phenotypic characters distinguish two species within the Colletogloeopsis zuluensis complex associated with Eucalyptus stem cankers. Studies in Mycology 55:113-146.

East African Community Protocol on SPS. Undated. 11 pp.

El Atta, H.A., 2000. Effect of diet and seed pretreatment on the biology of Bruchidius uberatus
(Coleoptera, Bruchidae). Silva Fennica 34(4):431–435.

El Tahir, B.A., K.E.M. Fadl and A.G.D. Fadlalmula, 2010. Forest biodiversity in Kordofan Region, Sudan: Effects of climate change, pests, disease and human activities. Biodiversity 11(3 & 4):34-43.

Fact Net, 1998. Grevillea robusta Fact Sheet. A publication of Forest, Farm, and Community Tree Network. Winrock International. 5pp.

FAO, 1991. Workshop Proceedings. Exotic Aphid Pests of Conifers: A Crisis in African Forestry.
Social Forestry Centre, KEFRI, Muguga, Kenya. 3-6 June, 1991.

FAO, 1994. Decline and dieback of trees and forests A global overview. FAO Forestry Paper 120. 90 pp.

FAO, 2001. Protecting plantations from pests and diseases. Report based on the work of W.M. Ciesla.
Forest Plantation Thematic Papers. Forest Resources Development Service, Forest Resources Division. Working Paper 10.

FAO, 2003a. Forestry Outlook Study for Africa: Sub regional Report for Eastern Africa. FAO, 2003b. Forestry Outlook Study for Africa: Sub regional Report for Central Africa. FAO, 2003c. Forestry Outlook Study for Africa: Sub regional Report for

West Africa. FAO, 2003d. Forestry Outlook Study for Africa: Sub regional Report for Southern Africa. FAO, 2007a. Overview of forest pests in Kenya. Working Paper FBS/20E.

FAO, 2007b. Overview of forest pests in the Sudan. Working Paper FBS/31E.

FAO, 2009. Global Review of Forest Pests and Diseases. A thematic study prepared in the Framework of the Global Forest Resources Assessment 2005. FAO Forestry Paper No. 156.

FAO, 2010. Global Forest Resources Assessment. Main Report. FAO Forestry Paper No. 163. 378pp.

FAO, 2011. Guide to implementation of phytosanitary standards in forestry. FAO Forestry Paper 164.

FAO, 2012. Forest Pest Species Profiles. Leptocybe invasa. Blue Gum chalcid (Hymenoptera: Eupholidae).

FAO, 2015. Global Forest Resources Assessment 2015. How are the world's forests changing? FAO, Rome, ISBN 978-92-5-108821-0 56 pp. http://www.fao.org/3/a-i4793e.pdf

FAO, undated. Cypress aphid pest control in Ethiopia. Sub regional Office for East Africa.5 pp

FNC, 2011. Supplement to Expression of Interest in Joining the Forest Carbon Partnership Facility (FCPF). 6 pp.

Forestry South Africa, 2014. South African Forestry Facts 2012-2013

Francl, L.J. 2001. The Disease Triangle: A plant pathological paradigm revisited. The Plant Health Instructor. DOI: 10.1094/PHI-T-2001-0517-01 Reviewed, 2007.

Garnas, J.R., M. Auger-Rozenberg, A. Roques, C. Bertelsmeier, M.J. Wingfield and D.L. Saccaggi, 2015. Complex patterns of global spread in invasive insects: eco-evolutionary and management consequences. Biol Invasions DOI 10.1007/s10530-016-1082-9.

Gbadegesin, R.A, J.O. Adegbehin and E.B.Tologbonse, 1999. Major disease and pests of forest trees and their control in Nigeria. Extension bulleting 178, Forestry Series No. 3. pp.28.

Gibson, I.A.S., 1964. The impact of disease on forest products in Africa. In Proc. FAO/IUFRO Symposium on Internationally Dangerous Forest Diseases and Insect Pests, pp. 1–13, Oxford.

Gibson, I.A.S., 1972. Dothistroma blight of Pinus radiata. Ann. Rev. Phytopath. 10:51–72.

Gichora, M., 2016. The status of tree and forest pests and diseases in Eastern Africa Sub-region.

Technical Report, African Forest Forum.
Gonthier, P. and G. Nicolotti (eds.), 2013. Infectious forest diseases. CABI, 672 pp. ISBN 9781780640402.

Heath, R.N. and M.J. Wingfield, 2005. Diseases of plantation forestry trees in Eastern and Southern Africa.

