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ABOUT THE JOURNAL

More than ever before there is a great challenge for developing countries in sub-Saharan Africa to improve the quality of life. The large proportion of this population consists of smallholder farmers whose livelihood is hinged on agriculture. As such, scientists are faced with the task of improving agricultural productivity, farmer incomes and the overall livelihoods of smallholder farmers. To respond to this challenge, universities and other institutions are intensifying efforts of working with rural communities to improve agricultural productivity and livelihoods.

Universities are increasingly institutionalizing outreach programmes to strengthen entrepreneurship along value chains; and to infuse experiential learning for graduate students, academic staff and other actors they interact with including communities. Other agencies notably NGOs and National Agricultural Research Institutes (NARIs) have well-established programmes for reaching not only to farmers but also to emerging agribusinesses along the entire agri-food systems and value chains. As part of its mandate to share lessons, the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) has launched the African Journal of Rural Development (AFJRD) in 2014.

The AFJRD is an on-line open-access journal published quarterly with an Editorial office at the RUFORUM Secretariat, Kampala, Uganda. The AFJRD publishes original research papers comprising emerging issues in rural development; authoritative reviews; synthesis articles and editorials; chapters and book reviews as well as short communications that may not warrant publication as full papers. All submissions must have a focus on sustainable development of rural communities and improving livelihoods generally and as such, authors and contributors will be required to contextualize their work to fit this focus and scope. The primary purpose of the AFJRD is to share knowledge, on all aspects that contribute to sustainable rural development and improving livelihoods and development broadly as widely as possible. All articles and opinions therein published in the AFJRD reflect views of the authors and not necessarily those of the African Journal of Rural Development.

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Some key issues in Africa's Forestry Sector

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FOREWORD

There is an increasing recognition of the importance of forest and tree-resources in the social and economic development of African countries. This is because the African forestry sector is currently contributing to reduction of poverty and improving livelihoods among forest dependent people by providing access to forest products such as fuelwood, timber, and non-timber forest products for home consumption and sale. The Forestry sub-sector is a critical driver with regard to enhancing contributions of other sectors of national economies, including agriculture, energy, tourism and water, among others. However, the African forest cover has been declining at a rate of 2.8 million hectares per year from 2010 to 2015; a rate that is much higher than that of other regions in the world. Thus, sustainable forest management is paramount in order to guarantee the sustained contribution of forests to the people of Africa and the environment they live in.

Sustainable forest management is defined as a dynamic and evolving concept that aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations". It is key to securing, maintaining and enhancing the contribution of forest ecosystems goods and services. Sustainable forest management deploys an inclusive approach that is focused on the productive, ecological and socio-economic functions of forests. This approach is particularly valuable in containing the current challenges of deforestation and forest degradation whose root causes are often multifaceted.

Focus areas addressed and featuring in papers published in this Issue
Inevitably decisions that guide employment of sustainable forest management have to be based on empirical evidence. In this regard, scientific research is valuable in highlighting many issues for policy decision-makers and practice. Further, the evidence-base from empirical investigations is a crucial building block for policy makers and practitioners.

In efforts to contribute to best practices for sustainable forest management, the African Forest Forum (AFF), a pan African institution that provides independent analysis of forestry issues in Africa, has sought to deepen our understanding of several prioritised policy and technical issues in African forestry, specifically by commissioning African experts to conduct multi-country studies, in various African forest types in the different sub-regions of Africa, on the status and future of : quality tree germplasm and tree improvement; forests pests and diseases; forest certification; forest governance; private sector in forestry; and green economy.

This Issue of the African Journal of Rural Development contains peer-reviewed papers written by the experts who carried out these studies. The issues addressed in these articles are important for advancing research for development, policy and practice in Africa; and, for each paper, these include among others the following:

(a) The Africa-wide studies on provision of high-quality tree germplasm management and those related to improving tree performance and productivity, as well as those on protection of forests from pests and diseases, offer solutions that would be valuable in ensuring afforestation projects are cost effective, profitable and secure;
(b) The study on forest certification in eastern and southern Africa points to the capacity needs

that if addressed would improve the pace of implementing forest certification in Africa. This has potential to reduce illegalities in harvesting the forests and in trade in forest products, in addition to understanding and possibly improving the value chains in the forest sector. Also, increased forest certification would enhance access to international markets for African forest products;

(C) The studies on forest law enforcement, good forest governance and fair trade in Africa investigated institutional, legislative and policy factors that could mitigate illegal harvesting and trade in forest products. In this regard, strengthening forest governance would ensure that benefits derived from forests, that is forest ecosystem goods and services, contribute to livelihoods, national economies and stability of the environment;

(d) The private sector in African forestry is an important player, much as most of its activities are informal. This sector is critical in maintaining, among other things, the productive functions of forests to, among many things, support poverty eradication, generate national incomes and ensure stability of the environment. The studies on the African forestry sector looked into all these and other aspects. Among its recommendations is one on the necessity for development of sustainable public-private-partnership models that are all inclusive in that they cater for the needs of all stakeholders and have potential for attracting more investments into the sector. Further, country studies undertaken in Nigeria and Cameroon demonstrate the magnitude of intra-African trade and the impact of such trade, and therefore providing another reason for better coordinated interplay between governments, private and the public sectors respectively; and

(e) The study on the forest sector contribution to green economy in West Africa provides evidence-based information to support policy formulation, review and implementation in the forest sector in Africa in ways that enhances green economy development. This would be valuable to many African governments that have adopted green growth pathways to accelerate progress in sustainable development that eradicates poverty and protects the environment.

This AFJRD Issue therefore aims to provide information that could guide actions at policy and operational levels to achieve sustainable forest management in Africa. It will be useful resource to policy makers, forest managers, scientists and students, and even the general public in the field of forestry and natural resources management.

The Secretariat
African Forest Forum

AVANT-PROPOS

On reconnaît de plus en plus l'importance des ressources forestières dans le développement social et économique des pays africains. En effet, le secteur forestier africain contribue actuellement à la réduction de la pauvreté et à l'amélioration des moyens de subsistance des populations dépendantes de la forêt en leur donnant accès à des produits forestiers tels que le bois de feu, bois d'œuvre et produits forestiers non ligneux destinés à la consommation et à la vente. Le sous-secteur de la foresterie est un moteur essentiel pour accroître les contributions d'autres secteurs de l'économie nationale, notamment l'agriculture, l'énergie, le tourisme et l'eau. Toutefois, la couverture forestière africaine a diminué à un rythme de 2,8 millions d'hectares par an de 2010 à 2015, un taux beaucoup plus élevé que celui des autres régions du monde. La gestion durable des forêts est donc primordiale pour garantir la contribution durable des forêts aux populations africaines et à l'environnement dans lequel elles vivent.

La gestion durable des forêts est définie comme un concept dynamique et en évolution qui vise à maintenir et à améliorer les valeurs économiques, sociales et environnementales de tous les types de forêts, au profit des générations actuelles et futures ». Elle est essentielle pour assurer, maintenir et améliorer la contribution des biens et services des écosystèmes forestiers. La gestion durable des forêts adopte une approche inclusive axée sur les fonctions productives, écologiques et socio-économiques des forêts. Cette approche est particulièrement utile pour contenir les défis actuels de la déforestation et de la dégradation des forêts dont les causes profondes sont souvent multiples.

Domaines d'intérêt abordés et présentés dans les articles publiés dans ce numéro
Inévitablement, les décisions qui orientent l'emploi de la gestion durable des forêts doivent être fondées sur des données empiriques. À cet égard, la recherche scientifique est précieuse pour mettre en évidence de nombreux enjeux pour les décideurs politiques et la pratique. De plus, la base de données probantes des enquêtes empiriques est un élément de base crucial pour les décideurs et les praticiens.

Afin de contribuer aux meilleures pratiques de gestion durable des forêts, le Forum forestier africain (AFF), une institution panafricaine qui fournit une analyse indépendante des questions forestières en Afrique, a cherché à approfondir notre compréhension de plusieurs questions politiques et techniques prioritaires en foresterie africaine, notamment en mandatant des experts africains pour mener des études multi-pays, dans différents types de forêts africaines dans les différentes sous-régions d'Afrique, sur le statut et l'avenir du matériel génétique et de l'amélioration des arbres de qualité, des ravageurs et des maladies des forêts, de la certification des forêts, de la gouvernance forestière, du secteur privé en foresterie et de l'économie verte.

Ce numéro du Journal Africain de Développement Rural contient des articles rédigés par les experts et relus par les pairs. Les questions abordées dans ces articles sont importantes pour l'avancer la recherche au profit du développement, des politiques et des pratiques en Afrique. Elles comprennent entre autres :
a) Les études menées à l'échelle continentale sur la gestion du germoplasme arboricole de qualité et celles liées à l'amélioration de la performance et de la productivité des arbres, ainsi que sur la protection des forêts contre les ravageurs et les maladies, proposer des solutions qui seraient utiles pour garantir que les projets de boisement sont rentables et sûrs;
b) L'étude sur la certification forestière en Afrique orientale et australe fait ressortir les besoins de capacité qui, s'ils étaient comblés, amélioreraient le rythme de mise en œuvre de la certification forestière en Afrique. Ceci a le potentiel de réduire les illégalités dans la récolte des forêts et dans le commerce des produits forestiers, en plus de comprendre et éventuellement d'améliorer les chaînes de valeur dans le secteur forestier. De plus, une certification forestière accrue améliorerait l'accès aux marchés internationaux pour les produits forestiers africains;
c) Les études sur l'application de la législation forestière, la bonne gouvernance forestière et le commerce équitable en Afrique ont examiné les facteurs institutionnels, législatifs et politiques qui pourraient atténuer la récolte illégale et le commerce des produits forestiers. À cet égard, le renforcement de la gouvernance forestière garantirait que les avantages tirés des forêts, c'est-à-dire les biens et services des écosystèmes forestiers, contribuent aux moyens de subsistance, aux économies nationales et à la stabilité de l'environnement;
d) Le secteur privé de la sylviculture africaine est un acteur important, tout comme la plupart de

ses activités sont informelles. Ce secteur est essentiel pour maintenir, entre autres, les fonctions productives des forêts, notamment pour soutenir l'éradication de la pauvreté, générer des revenus nationaux et assurer la stabilité de l'environnement. Les études sur le secteur forestier africain se sont penchées sur tous ces aspects et sur d'autres. Parmi ses recommandations, il y a une sur la nécessité pour le développement des modèles durable de partenariat public-privé qui sont tous inclusifs en ce sens qu'ils répondent aux besoins de toutes les parties prenantes et qu'ils ont le potentiel d'attirer davantage d'investissements dans le secteur . En outre, des études par pays menées au Nigeria et au Cameroun montrent l'ampleur du commerce intra-africain et l'impact de ce commerce, et fournissent donc une autre raison pour une meilleure coordination entre les gouvernements, les secteurs privé et public respectivement; et

e) L'étude sur la contribution du secteur forestier à l'économie verte en Afrique de l'Ouest fournit des informations factuelles pour soutenir la formulation, l'examen et la mise en œuvre de politiques dans le secteur forestier en Afrique d'une manière qui favorise le développement de l'économie verte. Cela serait précieux pour de nombreux gouvernements africains qui ont adopté des voies de croissance verte pour accélérer les progrès en matière de développement durable qui éradiquent la pauvreté et protègent l'environnement.

Ce numéro du journal vise donc à fournir des informations qui pourraient guider les actions aux niveaux politique et opérationnel pour réaliser la gestion durable des forêts en Afrique. Ce sera une ressource utile pour les décideurs, les gestionnaires forestiers, les scientifiques et les étudiants, et même le grand public dans le domaine de la foresterie et de la gestion des ressources naturelles.

Le Secrétariat
Forum forestier africain

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Situational analysis of trends in tree improvement and germplasm production and impacts on sustainable forest management in Southern Africa

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ABSTRACT

Tree improvement and the production of high quality germplasm have been the cornerstone for successful tree plantation establishment in Southern Africa for nearly a century. Investments in forestry research focusing on tree improvement and tree seed systems have been declining in most southern African countries in recent times with possible negative effects on the supply of good tree planting stock and consequently on sustainable forest management. This paper summarises the findings of a study commissioned by the African Forest Forum in 2014 that analyzed the trends in tree breeding and tree germplasm production, afforestation and reforestation, priority tree species for planting in the regions, tree seed deployment pathways, and the associated impact on sustainable forest management in southern Africa. The study methodology involved extensive literature reviews, field visits to Malawi, Mozambique, South Africa, Zambia and Zimbabwe, and interviews with forestry experts. Most countries in Southern Africa except South Africa reported on reduced capacity to produce good quality germplasm for commercial species as well as lack of information on the demand and supply of germplasm for agroforestry and indigenous species. In the past two decades, corporate grower-processor companies especially in South Africa have developed in-house breeding programmes focused on the value derived from linking their forest resource to specific end-uses. Most government forest research/seed centres are no longer as active in traditional tree breeding research as they were decades ago. This has resulted in limited access to quality tree seed by tree growers. International non-governmental organizations have supported the development and deployment of agroforestry species, but progress on utilization of the species stopped when donor-funded projects ended. Collection and utilization of indigenous species are on an ad-hoc and opportunistic based. Countries such as Zimbabwe and Malawi that made modest investments in tree seed centres in the 1990s recorded high rates of afforestation and reforestation then but the rates are declining due to lack of investments in research and development. Institutional changes such as placing national tree seed centres under agricultural departments and not forestry (e.g. in Mozambique) have reduced the capacity

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to produce and deploy tree germplasm of a range of tree species. The study showed that there is a declining trend in investments in tree improvement and that national seed centres are failing to supply good quality germplasm. This could be having negative impacts on sustainable forest management as shown by low rates of afforestation and deforestation. The paper recommends that Southern African countries should focus research on common priority tree species for commercial and agroforestry purposes, increase skills and capacity of personnel, invest in tree seed centre infrastructure and exchange scientific information on growth and adaptability of tree species.

Keywords: Afforestation, tree breeding, tree germplasm, reforestation, sustainable forest management, Southern Africa

RÉSUMÉ

L'amélioration des arbres et la production de germoplasme de haute qualité sont la pierre angulaire du succès de la plantation d'arbres en Afrique Australe depuis près d'un siècle. Les investissements dans la recherche forestière axée sur l'amélioration des arbres et les systèmes de semences d'arbres ont récemment diminué dans la plupart des pays d'Afrique Australe, ce qui pourrait avoir des effets négatifs sur l'offre d'un bon matériel de plantation d'arbres et par conséquent sur la gestion durable des forêts. Cet article résume les conclusions d'une étude commandée par African Forest Forum en 2014, qui analysait les tendances en matière de sélection des arbres et de production de matériel génétique d'arbres, d'afforestation et de reboisement, les essences forestières prioritaires à planter dans les régions, les voies de déploiement des semences d'arbres et l'impact associé. sur la gestion durable des forêts en Afrique Australe. La méthodologie de l'étude comportait des analyses approfondies de la littérature, des visites sur le terrain au Malawi, au Mozambique, en Afrique du Sud, en Zambie et au Zimbabwe et des entretiens avec des experts en foresterie. La plupart des pays d'Afrique Australe, à l'exception de l'Afrique du Sud, ont fait état d'une réduction de leur capacité à produire du matériel génétique de bonne qualité pour les espèces commerciales, ainsi que d'un manque d'informations sur la demande et l'offre de matériel génétique pour l'agroforesterie et les espèces indigènes. Au cours des deux dernières décennies, de grandes compagnie de transformation, spécialement en Afrique du Sud, ont mis au point des programmes de sélection internes axés sur la valeur découlant de la liaison de leurs ressources forestières avec des utilisations finales spécifiques. La plupart des centres gouvernementaux de recherche forestière et de semences ne sont plus aussi actifs dans la recherche traditionnelle sur la sélection des arbres qu'ils ne l'étaient il y a quelques décennies. Cela a eu pour effet de limiter l'accès des producteurs d'arbres aux semences de qualité. Des organisations non-gouvernementales internationales ont soutenu le développement et le déploiement d'espèces agroforestières, mais les progrès en matière d'utilisation de ces espèces ont été interrompus à la fin des projets financés par les donateurs. La collecte et l'utilisation des espèces indigènes se font sur une base ad hoc et opportuniste. Des pays tels que le Zimbabwe et le Malawi, qui investissaient modestement dans les centres de semences d'arbres dans les années 90, affichaient alors des taux élevés d'afforestation et de reforestation, mais ces taux sont en baisse en raison du manque d'investissements dans la recherche et le développement. Des changements institutionnels tels que la mise en place de centres nationaux de semences d'arbres sous le département de l'agriculture et non de la foresterie (par exemple au Mozambique) ont réduit la capacité de production et de déploiement de matériel génétique d'arbres de certaines espèces. L'étude a montré que les investissements dans l'amélioration des arbres ont tendance à diminuer et que les centres nationaux de semences ne parviennent pas à fournir du matériel génétique de bonne qualité. Cela pourrait avoir des impacts négatifs sur la gestion durable des forêts, comme en témoignent les faibles taux d'afforestation et de reforestation. L'article recommande que les pays d'Afrique Australe concentrent leurs recherches sur les essences forestières prioritaires communes utilisées à des fins commerciales et agroforestières, accroissent les compétences et les capacités du personnel, investissent dans l'infrastructure des centres de semences d'arbres et échangent des informations scientifiques sur la croissance et l'adaptabilité des essences ligneuses.

Mots clés: Afforestation, amélioration des arbres, matériel génétique d'arbres, reforestation, gestion durable des forêts, Afrique Australe

INTRODUCTION

The Southern African region has a long history of tree planting mainly for development and expansion of commercial plantations based on three genera, namely *Eucalyptus, Pinus* and *Acacia*. These forest genetic resources (FGRs) have formed the backbone of commercial forestry development for the past 100 years and progress was firmly supported by investments in tree breeding, tree seed production and silviculture (Shonau, 1990; Tembani *et al.,* 2014). The first extensive plantings of industrial tree crops in Southern Africa occurred during the period 1900-1945, mostly in countries with little utilisable natural forests and where there had been an early influx of European settlers (Evans, 1992). In 1938, for example, South Africa had 520 000 ha of plantations of which 370 000 ha were privately owned (SAIF, 2000). Hence, the backbone of the plantation forestry was founded on importing exotic species, testing a number of seed sources (provenances) and selecting superior trees for plantation establishment.

Eucalyptus spp. are the most widely planted species throughout Africa mainly for poles, sawlog and pulpwood and also as community woodlots for building poles and fuelwood. The first *Eucalyptus* species to be used in plantation development in South Africa was the blue gum, *Eucalyptus globulus* (Poynton, 1977). The genera also has the most widely planted hardwood species in the world (Doughty, 2000). Most of the species fall in the sub-genus Symphyomyrtus with the following species as the most widely planted; *Eucalyptus camaldulensis, Eucalyptus dunnii, Eucalyptus globulus, Eucalyptus grandis, Eucalyptus nitens, Eucalyptus pellita, Eucalyptus saligna, Eucalyptus tereticornis* and *Eucalyptus urophylla* (Harwood, 2011). The eucalypt genetic resource in Southern Africa is the most researched and a number of introduction trials, provenance and progeny testing trials have been established mainly in South Africa and Zimbabwe (Mullin *et al.,* 1981) highlighting the importance of tree breeding and improvement as key components of successful tree establishment.

The second most planted genera is *Pinus. Pinus patula* was the first exotic coniferous species introduced in South Africa from collections made in Mexico in the early 1900s (Butterfield, 1990). These early plantings served as a source of genetic material for other countries in Southern Africa for many years (Butterfield, 1990; Poynton, 1977). The most successful species include *P. patula*, *P. taeda, P. elliottii* and *P. kesiya*. Other potential *Pinus* spp. tested were *P. tecunumanii, P. maximinoii, P. hererrai* and *P. greggii* (Nyoka, 1994). Breeding and selection of these species were initiated and today their selected populations are in advanced generations of selection and supplying genetically superior clonal orchard grade seed and clonal hybrids to tree planting programmes. Several other Pinus species, mostly originating from the American or Asian tropics and sub-tropics are now widely cultivated and commonly planted species include *Pinus caribaea, P. elliottii, P. greggii, P. kesiya, P. maximinoii, P. patula, P, oocarpa,* and *P. tecunumanii. P. kesiya* is a tropical pine species from Asia and is widely planted in Madagascar and Zambia (Sekeli and Phiri, 1999). A number of inter-specific hybrids have been developed and are now the backbone of clonal forestry in countries such as South Africa (Hongwane *et al.,* 2017).

More recently, tree planting in the region has expanded to include planting of agroforestry species, indigenous fruit trees and to a limited extent indigenous commercial species. The term agroforestry species has been applied to refer to Forest Genetic Resources (FGRs) which include multi-purpose tree species planted for provision of a range of products used by farming communities such as timber, fodder and provision of environmental services such as soil amelioration, restoring degraded lands and watershed protection.

A group of FGRs that is gaining popularity amongst development communities and researchers is indigenous fruit trees (IFT). They are attractive to farmers as they provide a ready source of food for forest depended communities (Akinnifesi *et al.,* 2006). Many domestication and commercialization programmes have been initiated to improve the quality of priority species in the Southern African region (Maghembe *et al.,* 1998). The choice of species is highly localised. Domestication of IFT has been done in a participatory way as in all the regions of Africa, and the involvement of farmers in the selection of species and seed/fruit trees/source has explicitly involved genetic selection of the best trees or provenances (Tchoundjeu *et al.,* 2006). However, farmers have continued to rely on wild fruits leading to over harvesting where there is commercialization. This may lead to reduced regenerative capacity and genetic erosion of species, e.g. commercial harvesting of *Uapaca kirkiana* in Zimbabwe (Tembani *et al.,* 2014).

Indigenous commercial species (ICS) form an important FGR for valuable timber notably, in Zambia, Mozambique, Zimbabwe and Angola. However, these have also been subjected to illegal harvesting and poor silvicultural management such as uncontrolled fires. Understanding the genetic impacts of forest management practices is crucial for conservation and management of forest genetic resources. Forest management practices based on selective and clear-cut systems followed by natural or artificial regeneration can impact population structure and mating patterns, thus gene flow and genetic diversity (Ratnam *et al.,* 2014). This suggests that forest management plans need to take into account the genetic diversity and population structure of the species.

Besides the use of FGRs for plantation development, agroforestry, IFTs and ICS, the forests of Southern Africa comprise a multitude of forest types and ecosystems, ranging from mangroves to rainforests, dry and humid ecosystems and are home to an incredible wealth and diversity of fauna and flora. There are over 1200 species, as well as subspecies and variations on the mainland of Southern Africa (van Wyk and van Wyk, 1997). The trees and forests are protected through a network of national parks, forest reserves, protected species areas, sacred community forests and botanical gardens. Depending on the tenure systems, resourcing, and access by the public, these forests are protected to various levels. The status of natural genetic resources is not widely known, and it is doubtful whether the genetic pools are adequately and comprehensively protected. This is more so in the communal areas where there is public access to all forest resources and un-regulated harvesting levels through tree cutting for firewood, agricultural expansion and collecting of tree products.

This paper therefore addressed the trends in tree breeding and tree germplasm management in Southern Africa for sustainable forest management. It specifically focuses on trends in afforestation and reforestation in the region, status of tree breeding, seed production for priority species for all types of forest genetic resources (FGRs), seed deployment pathways, and institutional issues that would affect tree germplasm improvement in the sub region.

METHODOLOGY

The study was commissioned by the African Forest Forum based in Nairobi, Kenya in response to an identified gap in the supply of good quality tree stock to tree growers in Southern Africa. The approach to the study was divided into two parts involving desktop literature reviews and field visits to five countries in Southern Africa selected on the basis of the scale of tree planting and history of tree improvement research. Literature on sustainable forest management was reviewed with a special focus on commercial and community tree planting activities, the different species researched on or planted for commercial or research purposes and rates of afforestation and reforestation. Particular attention was given to field research on species introductions and provenance testing trials, and conservation plantings of key species as this would give insights on the forest genetic resource base.

Five countries were visited namely; Malawi, Mozambique, South Africa, Zambia and Zimbabwe. These countries were chosen on the basis of the extent of their forestry plantations as well as tree planting activities by small-scale farmers. For those countries not visited namely; Angola, Namibia, Botswana, Lesotho, Madagascar and Eswatini, telephone interviews were conducted with personnel working on tree breeding, seed production, as tree growers, and from literature searches. Visits were made to government forestry departments, private forestry companies, NGOs, universities and expert opinions were gathered from people with a good knowledge of forestry in selected countries. A list of questions were asked covering topics such as the main priority species planted, sources of seed, supply and demand of tree seed and main actors in tree seed trade, afforestation and reforestation rates, gaps in planting activities and policies impacting on tree planting and conservation. By reviewing forest statistics, the rates of afforestation and reforestation and identifying the supply and demand of tree germplasm in each country, it was possible to build a picture of the trends in tree planting activities and the gaps in tree germplasm production and deployment in the region.