Hurley, B.P., B. Slippers and M.J. Wingfield, 2007. A comparison of control results for the alien invasive wood wasp, Sirex noctilio, in the southern hemisphere. Agricultural and Forest Entomology 9(3):159–171.

Kenya Forest Service, 2009. A Guide to On-Farm Eucalyptus Growing in Kenya. 36 pp.

Kojwang, H., 2015. Forest Pests and Diseases in Southern Africa. Main Report. African Forest Forum. Kuhlmann K. and Y. Zhou, 2015. Seed Policy Harmonization in the EAC and COMESA: The Case of Kenya. Working paper. Syngenta Foundation for Sustainable Agriculture. 29 pp

Lale, N.E.S., 1998. Neem in the Conventional Lake Chad Basin Area and the threat of Oriental yellow scale insect (Aonidiella orientalis Newstead) (Homoptera: Diaspididae). Journal of Arid Environments 40(2):191-197.

Lombaert E., T. Guillemaud, J-M. Cornuet, T. Malausa, B. Facon and A. Estoup, 2010. Bridgehead effect in the worldwide invasion of the biocontrol Harlequin ladybird. PLoS ONE 5:e9743.
Louppe D., 2008. In: D. Louppe, A.A. Oteng-Amoako and M. Brink (eds.): Plant resources of tropical Africa. Prota 7(1): Timbers. Wageningen. p. 540-546.

Louw, W., 2012. A brief history of the South African Forest Industry. In: Bredenkamp B.V. and S.J. Upfold (eds): South African Forestry Handbook, 5th Edition. The South Africa Forestry Institute.

Mausse-Sitoe, S.Nd,, Shuaifei Chen, M.J. Wingfield and J. Roux, 2016. Diseases of eucalypts in the Central and Northern Provinces of Mozambique. Southern Forests 78(3):169-183.

Mery, G., S. Västilä and M. Lobovikov, 2014. In: P. Katila, G. Galloway, W. de Jong, P. Pacheco and
G. Mery (eds.): Forests under pressure: local responses to global issues. IUFRO World Series Volume 32:513-526.

Moore, B.A., 2005. Alien Invasive Species: Impacts on Forests and Forestry. A Review. FAO Forest Resources Development Service Working Paper FBS/8E.

Murphy, S.T., 1996. Status and impact of invasive conifer aphid pests in Africa. Proceedings IUFRO Symposium on Impact of Diseases and Insect Pests in Tropical Forests, pp. 289-297.

Mutitu et al., 2008. Pests and Diseases Associated with Eucalyptus in Kenya. Research Note No. 7.

KEFRI.
Mutitu et al., 2013. Biology and rearing of BC for Thaumastocoris peregrinus. J. Econ. Entomology106(5):1979-1985.

Mwangi, L., 2014. Pests and diseases of Eucalyptus and their management. KEFRI Brochure.

Ngaga, Y.M., 2011. Forest Plantations and Woodlots in Tanzania. African Forest Forum 1(16). 80 pp. Njuguna, J.W., 2011. Stem canker and die back disease of Grevillea robusta in Kenya.

Nsolomo, V.R. and K. Venn, 1994. Forest Fungal Diseases of Tanzania: Background and Current Status. Norwegian Journal of Agricultural Sciences 8:189-201.

Nsolomo, V.R. and K. Venn, 2000. Capacity of fungi to colonise wood of the East African camphor tree, Ocotea usambarensis. Mycological Research 104:1468-1472.

Ofosu-Asiedu, A. and P. Cannon, 1976. Terminalia ivorensis decline in Ghana. Pest Articles and News Summaries 22(2):239-242.

Okelo, O., 1972. Life History Studies of Gonometa Podocarpi Aurivillius (Lepidoptera: Lasiocampidae) in East Africa. Ohio Journal of Science 72(5):301-303.

Oldfield, S., C. Lusty and A. MacKinven, 1998. World List of Threatened Trees. World Conservation Press, Cambridge.

Paine T.D. and F. Lieutier, (eds), 2016. Insects and Diseases of Mediterranean Forest Systems. Springer Verlag.
Parfitt, D., J. Hunt, D. Dockrell, H.J. Rogers and L. Boddy, 2010. Do all trees carry the seeds of their own destruction? PCR reveals numerous wood decay fungi latently present in sapwood of a wide range of angiosperm trees. Fungal Ecology 3(4):338-346.

Rao Y.R.A., 1961. Shade trees for Coffee. II. Grevillea robusta A. Cunn. Indian Coffee 25(11):329-32 + 1 set of drawings).

Rijkers T., W. Ogbazghi, M. Wessel and F. Bongers, 2006. The effect of tapping for frankincense on sexual reproduction in Boswellia papyrifera. Journal of Applied Ecology 43:1188-1195.

Roy, H.E., B. Slippers and K. Gebrehiwot, 2003. Ecology and management of Boswellia papyrifera (Del.) Hochst. Dry forest in Tigray, Northern Ethiopia. Georg-August-University of Göttingen, Germany. PhD thesis.

Ryvarden, L., 1980. A preliminary Polypore Flora of East Africa. Fungiflora, Oslo. Publ. 636pp.

Roux, J., G. Meke, B. Kanyi, L. Mwangi, A. Mbaga, G.C. Hunter and G. Nakabonge, 2005. Diseases of plantation forestry trees in eastern and southern Africa. South

African Journal of Science 101:409-413.

Roux, J., B.P. Hurley and M.J. Wingfield, 2012. Diseases and pests of Eucalypts, Pines and Wattle. In: Bredenkamp B.V. and S.J. Upfold (eds): South African Forestry Handbook, 5th Edition. Published by The South Africa Forestry Institute.

Rural Industries Research and Development Corporation, 2008. Trees for Farm Forestry: 22 promising species. Publication No. 09/015 Project No. CSF-56A

Santana, Q., M. Coetzee, E. Steenkamp, O. Mlonyeni, G. Hammond, M. Wingfield and B. Wingfield, 2009. Microsatellite discovery by deep sequencing of enriched genomic libraries. Biotechniques 46:217–223.

Schabel, H., 2006. Forest Entomology in East Africa: Forest Insects of Tanzania. Springer Science & Business Media. 328pp.

Schmutterer, H., 1998. Some Arthropod Pests and a Semi-parasitic Plant Attacking Neem (Azadirachta indica) in Kenya. Anz. Schiidlingskde. Pflanzenschutz,Umweltschutz 71: 36-38. Blackwell Wissenschafts-Verlag, Berlin. ISSN 0340-7330

Sidibe, B., 2009. Mission Report to Liberia (Monrovia) from January 30th to February 8th, 2009. Slippers, B., B.P. Hurley and M.J. Wingfield, 2015. Sirex Woodwasp: A Model for Evolving Management Paradigms of Invasive Forest Pests. Ann. Rev. Entomol. 60:601–619.

Speight, M.R. and Wainhouse, D. 1989. Ecology and management of forest insects. Clarendon Press, Oxford, UK, 374 pp.

Spiers, N. and M. Stewart, 1992. Use of G. robusta in Embu and Meru districts of Kenya. In: Harwood

C.E. (ed.): Grevillea robusta in Agroforestry and Forestry. Proceedings of an International workshop. Nairobi, Kenya: ICRAF. Pp. 37-48.

Stevens, R.B., 1960. In: J.G. Horsfall and A.E. Dimond (eds.): Plant Pathology, an Advanced Treatise., Vol. 3:357-429. Academic Press, NY.

Tea Research Institute of East Africa, 1969. Tea Growers Handbook 1969. Tea Boards of Kenya, Tanganyika and Uganda.

UNEP-FNC. 2011. Forestry and Woodfuel Project. Concept Note for a Joint Project by The Forests National Corporation and UNEP.

van Lierop, P., E. Lindquist, S. Sathyapala and G. Franceschini, 2015. Global forest area disturbance from fire, insect pests, diseases and severe weather events. Forest Ecology and Management 352:78- 88.

Wagner, M.R., J.R. Cobbinah and P.P. Bosu, 2008. Forest Entomology in West Tropical Africa: Forest Insects of Ghana. 2nd Edition. Springer. The Netherlands. 244pp.

Wingfield, M.J. and P.S. Knox-Davies, 1980. Observations on diseases in pine and eucalyptus plantations in South Africa. Phytophylactica 12:57-63.

WWF Mediterranean Programme Office, 2001. The major forest types in the Mediterranean. Map. Wylie F.R. and M.R. Speight, 2012. Insect pests in tropical forestry. ISBN 978-1-84593-635-5. 365pp. CABI.

Zwolinski J.B., W.J. Swart and M.J. Wingfield,1990. Economic impacts of post-hail dieback induced by Sphaeropsis sapinea. Eur. J. For Path. 20:405-411.