FINDINGS AND DISCUSSION

Declining rates of afforestation and reforestation. Table 1 shows plantation statistics in the southern African countries. It is clear that most countries have had a negative net change in forest areas suggesting that most countries in Southern Africa need to invest more to achieve SFM. Afforestation and reforestation rates in the region show a declining trend in most countries except for Lesotho and Eswatini. Zimbabwe had the highest negative net change whilst South Africa had no significant change in forest area over the past decade. The data also revealed a dearth in the collection of forest statistics in the region.

Table 1. Forest statistics for countries in the Southern Africa region (adapted from FAO, 2015)

Country	Forest cover (ha)	% cover	2010 Deforestation (ha yr^{-1})	2010 Afforestation (ha yr^{-1})	2010 Reforestation (ha yr^{-1})	2015 Plantations (ha)	Net change (2015)
Angola	57 856 000	46.4	0			125 000	-0.1
Botswana	10 840 000	19.1	0				-0.9
Lesotho	49 000	1.6	200			17 000	0.8
Madagascar	12 473 000	21.4	57 000	11 400	28 000	312 000	-0.4
Malawi	3 147 000	33.4	17 900	18 000	3 000	419 000	-0.9
Mauritius	39 000	19.2	0	100		18 000	-0.3
Mozambique	37 940 000	48.2	219 000	12 000	0	75 000	-0.5
Namibia	6919 000	8.4		0			-0.9
South Africa	9241 000	7.9		2 200	50 600	1 763 000	0
Eswatini	586 000	34.1		0		135 000	0.9
Zambia	48 635 000	65.4	287 000	0	1 500	87 000	-0.3
Zimbabwe	14 062 000	36.4	309 000	0	6 000	6 000	-1.8

Blanks denote very small number rounded off to zero

Table 2. Summary of reasons behind decline in forest areas and low tree planting rates in Southern Africa

Country	Reasons for reduction in forest areas and low rates of tree planting
Malawi	• Increased demand for charcoal and firewood • Increasing population pressure on forest lands for agricultural expansion • Pest and diseases, alien invasive species impacting on tree growth • Inadequate resources for research and development in the forest sector • Diminished access to superior tree germplasm for pines and eucalypts • National tree seed centre not fully operational (Mike Likoswe, personal communication 2014)
Mozambique	• Illegal logging of commercial species • Lack of forest management plans to rehabilitate harvested areas • Limited funding for research and development • Limited access to good tree germplasm by companies establishing plantations in the northern part of the country (Gilbet Kachale, Managing Director, Niassa Florestal, 2014) • Changes to the location of the national tree seed centre into the agricultural ministry reducing its effectiveness (Alima Isofu, personal communication, 2014)
South Africa	• Cumbersome licensing processes for tree planting, e.g. water permits • Marked decline in both softwood and hardwood planting since the mid-1990s • Increasing plantings for pulpwood compared to saw-logs and mining timber • Unavailability of land for extension planting due to other competing land-uses and land claims • Temporarily unplanted areas have become permanently unplanted areas due to strict reforestation permits • Illegal timber harvesting • Lack of investment in forestry research and development, tree germplasm production and deployment systems (Makumba, Director of Forestry, personal communication, 2014).
Zimbabwe	• Increasing demand of firewood for tobacco curing • Lack of funding to support sustainable forest management practices • Land reform policy resulting in plantation forest lands being illegally occupied • Capital flight, “cut and run” mentality under an uncertain policy environment • Decreasing investment in research and development, resulting in un-availability of good quality tree germplasm • High levels of encroachment in forested areas • Increasing incidences of pests and diseases especially on eucalypt trees • Brain-drain of well-trained skilled personnel over the years (Mdu Tembani, personal communication, 2014)

Discussions with forestry departments, review of government reports and literature and interviews with foresters showed overall that there was a decline in tree planting in most countries especially for commercial plantations. The reasons for the decline in tree planting rates varied from policy constraints, lack of suitable plantation land, un-regulated harvesting, environmental constraints inadequate investments and lack of good tree germplasm.

The study revealed a number of reasons for the declining rates of tree planting and forest cover in selected countries (Table 2). The reasons were deduced from discussions with forestry experts in the five countries visited. The factors leading to reduced rates of planting and growth of the forests resource could impact on future supply of products. For example, South Africa is projecting a decline in the supply of saw-logs and could soon become a net importer (DAFF, 2013). In Zimbabwe, there is a surge of demand for eucalypt firewood for providing energy to cure tobacco from the many small-scale growers, and this has resulted in increased demand for eucalypt seed. In Mozambique, the opening up of the northern part of the country to plantation development has created the need to introduce new species, clones and hybrids best suited for the area. The private companies have reported on the shortage of high quality seed and most have resorted to importing un-tested tree germplasm to meet their planting targets (Kachale, personal communication, 2014). The renewed demand of germplasm is happening against a background of a decline in basic forest research due to diminishing investments, policy shifts and institutional reforms. The gap analyses from the country visits and literature reviews showed that most countries are realizing the importance of tree breeding and tree germplasm development and deployment, and indicated the urgency needed to invest in research and development.

Forest genetic resources for commercial plantations. The Southern African region has had a long history of assessing the survival, growth and productivity of exotic species for the establishment of commercial plantations. Species introduction, provenance and progeny trials are found in most countries, although the levels of investment in trial management vary from country to country. The data collected in the trials provide valuable information about species and provenance choice for plantation establishment in areas with different climates and soil conditions. The real value of these provenance trials is that they can provide seed that can be used to initiate a breeding programme should such a need arise. Additional values of the trials include providing information on species productivity and adaptation to a changing climate. All countries visited, except South Africa and, to some extent, Zimbabwe, reported on the lack of documentation of the trials, lack of data collection and absence of capacity to analyse the data and to provide science–based information on species choice.

Eucalyptus forest genetic resources. Southern Africa has a long history of establishing eucalypt plantations. The climate in the region favours all the commonly planted *Eucalyptus* spp. namely *E. camaldulensis, E. dunni, E. grandis, E. globulus, E. nitens, E. pellita, E. saligna, E. robusta, E. tereticornis* and *E. urophylla.* Through-out the region, *E. camaldulensis* is the preferred species for community planting for firewood. Some of the countries have a comprehensive set of trials and some countries have recently introduced new species for evaluation for sub-optimal sites (Table 3). Examples of the new species include *E. badjensis* and *E. bethamii* for cold and frost prone sites, *E. longirostrata* for drier sites and forestry zones prone to pest and diseases. *E. dunni* is also a new species that has been introduced in Zimbabwe and South Africa (Shaw, 1994) for planting on drier and frost prone sites not optimal for *E. grandis.*

Most of the hardwood plantations in Southern Africa, especially *E. grandis* plantations are limited to high-rainfall and moderate-altitude. Most of the suitable areas have been planted and land for extension planting is only available in marginal areas prone to drought, frost and diseases. To overcome these environmental limitations, *E. grandis* hybrids have been tested in South Africa, Mozambique, Zambia and Zimbabwe (Table 4). In recent years, the areas planted to cloned hardwood species has increased especially in South Africa. The statistics on areas planted in South Africa with pure eucalypts (*E. grandis*) and clonal material is difficult to estimate as most plantation owners confuse the two and usually record as pure species (Forest Economic Services, 2012).

The hybrid material in Southern Africa presents a good resource that can be used as propagation material for establishing plantations and woodlots especially in marginal areas not suitable for the traditional species. There is no doubt that eucalypt hybrids and clonal forestry can be substantially strengthened by investments in biotechnology and increased capacity in the field especially in a country like South Africa. The technology is rapidly changing and more investment to test clones in different climatic and edaphic conditions and collaboration across countries is required. The equipment and facilities required for advanced biotechnology research and development is generally costly and certainly will not be within the reach of other countries. The planting of hybrids has its own disadvantages. For example, there are concerns that clonal hybrids may lead to a narrowing of the genetic resource base, creating conditions perfect for the spread of diseases and pests (Harwood, 2014) and the costs and labour for raising propagation material may be prohibitive (Griffin, 2014).

Table 3. Examples of *Eucalyptus* species and number of provenances tested in Southern Africa

Species	#Provenances	Country tested	#provenance tests	Reference
Eucalyptus grandis	26	Zimbabwe	11	Nyoka *et al.,* 1996
		Angola		Delgado-Matas and Pukkala, 2011
E. urophylla	35	South Africa	23	Dvorak *et al.,* 2008
E. tereticornis	19	Zimbabwe	7	Gapare, 1995
E. camaldulensis	38	Zimbabwe	3	Nyoka *et al.,* 1996
	12	Mozambique	1	Chamshama *et al.,* 1999
		Angola		Delgado-Matas and Pukkala, 2011
E. macarthurii	-	South Africa	30	ICFR, 2014
E. nitens	6	South Africa	8	Swain *et al.,* 2013
E, henryi	-	South Africa	5	ICFR, 2014
E. badjensis	-	South Africa	6	ICFR, 2014
E. benthamii	-	South Africa	3	ICFR, 2014
E. bicostata	-	South Africa	3	ICFR, 2014
E. biturbinata	-	South Africa	2	ICFR, 2014
E. cloeziana	-	Zimbabwe	-	
E. cypellocrapa	-	South Africa	3	ICFR, 2014
E. dorrigoensis	-	South Africa	1	ICFR, 2014
E. dunnii	-	South Africa	29	ICFR, 2014; Swain and Gardner, 2000
E. smithii	-	South Africa	13	ICFR, 2014

Table 4. Eucalyptus species and hybrids introduced in Southern

Country	Hybrids	Advantage over pure species	References
Mozambique	*grandis x urophylla*	grows well in warm moist areas	Mudekwe personal communication, 2014
South Africa	*grandis x nitens* *grandis x urophylla* *grandis x macarthurii*	frost tolerant grows well in warm moist areas, disease resistant, good growth, good wood properties	SAPPI, MONDI, ICFR, 2014 Denison and Kietzka, 1993 Van de Berg *et al.,* 2015
Zimbabwe	*grandis x camaldulensis* *grandis x tereticornis* *grandis x saligna* *grandis x saligna*	Drought and disease resistant, good survival in marginal areas	Gwaze *et al.,* 2000 Madhibha *et al.,* 2013

Emerging threats to Eucalyptus forest genetic resources. In the past few years, three eucalypt pests have been reported in a number of countries in the region. The pests namely; *Leptocybe invasa* (Blue Gum Chalcid), *Thaumastocoris peregrinus* (Bronze bug) and *Glycapsis brimblecombei* (Red Gum Lerp Pysllid) have been reported in Zimbabwe (Mushongahande, 2012 and 2014), South Africa (Nadel *et al.,* 2009; FAO, 2012), Mozambique (Chirinzane *et al.,* 2014), Malawi (Chilima *et al.,* 2008) and other diseases in Zambia (Chungu *et al.,* 2010). The pests are thought to have been introduced through importation of eucalypt clonal hybrids from South Africa and through movement of logs with bark. For example, in Zimbabwe, 500 ha that were planted with grandis x camaldulensis hybrids imported from South Africa was wiped out by the blue gum lerp (Mushongahande, personal communication 2014). Control is being tried using biological means through parasitic wasps and putting in place phytosanitary measures such as restricting movement of seedlings (Mushongahande, personal communication, 2014).

Eucalpyt seed production.Seeds of most of the species are available, but concerns for the genetic and physiological quality were reported in Zimbabwe and Malawi. Figure 1 shows the amount of eucalypt seed collected and distributed from 2001 to 2013 in Zimbabwe. The amounts vary from year to year. In Zimbabwe, a number of seed orchards for *E. camaldulensis* and *E. tereticornis* were destroyed by fire and illegal harvesting and comprehensive assemblages of provenances have been lost (Tembani, personal communication, 2014). The country might have to re-acquire research seedlots from Australia. There is an indication of a steady increase in the sale of seed due to high demand arising from the tobacco wood energy demand. There are reports of low viability of some seed originating from the Zimbabwe tree seed centre (Marufu, Kwesha, personal communication, 2014). In South Africa, private companies have their own capability to conduct tree breeding and research and produce their own seeds especially for eucalypts. For example, SAPPI has its own seed centre that produces and supplies seeds of a number of species including; *E. dunni, E. grandis, E. macarthurii, E. nitens, E. smithii, E. badjensis, E. benthamii, E. dorrigoensis, E. pellita, E. saligna, E. urophylla* and *E. viminalis.*

For many temperate (cold tolerant) eucalypt species such as *E. badjensis, E. dunnii, E. nitensi* and *E. smithii*, introduced in South Africa, poor flowering and seed production are significant constraints to the achieved genetic gain being effectively deployed commercially. This also delays the turnover of generations in the different breeding programmes and subsequent genetic improvement. To improve flowering and seed production, soil application of the hormone paclobutrazol is being used to hasten onset of flowering and increase floral bud and seed production in these species (Gardner and Bertling, 2005). Most eucalypt species planted in Africa are managed on coppice rotation (5-20 years), and it is only then when the old moribund stumps are removed and new seed sources planted. This cycle, if not managed carefully, might lead to the planting of inferior planting stock or in the case of trials, losing or depleting the original genetic diversity. The need for enrichment collection was mentioned in many countries and it is recommended that countries can engage with the Australian Tree Seed Centre (ATSC) – a unit under the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and acquire more seed from a diverse range of provenances.

Systems for germplasm development and deployment for most eucalypt species are well advanced, although some countries indicated the need to re-invigorate their tree improvement programmes through enriching genetic diversity of species to improve productivity, expand afforestation in new green-fields (e.g. planting *Eucalyptus* in frost prone and cold environments), to increase resistance to new pests and diseases and mitigate the potential impacts of climate change by importing provenances from the extreme ends of natural distribution of some species. Since *Eucalyptus* spp are the most widely grown and used in the region, a key issue is whether the genetic resources assembled so far are robust enough to be further improved for yield since national economies are growing and the demand of wood is projected to increase.

Pinus forest genetic resources. *Pinus* spp. were first introduced in South Africa and the country initially was the main source of seed for other countries in Southern Africa. The first species

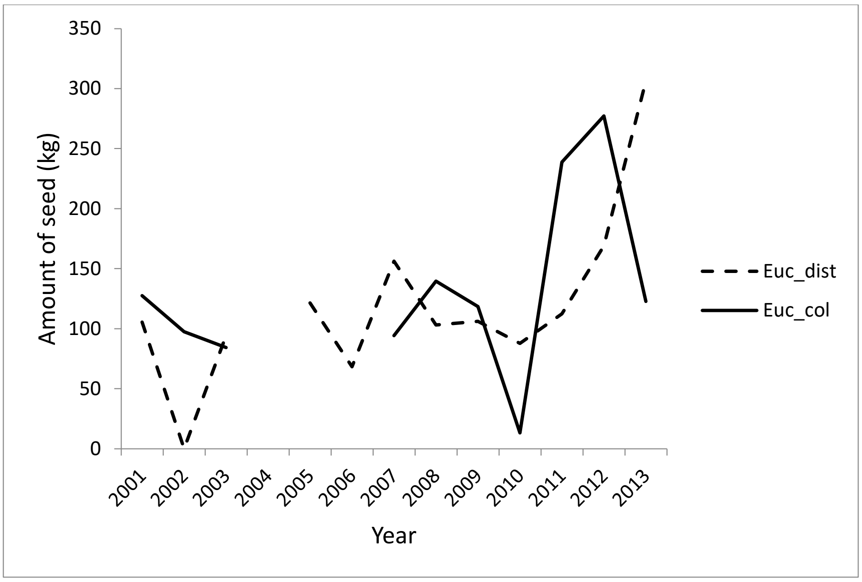

Figure 1. Trends in the amount of eucalypt seed collected and distributed by the seed centre in Zimbabwe (Zimbabwe Tree Seed Centre)

introduced was *Pinus patula* in the early 20th century followed by systematic introduction and testing of a range of species which included *Pinus caribaea, Pinus elliottii, P.greggii, Pinus oocarpa, Pinus maximinoii* and *Pinus tecunumanii* all from Central America, Mexico and southern parts of the United States of America. Another species introduced was *Pinus kesiya* from Asia which became an important species in Madagascar, Zambia and Zimbabwe. Recently countries such as Mozambique, South Africa and Zimbabwe have partnered with Central American Coniferous Resources (CAMCORE) to import new genetic material of selected *Pinus* spp. for enriching genetic diversity of existing species. Other potential Pinus spp. being tested are *P. tecunumanii, P. maximinoii, P. hererrai* and *P. greggii* (Nyoka, 1994) (Table 5).

For most of the pine species introduced in Southern Africa, notably in South Africa and Zimbabwe, the tree breeding programmes have moved into advanced generation breeding. For example in Zimbabwe, first generation selection of *P. patula* material in progeny trials resulted in 17 % genetic gain in volume compared to wild material with subsequent cumulative gains of 30 % and 45 % in second and third generation selections, respectively (Barnes, 1993). In South Africa, corporate grower-processor companies have developed in-house breeding programmes focused on the value derived from linking their wood resource to specific end-uses such as fibre gain for SAPPI. This targeted breeding programme has yielded significant gains for the companies, but has meant that the national seed production system to meet seed demands for other clients (e.g. farmers, communities and councils) has been neglected and there are reports of shortages of non-commercial tree germplasm (Modise, personal communication, 2014).

Table 5. Examples of *Pinus* spp. introduced and tested in a number of countries in Southern Africa

Species	#Provenances	Country tested	#provenance tests	Reference
Pinus caribaea	16	Zimbabwe	3	Gapare and Musokonyi, 2002
		Mozambique		
P. oocarpa	8	Zimbabwe	2	Crockford *et al.,* 1990
		Zambia		Mikkola, 1989.
P. maximinoii	22	South Africa	16	Gapare *et al.,* 2001
		Zimbabwe	3	Crockford *et al.,*1991
		Mozambique		
P. tecunumanii	9	South Africa		
	16	Mozambique	2	Dvorak and Shaw, 1992
			4	Nyoka and Tongoona, 1998
				Munthali and Stewart, 1998
P. greggii	9	South Africa	9	Dvorak *et al.,* 2000
P. patula	8	Zimbabwe	6	Barnes *et al.,* 1992
		South Africa		
		Malawi		Nkonja, 1982
P. taeda		Zimbabwe	12	
	30	Malawi		Ingram, 1984
P. taeda	30		5	
P. elliottii	25	Malawi	5	Ingram, 1984
	18	Zimbabwe		
P. kesiya	18	Zimbabwe	6	Hansen *et al.,* 2003
		Zambia		Armitage and Burley, 1980

Species hybridisation is now an established option for breeders to generate new variability, to take advantage of hybrid vigour and to combine specific traits from different species. In South Africa, a number of hybrids are being tested in cooperation with Camcore (Table 6). One of the popular hybrids is *P. elliottii* x *P. caribaea* which has shown good growth and form consistently and field evaluation trials are indicating that the *P. patula* and *P. tecunumanii* exhibit a lot of promise (CAMCORE, 2013). A number of hybrids are being tested in South Africa and Mozambique in partnership with CAMCORE. The potential of infusing genetic material and hybridisation has also been done to increase productivity and broaden the genetic base and increase resistance to diseases e.g. pitch canker in *P. patula* caused by *Fusarium circinatum* (Cuitinho *et al.,* 2007).

Recent expansions in afforestation have tended towards marginal lands with regard to rainfall, temperature and soils. Liebing *et al.* (2013) for example showed the need to choose *P. patula* provenances, with greater tolerance towards different temperature and precipitation regimes for planting on sites with uncertain climatic conditions in South Africa.

Pine seed production. South Africa and Zimbabwe are the leading countries in the production and supply of pine seed. Zimbabwe used to be a net exporter of pine seed, but this has changed over the years due to diminishing investment in forestry research and development of seed production in other countries e.g. South Africa. Since 2000, investment in forestry research in Zimbabwe has declined significantly resulting in the forest research/seed centre failing to maintain seed orchards and unable to meet seed demand for all species (Tembani *et al.,* 2014). A number of seed orchards and breeding seedlings orchards have been lost to vandalism and fire outbreaks. For example, 40-year old seed orchards of *P. taeda, P. elliotti*i and *P. kesiya* are no longer as productive. Most private companies who used to buy seed from Zimbabwe developed their own in-house breeding programmes on the value derived from linking their wood resource to specific end-uses. For example, SAPPI produces seed of the following species, *P. elliottii, P. patula, P. taeda*, *P. kesiya, P. greggii, P. caribaea* and *P. tecunumanii.*

P. maximinoii and *P. tecunumanii* clonal seed orchards were established in Zimbabwe in 2011, and these are beginning to produce although the quantities are low due to poor flower setting. There is some evidence that the two species are generally shy seed producers (Nyoka and Tongoona, 1998; Gapare *et al.,* 2001). Low seed set is a cause for concern since the two species out-perform the traditional *P. patula* species.

Table 6. Some of the hybrids planted or being evaluated in South Africa

Species	*P. patula*	*P. elliottii*	*P. radiata*	*P. tecunumanii*	*P. greggii*	*P. caribaea*
Crossed with	*P. pringlei* *P. greggii* *P. tecunumanii* *P. oocarpa* *P. elliottii*	*P. tecunumanii* *P. caribaea* *P. maximinoii* *P. taeda* *P. greggii*	*P. patula*	*P. oocarpa*	*P. maximi noii*	*P. tecunumanii*

Source: Camcore, 2013

More research needs to be done to identify the best sites to maximise seed production. In Mozambique, pine tree seed availability is a constraint and most private companies involved in plantation establishment in the northern part of the country depend on importation of seed from source countries e.g., Zimbabwe, South Africa, Australia, Argentina, Chile and Brazil. The development of joint seed orchards with other companies or countries (e.g. Zimbabwe for *P. caribaea, P. tecunumanii* or *P. maximinoi*i) was mentioned as a possible option to improve the seed situation in the country (Kachale, personal communication 2014).

In Malawi, the forest research institute of Malawi (FRIM) has a number of seed orchards for most of the commercially important pine species. Some of the seed orchards are very old and are no longer as productive and Malawi has been buying seed from Zimbabwe and South Africa. Due to lack of funding, most species are still in the first generation of selection. Most of the seed from the FRIM is sold to concessionaires who replant after extracting timber. FRIM is responsible for making sure that the right site-species matching is done to ensure optimum performance and growth and for training the contractors on the importance of using high quality tree seeds. However, in most situations the contactors are not using improved seed resulting in poor performing plantations.

In Zambia, discussions with the forestry department revealed that Zambia had to purchase *P. kesiya* seed from Vietnam to support tree planting programmes. A seed orchard of *P. oocarpa* was established a few years ago and is being assessed for flowering. This seed orchard can become an important seed source for most tree planting activities in the region that use this species e.g. in Mozambique where seed shortages for the species were reported.

***Acacia mearnsii* forest genetic resources**. *Acacia mearnsii* species is the third mostly planted species in Southern Africa. Plantations of Acacia were established in Malawi, South Africa, Eswatini and Zimbabwe for tannin bark, poles, firewood and charcoal with a total estimated net area of about 325,000 ha. The wood is suitable for charcoal, firewood and for building purposes. The species is widely grown on poor sites (SAPPI, 2006) and has the advantage of enriching soil through nitrogen fixation (Brockwell *et al.,* 2005). South Africa is the only country in the region with a comprehensive breeding strategy for *A. mearnsii.* The breeding programme used to focus on improving bark yield but the focus has changed to improve timber yield and quality, and disease resistance (Dunlop *et al.*, 2013; ICFR, 2014). A rust fungus caused by *Uromycladium* has been reported affecting the species in South Africa and there are fears that the disease could threaten the genetic diversity of the species. Little is known about the biology of the rust and its impact on productivity. The ICFR (2014) is working to better understand and manage this pathogen. One approach being tested is to identify resistant clones and use root cuttings to establish clonal seed orchards. A number of seed orchards have been established for the supply of wattle seed. Countries like Zimbabwe still depend on select seed (i.e., seed from thinned stands) for plantation establishment.

Agroforestry FGRs for soil improvement and fodder provision. The Southern Africa regional agroforestry programme initiated by the International Centre for Research in Agroforestry (ICRAF) in 1987 in partnership with the national research systems in Malawi, Zambia, Zimbabwe and Tanzania resulted in a systematic introduction of species for integrating into farming systems, for provision of food and fodder, for soil amelioration and for rehabilitating degraded lands (Kwesiga *et al.,* 2003). Species and provenance assessment trials were established in Madagascar (Downey and Richter, 2013), Malawi (Akinnifesi and Kwesiga, 2002), Mozambique (Alves and Sousa 1989; da Silva Ruas *et al.,* 1994), Zambia (Sileshi *et al.,* 2008) and Zimbabwe (Mutambara *et al.*, 2012). The trials were initially established to evaluate the growth and performance of several species, and were gradually converted to seed sources.

The classical breeding and seed deployment approach applicable to commercial species may not be applicable because of the multipurpose nature of the species and varied growing conditions and context under which the species where planted. New approaches needed to be developed. Simmons (1992) suggested establishment of breeding seedling orchards that perform the combined functions of resource population, breeding population, progeny testing and seed production areas. Thus the trials established in the region also serve as a source of tree germplasm. For example, a provenance trial of *Gliricidia sepium* was established as part of an international trials network and the results showed that two provenances namely; Belen Rivas and Monterrico combined high phenotypic stability and leaf biomass yield across five diverse sites (Australia, Indonesia, Malawi, Nigeria, Zambia) and seed from these two provenances are routinely recommended for planting (Nyoka *et al.,* 2012).

Research and promotion of agroforestry has been promoted by international organisations and there is always a perception that donors will continue supporting agroforestry tree planting programmes. For example, in Zambia, discussion with the forestry department officials on the improvement and domestication of MPTS and other indigenous species raised the point that the demand for agroforestry species was largely driven by donor funded projects and when the projects end, the priorities of farmers also change, meaning that any efforts to improve the species also ended. The end-users are diverse and so are the end products and services. The target end users are usually rural farmers whose needs are continuously changing and who are risk-averse and may take long periods to adopt new technologies. This has led to low up take of agroforestry FGR and technologies by local farmers. Key strategies to upscale use of agroforestry FGRs have been proposed by Kwesiga *et al.* (2003) and these include: demonstrating and increasing the benefits of agroforestry species and targeting agroforestry technologies, improving diversification, marketing and processing of agroforestry products, and promoting information-sharing, training and collaborative partnerships in implementation and dissemination of agroforestry options in the region with all major stakeholders (farmers, non-government organizations, extension services, educational institutions, and policy-makers).

Seed supply for agroforestry FGRs. While improvement strategies and seed supply for commercial species is very clear, it is not so for multipurpose tree species. The challenge of producing seed and deploying the germplasm still remains unresolved for many species. There are concerns on the availability of information on seed source and the use of seed of unknown performance (Nyoka *et al.,* 2011). Various deployment pathways have been suggested, e.g. deployment via centralised government seed centres, NGOs, farmer-to-farmer exchanges and private seed merchants (Lillesø *et al.,* 2011).

Compared to other countries in Southern Africa, Malawi has an advanced deployment system for agroforestry germplasm. Tree seed production is handled by three main players namely; the National Tree Seed Centre (NTSC) at FRIM, Land Resource Centre (LRC) in Lilongwe, and the WAC based at Chitedze Agricultural Research Station. Surveys on tree seed producers and distributors by Pedersen and Chirwa (2005), showed that apart from these three permanent seed suppliers, there is a large number of NGOs, Government organisations and village groups involved in seed production and distribution.

Since there are several players in the agroforestry species seed trade, it is difficult to monitor genetic quality of the seed distributed. Good effort has been made in the region to identify the priority species. Traditionally, tree breeding and seed orchards establishment have been done by government institutions, but somehow most government departments are not fully engaged in the development of agroforestry species, perhaps due to the legacy of donor dependency. Agroforestry species have been researched on and there is now considerable experience in Southern Africa. The question to ask is why are the issues of tree breeding, seed orchard establishment and supply of certified seed still bottlenecks? Perhaps the short-term nature of funding by donors, and dwindling resource allocation to research and development could be contributory factors. Also, the end uses of the species vary from area to area. Besides, priorities change as projects end and others start. So, any breeding programme may face challenges in setting breeding objectives and maintaining the programme over long periods of time.

The need for formalised seed delivery pathways have been discussed extensively in Malawi (Lillesø *et al.,* 2011). As long as there is no formalised genetic quality control through establishment of seed orchards and demonstrating the actual demand of the species (beyond donor projects and government subsidies), any formalised delivery pathway will face challenges. While a large number of players in the distribution of seed for agroforestry species may appear confusing, it might be the only way to diffuse the germplasm to the end-users on the ground.

Indigenous fruit trees forest genetic resources. A number of indigenous species have been identified in the region as important sources of food for communities or raw materials for a wide variety of products. The list of priority species was identified by the World Agroforestry Centre (WAC) in partnership with national institutions using participatory mechanisms (Maghembe *et al.,* 1998). A number of trials of selected species were established in a number of countries. In Malawi, trials were established to assess growth and fruit production of a number of species. Out of 24 species, the following showed fast growth and produced flowers within a short period of time; *Annona senegalensis, Azanza garckeana, Bridelia micrantha, Flacourtia indica, Syzygium cordatum, Tamarindus indica, Vangueria infausta, Vitex doniana, Ziziphus mauritiana, Sclerocarya birrea* and *Strycnos spinosa* (Maghembe, 1998). Trials were also established in Zimbabwe for *Z. mauritiana, Uapaca kirkiana, Strychnos cocculoides* and *S. spinosa* (Kadzere *et al.,* 1997). Improved varieties of *S. birrea* have been produced through selection in South Africa for the production of marula cream liqueur. Table 8 lists the most common species and references on geographic variation studies. It is quite evident that a lot of research has been done in assembling genetic material which can form the basis for tree breeding programmes in the region.

A large proportion of the fruits are still being collected from wild populations and sold at road sides and urban markets. Studies on the genetic variation of the species are done at two levels. First, the quality of fruits in terms of size, colour and test is usually done on fruits collected from wild populations (Kadzere *et al.,* 2006). Such information helps to inform the fruit collectors and processors on the best sources of good quality fruits. The second level is when seedlings are raised and planted at different sites to test for growth, performance and ultimately fruit characteristics. For example, the WAC is taking a lead on this work with the establishment vegetative propagation trials of some species such as *Uapaca kirkiana* and *Z. mauritiana* where scions from mother trees with good fruit characteristics are grafted on rootstock, or propagated using air-layering or marcotting (Kalinganire and Koné, 2010).

Despite the significant effort by international organisations to domesticate IFTs, demand is still being met from natural populations. The commercialisation of harvesting and trade of some species such as *U. kirkian*a and *Z. mauritiana* from natural populations could be leading to genetic erosion and reduction of the regenerative capacity of the species since the seeds are removed from their natural environment. Indigenous fruit trees are scattered, populations are small and fragmented, and in some cases they have completely disappeared from the landscape. The genetic make-up of some of the species may have been altered by farmers retaining desirable trees and felling others (Tembani *et al.,* 2014). It would appear that the push for commercialization of indigenous fruit trees is in direct conflict with traditional norms, conservation biology and conventional conservation laws and regulations. To address some of these issues, the region could seek ways to protect IFTs in their natural environment, and increase productivity of trees in farming systems.

Indigenous commercial forest genetic resources. The natural forests in southern Africa have high species diversity and some species have high valuable timber qualities. For example, the flagship species for the Zambezi teak forests that include *Baikiaea plurijuga, Pterocarpus angolensis, Guibourtia coleosperma* and *Afzelia quanzensis* are harvested for their timber. Other species harvested for their timber include *Dalbergia melanoxylon, Milicia excelsa* and *Khaya anthotheca* (nyasica). These species are harvested mostly by contractors given concession by forestry departments. In Zambia, many indigenous species are threatened from over-exploitation for charcoal production and locally managed charcoal production systems can be adopted to restore species and forests (Gumbo *et al.,* 2013). In Zimbabwe, good trees (superior phenotypes) or seed trees are not being marked and protected during harvesting resulting in loss of seed reducing the regenerative capacity and eroding the genetic diversity of the forests (Auditor-General of Zimbabwe, 2103). In Mozambique, there are reports of uncontrolled and un-sustainable harvesting of commercial timber species to meet international demand resulting in degrading the forest resources (Mackenzie, 2006) with 81% of the timber harvested classified as illegal (EIA, 2013). There is an expectation that contractors/concessionaire plant seedlings of the species that they harvest, but surveys by Savcor (2005) on 25 companies in Sofala show that only seven produce seedlings of native species for reforestation in cooperation with local community where the nurseries are located. These are very low numbers taking into consideration that almost 50% of the companies operate concessions, the management plans of which include reforestation activities. Given these scenarios, there is generally a lack of attention to the importance of managing FGRs for commercially exploited natural timber species.

It is clear from the foregoing that while management plans are in place, they do not take account of the genetics and population structures of the species. A few species have received attention (Table 9). The net effect could be that the region is progressively lowering the genetic diversity and altering the population structures of the species and the consequences could be dire in the generations to come. The current emphasis is on conserving populations *in situ,* but whether these are comprehensive and adequately representative of the species geographical distribution is unclear. The expectation is that after harvesting, the forests are allowed to regenerate or re-planted using

Table 7. List of the most important agroforestry species for soil improvement and fodder production in Southern Africa

Species	Country									
	Angola	Botswana	Lesotho	Madgascar	Malawi	Mozambique	South Africa	Eswatini	Zambia	Zimbabwe
Calliandra calothyrsus	++									
Faidherbia albida	+	++			+++	+++	++	+	+++	+++
Gliricidium sepium	+				+++	++		+++	++	
Leucaena leucephala	+	+		++	+++	++	+	+	+++	+++
Senna siamea					++	++			+++	++
Senna spectabilis					+++	+			++	+
Sesbania sesban	+	+		+	+++	++	+	+	+++	++
*Tephrosia vogelli*i					+++				++	+

+ cited in literature, ++ important +++ identified as a priority species/grown widely

Table 8. List of the most common indigenous fruit species and references on geographic variation studies

Species	Country	Reference
Adansonia digitata	Malawi	Nyoka *et al.,* 2014
	Malawi	Munthali *et al.,* 2012a
	Malawi	Munthali *et al.,* 2012b
	Malawi	Sanchez, 2011
	Namibia	Nghitoolwa *et al.,* 2003
	South Africa	Shackleton, 2002
	South Africa	Leakey *et al.,* 2005
Parinari curatellifolia	Eswatini	Akinnifesi *et al.,* 2006
	Malawi	
	Mozambique	
	Zimbabwe	
Sclerocarya birrea	Botswana	Mutakela, 2001
	Malawi	Mkwezalamba *et al.*, 2015
	Malawi	Nyoka *et al.,* 2014
	Malawi	Chirwa *et al.,* 2007 (a)
	Namibia	Nghitoolwa *et al.,* 2003
	Namibia	Leakey *et al.*, 2005
	South Africa	Leakey *et al.*, 2005
	South Africa	Shackleton, 2002
	Zimbabwe	Nyoka and Musokonyi, 2002
Strychnos cocculoides	Botswana	Oppelt *et al.,* 2005a
	Botswana	Oppelt *et al.,* 2005b
	Zambia	Mkond*a et al.,* 2003
Uapaca kirkiana	Malawi	Chirwa *et al.*, 2007 (b)
	Malawi	Mwase *et al.*, 2006
	Zimbabwe	Rukuni *et al.,* 1998
Ziziphus mauritiana	Botswana	Akinnifesi *et al.,* 2006
	Malawi	
	South Africa	
	Zambia	
	Zimbabwe	

seed collected from the forest before harvesting. Forest management plans usually require rehabilitation of the harvested areas, but most forestry departments are under-resourced to be able to monitor the regeneration and restorative processes. The process of harvesting alters the population structure with the largest and well-formed trees usually targeted for harvesting. The remaining tree population is usually impoverished in terms of genetic make-up.

In Mozambique, harvesting contractors are required to plant seedlings of harvested species. But rarely is the survival monitored. Forest departments need to come up with management plans that ensure compliance which ensure that harvested forests are restored. These plans may include collecting seed of all the species in the area to be harvested and replanting the areas using the retained seed. Natural regeneration from stumps can be encouraged, and ecological restoration using short-lived canopy species (e.g. in Madagascar, see Manjaribe *et al.,* 2013) can be tried in the degraded forests. Such approaches require detailed knowledge of the ecology of the forests. The artificial regeneration disrupts the continuous evolution of tree populations at a given site, but opens opportunities for increasing genetic diversity and enhancing productivity through the selection of superior provenances (White *et al.,* 2005). Some species like *K. nyasic*a are fairly widely grown in plantations within their natural areas of distribution, but also in South Africa, tropical Asia and tropical America, and there should be active promotion of the planting of such species using superior provenances.

Seed deployments pathways. Seed deployment pathways in the region have evolved into four main systems depending on country, size of the commercial forestry areas and the participation of communities in agroforestry (Lillesø *et al.,* 2011). The following are common pathways; the government model – national tree seed centre, the NGO model, informal decentralised model and the private sector.

Most countries with established NTSCs use the government model, where research on tree breeding and tree seed production is conducted by national institutions. Seed production areas are established in different ecological regions to maximise seed production. The seed is collected and stored at a central location for future distribution to tree planting projects or for exporting to international markets. This model ensures good control of genetic and physiological parameters. The government model allows for better forecasting seed demand through access to national forest statistics. This model has been supported by donors and has worked well in many countries, although this study has shown that most NTSCs are struggling to meet demand. The limitation was that the government model focused on traditional commercial species (pines and eucalypts), leaving a gap on the supply of other FGRs.

The NGO model has been applied mainly to agroforestry and indigenous species, especially fruit trees. The World Agroforestry Centre (formerly ICRAF) has been on the forefront providing tree germplasm to farmers. In collaboration with its partners in Southern Africa, it has promoted participatory tree domestication approaches to better share the benefits at a local level and to make use of tree species that are important both at local and regional levels. Most of the seed originates from genetic trials, source countries or from farmers' fields. A number of NGOs have advocated for tree planting projects in many African countries, and have been supplying seed to rural communities. The NGO model is effective as it reaches out to the small-scale growers who are disadvantaged and geographically dispersed.

The informal decentralised model involves individual farmers exchanging seed amongst themselves. Traditionally, farmers have been exchanging crop seeds for many generations. Many fruit trees have been introduced through this model. It is difficult to quantify the level of tree seed exchanges currently taking place and to monitor the genetic quality of the tree germplasm. This calls for the need to raise awareness on the importance of genetic quality and for a national system to control access and use of such genetic resources.

In countries with large private forest companies such as South Africa, tree germplasm is being produced and distributed by private companies. The seed is primarily used by the company and the excess is sold to other customers. The private model guarantees seed supply but is often limited to a few commercial species. In South Africa, for example, the Department of Agriculture, Forestry and Fisheries (DAFF) reported on shortages of seed of other non-commercial species for community tree planting projects.

Institutional issues. Historically, forest departments in most countries in the region were mandated to conduct forest research and contribute to the development of science-

Table 9. List of the most common indigenous timber species and references on geographic variation studies

Species	Country	Reference
Pterocarpus angolensis	South Africa Zambia Zimbabwe Mozambique	Shackleton 2002 Mitwa *et al.,* 2010 Chisa-Kasumu *et al.,* 2009
Baikiaea plurijuga	Zambia Zimbabwe	Theilade *et al.,*2001
Melicia excelsa	Mozambique Angola Malawi	
Khaya anthotheca	Mozambique Malawi Zimbabwe	
Afzelia quanzensis	Malawi Mozambique	Mtambalika *et al.,* 2014
Delbargia melanoxylon	Mozambique Zimbabwe Malawi	

based management practices and distribution of germplasm. Forest departments in Malawi (FRIM), Zimbabwe (Forest Research Centre), Mozambique (Centro Experimentacao Florestal) played a leading role in the distribution of commercial seedlots whilst in South Africa, the private sector imported seed for plantation establishment but subsequently started their own tree breeding programmes for specific products. During the 1980s, the demand of tree germplasm and new species such as agroforestry and indigenous tree germplasm grew and there was need to increase the capacity of existing seed centres to collect and distribute tree germplasm. Twelve national tree seed centres were established in Angola, Botswana, Lesotho, Mozambique, Namibia, Eswatini and others strengthened in Malawi, Mauritius, South Africa, Tanzania, Zambia and Zimbabwe under the SADC tree seed centre network project with assistance from the Canadian International Development Agency from 1992 to 1998 (Shumba and Mwale, 1999). The support included vehicles and equipment, training, and a cadre of seed professionals was set up in the region. There were a lot of regional training workshops, scientists exchanged visits and research seed-lots. This resulted in increased capacity of the region to collect, test, store and distribute tree seeds and exchange research seed-lots for trialing.

However, over the years there has been no significant investment in national tree seed centre activities. Seed centres in Malawi and Zimbabwe are still functional to some extent, whereas those in Zambia and Mozambique are experiencing shortages in human capacity and funding. The seed centres are failing to meet domestic seed demands and private forest companies and tree growers are relying on seed imports. The physiological quality in terms of purity and viability is often poor as most seed centres have dilapidated seed testing and cleaning equipment, and some like Zimbabwe are facing frequent power cuts resulting in loss of seed viability. Seed testing protocols like International Seed Testing Association rules are not being followed in most countries except for commercial seed of pines and eucalypts for export like in the case of Zimbabwe. In South Africa, most private forest companies have their own seed orchards and have progressed to clonal forestry practice. A number of private growers in the region have imported eucalypt clones from South Africa into other countries and reports seems to suggest more failures than success and there is a possibility that the vegetative material is helping the spread of diseases and pests.

Overall, this study has shown that Southern Africa has a unique assemblage of forest genetic resources both for exotic and indigenous species that are being used now and into the future. However, individual countries are at different levels of sophistication in terms of their breeding initiatives and programmes. South Africa has a very advanced breeding programme, largely driven by the private sector with support from government with the benefits internalized by the companies. In Malawi, Zambia and Zimbabwe tree breeding research is still done by government institutions, and the benefits of the research are deployed to the industry as improved tree germplasm. Lack of investments in research has hampered the capacity of these countries to produce enough seed to sustain planting programmes.

The shortages of tree seeds are happening against a background of high deforestation and low rates of tree planting and projected deficits in timber supply. This, coupled with a growing backlog in tree planting, a finite plantation forest resource, increasing temporarily-unplanted areas, potential negative impacts of climate change, and threats of diseases and pests, there is an urgent need for the region to address SFM issues. There is also an expectation of the risk of plantation failure or suboptimal performance due to changed site conditions as a result of climate change. The region will have to work collaboratively to ensure the risk of reduced species performance is minimised across all the range of environments and site conditions.

Trials and plantations of the exotic species throughout Southern Africa will be particularly valuable to assess the effects of climate change on growth, form characteristics and secondary effects such as pests and diseases triggered by changes in climate. The information will determine the extent to which genetic selection can be done to mitigate some of the predicted negative effects of climate change on timber, other products and environmental services from the genetic resources thus far assembled in the region. For indigenous fruit trees, the development of vegetative propagation technologies has shown some promise and could make deployment easier. Collections for commercially important indigenous species is still very much *ad-hoc* and limited to research projects. Forest management plans in Mozambique and Zimbabwe are not fully addressing the restoration of logged areas using seed from superior trees. There are concerns of erosion of the genetic base of the target species. The same concerns exist for IFT that are harvested commercially and sold on local urban markets effectively removing potential propagules from their natural habitat.

The declining investments in research have also affected the seed centres. Most of the seed centres have reported on the reductions in skills and lack of equipment. This is creating bottlenecks in the seed production and supply with reports of loss of viability and poor germination of seeds. There has also been a significant brain drain in the region resulting in the loss of capacity and skills in tree improvement and germplasm production. Governments can play a pivotal role in ensuring that policies and strategies are spread as widely as possible, so that the importance and benefits of the industry are better understood. Forestry departments can play direct facilitation roles in ensuring a coordinated effort and linkages with the industry.

There are also opportunities to unlock value in the forestry industry by leveraging the tree breeding and seed supply strengths of the various countries in Southern Africa. This would require information exchanges at the regional levels. There is one opportunity that exists through the Southern African Tree Seed Working Group (SATS) that was formed in 2002 by forestry stakeholders in South Africa to create a forum for discussion, debate and the exchange of scientific ideas around tree seeds and seed orchards (Luke Solomon, personal communication, 2014). The AFF also offers a platform for forestry experts to share and exchange information and technical information on tree breeding and tree germplasm development and deployment.

CONCLUSION AND RECOMMENDATIONS

The study highlighted the importance of tree breeding in guaranteeing the production of good tree germplasm. The capacity of a majority of southern African countries to produce good quality tree germplasm was generally low, weak and varied from country to country for most of the forest genetic resources. All countries except South Africa highlighted the need to improve seed centre infrastructure as a key component to the production and deployment of tree germplasm. The decline in forest investments against a background of projected timber shortages is resulting in increased rates of deforestation, reduced tree planting, increased pest and diseases. Tree growers, especially private companies, expressed the absence of research by national governments and highlighted shortages in the supply of good quality stock. The seed deployment pathways of agroforestry species are still not clearly defined with most tree planting projects still depending on donor support. Sustained demand beyond the projects is still yet to be ascertained. Genetic erosion of commercial timber species, and indigenous fruit trees was noted as a major concern and there were calls for making sure that the populations of the species were adequately represented in conservation as part of SFM programmes. The study recommends that governments, private sector and international community work collaboratively to support tree breeding and seed germplasm production to achieve sustainable forest management in the region. The different custodians of tree genetic material in the region have a unique resource, and through policy and regional programmatic support, there are opportunities to share the information and materials to improve performance of planted trees and plantations and achieve sustainable forest management (SFM) in Southern Africa.

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STATEMENT OF CONFLICT OF INTEREST
The authors declare that there is no conflict of interest in this paper.

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Tree germplasm management systems and their potential for sustaining plantation forestry in West and Central Africa

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ABSTRACT

In West and Central Africa (WCA), despite the significant increase in plantation forest establishment, quality and quantity tree germplasm supply is still challenging. This study explored institutional and operational frameworks for tree seed management and analysed the extent of forestry and agroforestry plantation within the WCA countries. The study approach was based on literature review, field visits, interview of staff of tree seed centres and other institutions in charge of reforestation/afforestation in four countries. The findings show a net increase of forest plantation by 122% from 1990 to 2015, driven by an enabling political and institutional framework and the domestication of various indigenous fruit and timber tree species. Trees and germplasm improvement in the region are still in their early stage. Tree seeds supply is adequate for exotics, but grossly inadequate for indigenous species. Overall, seed policies are either inadequate or lacking. The contribution of the informal sector to seed supply chain remain high, therefore offsetting the quality, quantity and diversity of germplasm deployed. The study urges for the development and harmonisation of sound seed policies, technology transfer among countries and the establishment/strengthening of national tree seed centres for sustainable production and supply of quality tree germplasm for plantation forestry in WCA.

Keywords: Germplasm sources and supply, informal sector, plantation drivers, priority species, seed policies and markets, West and Central Africa

RÉSUMÉ

En Afrique de l'Ouest et du Centre (AOC), malgré l'augmentation significative des plantations forestières, l'approvisionnement en semences d'arbres de qualité et en quantité reste contraignant. Cette étude a exploré les cadres institutionnels et opérationnels pour

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la gestion des semences forestières et analysé l'étendue des plantations forestières et agroforestières dans les pays de l'AOC. L'approche méthodologique était basée sur une analyse documentaire, des visites de terrain, des entretiens avec le personnel des centres nationaux de semences forestières et d'autres institutions en charge du reboisement et du boisement dans quatre pays de la sous-region. Les résultats montrent une augmentation nette de 122% des plantations forestières entre 1990 et 2015, grâce à un cadre politique et institutionnel favorable et à la domestication de diverses espèces locales d'arbres fruitiers et forestiers. L'amélioration des arbres et du matériel génétique dans la région en est encore à ses débuts. L'approvisionnement en semences d'arbres est adéquat pour les espèces exotiques, mais reste largement inadéquat pour les espèces locales. Dans l'ensemble des pays, les politiques semencières sont soit inappropriées, soit inexistantes. La contribution du secteur informel à la chaîne d'approvisionnement en semences reste élevée, ce qui remet en question la qualité, la quantité et la diversité du matériel génétique utilisé. L'étude préconise le développement et l'harmonisation de politiques semencières saines, le transfert de technologie entre les pays et la création/le renforcement de centres nationaux de semences d'arbres pour la production durable et la distribution de matériel génétique de qualité pour la plantation forestière en AOC.