References from World-Wide Web (www), mentioned in text:

1. https://en.wikipedia.org/wiki/Mediterranean_woodlands_and_forests
2. http://www.worldwildlife.org/ecoregions/pa1214
3. http://www.iufro.org
4. http://www.iufro.org/science/divisions/division-7/
5. http://www.cabi.org/isc/datasheet/109741
6. http://www.fabinet.up.ac.za/index.php/people-profile?profile=936
7. http://www.iufro.org/publications/proceedings/proceedings-meetings-2014/#c21355
8. www.fao.org/forestry/fisna/en/
9. www.fao.org/forestry/26951
10. http://www.cabi.org/isc/datasheet/49497
11. http://www.uneca.org/oria/pages/history-africa%E2%80%99s-regional-integration-efforts
12. www.nepad.org/resource/au-2003-maputo-declaration-agriculture-and-food-security

12.0 APPENDICES

Appendix 1: Major pests of indigenous trees in the humid forest zone of West and Central Africa (Source: Bosu, 2016).

Insect pest species	Order: Family	Countries of occurrence	Host species	Feeding habit
Anaphe venata	Lepidoptera: Notodontidae	Ghana, Nigeria	*Triplochiton scleroxylon*	Defoliator
Analeptes trifasciata	Coleoptera: Cerambycidae	Ghana, Nigeria, Sierra Leone, Benin, Côte d'Ivoire	*Ceiba pentandra, Tectona grandis, Bombax costatum, Eucalyptus alba, E. territicornis, Adansonia digitata, Anacardium occidentalis, etc.*	Stem borer, mainly in the savannah zone and dry forest
Apate monachus	Coleoptera: Bostrichidae	Ghana	*Azadirachta indica, Terminalia ivorensis, Antiaris africana, various other species*	Stem borer
Apate terebrans	Coleoptera: Bostrichidae	Ghana	*Tectona grandis, Terminalia ivorensis, Cedrela odorata, T. scleroxylon, Eucalyptus* spp., *Khaya senegalensis, various other species*	Stem borer
Diclidophlebia eastopi	Homoptera: Psyllidae	Nigeria, Ghana, Côte d'Ivoire	*Triplochiton scleroxylon*	Sap feeder
Hypsipyla robusta	Lepidoptera: Psyllidae	Ghana, Nigeria, Togo, Côte d'Ivoire, Cameroon	*Khaya ivorensis, K. anthotheca, K. grandifoliola, K. senegalensis, Entandrophragma utile, Eucalyptus cylindricum*	Shoot borer, also bores into fruits and seeds
Lamprosema lateritialis	Lepidoptera: Pyralidae	Ghana	*Pericopsis elata*	Defoliator, leaf roller
Orygmophora mediofoveata	Lepidoptera: Noctuidae	Ghana, Nigeria, Togo	*Nauclea diderrichii*	Shoot borer
Phytolyma lata	Homoptera: Psyllidae	Ghana, Sierra Leone, Liberia, Côte	*Milicia regia*	Gall maker

Insect pest species	Order: Family	Countries of occurrence	Host species	Feeding habit
		d'Ivoire		
Phytolyma fusca	Homoptera: Psyllidae	Ghana, Nigeria, Togo, Cameroon	*Milicia excelsa*	Gall maker

Appendix 2: Forest and tree pests of Sudan (Source: Gichora, 2016).

Description of Pest	Scientific name	Causal agent (Order:Family)	Indigenous or exotic	Forest type	Host trees
Sahelian tree locust	*Anacredium melanorhoden melanorhoden*	Orthoptera:Acrididae	Indigenous	Semi-desert	*Acacia senegal; Balanites aegyptica; Zizyphus spina-christi*
Silver tree borer	*Sphenoptera chalcichroa subsp. arenosa*	Coleoptera:Buprestidae	Indigenous	Plantation	*Acaia nilotica.; A. arabica; Betula allegheniensis*
Root-boring beetle	*Sphenoptera fulgens*	Coleoptera:Buprestidae	Indigenous	Semi-desert	*Broadleaf spp.*
Seed beetle	*Bruchidius uberatus*	Coleoptera:Bruchidae	Indigenous	Plantation, Seed in storage	*Acacia spp., A.nilotica, A. tortilis, A. mellifera, A. burkei, A. eriloba, A. robusta*
Tamarind seed weevil	*Caryedon serratus*	Coleoptera:Bruchidae	Indigenous	Plantation, Seed in storage	*Acacia spp., Cassia spp., Tamarindus spp., Bauhinia spp.*
Jewel beetle	*Chrysobothris dorsata*	Coleoptera:Buprestidae	Introduced	On farm	*Mangifera spp.*
Bag worm	*Anchmophila kordofensis*	Lepidoptera:Psychidae		Semi-desert	*Acacia nubica, A. tortilis, Grewia tenax*
Bark borers		Unspecified bark borers		Semi-desert	*Sclerocarya birrea*
Seed borers		Unspecified seed borers		Semi-desert	*Acacia spp., Faidherbia*