Mots-clés : Sources des semences, secteur informel, moteurs des plantations, espèces prioritaires, politiques et marchés des semences, Afrique de l'Ouest et du Centre

INTRODUCTION

West and Central Africa (WCA) region is known to host the second most important forest landscape in the world (Malhi *et al.,* 2018). This region is home to a variety of ecosystems ranging from lowland evergreen rainforests, semi-deciduous forests, to tropical savannahs and other woodlands. These ecosystems are known as the main source of industrial timber for the continent (Okali and Eyog, 2004). They also provide non-timber products to meet subsistence needs of local populations and contribute to national economy of producing countries (Eba'a *et al.,* 2015; Hetemaski and Hurmekoski, 2016). Many people in WCA countries depend on tree products and services for food, health, shelter, energy as well as many other livelihoods needs, and their demand is estimated to increase given the population growth and the development of new markets and products (Leakey and van Damme, 2014; Endamana *et al.,* 2015; Rasmussen *et al.,* 2017). However, these forests are under high pressure of deforestation and degradation, driven by unsustainable agricultural practices, infrastructure development and overexploitation of some high value species. In Côte d'Ivoire for example, the forest cover decreased from 16 million ha in early 1900 to 2.5 million ha in year 2000 (FOSA, 2000). In some countries like Cameroon, although the forest cover did not significantly change, their economic and ecological values have been reduced by selective logging and many other anthropogenic factors (Marien and Mallet, 2004; EDF, 2013; Shu, 2013). Recent estimates indicate an overall decrease of 10% of the forested land in WCA (FAO, 2014). For the Congo Basin Forest, reduction in forest area include 20% for humid forest and 40% of dry forests. Meanwhile, more than 70% of the forest cover has already been lost in many Sahelian countries (Ariori and Ozer, 2005; EDF, 2013; FAO, 2014). Therefore, to meet increased demand for forest and tree products, many plantations have been established in different countries in the region since early 1900s (FAO, 2000; Chamshama *et al.,* 2009). Of the 8 million ha of forest plantations estimated in year 2000 in Africa, 42% were found in West and Central Africa (FAO, 2003a; FAO, 203b; Chamshama, 2011; Koskela *et al.,* 2014). It is estimated that the increasing demand for ecological services (trees for soil fertility improvement, conservation of water catchment), forest products (fruit, fuelwood, fiber, fodder and timber), climate change adaptation and mitigation will only be met from expanding cover of planted forests rather than from natural forest (FRA, 2015; Sloan and Sayer, 2015). Therefore, an efficient tree germplasm supply system is of critical importance for establishing sustainable forest plantations and agroforestry programs (Nyoka *et al.,* 2011; Thomas *et al.,* 2015).

Tree Seed System is composed of actors (organisations, individuals) involved in different roles/functions (breeding, multiplication, testing, processing, storage, marketing) toward tree seeds production and distribution to meet different tree planting objectives (Figure 1). Lillesø *et al.* (2011) described eigth tree seed supply systems based on the three main components of the input supply chain (seed sources, seed procurement, seeds and seedlings distribution) and the dichotomic (centralised or decentralised) control approach involved in the management at each component level. These were further grouped into three major models namely the Government Model, the Non Govenmental Organisation Model (NGO Model) and the decentralised Model. The application of this approach of seed systems classification is important in all countries to rightly understand the type of tree germplasm sources being used as well as the logistical and institutional processes involved in their deployment (Lillesø *et al.,* 2018).

One key element for improving tree performance and production is to ensure the availability of high-quality germplasm to meet plantation needs (Koskela *et al.,* 2014; Thomas *et al.,* 2015). National tree seed centers are therefore expected to play an important role in the procurement, collection, processing, storage and distribution of high-quality forest tree seeds. In addition, they serve as *ex situ* seed gene banks use for the conservation of forest genetic resources, to undertake research and to formulate policies that guide tree seed procurement and deployment (Phartyal *et al.,* 2002; Koskela *et al.*, 2014; Thomas *et al.,* 2015). However, an earlier evaluation indicated that most of the 50 National Tree Seeds Centers established from 1960 to 2005 in tropical

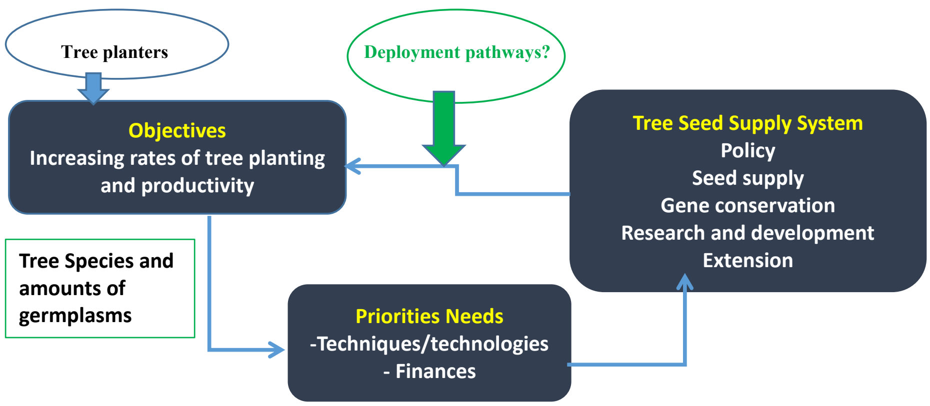

Figure 1. Principles of tree germplasm Deployment/flow (Adapted from Nyoka *et al.,* 2015)

countries were either not fully operationals or unable to satisfy the increasing need for quality tree seeds for afforestation/reforestation projects (Nyoka *et al.,* 2015). There is therefore a need to document alternative approaches of tree seed systems being developed in different contexts (Dedefo *et al.,* 2017).

Climate change will exacerbate the current constraint related to poor access to quality tree germplasm by affecting distribution, productivity, pests and diseases risks, grow and development performance for many tree species. A recent evaluation of 38 Project Design Documents (PDD) for 38 Afforestation/ Reforestation Clean Development Mechanism (CDM) projects had raised a concern about how to ensure germplasm access to meet the tree planting objectives (Roshetko *et al.,* 2017). To address these shortfalls, tree seeds management systems should build on specific germplasm-based climate change opportunities as suggested by Dawson *et al*. (2011).

In this paper, tree seed production and supply system in WCA is reviewed with a focus on the extent of forest plantations and associated tree germplasm needs, current state of tree improvement activities, techniques to produce improved germplasm and planting stocks, status of existing seedbanks and gene-bank in the region as well as seed supply, processing and distribution networks in WCA countries.

RESEARCH APPROACH

This study was carried out in two parts, as a desktop literature review and field visits in four west and central African countries namely the Republic of Congo, Cameroon, Senegal and Burkina Faso. The study countries were chosen based on the extent of their forestry plantations and tree planting activities (Cameroon and Congo) as well as the existence of an operational Tree seed centre or programme (Burkina Faso and Senegal).

Literature review was based on the following thematic areas:

a) sustainable forest management issues as they relate to commercial and community tree planting activities in WCA;
b) species introductions, provenance testing, and conservation of key species;
c) policies that are affecting afforestation and reforestation programmes.

The country visits were designed to meet with key forest plantation industry players, policy makers, foresters and development practitioners. Discussions with these actors yielded information on reforestation and afforestation rates, the range of species planted, seed deployment strategies and constraints, seed demand and supply, mains species being used in forestry and agroforestry plantations and on-going forestry and agroforestry projects. A standard questionnaire was designed and administered during field visits to managers of tree seed centres/programmes and other institutions involved in afforestation and reforestation activities. These informations were analysed to understand their seed sources, procurement and distribution strategies as well as their national and international collaborating partners. Information was also collected on activities for tree planting for both commercial, non-commercial, indigenous and exotic trees species, afforestation and reforestation rates, gaps in planting activities, seed and seedling production capacities, opportunities and constraints, institutions and policies impacting on germplasm production, research and development.

For countries not visited, information was searched in the literature. Telephone conversations were also conducted with key actors when possible on some important points of the questionnaire. The questionnaires were also sent via emails to those who agreed to fill them out.

Information from filled questionnaire were analysed together with those from literature review to document the extent of forestry plantation and tree seed systems in WCA countries.

FINDINGS AND DISCUSSION

State of forest plantations in WCA. According to FAO (2015), the planted forests in WCA covered 16 million ha representing 2.56 % of the African total forest cover, and accounting for 5.8 % of the global forest planted area. There has been a significant increase in tree planting during the past decades in many countries within the region. The total area of forest cover in the region changed from 346.6 to 313.0 million ha from 1990 to 2015 of which only 3.3 million ha is planted (Payn *et al.,* 2015). The area of forest plantation increased from 1, 204, 000 ha in 1990 to 2, 089, 000 ha in 2010 and 3, 300, 000 ha in 2015, representing roughly 20 % of the forest plantation cover on the African continent (Table 1). The annualised change in planted forest area from 1990 to 2015 was estimated to be 3.2 % (Payn *et al.,* 2015). The increasing rate of planted forest cover in some WCA countries was estimated using the benchmark forest areas in 1990's for Ghana (220 %), Côte d'Ivoire (118 %), Rwanda (85 %), Nigeria (80 %), and Senegal (75 %) (FAO, 2010). Since 1990, the change in planted forest in WCA FAO-sub region has been estimated to be 122 %, indicating very high rates of tree planting (Payn *et al.,* 2015).

The planting approach adopted by many countries is consistent with the concept of "Forest Landscape Restoration". In this approach, many actors such as farmers plant trees as part of their land-use, while governments, NGOs and private sectors are involved in agroforestry promotion and forestry plantations management, respectively (Harris, 1993; Eyog Matig *et al.,* 2002; Marien and Gourlet-Fleury, 2013; Laestadius *et al.,* 2015).

Most forest plantations within the region are established and managed by public forestry agencies, except for the Republic of Congo. These publicly owned forest plantations are generally reported to be in poor state due to inadequate governance frameworks, weak capacity of forestry departments, inappropriate silvicultural management, financial constraints, and lack of purposeful research (MacDicken *et al.,* 2015). Côte d'Ivoire is reported as the only WCA country with well managed publicly owned forest plantations (Payn *et al.,* 2014).

In Central African countries, the new silvicultural approach for sustainable natural forest management combined with the development of forest plantations in degraded forest and savanna areas constituted the main strategy to maintain or even extend forest cover within the region (Marien and Gourlet-Fleury, 2013). In the dryland part of the region, many plantations have been established to try to stop, or even to reverse, the desertification process, which is the main ecological problem of numerous countries with arid climates like Niger, Chad, Mali, Nigeria, Burkina Faso, Mauritania, Senegal (FAO, 2000a; Sacandé *et al.,* 2015). Among these tree plantation programmes, is the Great Green Wall initiative, launched since 2011 in the Sahel and Sahara involving 12 countries of which more than 90% are from West Africa (Sacandé *et al.,* 2015).

At the same time, individually owned woodlots are now widespread in some WCA countries like Cameroon, Ghana and Nigeria. Though information on their extent is still unreliable, these privately-owned woodlots are known to significantly contribute as major source of fuelwood, poles and common non-timber forest products and continue to play an important role in the livelihoods of rural communities and national economies (Buongiomo and Zhu, 2014; Whiteman *et al.,* 2015).

Constraints and opportunities for forest plantation development in WCA countries. Despite several forest plantation initiatives, Ariori and Ozer (2005) demonstrated a continuous decline, at a rate of -2% of forest cover per year in some Sahelian countries (Burkina Faso, Chad, Guinea Bissau, Mauritanie, Mali, Niger, Sénégal) during the second half of the 20th century. From their study, it was shown that 15 out of 44 sites covered by forests in 1955 had disappeared, while many other forested lands were reduced by more than 70% of their initial surface area. The main cause of planted forest loss identified were increased demand for fuel and other wood products (93% of respondents) and forest land conversion into agriculture (89% of respondents). A similar trend was reported in other WCA countries (Payn *et al.,* 2015).

In Cameroon, the planted forest cover estimated at 35800 ha in 1990 was reduced to 6631 ha in 2007, driven mainly by human activities such as agriculture expansion, firewood exploitation and settlements (MINEF, – FAO, 2007; Ngueguim, 2014). In 2006, the Government launched a national program of reforestation with the aim of sustaining its forest capital and support decentraliszed organisations (city councils, community based organiszations, NGOs, schools, and universities) for the creation and management of forest plantations for social, economic and environmental benefits (MINFOF, 2006). As a result of this initiative, recent estimates indicated that up to 4665 ha of forest have been planted from 2010 to 2015 (MINFOF, 2016). However, new data on Cameroon forest cover missed these reforestation initiatives.

In the Republic of Congo, among the 70,000 ha of forest plantations estimated in 2007, 42 000 ha were made of clonal Eucalyptus established in the coastal plains of Kouilou and owned by a private industrial company called Eucalyptus-Fibre du Congo (EFC). Moreover, the National Society of Reforestation (SNR) in collaboration with some forestry industries had undertaken a programme of enrichment planting of exploited forests as well as establishment of forest plantation using species such as *Aucoumea klaineana* (Okoumé), *Entandrophragma cyndricum* (Sapelli), *E. util*e (Sipo), *T. superba* (Limba) (Marien and Gourlet-Fleury, 2013). Agroforestry plantations involving community-based organisations are being promoted through the production and distribution of seedlings of nitrogen fixing shrubs such as *Albizzia lebbeck, Flemingia congesta, Gliricidia sepium*, *Leucaena leucocephala* and *Piliostgma malarborium* (Matondo, 2013).

In Benin, forest plantations have been estimated to cover 19000 ha mainly dominated by *Tectona grandis* planted both by state institutions and farmers for pole production (Aoudji *et al.,* 2014). A recent assessment in 2013 of land use and land cover change for a 33 years period in the country indicated that although tree plantations are expected to double by 2025, they will not compensate for the loss of natural woody vegetation (Toyi *et al.,* 2013). The situation is different in Senegal, where the area planted during the period from 1933 to 1998 was estimated at 65 000 ha, located mainly in the central northern zone of the groundnut basin. Since 1990s, State-controlled plantations were being replaced by village-based and private planting programmes showing the beginnings of enthusiasm among local people to participate in natural resource management programmes (Diouf *et al.,* 2001).

In Niger, the most important forest ecosystem of the country is represented by agroforestry parks dominated by *Faidherbia albida, Borassus aethiopum, Hyphene thebaica, Vitellaria paradoxa, Prosopis africana* and *Neocarya macrophylla*, covering an estimated surface area of 5 000 000 ha for Zinder and Maradi (CNEDD, 2014). This agroforestry effort is supplemented by urban and peri-urban forestry plantations under the umbrella of the Great Green Wall Initiative, with 2500 ha of plantation for the town of Niamey (CNEDD, 2014). In Togo, forest plantations have been established since the colonial period, using exotic species such as *T. grandis, Eucalyptus* spp.*, Cassia* spp.*, Acacia* spp.*, Leucaena* and *Anacardium occidentale.*

Other success stories on indigenous and exotic forest/agroforestry tree plantations in some Central African countries have been reported to include *A. klaneana* in Gabon, *Terminalia superba*, *Eucalyptus* spp. and *Pinus* spp. (Republic of Congo), cocoa agroforests under the shade of timber species (Cameroon), *Acacia auriculiformis* based agroforestry plantation (Democratic Republic of Congo) (Marien and Mallet, 2004; Biseaux *et al.,* 2009).

The statistics on planted forests are not reliable in several countries (e.g. Guinea, Ghana, Liberia, and Chad) because of lack of inventories, frequent fires, poor maintenance and/or uncontrolled clearing (Payn *et al.*, 2014). Although some countries (e.g. Republic of Cameroon, Congo, Côte d'Ivoire, Benin, and Nigeria), have significant areas of industrial forest plantations using mainly exotic species, plantations for timber production, which are expensive and difficult to manage, have been insufficient to compensate for the extensive exploitation of natural forests. In addition, the

Table 1. Forest statistics changes for countries in the West and Central Africa region from 2010 to 2015

Country	Forest cover (ha)	% cover	2010 De-forestation (ha yr^{-1})	2010 Af-forestation (ha yr^{-1})	2010 Re-forestation (ha y^{r-1})	2015 Plantations (ha)	%Net change (2015)
Central Africa							
Central Africa Republic	22 170 000	35.6		400		2 000	-1.0
Cameroon	18 816 000	39.8				260 000	-1.0
Congo	22 334 00	65.4			100	71 000	-1.0
Democratic Republic of Congo	152 578 000	67.3		300		60 000	-0.2
Equatorial Guinea	1 560 000	55.9				58 500	-0.7
Gabon	23 000 000	89.3				30 000	0.2
Tchad	4 875 000	3.9					
West Africa							
Benin	4 311 000	39.0			14 600	23 000	-1.2
Burkina Faso	5 350 000	19.6		15 000	14 000	239 000	-1.0
Côte d'Ivoire	1 040 000	32.7				427 000	0.1
Gambie	488 000	78.8				1 000	0.4
Ghana	9 337 000	41.0		0	20 000	325 000	0.3
Guinee	6 364 000	25.9		2 100	0	104 000	-0.5
Guinee Bissau	1 972 000	70.1				1 000	-0.5
Liberia	4 179 000	43.4	200	0.0	300	8 000	-0.7
Mali	4 715 000	3.9	146 000	0.0	67 000	135 000	-1.4
Niger	1 143 000	0.9				150 000	-2.1
Nigeria	6 993 000	7.7			214 000	420 000	-3.5
Senegal	8 273 000	43.0			19000	561 000	-0.5
Sierra Lone	3 044 000	42.5		700	300	16 000	-0.1
Togo	188 000	3.5		0.0	1000	46 000	-5.0

Blank denotes very small number rounded off to zero

Source : FAO, 2015; Rodney *et al.,* 2015) area planted with high-grade hardwood timber like that which is extracted from the natural humid forests is insufficient to have any impact on the supply of such timber in the foreseeable future (Toyi *et al.,* 2013). Many plantations in Cameroon, Gabon and Democratic Republic of Congo have failed owing to lack of maintenance and poor management (Chamshama *et al.,* 2009; Whiteman *et al.,* 2015).

The forest statistics indicate that there is a strong political commitment in WCA countries for tree plantation as a major contribution to environmental restoration and people's livelihoods. Expansion of plantations and the growing of trees by communities need to be further supported through capacity development in different domain related to sound forestry plantation management including tree germplasm production and improvement (Koskela *et al.,* 2014; Thomas *et al.,* 2015).

Overview of current state of tree improvement activities in WCA. In response to the depletion of forest resources, several activities have been carried out in recent decades within the region, on tree germplasm improvement and production to meet demand from public and private plantation owners. The aim of tree improvement is to (i) maximize adaptability of a species to potential planting sites (and thus its survival), (ii) maximise growth rate, (iii) increase resistance to diseases, and (iv) improve the quality of the end-use products such as timber, fuel-wood, fodder and soil stabilisation (Barner *et al.,* 1992). The adaptability to planting site is among the first-generation improvement programmes in which the environmental conditions of the potential planting sites are screened along with those of the natural distribution range of the species. This is mainly done using field provenance trials with the aim to identify which provenance of the species can perform well in each site (Koskela *et al.,* 2014). In the context of climate change, provenance trials are also useful to assess the plasticity of different provenance through their adaptability to a wider range of conditions using multilocation field trials and environmental data (Dawson *et al.,* 2011). Survival and growth performances are the main parameters used in evaluating the suitability of a species or provenance for a planting site. Meanwhile, different growth conditions are tested together with the provenance trials to determine the appropriate growing conditions for each tested provenance (Koskela *et al.,* 2014). Resistence to diseases and quality of end-products are improved either by selection of provenance or individual tree providing the preferred products or expressing better resistance. For timber species, this could be done by focusing on sustainable management of genetic variation to generate, identify and multiply well-adapted genotypes for operational planting based on characters such as wood characteristics, height, stem straightness, and fast growth (Haines, 1994).

The forest tree improvement activities commonly depend on the expected outcome of the tree plantation either for income generation, germplasm conservation, forest resource conservation or farm diversification (Simons, 1996). In forestry, seed-based tree breeding approaches are the most commonly used.
The main tree improvement activities widely undertaken within the region are:

a) provenance and progeny testing (almost all planted tree species);
b) multi-criteria and clonal selection and subsequent vegetative propagation of improved clones (*Eucalyptus* and *Pinus* spp. in the Republic of Congo; teak varieties in Côte D'Ivoire);
c) varietal creation (improved Eucalyptus hybrids for pulp production in the Republic of Congo), and
d) selection for marketable characters such as physical, mechanical and chemical properties of wood, pest and disease

resistance (e.g. Iroko in Ghana).

Tree improvement methodology adopted in the WCA region for exotic species included many phases among which elimination and selection phase are, followed by testing and selection of adapted provenances. “Plus trees” and “families” are selected to establish seed orchards for the most advanced programmes. Provenance and progeny testing are known as the most common and oldest research activity for more than 75% of the tree species involved in forestry plantation. Several provenance trials for exotic and indigenous species have been established in almost all WCA countries. The aims of these trials were to conserve gene pool, provide information on the nature and extent of genetic variation within and between provenances throughout the species native ranges and set a basis for selection of species for afforestation (Peprah, 1999; FAO, 2001). For some few species such as *F. albida* (Burkina Faso, Cameroun), *Parkia biglobosa* (Burkina Faso) and *Vichellia* spp., the provenance trials were based on systematic prospection, germplasm collection and comparative testing covering the distribution range of the species within the region (FAO, 2001).

According to FAO national reports from Cameroon, Cote d’Ivoire, Burkina Faso, Nigeria, Niger, Mauritania, Mali, Benin, Senegal, Togo, provenance and progeny trials were established for more than 30 tree species including *A. occidentale, Anogeissus leiocarpus, Atriplex* spp.*, Azadirachta indica, Casuarina equisetifolium, Eucalyptus camaldulensis, F. albida, Khaya senegalensis, Nauclea diderrichii, P. biglobosa, Prosopis* spp.*, T. grandis, Vichellia* spp. and *Ziziphu*s spp. (FAO, 2001).

In Cameroon, progeny trials were set up according to agroecologic areas. Henceforth, trials for many Acacia species were established in the dryland area of the Northern part of the country, those of *Eucalyptus* spp., *Pinus* spp. and *Araucaria* spp. were planted in the humid highland savannah areas in the western regions while indigenous timber forest species were planted in the coastal (around Kribi) and deciduous (Belabo area) forest zones (Ngueguim *et al.,* 2009). In Senegal, almost 2000 trials involving nearly 30 species have been established in agricultural, forestry, littoral and valley zones of the country by the national tree seed programme (Programme National de Semences Forestières), the PRONASEF, in collaboration with the National Centre for Forestry Research (CNRF).

In the Republic of Congo, improved vegetative propagation techniques have been developed to produce high-quality germplasm of many exotic species including *Eucalyptus*, *Pinus* and *Acacia* species (Matondo, 2013). In this country, genetic gains for adaptability, growth, bole shape, wood quality and rooting ability were obtained with hybrids developed from *E. urophyla* and *E. grandis.* The hybridisation processes included early selection in the field, controlled pollination and mass propagation. The Republic of Congo is reputed for the development of high performing Eucalyptus hybrids used in their forestry plantations in the savannah areas.

In Ghana, techniques have been developed for production of *Milicia excelsa* (Iroko) clones that are resistant to the gall forming insect *Phytolyma lata* using vegetative and tissue culture protocols to capture resistant lines. The techniques and protocols developed have opened opportunities for large scale planting of this important timber species in Ghana and Cote d’Ivoire and as a template for addressing plantation failure of the African Mahoganies (*Khaya* and *Entandrophragma* spp) as well as other indigenous species with endemic pest problems (Aquah *et al.,* 2013). Similarly, effective establishment of *Pinus caribaea* with improved wood physical property has been achieved using a mycorrhizal based technique during the nursery phase to correct certain deficiencies in the growth of the species (Aquah *et al.,* 2013).

In Benin, tree improvement mainly focused on Teak (*T. grandi*s) which is the most used species in reforestation programme. In Gambia, trials have been established using indigenous and exotic species with the objectives of testing their adaptability in different site conditions, identifying their nursery requirements for propagation and to select the most suitable tree species for each of their needed end-products or services (firewood, timber, fruits, fodder, medicine, ornaments and soil improvement). The tested species included *T. grandis*, *K. senegalensis, Albizzia ferruginea, Pterocarpus erinaceus, Prosopis africana, P. biglobosa* and *E. camaldulensis*. These species were selected based on the demand and acceptability by the local communities, legal restrictions, experience and available information on their silviculture, compatibility with other land use systems, among others (Danso, 2001).

A compilation of 88 species involved in improvement research activities, recorded mainly from FAO national reports on forest genetic resources within the region is presented in Table 2. A synthesis of these activities for all priority species is presented in Figure 2.

It can be observed from Figure 2 that tree improvement activities in WCA are still in their early stages for both indigenous and exotic species. Also, many of the provenance and progeny trials were set from external funding and were reported to be poorly managed, with inappropriate monitoring and documentation approach, thus contributing poorly to the species improvement (Kokesla *et al.,* 2014). This could explain the low performance usually reported for many forestry plantations in the region (Ngueguim *et al.,* 2015).

It is therefore important to raise more awareness for the need for more investment into tree breeding for better quality seed sources and associated benefits expected from tree plantations. According to Lillesø *et al.* (2018), a relatively low level of improvement could be appropriate provided specific species/ provenances recommendations are developed for relevant species, and avoiding the use of clearly inferior planting materials. Such low-input breeding strategies have been applied in WCA countries by the World Agroforestry Centre in the framework of their programme on the participatory domestication of indigenous fruit tree species (Tchoundjeu *et al.,* 1998).

Priority forestry and agroforestry tree species for improvement research in WCA. Since 1990s, there has been a rapid development and wide-scale adoption of agroforestry practices in West and Central Africa, because of increased demand for non-timber forest products and increased collection, distribution and use of agroforestry tree germplasm. The domestication strategy usually started with the selection of priority species at national and regional level based on indigenous knowledge, socio-economic and improvement potentials of the candidate species (Franzel *et al.,* 1996). In the African Humid Tropics, agroforestry tree species ranking studies were conducted in Nigeria and Cameroon, which were thereafter validated and generalised for all the humid countries of the region (Franzel *et al.,* 2008). Fourtheen indigenous species were identified as priority for domestication including six fruit trees, three medicinal plants, one vegetable, three spices and oily plants. Six ranking criteria based on the value of expected benefits from domestication were used to identify the top five priority fruit trees species as follows: *Irvingia gabonensis, Dacryodes edulis, Chrysophyllum albidum, Ricinodendron heudelotii* and *Garcinia kola* (Franzel *et al.*, 1996). Although some species had a broad geographical spread

Table 2. Priority forestry species for improvement activities in WCA

No	Species	Provenance & progeny trials	Sexual or veg. propagation	Hybridisation	Molecular analyses
1	*Acacia auriculiformis*	Cmr, Be, CI, Gh, Ma,			
2	*Acacia macrostachya*				Bf
3	*Acacia mangium*	Co, Cmr, Ma		x	
4	*Acacia nilotica*	Bf, Cmr, Ma, Nr, Nia, Sen	Bf, Cmr, Ma, Nr, Nia, Sen		Bf, Cmr, Ma, Nr, Nia, Sen
5	*Acacia senegal*	Bf, Cmr, Ma, Nr, Nia, Sen	Bf, Cmr, Ma, Nr, Nia, Sen		
6	*Acacia seyal*	Bf, Nr			
7	*Acacia tortilis*	Bf, Ma, Nr, Sen			
8	*Acacia albida*	Ma		X	
9	*Acacia holosericea*	Cmr			
10	*Adansonia digitata*	Be, Bf, Cmr, Gh, Ma, Nr, Nia, Sen	Be, Bf, Cmr, Gh, Ma, Nr, Nia, Sen		Be, Bf, Cmr, Gh, Ma, Nr, Nia, Sen
11	*Afzelia africana*	Bf			
12	*Albizialebbeck*	Ma			
13	*Allanblackia floribunda*		Cmr		
14	*Allanblackia parviflora*	Gh			
15	*Anacardium occidentale*	Sen			
16	*Anogeissus leiocarpus*	Be, Bf, Ma,			Be, Bf, Ma,
17	*Aphania senegalensis*	Sen			
18	*Azadirachta indica*	Bf, Cmr, Nr, Sen	Bf, Cmr, Nr, Sen		Bf, Cmr, Nr, Sen
19	*Balanites aegyptiaca*	Bf, Nr, Sen, Ch			Bf, Nr, Sen, Ch
20	*Bombax costatum*			x	
21	*Borassusaethiopum*	Ma			
22	*Boscia senegalensis*	Nr			
23	*Casuarina equisetifolia*	Sen			Sen
24	*Cedrela odorata*	Be, Cmr, Car			
25	*Ceiba pentandra*		Gh		
26	*Cola nitida*		Cmr		
27	*Cola nitida*		Nia		
28	*Cola cordifolia*	Ma			
29	*Combretum ghasalense*	Ma			
30	*Combretum glutinosum*	Ma			
31	*Combretum micranthum*	Ma			
32	*Cordia alliodora*	Gh			
33	*Cordyla pinnata*	Ma			
34	C*rossoptyx febrifuga*	Ma			
35	*Dacryodes edulis*		Cmr	Cmr	Cmr

No	Species	Provenance & progeny trials	Sexual or veg. propagation	Hybridisation	Molecular analyses
36	*Dalbergia sissoo*	Cmr	Cmr		
37	*Delonixregia*	Cmr, Ma			
38	*Detarium microcarpum*	Bf, Sen			
39	*Detarium senegalensis*		Sen		
40	*Eucalyptus alba*			Co	
41	*Eucalyptus cloeziana*	Co	Co		
42	*Eucalyptus citriodora*	Co	Co	Co	
43	*Eucalyptus grandis*	Co	Co	Co	
44	*Eucalyptus pelleta*	Co	Co		
45	*Entandrophragma angolense*		Gh		
46	*Eucalyptus camaldulensis*	Bf, Cmr, Car, CI, Ma, Nr, Nia, Sen, To	Bf, Cmr, Car, CI, Ma, Nr, Nia, Sen, To		Bf, Cmr, Car, CI, Ma, Nr, Nia, Sen, To
47	*Eucalyptus urophylla*	Co	Co	Co	
48					
49	*F albida*	Bf, Cmr, Nr, Sen			Bf, Cmr, Nr, Sen
50	*Garcinia cola*		Cmr		
51	*Glyricidia sepium*	Bf, Ma			
52	*Gmelina arborea*	Cmr, Car, Gh			
53	*Gnetum africanum*		Cmr		
54	*Irvingia gabonensis*		Cmr		
55	*Irvingia wombolu*		Cmr		
56	*Khaya ivorensis*	Gh			
57	*K senegalensis*	Be, Bf, Cmr, Ma, Nr, Nia, Sen	Be, Bf, Cmr, Ma, Nr, Nia, Sen		Be, Bf, Cmr, Ma, Nr, Nia, Sen
58	*Landolfia senegalensis*	Ma	Ma, Sen		
59	*Lannea microcarpa*	Bf			
60	*Leucaena leucocephala*	Bf, Cmr, Ma			
61	*Milicia* sp.		Gh		
62	*Moringa oleifera*	Bf, Cmr			
63	*P biglobosa*	Bf, Cmr, Ma, Nr, Sen, Ch	Bf, Cmr, Ma, Nr, Sen, Ch		Bf, Cmr, Ma, Nr, Sen, Ch
64	*Pausinystalia johimbe*		Cmr		
65	*Pericopsis elata*	Cmr, Gh			
66	*Pinus* spp	Co	Co		
67	*Prosopis africana*	Bf, Nr, Sen			
68	*Prosopis juliflora*	Nr, Sen			Nr, Sen
69	*Prosopis juliflora*	Sen			Sen
70	*Prunus africana*	Cmr	Cmr		
71	*Pterocarpus erinaceus*	Be, CI, Ma			
72	*Pterocarpus lucens M*a				
73	Ricinodendron heudelotii		Cmr		

No	Species	Provenance & progeny trials	Sexual or veg. propagation	Hybridisation	Molecular analyses
74	*Saba senegalensis*	Sen	Sen		
75	*Sclerocarya birrea*	Cmr, Ma	Cmr, Ma		
76	*Senna siamea*		Cmr		
77	*Strychnos spinosa*	Ma			
78	*Tamarindus indica*	Be, Bf, Gh, Ma, Nr, Nia, Sen, Ch	Be, Bf, Gh, Ma, Nr, Nia, Sen, Ch		
79	*Tectona grandis*	Be, Car, CI, Gh, Nia, To	Be, Car, CI, Gh, Nia, To		
80	*Terminalia catappa*	Co	Co		
81	*Terminalia ivorensis*	Cmr, Gh, Co, Nia	Co		
82	*Terminalia superba*	Co	Co		
83	Triplochiton scleroxylon	Cmr, CI, Gh, Nia	Cmr, CI, Gh, Nia		
84	Vepris heterophylla	Ma	Ma		
85	Vitellaria paradoxa	Be, Bf, Gh, Ma, Nia, Sen, Ch	Be, Bf, Gh, Ma, Nia, Sen, Ch		Be, Bf, Gh, Ma, Nia, Sen, Ch
86	Vitex doniana		Cmr		
87	Ximenia americana	Cmr, Ma	Cmr, Ma		
88	Ziziphus mauritiana	Bf, Ma, Nr, Sen	Bf, Ma, Nr, Sen		

Be=Benin, Bf= Burkina Faso, Ch= Chad, CI= Côte d'Ivoire, Cmr=Cameroon, Gh=Ghana, Ma=Mali, Nr=Niger, Nia=Nigeria, Sen= Senegal.

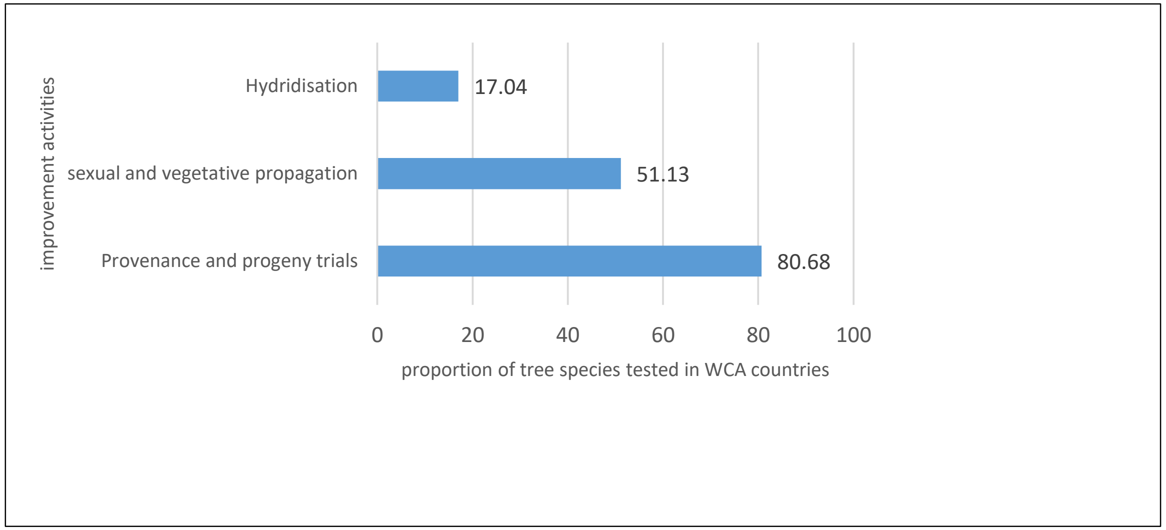

Figure 2. Synthesis of tree improvement activities undertaken on priority trees in West and Central African Countries

within the region, none of them were finally accepted as of interest to the rest of the WCA region. However, two of the priority tree species, namely *I. gabonensis* and *G. kola*, are now gaining importance for domestication in some west African countries (Benin) (Padonou *et al.,* 2017; Codja *et al.,* 2018) showing the recognition of their social and economic value and the need to take in account these countries in the regional domestication programme on these species.

In the semi-arid Sahelian zone of West Africa, more than 28 species were identified as important. The top ten priority species for each of the four countries used for the study are presented in the Table 3. Three species, namely Baobab (*A. digitata*), karite (*Vitellaria paradoxa*), and Tamarind (*Tamarindus indica*) were of general interest throughout the region and therefore recommended for a regional domestication initiative (Franzel *et al.,* 2008).

According to Leakey (2012), existing variability within agroforestry tree species provides great potential for the improvement of marketable characters through selection and vegetative propagation. Therefore, for species under domestication, improvement firstly included phenotypic, molecular, chemical and nutritive characterisation of the species products in order to identify improved varieties that could be used to develop ideotypes (Leakey and Tchoundjeu, 2001). The reduction of tree height to ease harvesting and collection of products and facilitate controlled pollination is also

Table 3. The top priority species for domestication in some dryland countries of WCA (adapted from Franzel *et al.,* 2008)

Species	Burkina Faso	Mali	Niger	Senegal
Adansonia digitata	x	x	x	x
Azadirachta indica				x
Balanites aegyptiaca	x		x	x
Bombax costatum	x			
Borassus aethiopum		x	x	
Cordyla pinnata		x		x
*Detarium microcapu*m				x
Diospyros mespiliformis	x		x	
F. albida	x	x	x	x
Ficus iteophylla				x
Hyphaene thebaica			x	
K. senegalensis		x		
L. microcarpa	x	x		
Parinari macrophylla			x	
P. biglobosa	x	x		x
S. birrea		x		
Tamarindus indica	x	x		x
Vitelaria paradoxa	x	x	x	
Vitex doniana			x	
Ziziphus mauritiana	x		x	x
Total	10	10	10	10

an important characteristic that is included in the improvement programme (Leakey and Akinnifesi, 2008; Makueti *et al.,* 2012). Standard horticultural techniques namely marcotting (air-layering), grafting and rooting juvenile cuttings were developed with the aim of selecting, propagating and mass-producing identified ideotypes. The expansion of tree domestication programme within the region had favoured the integration of many indigenous species providing edible fruits and nuts, vegetables, medicines and other products in tree improvement research. An assessment done in 2008 indicated that 14 provenances trials of *A. digitata, Tamarindus indica, V. paradoxa* and *Z. mauritiana* were established from 1990 to 2002 in Burkina Faso, Mali and Senegal (Kalinganire et al., 2008). In Cameroon, vegetative and seed genebanks were established for *Dacryoides edulis, Irvingia gabonensis* and *Prunus africana* (Tchoundjeu *et al.,* 1998).

With the support of local NGOs, community-based organisations, World Agroforestry Centre (ICRAF) and other international organisations, many forestry and agroforestry projects were implemented or still under implementation in several countries of WCA as a means of creating alternative sources of supply for timber and non-timber products while addressing environmental challenges such as desertification and natural resources degradation. The implementation of these projects has generated demand for improved germplasm of high value for priority tree species within the region. Although it was observed that priority species highly varied according to climatic, agro-ecologic and socio-economic conditions of each country, some species cited in more than 50% of the WCA countries were selected as regional priority and included the following:

a) For agroforestry species: *A. digitata,* B*orassus aethiopum, Cola* spp., *F. albida, Garcinia spp., K. senegalensis, P. biglobosa, Tamarindus indica, Vitellaria paradoxa* and *Ziziphus mauritian*a;
b) For indigenous forest tree species: *Acacia* spp., *Anogeissus leiocarpum, Ceiba pentandra, Diospyros mespiliformis, K. senegalensis, Prosopis africana, Pterocarpus erinaceus, Triplochiton scleroxylon* and *T. superba*; and
c) For exotic forestry and agroforestry species: *E. camaldulensis, Acacia nilotica, A. auriculiformis, T. grandis, Azadirachta indica, C. equisetifolia, Pinus caribaea, Anacardium occidentale* and *Gmelina arborea.*

Techniques for production of improved germplasm and planting stocks. The WCA countries such as Cameroon, Burkina Faso, Congo, Côte d'Ivoire and Ghana have developed technologies for tree seedling production with the assistance of international research and development organisations. Vegetative propagation is critical in improving productivity of timbers species and reducing the time to fruiting of most indigenous fruit trees (Leakey, 2004). The vegetative propagation technologies developed within the framework of the partipatory domestication programmes were of low cost and targeted a few priority species. The technology involved many steps which were:

a) the identification of plus trees in the natural or planted stands based on the end-users's knowledge on the species products and services (quality of the timber, fruits/kernels, straightness of the bole, pest and disease resistance, etc.);
b) pruning and management of the identified trees to induce the production of juvenile and vigorous shoots to be used as cuttings;
c) establishment of the mist and non-mist propagation systems as developed by Leakey *et al.* (1990);
d) fine-tuning and adaptation of the techniques through the identification of best treatments for each of the factors affecting rooting

ability (rooting substrate, cutting length and leaf area, auxin application, etc.);

e) Establishment of clonal orchards using vegetatively propagated seedlings. Species already planted in clonal orchards included among others Eucalyptus, Pinus, Teak and Acacia species in the Republic of Congo, Cameroon, Côte D'Ivoire and Ghana (FAO, 2001).

A few indigenous timber tree species have also received some level of attention in Burkina Faso, Congo, Cameroon, Côte D'Ivoire and Ghana. Within the region, vegetative propagation by stem cuttings is being applied to propagate many indigenous and exotic tree species with the aim of determining their rooting potential and to improve the quantity and quality of planting materials. Species already tested included *A. klaineana* (Okoumé), *Baillonnella toxisperma (Moabi), Ceiba pentandra, Diospyros crassifolia, Entandrophragma angolense, Khaya ivorensis, K. senegalensis, Lovoa trichilioides, Milicia sp., Milletia laurentii, Terminalia* spp., *Lovoa trichilioides, Triplochiton scleroxylon,* and *Pericopsis elata,* among others) (Ofori *et al.*, 1996; Tchoundjeu and Leakey, 1996; 2001; FAO, 2003a; 2003b; Ngo Mpeck and Atangana, 2007; Ky-Dembele *et al.,* 2014; Kenfack, 2016; Na-Karian, 2018).

In Congo, an industrial vegetative propagation process using cuttings was developed by The Centre for International Research for Agricultural Development (CIRAD) and CRDPI (Centre de Recherche pour le Développement des Plantations Industrielles) to optimise the quality and the number of seedlings, reaching 625 million produced per year compared to 25000 cuttings obtained with the formal cutting process.

In Côte d'Ivoire, the process for the selection of improved varieties of teak combined with the development of molecular markers, infrared spectroscopy techniques, chemically-based determination of wood properties and micro-propagation was used to produce improved germplasm for commercial forestry plantation. In both countries, the improved hybrids of eucalypts and teak developed with the contribution of CIRAD were used to establish clonal orchards to produce superior planting materials (Bouvet, 2011). The Society for the Development of Forests (SODEFOR) of Cote D'Ivoire and CIRAD developed a micropropagation technique to produce millions of vitro-plants from the improved clones of teak (Bouvet, 2011).

In Cameroon, the Agricultural Research Institute (IRAD) offices in dryland regions have developed a suite of appropriate techniques which include seed collection, processing, testing and storage, seedling production and vegetative propagation for the production of true-to-type clones for many indigenous and exotic species. In Ghana, Aquah *et al.* (2013) reported the development of successful technologies to produce superior planting materials for major native species including *Khaya ivorensis, Entandrophragma utile, Triplochiton scleroxylon* and *M. excelsa*. The establishment of clonal trials that would allow the assessment of the extent of genotypic variation is not yet a common practice except for a few species such as *T. grandis, Pinus* spp. and *Eucalyptus* spp. in Ghana, Côte D'Ivoire and Republic of Congo (Aquah *et al.,* 2013).

The challenge of WCA countries in producing improved germplasm is the lack of a seed certification scheme. There is no means to distinguish between improved germplasm and unselected or wild seeds. The certification scheme aims to encourage the production and use of forest tree seeds or propagules that have been collected, processed, raised, labeled and distributed in a manner that ensures their trueness to name (Nyoka *et al.,* 2011; OCDE, 2013; Thomas *et al.,* 2015). Burkina Faso is the only country registered by the Organisation for Economic Co-operation and Development (OECD) in the WCA region, and therefore internationally recognised to produce quality certified tree seeds (kokesla *et al.,* 2014).

Existing, seedbanks and gene-bank in WCA. In WCA countries, tree seed centres are the major repositories of tree germplasm. Burkina Faso and Senegal are the only countries with well-established National Tree Seed Centres in the region. However, many countries in the regions have developed ex-situ conservation stands (e.g. Burkina Faso, Senegal, Togo, Nigeria and Niger), botanical gardens, herbaria, seed orchards (Burkina Faso, Nigeria, Ghana, Nigeria, Niger, Senegal and Togo) and experimental plantations such as provenance and progeny trials.

The National Tree Seed Centre of Burkina Faso was established in 1983 and serves almost all the WCA countries (Nikiema *et al.,* 2001). With a storage capacity of 10 tons of seeds and a catalogue of more than 150 species, the Centre (CNSF) has facilities such as a seed laboratory, greenhouses and nurseries distributed in different agro-ecological zones of the country. Several native tree species (*A. nilotica var. adansonii, A. senegal, F. albida, K. senegalensis, P. biglobosa* and *T. indica*) and exotics (*E. camaldulensis, L. leucocephala*, *Prosopis chilensis*, and *Prosopis juliflora*) are conserved in a network of experimental plots including field collections, clone and seed banks under the management of research institutions (CNSF, INERA). The tree species with the largest number of stands are *P. biglobosa*, *F. albida* and *E. camaldulensis* represented by 101 clones in two gene banks (FAO, 2015). In situ conservation of genetic resources is done through traditional agroforestry parklands dominated by *P. biglobosa, V. paradoxa, F. albida, S. birrea, L. microcarpa, B. costatum, K. senegalensis, F. platiphylla, D. mespiliformis, T. indica* and *C. glutinosum.*

In Senegal, PRONASEF (the National Programme for Tree Seeds) operates as the National Tree Seed Centre with a storage capacity of 8 tons. A forest tree seed catalogue exists although not updated since 2010. In Cameroon, tree genetic resources conservation is done mainly through planted or naturally conserved forest reserves distributed according to the agro-ecological zonation of the country. A feasibility study for the creation of a national tree seed centre has been launched, but the proper implementation of the suggested recommendations is still awaited. In Congo, an arboretum of 20 ha exists in Brazzaville and is being used for the conservation of more than 80 indigenous and exotic tree species.

In Togo, agroforestry parklands constitute in situ conservation model and natural gene banks and act as seed sources for certain useful species such as *P. biglobosa, Vitellaria paradoxa, Faidherbia albida, S. birrea, Lannea microcarpa, Bombax costatum, Khaya senegalensis, Ficus phatiphylla, Milicia excelsa, Antiaris africana, Afzelia africana, Diospyros mespiliformis, Tamarindus indica,* and *Combretum glutinosum.* Two managed woodlands (Haho-Baloe (300 ha) and Eto (400 ha) have permitted the conservation of many Eucalyptus species as well as some rare species such as *Garcinia* sp and *Anogeissus leiocarpum*. The presence of a National Tree seed Centre is reported in many forestry documents, but the activities and capacity of the centres are still poorly documented.

Nigeria has two properly equipped seed centres with professional and trained support staff. These tree seeds centres were reported to be the main sources of seed, for all stakeholders involved in the forestry sectors (Oni, 2001). However, an evaluation indicated that the proper operationalisation of these centres will require more sophisticated equipment for seed collection, handling and processing as well as standardised and up to date documentation, gene bank management and computer skills. *Ex-situ* conservation activities started in Nigeria with *P. biglobosa* in 1993 using 94 accessions collected and conserved in the seed gene banks of the Forestry Research Institute (FRIN), 54 of which were collected from the rest of West Africa (Oni, 2001). Seed orchards exist on State and Federal Department of Forestry and Forestry Research stations along with *ex-situ* conservation of some of the indigenous species including *P. biglobosa, V. paradoxa, A. digitata, T. indica, Entada africana, Moringa oleifera, D. mespiliformis, A. senegal* and *A. nilotica*. In 2001, it was reported that within the framework of the World Bank Assisted National Agricultural Research Project, (NARP) the Forestry Research Institute of Nigeria (FRIN) had embarked on the production of one million seedlings for afforestation and agroforestry projects partly supplied by these orchards (Oni, 2001).

In Ghana, several clonal seed orchards have been established to supply genetically high-quality planting materials using a seed production and management technology developed by the council for Scientific and Industrial Research of the Forestry Research Institute (CSIR-RORIG). The same technology has also been used to establish ten priority species for plantation development under the National Forest Plantation Development Programme (Aquah e*t al.*, 2013).

Traditional practice for genetic resources conservation includes planting pits (Zai) in degraded area of Burkina Faso as in many other countries in WCA with rainfall between 300 – 800 mm (Roose *et al.,* 1993; Sawadogo *et al.,* 2001). This practice also provides an effective way of improving the management of degraded lands and reducing soil erosion, vegetation loss and biodiversity as well as crop yields (Danjuma and Mohammed, 2015).

Seed supply, processing and distribution networks. *Seed sources and supply in WCA countries.* The seeds directly collected from natural trees within and outside forests constitute the main and sometimes the only source of planting stocks for reforestation specially for many indigenous species in countries without an operational Tree seed Centre such as Cameroon, Republic of Congo, Gabon, Central African Republic, Chad (Ngueguim *et al.,* 2015; FAO, 2014; Kokesla *et al.,* 2014). Vegetative propagation, even for high value fruit tree species is not yet a common practice within the region except in the Republic of Congo, Ghana and Cote D'Ivoire for some few exotic species (Tchoundjeu *et al.,* 1998; Aquah *et al.,* 2013; Marien *et al.*, 2013; Matondo, 2013). Therefore, the challenge for tree planting in WCA countries is to answer the question on how to achieve adequate supply of genetically superior seeds since existing seed trees are continually being depleted by indiscriminate felling, deforestation and forest degradation.