Description of Pest	Scientific name	Causal agent (Order:Family)	Indigenous or exotic	Forest type	Host trees
					albida, Prosopis spp., Khaya
					senegalensis, Adansonia digitata
Termites	*Odontotermes sudanensis, Microtermes sudanensis, Ancistroterme s crucifer*	Isoptera :Termitidae	Indigenous	Plantation	*Cupressus lusitanica, Eucapyptus camaldulensis , E. citriodora, E. Tereticornis,*
					Acacia
					senegal, A.
					nilotica
Leucaena	*Heteropsylla*	Hemiptera:Psyllidae	Introduced	On farm	*Leucaena*
psyllid	*cubana*				*spp., L.*
					leucocephala,
					Albizia spp.,
					Mimosa spp.,
					Albizia saman
Gall wasp	*Leptocybe*	Hymenoptera:Eulophid	Introduced	Plantation	*Eucalyptus*
	invasa	ae			*spp.*

Appendix 3: Tree and forest disturbance by pests in North Africa (Source: www ref. 7)

Country/ Region	Pest/Disturbance description	Scientific name of pest	Order: Family	Pest type	Region/forest type	Host
North Africa	Winter pine processionary moth	*Thaumetopoea pityocampa, T. wilkinsoni*	Lepidoptera	Defoliator	Mediterranean basin and Middle East	Pines
Algeria		*Thaumetopoea pityocampa*	Lepidoptera: Notodontidae	Defoliator	Mediterranean basin and Middle East: Algeria	Pines and cedars
	Coprophagous, Saproxylic, Predatory, Herbivorous or Decomposers		Coleoptera (17 families, 59 species)	Defoliator	Cork oak forests	
			Lepidoptera Coleoptera	Defoliators Borers	Cedar indigenous forests	*Cedrus atlantica*
	Gall formers on leaves, buds, twigs and flowers		*12 species*			*Quercus suber* and *Q. faginea,*
Morocco	Phytophagous, Xylophagous			Host switches documented	Planted cedar under stress	
Tunisia	Eucalyptus long horn borer	*Phoracantha recurva*	Coleoptera	Borer	Exotic	*E. camaldulensis* and *E. gomphocephala*.
		Platypus cylindrus		Borer	Cork oak forests	*Quercus suber*
		Operophtera brumata (dominant of 14 species)	Lepidoptera: Noctuidae, Geometridae, Tortricidae and Pyralidae	Defoliators	Indigenous	*Quercus afares*

Appendix 4: Forest and tree diseases of Ethiopia (Source: Gichora, 2016).

Disease	Scientific name of disease	Indigenous or exotic	Type of causal agent	Forest type	Host
Coffee berry disease	*Colletotrichum kahawae*	Indigenous	Fungus	Plantation	*Coffea arabica*
Coffee Wilt disease	*Gibberella xylarioides*	Indigenous	Fungus	Plantation	*Coffea arabica*
Stem canker disease	*Coniothyrium zuluense*	Indigenous	Fungus	Plantation	*Eucalyptus camaldulensis*
Armillaria root rot	*Armillaria mellea*	Indigenous	Fungus	Plantation	*Pinus patula*
Mycosphaerella leaf blotch		Indigenous	Fungus	Plantation	*Eucalyptus globulus*
Pink disease	*Erythricium salmonicolor*	Indigenous	Fungus	Plantation	*Eucalyptus camaldulensis*
Botryosphaeria stem canker		Indigenous	Fungus	Plantation	*Eucalyptus camaldulensis, E. saligna, E. grandis, Pinus patula*
Canker on tapped trees	*Lasiodiplodia theobromae*	Indigenous	Fungus	Indigenous	*Boswellia papyrifera*

Appendix 5: Forest and tree diseases of Kenya.