Most afforestation projects in the WCA region are dominated by exotic species and seed supply and demand can be considered as relatively adequate. For these exotic species, the demand for their germplasm was firstly for large scale tree planting for timber production purpose and later for research and development (Koskela *et al.,* 2014). Consequently, many mature planted stands are spread according to ecological adaptation of each species as well as their end-uses. Within the region, seeds of *Eucalyptus* spp., *Acacia* spp., *T. grandis*, *C. equisetifolia* and others could be collected on existing stands distributed on farmlands, forest plantations, seed orchards and clonal orchards. The orchards are supplemented with many planted forest reserves and private plantations established in almost all the eco-zones of the region. The main constraints for sourcing seeds of exotic species in the region is the poor management of these orchards, provenance trials and forest reserves due to unsustainable funding and limited human and technical capacities. Reports from many countries indicated that the seed stands are under high anthropogenic pressures (FAO, 2012; Ngueguim, 2014; FAO, 2014). Moreover, for many of these planted stands, germplasm is always of unknown and poorly documented origins (Koskela *et al.,* 2014).

Indigenous tree species have often been unsustainably harvested from natural forests, but efforts are now being made to increase their use in reforestation programmes. In general, bulk seeds are collected from natural stands and from remnant trees scattered in farmlands and constitute the major source of planting material for establishing native forest trees. While most indigenous species are collected from the natural forests, a few species of high value and those that are threatened such as *A. senegal, A. digitata, F. albida, K. senegalensis, P. biglobosa*, and *T. indica*, have been tested in provenance trials. Countries with trials include Nigeria, Burkina Faso, Benin, Senegal and Togo. These trials are now the sources of selected seeds for some of these species. In the humid part of the region, seed orchards and provenance trials have been established for *T. scleroxylon, T. ivorensis, T. superba, N. diderrichii, C. pentandra,* and *M. excelsa* in Ghana, Côte d'Ivoire, Cameroon and Congo. However, seed supply for most of the indigenous tree species are grossly inadequate due to poor management of seed orchards, lack of intensive collections for high value species and inadequate facilities for seed collections and storage (Oni, 2001; FAO, 2012, Marien and Gourlet-Fleury, 2013).

Seed distribution networks and seed markets. Many seeds used in reforestation programmes in WCA were reported to be from unknown and non-documented origins. In Gambia, for example, there are no nationally recognised seed sources and seed collection in most cases is contracted to unprofessional individuals in the villages with little or no control of the provenances, collection process, seed handling and storage (Danso, 2001). In Cameroon, the National Agency for Forestry Development (ANAFOR) is the state institution responsible for sourcing and supplying forest tree seeds for reforestation programmes. Indeed ANAFOR had set up three main seed supply channels: (i) seeds collected from felled or standing trees by ANAFOR's trained technicians; (ii) seed collected and supplied by ANAFOR staff after identification and selection of seed trees in the forest or in plantations; (iii) germplasm exchanged between eco-regional offices. However, ANAFOR lacks technical and human capacity for quality seeds control, handling, processing and labelling. Moreover, their production capacity is unable to satisfy the high demand of planting materials needed to supply the numerous reforestation and agroforestry programs within the country (Takoutsing *et al.,* 2013). In Western Cameroon, where a large proportion of industrial forest plantations are found, some private Eucalyptus planters, use practices such as coppicing to increase the productivity of their plantation. The main species planted in this region are *E. saligna, Podocarpus mannii, Pinus* spp. and *C. equisetifolia.*

Limited information is available on tree seed trade in West and Central Africa, unlike other agricultural commodities. Tree seed deployment models in this region are like those described by Lillesø *et al.* (2011) for Eastern African countries and comprise: (i) the government model, (ii) the NGO model and (iii) the decentralised model (Figure 3). In the government model, a central governmental agency takes the lead over seed sources control, technical quality and supply chain. The seeds often go to NGOs, community projects and for some countries to the private sector. This model is characterised by a clear chain of activities, regulations and seed marketing. Seed sales take place in formal or officially recognised seed outlets. This situation is the same in the countries with an operational tree seed centre like Burkina Faso and Senegal for WCA region. In the NGO model, seeds are often collected from available seed trees in farmlands by NGOs themselves or through seed purchases from local communities. The physical (purity, appropriate weight, proportion of non-seeds materials) and physiological (maturity, viability, health status, dormancy) quality of the seeds are not always considered. The seeds are distributed to other NGOs or NGO clients which maintain direct contact with farmers and other stakeholders involved in reforestation programmes (tree seeds users). This model is gaining more and more importance within the region where many national and international NGOs are promoting tree planting as a win-win strategy to improve livelihoods and conserve natural forest resources. As an example, in Cameroon, Nigeria, Mali, Burkina Faso, Sierra Leone, ICRAF has been supporting national NGOs and community-based organisations in the production and distribution of improved germplasm of some high value indigenous tree species (Degrande *et al.*, 2012; Takoutsing *et al.,* 2013).

The decentralised model of seed deployment is characterised by farmers, former and active forest technicians, seeds dealers playing a central role in the control of sources which is often limited to availability of early seeding trees in planted and natural stands. These actors collect seeds which then goes to dealers, suppliers or distributors (some government, some private) and to users that include government, NGOs, farmers' organisations, and private forest companies. This model is common within the WCA region where many countries do not have tree seed centres.

Overall, tree seed markets in WCA region are not well organised. Non-governmental organisations, smallholder farmers and forestry technicians constitute the main tree seed providers especially in countries without Tree Seed Centres. The contribution of the informal seed sector to overall seed supply remains high indicating that the tree seed production and distribution has been devolved to many stakeholders. Private sector is increasingly taking the role of supplier for commercial seeds while NGOs and farmers are supplying seed for most community tree planting projects. However, statistics on tree seed production are missing for most countries (Thomas *et al.,* 2015).

Tree germplasm demand, production and distribution networks. The range of tree planting activities, from commercial to community tree planting requires diversified tree germplasm supply models. Moreover, the main distributors of tree's planting materials are nurseries rather than seeds dealers as tree species are mostly planted as seedlings rather than being sown as seeds (Lillesø *et al.,* 2018). It is not therefore surprising that privately and community owned nurseries play an important role in the production and supply of tree germplasm/ seedlings in many WCA countries. Many types of nurseries are found in the region ranging from industrial to semi-industrial nurseries found in Congo and Burkina Faso, medium-sized nurseries owned by state institutions such as ANAFOR in Cameroon to small-scale nurseries managed by forestry research institutes, individual and community-based organisations. However, most of the nursery's operators are not skilled in terms of appropriate methods of seeds collection, handling and processing as well as techniques to produce improved seedlings. Their performance strongly depends on their communication networks, their technical and financial capacity (Degrande *et al.,* 2012). Yet, as observed by Lillesø *et al.* (2018) many of these nurseries are either owned or committed to supply national and international NGOs in meeting their tree planting targets with limited concern on improving the productivity of the tree species being planted. Consequently, seeds and seedlings sold are always from unknown origins and are of poor genetic quality (Takoutsing *et al.*, 2013). Therefore, technical support should be given to small-scale nurseries if the production of high-quality seedlings is the top priority.

Table 5 shows the main activities and stakeholders involved in the tree seed supply systems in WCA countries as adapted from Lilleso *et al.* (2011) and Nyoka *et al.* (2015). It can be observed that the system is highly decentralised with the responsibilities for many activities shared among different actors. Even in countries with an operational tree seed centres, comminity-based organisations, nursery operators and NGOs are still major players in the the tree seeds/seedling supply chain.

Table 5. Synthesis of actors and their potential roles in the Tree germplasm production and supply chain in WCA countries (Adapted from Lillesø *et al.* (2011) and Nyoka *et al.* (2015).

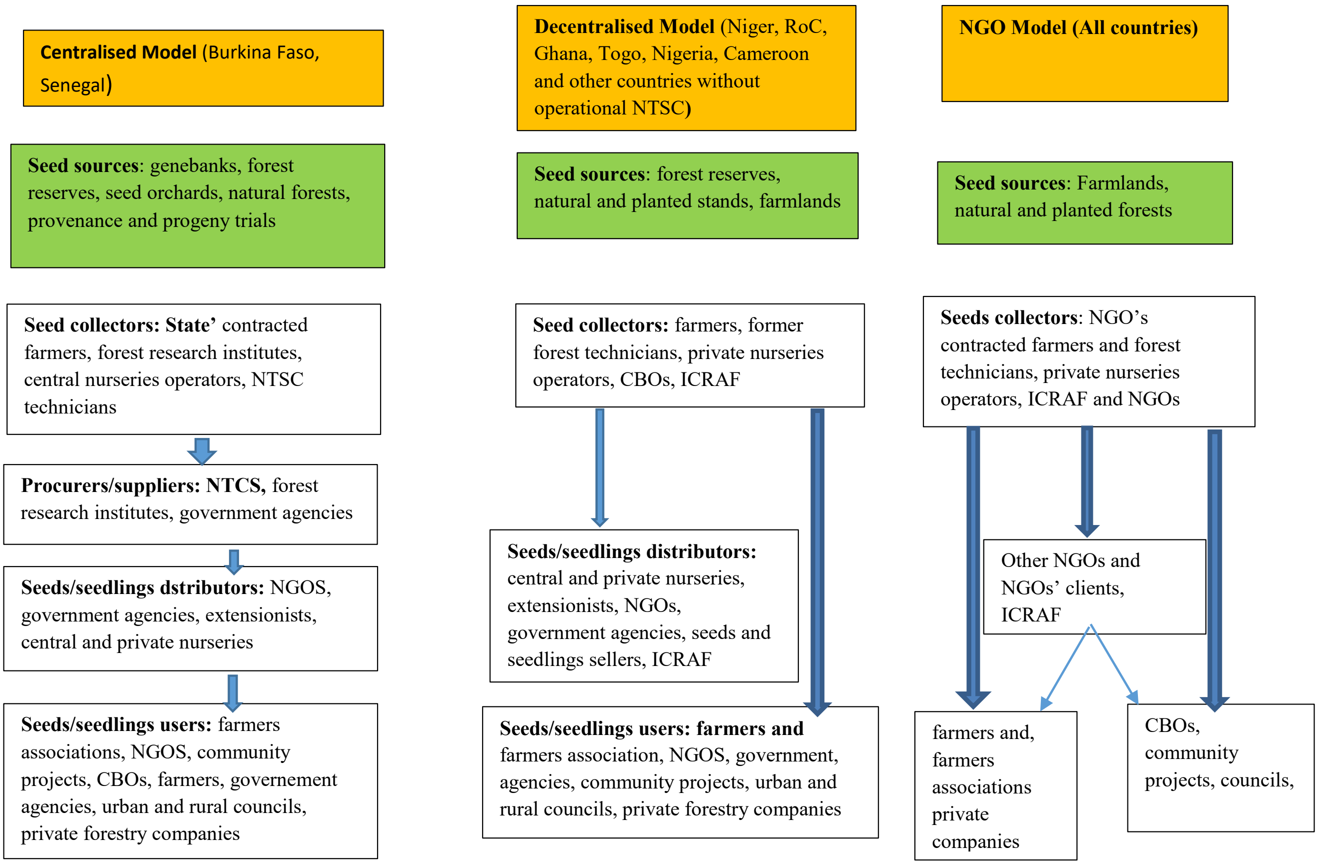

Figure 3. Tree germplasm procurement and deployment pathways in West and Central African Countries (adapted from Lilleso *et al.* (2011) and Nyoka *et al.* (2015).

Table 5. Synthesis of actors and their potential roles in the Tree germplasm production and supply chain in WCA countries (Adapted from Lillesø *et al.* (2011) and Nyoka *et al.* (2015).

Activities	Actors					
	Farmers, farmer's associations and private companies	CBOs and councils	NTSC	Public forestry Agencies	Nursery operators	NGOs
Regulations, Policies, laws and programmes				x		
Seed sources development and mapping			x	x		x (research-oriented NGO)
Seed sources establishment	x	x	x	x	x	x
Seed collection	x	x	x	x (ANAFOR and SNR)	x	x
Trees and seeds improvement research			x	x (Forestry Research Institute)		x (research-oriented NGO)
Seedling production	x	x	x	x (ANAFOR and SNR)	x	x
Seed testing/certification	x			x (ANAFOR and SNR)		
Seeds/seedlings quality control			x (compulsory)	x (compulsory)		x (voluntary) (research-oriented NGO)
Germplasm distribution/marketing	x	x	x	x (ANAFOR and SNR)	x	x
Seed reserve/seedbanks establishment and management			x	x (ANAFOR and SNR)		x (research-oriented NGO)
Germplasm conservation and maintenance (research-oriented NGO (ICRAF))			x	x		x
Facilitation for Germplasm translocation and exchange		x	x	x	x	x
Germplasm use for tree planting	x	x	x	x	x	x

*ANAFOR (Cameroon Agency for Afforestation and Forest Development) and SNR (Congo Service of Tree Planting) are public forestry institutions operating like National Tree seed Centres in their resective countries. CBOs: Community-based Organisations

Seeds storage behaviour of trees species used in Forestry plantation in WCA. The storage of seeds is one of the most important activities in germplasm management as a mean of securing the supply of good quality seeds for a planting programme whenever needed. This is particularly important for many tree species in WCA which exhibits irregular fruiting behaviour with one year of mass fruiting followed by three to four years of poor or sporadic seed production (Sacande *at al.,* 2004). However, the ability of storing many tropical seeds is limited by the lack of information on their seed storage behaviour known to be related to their desiccation tolerance ability. Seeds have been classified in 3 main categories according to their desiccation tolerance and longevity: orthodox, recalcitrant and intermediate seeds (Hong and Ellis, 1996). Out of the 59 Sub Saharan Forest genetic resources (SAFORGEN) listed priority species, 60% indicate good potential for medium to long term conservation (Sacande *et al.,* 2004). However, the storage requirements in terms of desiccation tolerance and conservation conditions are still very poorly documented for many of WCA priority species (Sacande *et al.*, 2004).

Many species in the region have dormant seeds, with seed-coat dormancy being the most common type observed. In fact, many species exhibit hard seed-coats that either prevent seed imbibition or constitute a physical barrier limiting the growth of radicle during germination. Methods used to break seed coat dormancy varied from soaking seeds in water from 24 to 72 hours for moderately hard seeds species such as *Combretum* spp., *Isoberlinia doka*, *Pterocarpus* spp., *T. grandis*, *Saba senegalensis* and *S. birrea,* to manual scarification, thermal and chemical treatments for more harder seed species such as *Ricinodendron heudelotii* (Djeugap *et al.*, 2014), *Canarium schweinfurthii*, *Tamarindus indica, Prosopis* spp. *Pilostigma* spp. among others. The Burkina Faso tree seed centre has proposed in their 2012-2015 catalogue a list of 15 pre-treatments to break seed coat dormancy for many WCA priority tree species (CNSF, 2012).

Assessing tree germplasm adaptability to climate change. Tree plantation has been well documented to contribute both to climate change mitigation through reduction of greenhouse emission and adaptation by providing products and services to vulnerable populations. However, tree establishment, growth and development require a specific set of environmental conditions also known to be affected by climate change, therefore impacting on their geographic distribution and performance. Studies conducted in west African countries have contributed to assessing germplasm adapatability to climate change through the evaluation of their response to environmental stresses (Bayala *et al.,* 2017; Vihotogbe *et al.,* 2018). Moreover, the potential impact of a changing climate to geographic distribution of some high value indigenous species was evaluated using climatic parameters-based niche modelling (Kakai *et al.*, 2011; Djotan *et al.*, 2018; Vihotogbe *et al.,* 2018). This knowledge is important to identify future planting areas, facilitate germplasm translocation potential, determine species plasticity potentials and therefore fulfil species response to climate change (Dawson *et al.,* 2011). For example, climate change was proved to have positive consequences on the distribution in Benin protected area network and municipalities for Garcinia kola, a threatened medicinal tree species identified as regional priority for domestication in WCA (Djotan *et al.,* 2018). In the same line, Vitellaria paradoxa seedlings response to drought stress was not related to the climate at origin of the seed provenance, indicating that germplasm translocation within the species range will not affect growth performance of such species (Bayala *et al.,* 2018). In fact, shea butter tree morphology and productivity were found to vary according to bioclimatic conditions, demonstrating an ecological adaptation of the species to climate gradient (Kakai *et al.,* 2011). From ecological niches modelling, it was observed that *I. wombulu* was highly suited to Volta forest of the Dahomey Gap while *I. gabonensis* showed very poor environmental suitability, implying different ecological adaptation for the 2 species. These results, together with genetic investigation and field trials in contratsting ecological conditions could better guide the future domestication strategy of this top priority species (Vihotogbe *et al.,* 2018).

CONCLUSION

The study has shown that there has been an overall significant increase in the area of forest plantation despite the inadequacy of statistics on planted forests in WCA. The scale of forest plantations in the dryland areas is still far from adequate to meet the need for round wood, fuel wood, as well other forest economic good and environmental services (fight against desertification, climate change).

Throughout the region, there is a growing interest of public, private and community-based organisations for forest plantation activities. Many projects and programmes funded by international organisations are being promoted and are positively impacting on the demand for improved germplasms. The growing demand for quality tree seeds in recent decades has fueled much interest in tree germplasm production and improvement. Vegetative propagation has been developed for common commercially important exotic species and there but is an emerging interest for testing and adapting these techniques on indigenous fruit and forest tree species within the region.

The responsibilities of the development of the seed sector are shared among various institutions and individuals. The study showed that there is no effective coordination. Most of the government institutions in charge of tree germplasm, tree improvement and forest plantations lack adequate funding to perform their activities. The contribution of the informal seed sector to overall seed supply remains high. There is a widespread lack of trained personnel and laboratory facilities as well as an overall poor system of quality control over seeds distributed to end-users. Seed documentation capacities are limited. Hence, the seeds sold are often of poor quality, and improved germplasm is only produced at high cost by some few private research institutions, NGOs and nurseries operators. Most countries do not have viable seed centres as well as productive seed orchards and tree germplasm improvement has not yet taken advantage of biotechnology because of poor scientific and human capacity as well as unsustainable funding of forestry research institutions.

The following are the suggested priority intervention areas to address these shortcomings:

1. Capacity building and technology transfer specifically on tree germplasm improvement combining formal provenance trial with molecular technologies, taking into account emerging constraints associated with climate change.
2. Development of plant breeding and seed technology curricula in forestry research and education institutions and facilitate access to graduate fellowship opportunities in order to train future technicians and scientists needed in the private and public sectors.
3. Development of a network of seed systems actors to facilitate technology transfer among countries with advanced seed sectors and those with seed sectors in development.
4. Seed production quality assurance and certification: In almost all WCA countries, except for Burkina Faso, there is no quality control scheme for germplasm production and therefore no means to distinguish between improved and wild

seeds or germplasm sources. There is a need to strengthen national seed production programmes, support the emergence of a well organized local, private seed enterprises sectors through capacity building activities, infrastructure development, putting in place quality control schemes for priority species.

5. Because of the importance of the informal seed sector, there is also a need to strengthen stakeholder capacities in seed production and collection.
6. Seed storage, distribution and marketing: There is a need to support the establishment of seed storage infrastructure and seed processing equipment and assist farmers to improve traditional methods of seed packaging and storage. Also, facilitating the development of local and regional seed distribution networks is another priority intervention to consider.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Forest pests and diseases of Southern Africa: A review

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ABSTRACT
A review on the status of forest diseases and pests in southern Africa was conducted mainly in the last quarter of 2015, even though the process continued till the first quarter of 2016 when a report was produced. In line with the goals and objectives of the African Forest Forum which commissioned the review, it was considered timely because of the increasing incidences and severity of diseases and pests associated with the most widely planted commercial tree species in Southern Africa and beyond, and the interest to understand their economic impacts on forest production. The review relied on an extensive review of relevant literature, a visit to a key research and development facility on pests and diseases, and expert interviews during visits to four countries in the SADC Region. The existing SADC protocol on sanitary and phytosanitary issues of 2008 was also reviewed and during country visits its use and effectiveness was also assessed. One of the key revelations is that about 15 years prior to the review, a rise in the number of forests diseases and pests had coincided with the widespread planting of species of eucalyptus species and their hybrids, in both woodlots and large industrial plantations in east and southern Africa. Associated with this was that movement of live plants between countries, and in a few cases, also from overseas. For instance, the rapid spread of the Red Gum Lerp Psyllid (*Glycaspis brimblecombei*) and the Blue Gum Chalcid (*Leptocybe invasa*), from South Africa to other southern African countries in just the two years preceding the review period could be described as phenomenal. The paper describes the status and control practices of pests and diseases in southern Africa and in addition, makes a case for stronger collaborative measures using the existing but inactive mechanism known as the SADC Sanitary and Phytosanitary Protocol of 2008.

Keywords: Aphids, Beetle, forest plantations, *Fusarium, Sirex,* Southern Africa Development Community

RESUME
Un examen de l'état des maladies et des Pestes forestières en Afrique Australe a été principalement mené au cours du dernier trimestre de l'année 2015, même si le processus s'est poursuivi jusqu'au premier trimestre de l'année 2016, lorsqu'un rapport a été produit. Conformément aux buts et objectifs du Forum pour les Forêts Africaines qui avait recommandé l'examen, cet examen a été jugé d'opportun à cause des incidences et de la sévérité croissantes des maladies et des pestes associées aux essences commerciales les plus largement plantées en Afrique Australe et au-delà, et l'intérêt de comprendre leurs impacts économiques sur la production forestière. L'examen s'est appuyé sur une révision

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approfondie de la littérature pertinente, une visite dans un centre clé de recherche et de développement sur les pestes et les maladies et, des entretiens avec des experts lors des visites dans quatre pays de la SADC. Le protocole existant de la SADC sur les questions sanitaires et phytosanitaires de l'année 2008 a également été évalué et son utilisation ainsi que son efficacité ont été aussi évaluées lors de visites dans les pays. Une des révélations clés est qu'environ 15 ans avant l'examen, un accroissement du nombre de maladies et de pestes des forêts avait coïncidé avec la plantation répandue d'espèces d'eucalyptus et de leurs hybrides, à la fois dans des boisés et dans de grandes plantations industrielles, à l'Est et au Sud de l'Afrique. Ce mouvement de plantes vivantes entre les pays et, dans quelques cas, d'outre-mer était associé à cela. Par exemple, la propagation rapide du Glycaspis brimblecombei et du Leptocybe invasa de l'Afrique du Sud à d'autres pays d'Afrique australe juste au cours des deux années précédant la période d'examen, pourrait être décrite comme phénoménale. L'article décrit le statut et les pratiques de lutte contre les pestes et les maladies en Afrique Australe et, en plus, plaide pour des mesures de collaboration plus puissantes et strictes utilisant le mécanisme existant mais inactif connu sous le nom du Protocole sanitaire et phytosanitaire de la SADC de l'année 2008.

Mots-clés: Pucerons, Coléoptère, Plantations forestières, Fusarium, Sirex, Communauté de Développement de l'Afrique Australe

INTRODUCTION

Before the establishment of industrial plantations in the late 19th Century and early 20th Century in Africa, formal forestry practice was characterised by the exploitation, through selection cutting, of commercial tree species from natural forests in both the tropical rainforests and dry woodlands of sub-Saharan Africa. In general, the problems of pests and diseases were only recognized in terms of economic benefits unrealized as a result of incidences of heart rots, and insect damage to sawn timber, which affected their structural and strength properties and of course, market value (Ryvarden, 1980; Nsolomo and Venn 2000; Parfit *et al.,* 2010). In view of that history, formal or modern day interest in disease and pest management in African forestry started with the establishment of industrial plantations most of which were established in the early 20th Century using exotic tree species. The establishment of these industrial plantations in much of East and Southern Africa entailed massive investments in machinery, tree nursery infra-structure, species trial, breeding, seedling production, planting and tending. By their sheer sizes, the plantations represented significant investments by both the public and private sectors in southern Africa, as was indeed the case in countries such as South Africa, Swaziland and Zimbabwe. Because of those investments, pests and diseases that would impede growth increment, lower quality and quantities of wood and fibre represented economic losses that had to be addressed. Till today, industrial plantations continue to be dominated by exotic tree species. In effect, 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 (Evans, 1992; Roux *et al.,* 2005; Kojwang, 2009).