Disease description	Scientific name of the disease	Disease type	Forest type	Host
Armillaria	*Armillaria spp*	Indigenous	Indigenous	Ocotea usumbarensis; Cassipourea spp.
Armillaria root rot	*Armillaria mellea*	Introduced	Plantation	Pinus patula, P. elliotii, Acacia mearnsii
Armillaria root rot	*Armillaria heimii; Other scientific names: Armillariella elegans; Clitocybe elegans*	Introduced	Plantation	Pinus patula, E. grandis
Twig canker	*Lepteutypa cupressi ; Other scientific names: Cryptostictis cupressi; Monochaetia unicornis; Pestalotia unicornis; Rhynchosphaeria cupressi; Seiridium cupressi; Seiridium unicorne*	Indigenous	Plantation and indigenous conifer stands	Chamaecyparis spp.; Cupressus spp.; Juniperus spp.; Thuja spp.; Cupressocyparis spp. ; Cupressus macrocarpa
Botryosphaeria canker	*Botryosphaeria spp.*	Introduced	Plantation, farm	Eucalyptus grandis; E. nitens, E. camaldulensis, E. urophylla and hybrids of E. grandis and E. camaldulensis, Grevillea robusta
Wattle wilt	*Ceratocystis spp.*	Introduced	Plantation	Eucalyptus grandis, Acacia mearnsii
Mycosphaerella leaf spot	*Mycosphaerella pini; Other scientific names: Cytosporina septospora; Dothistroma pini; D. pini var. keniense ; D. pini var. ineare; D. septosporum; D. septosporum var. keniense; D. septosporum var. lineare; D. septosporum var. septosporum; Eruptio pini; Mycosphaerella pini; Septoria septospora*	Introduced	Plantation	Pinus radiata

Disease description	Scientific name of the disease	Disease type	Forest type	Host
Leader dieback, crown wilt, and whorl canker	*Sphaeropsis sapinea; Other scientific names: Botryodiplodia pinea; Diplodia conigena; D. pinastri; D. pinea; D. sapinea; Granulodiplodia pinea; G. sapinea; Macrophoma pinea; M. sapinea; Phoma pinastri; Sphaeria pinea; S. sapinea; Sphaeropsis ellissi; S. ellisii var. ellisii; S. pinastri*	Introduced	Plantation	Pinus radiata
Anthracnose	*Colletotrichum gloeosporioides*		Farm	Cashewnut, Mangifera indica
Powdery Mildew	*Oidium mangiferae*		Farm	Mangifera indica Oidium anacardii
			Farm	Cashewnut
	Oidium spp		Plantation	Eucalyptus spp, E. grandis x camaldulensis clones
Phytophthora root rot	*Phytophthora cinnamoni*		Farm,	Avocado, peach, pineaple, chestnut, macadamia, Acacia mearnsii, Eucalyptus spp
Cylindrocladium shoot blight, leaf spot blight and damping-off	*Cylindrocladium spp*		Plantation,	Most Eucalyptus spp, Eucalyptus grandis, GxC clones
Phytoplasma disease			Farm	Eucalyptus tereticornis, E. globulus
Eucalyptus rust	*Puccina psidii*		Farm	Most Eucalyptus spp
Cryphonectria canker	*Cryphonetria cubansis*		Farm	Eucalyptus grandis, E. saligna, E. camaldulensis, E. tereticornis, E. urophylla
Edothia canker	*Endothia gyrosa*		Farm	Eucalyptus grandis, E. saligna, E. camaldulensis, E. tereticornis, E. urophylla
Coniothyrium canker	*Teratosphaeria zuluense. Other scientific names: Coniothyrium zuluense*		Farm	Most Eucalyptus spp
Chrysoporthe canker	*Chrysoporthe spp.*		Plantation	E. grandis, E. urophylla

Disease description	Scientific name of the disease	Disease type	Forest type	Host
Charcoal leaf disease	*Phaeophleospora epicoccoides Other scientific names: Teretosphaeria epicoccoides, Kirramyces epicoccoides*		Plantation	Eucalyptus grandis, E. camaldulensis, E. urophylla and hybrids
Corky Leaf Spot	*Aulographina eucalypti spots*		Plantation	Eucalyptus botryoides, E. delegatensis, E. dendromorpha, E. diversicolor, E. fastigata, E. ficifolia, E. fraxinoides, E. globulus ssp. globulus, E. globulus ssp. maidenii, E. nitens, E. obliqua, E. pilularis, E. regnans, E. saligna, E. tasmanica Grevillea robusta
Grevillea canker and die-back			Farm	Grevillea robusta
Cashewnut dieback	*Phomopsis anacardii*		Farm	Cashewnut