From the outset and an important motivation for this review, diseases and pests of trees in Africa and elsewhere have historically caused and continue to cause significant economic losses, and as such, are of concern to sustainable forest management, particularly in industrial plantations that are costly to establish and maintain (Gibson, 1964; Zwolinski *et al.,* 1990; Ciesla, 1994). In natural forests, decay fungi associated with 'heart rots' and boring insects such as bark beetles which degrade wood are the most common (Nsolomo and Venn, 2000). Historical examples of plantation diseases that were recorded with the advent of plantation forestry using exotic tree species include *Dothistroma* needle blight caused by *Dothistroma septosporum* and *Diplodia* die back on pines (*Sphaeropsis sapinea* or *Diplodia pinea*), Cankers of cypress (*Monocaetia unicornis*) and Eucalyptus (*Chrysoporthe* cankers) and *Armillaria* root rot (Gibson 1972; Roux *et al.,* 2005; Heath and Wingfield, 2008). With respect to pests, defoliators such as *Gonometa podocarpi*, which is native to East Africa but became a defoliator of pines and even some species of *Eucalyptus* are important (E.A. Ochieng, Pers. Comm) and prohibited the commercial planting of *Eucalyptus globulus* in Kenya. In the late 1970s and early 1980s, pests such as the Pine Woolly Aphid and Cypress Aphids became problems in both East and Southern Africa (Heath and Wingfield, 2008) in plantations and ornamental hedges. Later in 1994, the *Sirex* Woodwasp (*Sirex noctilio*) invaded South Africa; a development which caused a big scare in the huge plantation industry since it is also a vector of a fungus which can cause high rates of tree mortality particularly in pines (Hurley, 2007; Slippers *et al.,* 2015) and in the process, spurred an impressive biological control initiative.

Owing to the parts of a plant or their preferred host tissues, diseases are often described as foliar, seed, wilts, stem cankers, crown gall, root and but rots and likewise, pests are characterized as those of seed, defoliators, shoot borers, sap-suckers, gall formers, bark beetles and others. Biotic agents of diseases which are mainly fungi, bacteria and viruses are responsible for a majority of known and well described problems. Besides biotic agents which affect their plant hosts through infection, abiotic agents of diseases, represented by factors of the physical environment are recognized and are described as mineral deficiencies, mineral toxicities, aerial pollution, droughts, hard pans and even waterlogging.

The review was commissioned by the African Forest Forum with the purpose to highlight the occurrence and distribution of tree diseases and pests, their economic and ecological effects on forest production and to hopefully generate a renewed 'sense of urgency' to manage or control them through improved forest practices. In this regard, it is crucial to note that the direct damage diseases cause and their impacts such as growth loss are detrimental to forest production, leading not only to direct economic losses to investors, but also hinders growth in new investments in the forest sector. In line with the above, it was decided that a review that focusses on the status of diseases and pests of major commercially grown tree species and their current management practices, be undertaken. Given the trans-boundary nature of most diseases and pests, the paper concludes by presenting and discussing ways and means through which southern Africa can collaborate to control the cross-border spread of the same and manage them in both plantations and other plantings. Similar reviews were also commissioned to cover East, Central and West Africa. Finally it is important to note that while some reference has been made in the review of pests and diseases of trees species indigenous to Africa and which occur mostly in natural forests, the focus of this review paper has concentrated on industrial plantation species in Southern Africa.

METHODOLOGY

The study was conducted through extensive reviews of relevant literature. Private sector participation in industrial forestry in South Africa and Swaziland supported by a research institution; the Forest and Agricultural Biotechnology Institute (FABI), based in

Pretoria turned out to be a key resource centre from which this paper drew much of the literature cited herein. The institute focuses on solutions to problems of South Africa's powerful forest industry which ccontrols 1.5 million hectares of industrial forest plantations and has also trained a majority of contemporary forest entomologists and pathologists, in both southern and eastern Africa. As such, the visit to FABI was quite useful, since it is both a producer and repository of publications pertaining to both forest pests and diseases. Besides that, the author, using a structured questionnaire, conducted expert interviews during visits to four countries in the SADC Region, all of which had a history of industrial forest plantation development. The countries in southern Africa which were visited, included Mozambique, South Africa, Zambia and Zimbabwe, all of which have a history of plantation forestry and some scientists from Malawi were interviewed. Based on all the information gathered, summary tables on the most important diseases and pests were prepared. Recognising the critical need to manage pests and diseases through relevant regional collaborative frameworks, the author reviewed the existing SADC protocol on sanitary and phytosanitary issues of 2008, to assess its effectiveness as a regional mechanism, and sought the views and opinions of experts in the region, on how and whether it has been used. In line with that, the paper has made, among others, recommendations pertaining to a more effective use of the protocol.

RESULTS AND DISCUSSION

Pests and diseases and their effects on sustainable forest management. In agriculture and forestry, insect pests and diseases are at the centre of crop management because of the economic damage they inflict, particularly those that attack in epidemic episodes (Ciesla, 1994). In this regard, famous pest outbreaks such as that of bark beetles, mainly species of Dendroctonus in Southern United States, Scolytus beetles in the Rocky Mountain Forests and Ips in North America and Europe, and the spruce budworm (*Christoneura fumiferana*) in North America, are all noteworthy. In East and Southern Africa, forest pests such as *Gonometa podocarpi,* a defoliator, which is native to East Africa are of interest, as are the Pine Woolly Aphid (*Pineus pini*) and Cypress Aphids (*Cinara cuppressi*) which have been detected in both East and Southern Africa (Odera, 1974; Ciesla, 1991, 1994). More recently, the *Sirex* Woodwasp (*Sirex noctilio* F) which invaded South Africa in 1914 (Slippers *et al.,* 2015) motivated South Africa's current biological programme. As southern Africa has increased plantings with recently developed hybrid cultivars of Eucalyptus, a new range of pests and diseases have appeared on the scene and in this regard, Mozambique, South Africa, Zambia and Zimbabwe illustrate this relatively new phenomenon (Roux *et al.,* 2005; Wingfield *et al.,* 2008; Chungu *et al.,* 2010a; Chungu *et al.*, 2010b; Mausse-Sitoe *et al.,* 2016). Consequently Kenya, Uganda and Tanzania that have imported tree germplasm from South Africa, particularly improved eucalypts which are clonally propagated, have reported incidences of both pests and diseases of eucalypts (Heath and Wingfield, 2005; Roux *et al,* 2005; Nakabonge *et al.,* 2006; FAO, 2007; Wingfield *et al.,* 2008). In one of the most recent global reviews on the introduction and spread of eucalyptus pests, Hurley *et al.* (2016) have listed a total of 42 pest introductions from Australia which is the home of the genus Eucalyptus. The introduced insect pests of eucalypts belong to different taxonomic groups and feeding types and in total,16 different families have been introduced. The introductions iclude Hemiptera (bugs, aphids, cicadas psyllids) being the dominant order with 17 species, and is followed by Coleoptera (the beetle family) with 12 species, Hymenoptera (bees, wasps and ants) with eight and Lepidoptera (butterflies and moths) with five. Most of the introduced insects belong to the sap-sucking taxa (17species), mainly psyllids, followed by defoliators (13) and gall formers (7). In contrast, there have been only three introductions of wood-boring insects from Australia, and all of which were first detected in New Zealand (Hurley *et al.,* 2016).

Diseases can also occur as complexes in which two or more organisms are involved or the organisms themselves interacting with an abiotic factor or the physical environment to cause damage on a host tree species. Such situations are described as pest-disease complexes. In this regard, some insects are vectors of plant diseases and help to disperse a disease to its hosts, as is exemplified by the Sirex Wood Wasp which posed a real threat to South Africa's and Swaziland's pine plantations (Hurley *et al.,* 2007), chiefly because of its association with *Amylostereum areolatum*, a white rot fungus which can disrupt sap movement, cause stress and may even kill a tree. Similarly, some root diseases may not on their own kill a tree but combined with drought, they can predispose a tree to attacks by defoliators and bark beetles. Die back of leading shoots in trees is also thought to be caused by a combination of environmental factors, offsite plantings, hard pans, drought and pollution (Manion, 1981).

With regard to economic damage, tree yields can be directly reduced through direct mortality and growth loss and in that regard, potential economic returns are not realized when damaged trees are prematurely salvaged and sold. In recorded history, a disease or a pest can eliminate a tree species from an ecosystem and by so doing, change ecosystem structure and reduce biodiversity. The Chestnut Blight (*Cryphonectria parasitica* or *Endothia parasitica*) which was introduced into eastern United States eliminated American Chestnut (*Castanea dentata*), a valuable timber species from the hardwood forests (Manion, 1981). In East Africa, the growing of *Pinus radiata* D. Don was massively reduced and eventually abandoned as a result of Dothistroma needle blight in plantations (Gibson, 1964; Gibson, 1972; Odera and Sang, 1980). In East Africa *Gonometa podocarpi* a native defoliator of indigenous trees, in East Africa made a 'host shift' and became a defoliator of pines and even some species of Eucalyptus, particularly *E. globulus* and basically curtailed its potential as a plantation species in Kenya (E.A. Ochieng, Pers. Comm). In a much less dramatic but equally damaging way, decay fungi, reduce and degrade lumber, while decay of wood in service can cause serious structural damage and is costly to replace. Because of this, wood preservation using chemicals is an expensive but useful process. Furthermore, damage caused by termites in Africa is a serious issue for wood in service and if termite control is not factored into any construction venture, structural damage to wood can be quite expensive to fix in buildings. In east and southern Africa economic damage by the cypress aphid *Cinara cupressivora* which caused tree mortality and economic damage was valued at an estimated US$ 41 million with a further US$ 14 million per year in growth loss. Furthermore, the two pine aphids, *Pineus boerneri* and *Eulachnus rileyi* were estimated to have caused a further loss of US$ 2.25 million per year in the region (Murphy, 1996) and in the process, strongly motivated a biological control programme, which led to substantial reductions of the cypress aphid (Murphy, 1996).

Drivers of pest and disease development in both plantations and natural forests. The 'drivers' of disease and pest development in forests are expressed in plant literature as the factors that influence the development of a disease or a pest to proportions in which they cause damage, growth loss and their associated economic impacts on forest or plant production.

In this regard, a useful way of describing disease development is the concept of the 'disease triangle' which was described by Stephens (1960) and worked on subsequently by several other plant pathologists such as Browning *et al.* (1977). The triangle concept simply explains the fact the amount of disease that will occur in a plant population is determined by the factors namely, the pathogen, host and the environment, which make the three sides of a triangle. Furthermore, it is the balance between the three factors that will determine the extent to which a disease will reach levels that can be considered destructive or will remain endemic with no major disturbances unless one or two of the factors change in some way. The illustration of the disease triangle (Figure 1) shows the variety of host, pathogen and environment factors that will interact in various and sometimes complex combinations to influence the course of disease or pest development.

Development of a disease epidemics for example, requires the interaction of a highly virulent pathogen and a susceptible plant host, in an environment that favours the development of disease, as was the case of Dothistroma needle blight in East Africa on *P. radiata*. The environment can therefore predispose a host species. A drought can also reduce the vigour of a forest stand and make it more susceptible to a pathogen than a vigorous stand. Similarly, a pathogen can affect the host by secreting chemicals or enzymes that break cell walls such as the pectic lyases of damping-off fungi in nurseries and in turn, a host plant can secrete defensive chemical compounds that may inhibit infection. In pest infestations the same

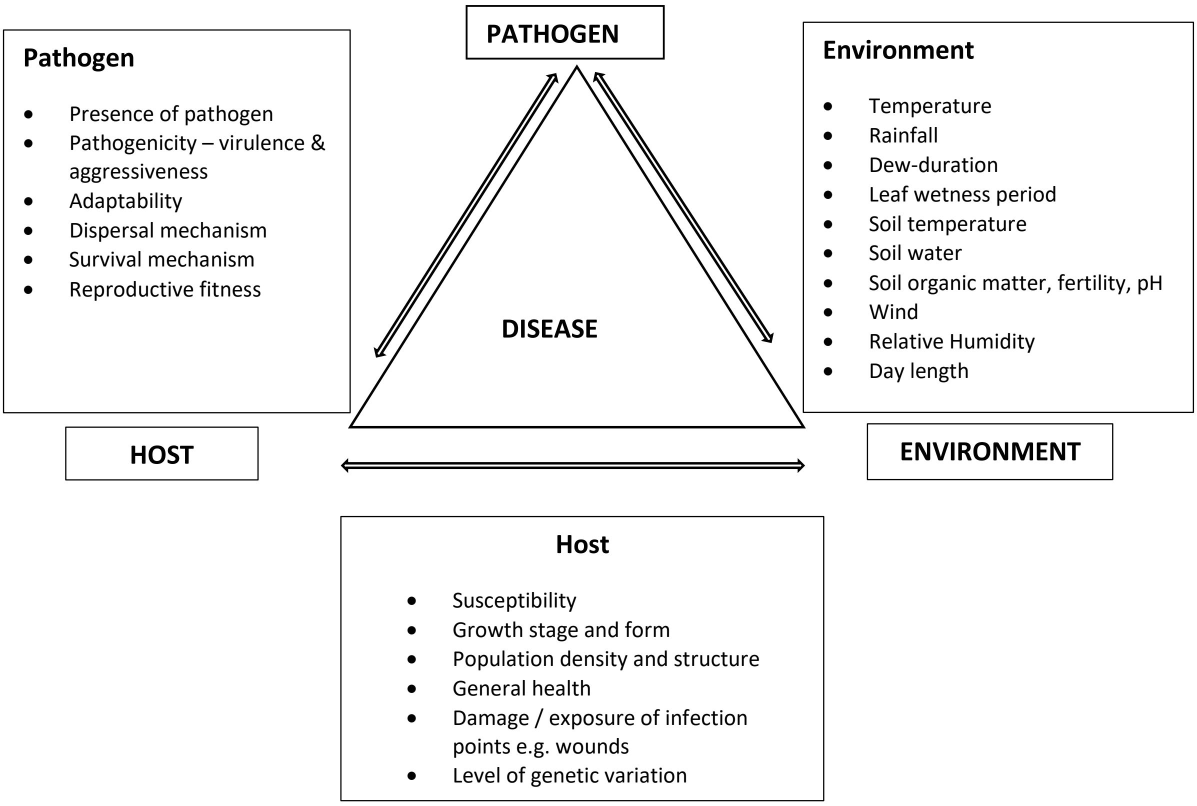

Figure 1. A generalized disease triangle, with three pillars: host, environment and pathogen. Each pillar has examples of factors in bullets (Adopted from Stephens, 1960; Browning *et al.,* 1977; Francl, 2001; Keane and Kerr (undated);

interactions occur and like many diseases the presence of natural enemies and vectors may influence levels of infestation and development of pest outbreaks.

In addition to the disease triangle, human or anthropogenic and other factors such as vectors and time also play a role, to the extent that subsequent pathologists have added more dimensions beyond a simple triangle (Browning 1960; Keane and Kerr, 1997; Agrios, 2005). The effect of humans through trade is immediately relevant to southern and eastern Africa, especially if one looks at the current spread of eucalyptus cankers all through southern Africa and also eastern Africa, aided by the presence of a virulent strain or strains and widely planted susceptible material such as genetically uniform cloned planting materials, commonly observed in the southern Hemisphere (Wingfield *et al.,* 2008). Similarly, the pitch canker problem caused by Fusarium circinatum (*Gibberella circinata*) was responsible for an epidemic affecting native *Pinus radiata* in California (Correll *et al.,* 1991; Gordon *et al.,* 2001), and has caused severe problems on seedlings in South Africa (Viljoen *et al.,* 1994). It is feared that it may jeopardize the future of East and Southern African high altitude species, *P. patula*.

Some of the key drivers of pest invasions not only demonstrate the interactions between the three elements of the disease triangle, but also the significance of anthropogenic factors. From their review Hurley *et al.* (2016) estimated that the time required for invasive pest insects of eucalypts to spread between different continents has become shorter in recent decades. Pests such as the wood borers; *Ctenarytaina eucalypti* and *Phoracantha recurva* required over 80 years to spread to a further two new continents after they were first detected outside their native range. In sharp contrast to the past history of spread, the three pests that have recently invaded southern Africa, namely *L. invasa, T. peregrinus* and *G. brimblecombei*, have spread alarmingly much faster to two or more continents in less than 10 years; a situation most likely facilitated by the increase in trade and travel as the key drivers. Going by observations in southern Africa in recent years, it also clearly illustrates the inefficiency of global quarantine measures in the face of their significant threat to eucalypt forestry. As such they conclude that, in order to ensure the sustainability of eucalypt forestry worldwide, an expanded suite of management options, beyond quarantine measures are needed to provide resilience against the rapid accrual and homogenization of eucalypt pests.

Diseases and pests of Forests in Southern Africa: Their occurrence, regional distribution and management

Pests. A comprehensive list of forest and tree 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 species (Hurley, 2007; Mutito *et al.,* 2013; Slippers, 2015). Establishment of pests of which termites are an important group, are also included. Besides their importance in the ecology of savannas and other ecosystems through nutrient cycling, some species of termites are important pests of plantation species particularly eucalypts (Atkinson, 1989; Atkinson *et al.,* 1991; Chilima 1991; Verma *et al.,* 2009) and also on wood in service. In this regard, Table 1 provides quite a long list of pest species that have been recorded in southern Africa, particularly in Mozambique, South Africa, eswatini and Zimbabwe. However at the scale of southern Africa, a separate table (Table 2) provides a list of eleven pests which are prioritized as the most economically important as of the year 2015. The table also provides brief descriptions on the type of damage caused by each pest and the countries in Southern Africa, in which its occurrence has been recorded. A sample of those are further described in terms of biology, symptoms, status of distribution and their respective management.

Description of selected pests of current and potential importance in southern Africa. The Sirex woodwasp (*Sirex noctilio*), a wood boring pest is distributed in South Africa and Swaziland and at some point in South African forestry, was considered the most serious pest of pines (Hurley, 2008). This perception led to the development of what has become a strong tradition of biological control (Slippers *et al.,* 2015) in South Africa. A native of Eurasia, it was first detected in South Africa in 1994 in the Cape Province of South Africa. It is not just because it is a wood borer that it is a problem but because it is also a vector of its mutualistic / symbiotic fungus (*Amylostereum areolatum* Chaillet). The fungus, together with a toxic mucus that the wasp secrets as it bores wood, act to block xylem tracheids, blocking active transport and kills its tree hosts. In general, the wasp attacks trees which are stressed and otherwise predisposed by droughts and high stocking. Its typical symptoms include; wilted pine needles, turning yellow then brown, small resin droplets on the bark of infested stems, circular exit holes 3-10 mm which go through the sapwood and larval tunnels, also in the sapwood. The management of the woodwasp is aided by improvement of tree vigour through silvicultural thinning to reduce competition and availability of suppressed trees, together with the application of biological control agents. The main biological control agents are *Deladenus siridicola* and *Ibalia leucospoides* (Slippers *et al.,* 2015).

The Cossid Moth (*Coryphodema tristi*s) also known as the Quince borer, is of scientific interest by virtue of the fact that being native to South Africa, it has selectively adopted the high elevation, *Eucalyptus nitens* as its only host among all other species of Eucalypts grown in South Africa. The adult with a 25-50 mm wingspan, is a short lived greyish brown moth, mottled brown front wings and mottled light grey front wings. The symptoms on *E. nitens* are round holes which penetrate the sapwood, trunks and branches of affected tree turn black, extensive tunneling by larvae in the sapwood and heartwood. Furthermore, pupal casings protrude from exit holes and forest floors and saw dust is deposited at the base of trees. The control of this pest is the planting of alternative species since it only affects *E. nitens*. According to reports from the Forest and Agriculture Biotechnology Institute (FABI) of South Africa, a pheromone has been identified with high potential for use in pheromone-baited traps to control populations of the moth (Brett Hurley, Pers. Comm.)

The Wattle bagworm (*Chaliopsis (kotochalia)* junodi) is a defoliator, which is distributed in South Africa and possibly Zimbabwe. It occurs in sporadic outbreaks and the caterpillars are housed in bags made of silk and wattle leaves and the size of the bag changes with the age of the larvae, ranging from 2 to 65 cm in length. While the adult female does not develop beyond a grub, the adult male is a small clear winged moth. Its typical symptoms are the bags and defoliation and is controlled chemically by spraying.

Among the gall forming pests, the best known in both Southern and East Africa is the Blue Gum Chalcid (*Leptocybe invasa* Fisher and La Salle). At the moment it is the most widespread pest of Eucalyptus in the region and occurs in high populations in plantations in Mozambique, South Africa and Zimbabwe. It is a small wasp measuring an average of 1.2 mm in length, brown head and body and a blue to green metallic shine. It causes small galls on leaf mid-ribs, petioles and stems, causing leaf malformations. Severe infestations results in leaf feathering, stunted growth and the occasional mortality. To manage the problem the use of resistant or tolerant planting material is advised in combination with a seemingly successful biological control agent (*Selitrochodes neseri*) which was released in 2012 in South Africa. Another pest, the

Eucalyptus gall wasp (*Ophelinus maskelli*) is of limited distribution in southern Africa, not having been recorded on commercial plantations but has been recorded in Gauteng Province of South Africa. It is described here because it is known to be a serious pest in other parts of the world where Eucalyptus is grown. It is a small brownish black wasp measuring 0.83 to 1.07 mm in length and causes green to reddish-blister like gall on both sides of leaves, producing galls that measure between 0.9 to 1.2 mm in diameter. Heavy galling may lead to premature leaf shedding. To manage the pest, selection of tolerant or resistant species and provenances of Eucalyptus is recommended alongside the application of biological control using its natural enemy, *Closterocerus chamaeleon*, which has also been detected in South Africa. This is clearly a pest that countries such as Mozambique and Zimbabwe should be on the lookout for.

The Bronze Bug (*Thaumastocoris pereginu*s Campintero and Dellape), a sap-sucking pest occurs in all the eucalyptus growing countries in southern Africa. The adult insect are small, measuring 2-4 mm in length, eggs are small oval and black occurring singly or in clusters. It is thought to have been accidentally introduced from Australia just before 2003 when it was first recorded in South Africa. Its key symptoms include an initial reddening of foliage, becoming reddish- yellow, or yellow-brown, and also leaf loss, associated with visible adults, nymphs and black egg capsules. Severe infestations can cause canopy thinning and shoot die-backs. To control its populations to less damaging levels, an egg parasitoid wasp (*Cleruchoides noackea*) was released in 2013 and so far it seems that it will be another successful biological control programme (Mutito *et al.,* 2013, Brett Hurley, Pers. Comm.)

The Red gum lerp psyllid (*Glycaspis brimblecombei)* is yet another sap-sucking pest on Eucalyptus species which is a cause for real concern in Southern Africa, since its high infestations are not only throughout South Africa but also in Malawi, Mozambique and spreading to Zambia (Chungu *et al.,* 2016). It is a small sap sucking insect measuring 2.5-5.1 mm in length, the nymphs have flattened bodies and covered in white conical structures called lerps, which consist of sugar and wax. Heavy infestations on leaves are associated with sooty molds growing on sugary secretions on leaves, heavily affected leaves droop and shoots may die from total defoliation. Currently the only form of management is planting of tolerant or resistant species and provenances while investigations on a possible biological control agent is underway in South Africa. In 2015 scientists in South Africa collected, reared and distributed *Psyllaephagus bliteus*, a parasitic wasp and a natural enemy of the red gum lerp psyllid, in the entire range of its hosts in South Africa (Brett Hurley, Pers. Comm.). In addition, the Shell lerp psyllid, which has been recorded in South Africa on ornamental plantings should be keenly observed since it has the potential to attack commercially grown species.

Perceived trends in pest populations and their spread in southern Africa. Based on discussions with scientists at the Forest and Agricultural Biotechnology Institute (FABI) in South Africa, what should be cause for serious concern in the entire SADC region is that since 1986, there has been a five-fold increase in pest movement. This is quite alarming in itself and it seems that the increases in pest incidences has closely followed the rapid spread of Eucalyptus as an Industrial Plantation species that is grown from South Africa all the way to Ethiopia and with regular exchange of germplasm between East and South Africa and even between South Africa and Brazil (Brett Hurley. Pers. Comm)

Table 1 . Insect pests of plantation forestry trees in Southern Africa

Insect Name	Scientific Name	Tree Host	Feeding Behaviour / Key Descriptor
Ambrosia beetles	*Xyleborus & Xyleorinus* spp	*Pinus*	Wood borer
Black pine aphid	*Cinara cronartii*	*Pinus*	Sap-sucker
Blue Gum Chalcid[1]	*Leptocybe invasa*	*Eucalyptus*	Gall forming
Bronze bug[1]	*Thaumastocoris peregrinus*	*Eucalyptus*	Sap-suckers
Brown lappet moth	*Pachypasa capensis*	*Acacia, Eucalyptus, Pinus*	Defoliator
Catamonus weevil	*Catamonus* spp.	*Acacia*	Defoliator
Cossid moth (*native to Africa*)[1]	*Coryphoderma tristis*	*Eucalyptus nitens*	Wood borer
Cutworms	*Agrotis* spp	*Acacia, Eucalyptus, Pinus*	Establishment pest
Deodar weevil[1]	*Pissodes nemorensis*	*Pinus*	Bark borer
Eucalyptus tortoise beetle	*Trachymela tincticollis*	*Eucalyptus*	Defoliators
Eucalyptus gall wasp[1]	*Ophelimus maskelli*	*Eucalyptus*	Gall forming
Eucalyptus longhorn beetle	*Phoracantha recurve* and *P. semipunctata*	*Eucalyptus*	Wood borer
Eucalyptus weevil[1]	*Gonipterus scutellantus*	*Eucalyptus*	Defoliator
Grasshoppers & crickets	**Various species**	*Acacia, Eucalyptus, Pinus*	Establishment pest
Green bronze beetle	*Colasposoma* spp.	*Eucalyptus, Pinus*	Establishment pest
Grey weevil	*Ellimenistes laesicollis*	*Eucalyptus*	Establishment pest
Lesser wattle chafer	*Monochelus calcaratus*	*Acacia*	Defoliator
Mediterranean pine engraver beetle	*Orthotomicus erosus*	*Pinus*	Bark borer
Pine bark beetle	*Hylastes angustatus*	*Pinus*	Bark borer
Pine brown tail moth	*Euproctis terminalis*	*Pinus*	Defoliator
Pine emperor moth	*Imbrasia cytherea*	*Acacia, Pinus*	Defoliator
Pine looper	*Cleora herbuloti*	*Eucalyptus, Pinus*	Defoliator
Pine woolly aphid	*Pineus boerneri*	*Pinus*	Sap-sucker
Poplar emperor moth	*Pseudobonea irius*	*Acacia, Eucalyptus, Pinus*	Defoliator
Red-haired pine bark beetle	*Hylurgus ligniperde*	*Pinus*	Bark borer
Red gum lerp pysllid[1]	*Glycaspis brimblecombei*	*Eucalyptus*	Sap-sucker
Shell lerp pysllid[1]	*Spondyliapsis c.f. plicatuloides*	*Eucalyptus*	Sap-sucker
Sirex woodwasp[1]	*Sirex noctilio*	*Pinus*	Wood borer
Termites[1]	**Various species**	*Acacia, Eucalyptus*	Establishment pest
Wattle bagworm[1]	*Chaliopsis junodi*	*Acacia*	Defoliator
Wattle chafer	*Hypopholis sommerii*	*Acacia, Pinus*	Defoliator
Wattle emperor moth	*Ginanisa maia*	*Acacia*	Defoliator
Wattle mirrid[1]	*Lygidolon laevigatum*	*Acacia*	Sap-sucker
Wattle semi-looper	*Achae lienardi*	*Acacia*	Defoliator
Whitegrubs	**Various species of scarab beetle larvae**	*Acacia, Eucalyptus, Pinus*	Establishment pest

[1] Further described in the paper in terms of status, feeding behavior, symptoms and management

Adopted from Roux *et al.,* 2012.

Table 2. Priority pests of commercial tree species in southern Africa

Pest	Host Species	Nature of Damage	Distribution (Reported)
Deodar Weevil Pissodes nemorensis *Sirex* Woodwasp *Sirex* noctilio	*Pinus Species* *Pinus Species*	Feeds on tips, kills shoots, causes forking and branching, tree mortality Wilting and mortality	South Africa South Africa,
Bronze Bug *Thaumastocoris peregrinus*	*Eucalyptus spp &* hybrids	Canopy reddening, yellowing and browning Canopy thinning and branch dieback	Mozambique, South Africa, Swaziland Zimbabwe
Blue gum chalcid – a wasp Leptocybe invasa	*Eucalyptus spp &* hybrids	Galls on leaf mid-ribs, petioles and stems, leaf curling, stems deformations, stunting and occasional mortality in small trees	South Africa, Swaziland Mozambique, Zimbabwe
Red gum lerp psyllid – sap sucking insect *Glycaspis brimblecombei*	*Eucalyptus spp &* hybrids	Waxy secretions and honey dew, drooping leaves and drying of leading shoots, defoliation and even mortality	South Africa, Swaziland Malawi, Mozambique Madagascar, Mauritius Zimbabwe
Eucalyptus weevil / Snout beetle *Gonipterus species*	*Eucalyptus species: E. dunnii, E. smithii, and* hybrids	Feeds on foliage and young shoots – causing stunting and mortality in severe cases	South Africa Swaziland Zimbabwe Mauritious Mozambique Malawi
Shell lerp psyllid – sap sucking insect *Spondyliaspsis c.f. pliocatuloides*	*Eucalyptus species*	Brown sea shell-like lerps and reddish brown foliage lesions	South Africa
Eucalyptus gall wasp *Ophelimus maskelelli*	*Eucalyptus species*	Small green to reddish blister like galls on leaves, premature leaf fall with heavy galling	South Africa, Zimbabwe?
Cossid Moth / Quince borer *Coryphodema tristis*	*Eucalyptus nitens*	Extensive tunneling (sap and heartwood) in the stems bases of standing trees. Saw dust on tree bases. A native pest of RSA	South Africa
Wattle bagworm – a caterpillar *Chaliopsis (Kotochalia) junodi*	*Acacia mearnsii*	Is a defoliator, caterpillars live in bags made of silk and wattle leaves, hanging on twigs	South Africa
Wattle mirid – a sap sucking insect *Lygidolon laevigatum*	*Acacia mearnsii*	Necrotic tissue around feeding sites, result of toxic saliva. Early aging of leaves, witches brooms – a result of	South Africa

(Sources: Roux *et al.,* 2012, Sappi Bulletin 5 , FABI Poster 2015

In Mozambique plantations of Eucalyptus are affected by two main pests; the Blue Gum Chalcid (*L. invasa*) in Maputo Province and the whole of Mozambique, while the Red Gum Lerp Psyllid (*G. brimblecombei*) has been mainly been observed in Manica Province.

In Zimbabwe, pest problems on Eucalyptus emerged in 2005 and today there are three serious pests just when Eucalyptus species are being promoted to substitute indigenous tree species that have traditionally been used to cure tobacco (Mushongahande, Pers Comm). Early reports on the Bronze Bug (*T. peregrinus*), emerged in 2005 and today it has spread to all parts of Zimbabwe where Eucalyptus is grown. What should be worrying indeed is that since its first sightings in Zimbabwe in April 2014, another pest, the Blue Gum Chalcid (*Leptocybe invasa*), had in one year, virtually spread in the whole country. Zimbabwe currently collaborates with FABI in the biological control of the two pests. So far there is no significant pest problem on pines and luckily the Sirex Wood Wasp has not been recorded in Zimbabwe, otherwise the country would be dealing with an even heavier load of multiple pest and disease problems. In the initial periods of infestations by Eucalyptus pests, farmers did not even realize that the Blue Gum Chalcid was a pest but today they are more proactive, some even make their own observations and bring reports to research and other forestry offices. It points to an important aspect of awareness creation on disease and pest problems and the effective use of leaders among farmers who can be further empowered to help organize others so that concerted control efforts can be initiated and run (Mushongahande, Pers Comm).

The rapid spread scenario has been repeated in both Malawi and Zambia. In Malawi both the Red Gum Lerp Psyllid and Blue Gum Chalcid were detected in March of 2015 and by October of the same year, the Red Gum Lerp Psyllid had spread throughout the entire country; a rate of spread that is linked to the widespread growing of Eucalyptus. The psyllid is particularly common to *Eucalyptus camadulensis* and *E. tereticornis*, both of which are widely grown in Malawi (Ustanzious Nthenda, Pers. Comm). Because it causes stunting, small rural farmers will disproportionately be affected since they do not have diverse income sources and will get less valuable products over longer periods of time. In Zambia, reports from the Forest Department of Zambia (Mulongwe, Pers Comm.) suggest that the Red Gum Lerp Psyllid crossed into Zambia from Zimbabwe in March 2015 (Chungu *et al.,* In Press) and was observed in stands of Eucalyptus hybrids (GT Hybrids), *E. tereticornis* and *E. grandis* in Southern province, soon after the rains. By October 2015 it had spread all over Lusaka, and Copper Belt in Central Province.

The reports from Zambia and Mozambique suggest parallel causes of spread in that in both cases some industrial plantation companies in both countries imported live seedlings from countries such as Brazil in the case of Mozambique and from Vietnam and South Africa in the case of Zambia (Pers. Comm). The sad thing is that in both countries phytosanitary controls and procedures do not seem to have been followed, as should be mandatory if live plants are imported.

From the reports, one can conclude that observed trends in the spread of forest pests and some diseases, and their effects on host trees species represent threats to SFM in southern Africa. The threat could become more serious due to the fact that the southern Africa has neither recognized nor done much as a region to address the threats. Clearly there is need for regional level programmes and concerted actions by individual states.

Table 3. Diseases of commercial plantation tree species in Southern Africa

Disease	Host Species	Nature of Damage	Distribution (Reported)
Mrytle Rust *Puccinia psidii*	*Eucalyptus species, Psidium guava, Zyzigium species*	Death of new young shoots, normally covered by bright yellow spore masses	South Africa
Chrysoporthe Canker *Chrysoporthe austroafricana*	*Eucalyptus, Tibouchina, Zyzigium species*	Stem cankers on older trees (cracking and splitting of bark, sunken, target cankers), discolouration of bark, cambium and mortality in young trees	Mozambique, South Africa, Zambia, Zimbabwe
Kirramyces stem canker *Teratosphaeria zuluensis*	*Eucalyptus species*	Small sunken necrotic lesions on young stems, measle-like spots that penetrate to the pith on older trees	Mozambique, South Africa, Zambia
Leaf Blotches on Eucalypts *Mycosphaerela* and *Teratosphaeria* (*Kirramyces*) *destructans*	*Eucalyptus nitens, E. globulus, E. smithii, E. grandis*	Leaf spots first appear on lower branches, causes defoliation and growth loss	Mozambique, South Africa,
Pitch Canker *Fusarium circinatum*	*Pinus patula, P. gregii, P. radiata*	Mostly occurs in nurseries but also on trees less than 5 years. Tip die back, discoloration of roots and root collar, dead branches, resinosis	South Africa
Wattle Rust *Uromycladium acacia* - a new disease in South Africa	*Acacia mearnsii, A. decurrens*	Chlorotic spots on pinnules, galls on leaves and branches, defoliation and death of young shoots – growth loss	South Africa
Ceratocystis Wattle Wilt *Ceratocystis albifundus*	*Acacia mearnsii, A. decurrens*	Rapid wilt and death, stem cankers, gummosis	South Africa
Botryosphaeriaceae Cankers: *Diplodia pinea* (on pines), *Botryosphaeria* & *Neophoscoccum* species	*Pinus species* *Eucalyptus species* *Acacia mearnsii*	Common on trees planted off-site hence stressed. Tip, branch death. Red/black lesions on bark, brown discoloration of cambium, blue stain, gummosis / resinosis	Mozambique, Zimbabwe, Zambia, Malawi?

Armillaria root rot *Armillaria fuscipes*	*Pinus, Eucalyptus, Acacia, Podocarpus species*	Crown thinning, foliage discoloration, tree death – signs mycelial fans in the bark and base of stems, mushrooms	Whole of Southern Africa
Phytophthora root rot *Phytophthora cinnamoni, P. nicotianea*e and others	*Acacia mearnsii, A decurrens, Eucalyptus species*	Rapid wilt of trees, basal cankers, bark discoloration, cracking and gummosis	Virtually whole of Southern Africa
Coniothyrium canker *Readerilla zuluensis*	*Eucalyptus species*	Spot lesions and kino exudation	Mozambique
Calonectria canker & blight – nursery and small trees	*Eucalyptus species*	Seedling deaths in nurseries, leaf blight in planted tress – mortality and growth loss	Mozambique
Holocryphia canker *Holocryphia eucalypti*		Stem cracking, stem lesions	Mozambique

Sources: (Roux *et al.,* 2012, Sappi Bulletin, FABI 2015 Poster)

Diseases. As already stated, the last fifteen years or so, which has seen the increasing popularity of some species of Eucalyptus and their hybrids, has brought about a number of disease and pest problems in many species and hybrids (Roux *et al.*, 2005; Chungu *et al,* 2010). In South Africa, the frequency and severity of diseases and pests increased almost exponentially between 2000 and 2012 (Louw, 2012). By 2015 the most serious diseases of plantations affected species of Eucalpytus and their hybrids (Roux *et al.,* 2005; Chungu *et al.,* 2010; Roux *et al.,* 2012; Mausse-Sitoe *et al.,*unpubl.). A list of the most important diseases are listed in Table 3.

Description of selected diseases of current and potential importance in southern Africa. To illustrate forest disease problems in southern Africa a selected set of diseases ranging from foliar pathogens, cankers, wilts and root rots are briefly described.

Pitch canker caused by the fungus *Fusarium circinatum* is currently a serious problem in Southern Africa. This is because since its introduction to the country in 1990 it was a largely a nursery pathogen but in the recent past young plantations of 3 to 5 years are being attacked. It affects the key Pinus species especially *Pinus patula* and *P. radiata* in South Africa, but also infects *P. elliottii* and *P. taeda.* In nurseries infection results in root rot and in some cases stem infection, the tips of trees start wilting and bend, followed thereafter by the death of the entire tree, roots and root collars become discoloured. In bigger trees lagging and resinous lesions on stems, resin running down stems and resin soaked timber are observed. It is an opportunistic pathogen, which largely relies on wounds for infection. Spores of the fungus are soil and air-borne but species of insects such as *Ips* spp, *Pityophthorus* spp., *Pissodes* spp., and *Conophthorus* spp. have been reported to be associated with the disease. Management methods include selection and breeding for resistance, avoidance of off-site planting as well as high nitrogen levels because combinations of stress and nitrogen are predisposing conditions for infection. Since it relies on wound entry, pruning should be done in the winter months when conditions are dry and unfavorable to infection. The management of insect populations is also advisable in view of their role as vectors.

Botryosphaeria canker and die-back is one of the most important and common diseases of *Eucalyptus* spp. in both southern and East Africa. The disease in South Africa is caused by *Botryosphaeria eucalyptorum* and *B. ribis*, which are largely opportunistic pathogens that follow stress related factors such as drought, offsite plantings and hail damage. They survive on Eucalyptus as endophytes and only become serious upon predisposing conditions. They affect all species of Eucalyptus especially *E. camaldulensis* and *E. grandis*. In addition *Acacia mearnsii* is also attacked. While it has many symptoms, a common one is the death of tree tops and this can lead to infection of the pith and a core of discoloured wood surrounded by a healthy sheath of outer wood that often extends throughout the entire length of the tree. This often develops after exposure to hot winds or tip damage by late frost. Furthermore, the deformation of stems is the more serious symptom of *Botryosphaeria* cankers, particularly on trees stressed by drought and are characterized by stem swelling, bark cracks and exudation of copious amounts of black/red kino. The kino pockets persist in the wood and render it unacceptable for saw timber production. *Botryosphaeria* spp. may infect trees through stomata on the leaves. Species of *Botryosphaeria* spread via airborne spores that can also be spread through rain splash.Management of the disease requires clone selection of species of *E. grandis* that have a high degree of tolerance to *Botryosphaeria.* In addition one has to avoid offsite plantings and instead go for evidence backed species site matching.

Chrysoporthe canker is the most widespread canker of eucalypts caused by the fungus *Chrysoporthe austroafrica* (*Cryphonectria eucalypi*) and occurs in the entire range of areas of East and Southern Africa where Eucalyptus is grown. In the United States of America the canker is caused Chrysoporthe (*Cryphonectria cubensis)*, one of the most important diseases of Eucalyptus in areas of the world where these trees are grown as exotics in plantations. It was first discovered in South Africa in 1988 and has already resulted in the elimination of a number of valuable Eucalyptus clones. Its key hosts are species *E. grandis*, *E. camaldulensis*, *E. saligna* and hybrids. In addition, relatives of Eucalyptus such as Syzygium and Tibouchina are also susceptible to the fungus. Symptoms in young trees foliage include changes in colour and dark –brown discolouration of bark in the cambium around the root collar and base. The canker can kill young trees in the first two years of growth by girdling stems at the base. Girdled trees wilt and appear to die suddenly in the summer during hot dry periods while those that escape death tend to have swollen bases surrounded by cracked bark and target like cankers on which the asexual fruiting structures of the fungus (long-necked dark pycnidia which are flask shaped spore bearing structure). *Cryphonectria cubensis* infects trees through wounds. Infection of the bases of young trees is the most common. Infection sites are presumed to be natural growth cracks at the root collar. The spores are dispersed by rain splash. Control or recommended means to reduce losses due to Chrysoporthe canker is to select disease tolerant clones. Relative susceptibility, tolerance and resistance of clones can be assessed by artificial inoculation of trees and such screening has proven to be particularly useful in reducing the incidence of the disease in South Africa.

Coniothyrium Canker/Kirramyces stem canker/ Measles Disease is yet another serious canker of eucalyptus species and their hybrid clones, particularly clones and hybrids of *E. grandis*. It is caused by a fungus which was first named *Coniothyrium zuluense* and later as *Teratosphaeris zuluense* and another species known as *T. gauchensi*s occurs not only in South America but also in Ethiopia (Cortinas *et al.,* 2006). The species *T. zuluense* was thought to be restricted to Southern Africa, particularly Southern Africa, but has since been reported in Central, South America and Asia. Symptoms which develop from the initial infections occur on the young, green stem tissue and give rise to small discrete necrotic (measle like) spots on the bark, hence its name 'measles disease' in South Africa. These lesions may merge to give rise to large patches of dead, black bark that is often cracked, exuding copious amounts of kino. Infection typically occurs at the start of the growing season and spores of the fungus are washed down the stem of the trees, resulting in infections lower down the stems, which may give rise to spindle shaped swellings and in severe cases 'epicormic branches' below the canker can develop and tips begin to die. The result is that lateral branches will attain apical dominance, become infected and result in stunted height growth. The canker is spread by small, single celled spores carried by wind and water, the spores infect the stems directly through the epidermis of the young stem tissue. For control, to date planting of resistant clones and hybrids remains the key recommended strategy.

Diplodia pinea (*Sphaeropsis sapinea*) is one of the most important pathogens causing canker and shoot dieback on pine, particularly in South Africa where *Pinus radiata,* its key host is grown. In this regard, it is worth noting that the growing of *P. radiata* was abandoned in East Africa because of its high susceptibility to Dothistroma needle blight caused by *Dothistroma septospora*. The host range of Diplodia canker and die-back includes all *Pinus* spp., but is especially common and most severe on *Pinus 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).The symptoms include shoot blight or die-back, stem cankers, blue stain and gummosis/ resin exudation. Many of these symptoms become apparent after hail damage or when trees are stressed due to factors such as drought. The root disease is always associated with stress from overstocking, drought or planting on poor sites. Characteristic symptoms of the root disease are dark-blue, radial lesions in young roots which extend to larger roots and into the trunk of diseased trees. Needles become yellow (chlorotic) and are shed. To understand its spread, one should note that *Diplodia pine*a exists as both an endophyte and saprophyte in/on healthy and dead tissue and becomes an opportunistic pathogen when wounds or other stress factors occur, and will also infect young, unwounded pine shoots, where moisture and warm conditions occur at the onset of growth. It is spread aerially through its spores. To control and manage the dieback, it is necessary to plant resistant species in hail prone areas and to improve stand vigour through tending practices and the timing of pruning should be when weather conditions do not favour infections.

Mycosphaerella leaf blotch and leaf blight is a serious disease on Eucalypts and is present in all countries in Southern Africa where Eucalpytus is grown; it is present in all the East African countries as well. In South Africa for example it is a disease of cold tolerant *Eucalyptus* spp. grown in South Africa, i.e., *E. nitens, E.globulus*, *E. grandis*, *E. smithii.* As a disease causing organism its more than 30 species have been reported on *Eucalyptus* spp. world-wide, but it would appear that its incidence and severity depends on favourable host and environmental conditions. Several *Eucalyptus* spp. are affected by *Mycosphaerella* spp. and the disease can be identified by the presence of necrotic spots or patches on the leaves. The foliage may be crinkled or distorted. In severe cases, premature abscission of leaves occurs. Lesions can vary in colour from light to medium brown. Differences in lesion colour have been recorded between the upper and lower surface of leaves. Control is through matching species to site and planting resistant or tolerant species.

Eucalpytus / guava/ myrtle rust, is a foliage rust which causes leaf spots in southern Africa and has been recorded in Mozambique, South Africa and Zimbabwe. The rust *Puccinia psidii* causes leaf spots and death of young new shoots that are often covered by bright yellow spore masses, 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. Management includes the destruction/ eradication of affected plants, use of resistant planting material and restriction in the movement of planting material with thorough checks on contamination.

Among the fungi causing root rots, 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, *Eucalyptus smithii*, *E. nitens*, *E. fraxinoides* and *E. fastigata* and occasionally *E. grandis*. The key symptom is a rapid wilting of affected trees; which follows the rotting of the cambium of the roots and root collar and the bark from these roots easily slips off the woody parts. If the root-collar of the tree is infected and girdling occurs, trees die. When older trees are infected, growth and subsequent yield is negatively affected and trees may yield to secondary damage caused by factors such as wind throws. A key predisposing factor is water logging, which results in poor aeration of the soil and enables its motile spores to move within the soil and water and infect roots and root collars. In addition, off-site planting also commonly predisposes trees to infection. As such, control has to consider the fact that *Phytophthora* spp. commonly occurs in irrigation and soil water and can cause serious losses in eucalypts nurseries. The chemical treatment of water, particularly river water, is necessary to control the disease caused by the pathogen and choice of resistant species and provenances. On *A. mearnsi*i, *Phytophthora nicotianea* causes the well-known 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. To manage the problem avoid sites such as those where waterlogging occurs and plant selected seed, tolerant to this disease. In addition one is advised to limit damage to the roots and bases of the trees.

Armillaria root rot is of historical importance in plantation establishment and the genus Armillaria occurs throughout much of Sub-Saharan Africa, and is caused by *Armillaria fuscipes* in South Africa, particularly on 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. Symptoms on infected trees develop yellow foliage, crowns may also become thinner with reduced shoot growth and in some cases, crown die-back occurs particularly after the dry season. In some instances, a flush of new cones are often produced on dying trees. Resin exudation of gum at the base of trees and bark cracking at the base of trees is observed. Usually conclusive evidence of Armillaria is the presence of white mycelial fans between the bark and the sapwood and under favourable conditions, a proliferation of yellowish brown mushrooms develop at the base. Usually it starts with a single tree then radiates through root contact to neighbouring trees. Management is to avoid establishing pines in recently cleared indigenous forests and to remove infected stumps to reduce inoculum spread, since it moves from tree to tree via root contact or by root-like fungal structures, called rhizomorphs. It may also spread via airborne basidiospores from its fruiting bodies.

Amongst the wilts in trees and forests, *Ceratocystis* is the main pathogen that affects wattle (A*cacia mearnsi*i) and was first described in South Africa in 1989 in KwaZulu Natal. The fungal pathogen belongs to a family of highly destructive tree pathogens, the *Ceratocystis* of which *Ceratosystis ulmi* of the 'Dutch Elm Disease' is one of the most famous pathogens in the history of plant pathology. On watlle the species is *Ceratocystis albofundus* which can kill a one-year old trees within six weeks and affects trees of all ages. It is known only in Africa and affects both *A. decurrens* and *A. mearnsii*, and its symptoms are rapid wilting of infected trees and in some cases stem cankers, black red mottled lesions, 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. For its management, one should avoid wounding of trees during hot, moist periods of the year and in addition, the planting of selected seed will reduce the chance of disease.

Perceived trends in disease development and spread. Unlike the pests of species and hybrids of Eucalyptus that have been described in the preceding chapters, diseases of trees, while serious do not appear to have spread as dramatically rapidly as their pest counterparts. Furthermore, and based on the author's discussions with specialists in four major tree growing countries of Southern Africa, there are no new diseases of a regional nature that have been described in the last two years. However, a new disease was recently described in Mozambique (Mausse Sitoe, Pers Comm) and named *Calonectria mozambisensis* and at the time of preparing this report, a paper on the same had been submitted for publication. In addition, Mozambique considers Chrysoporthe canker as the most damaging since it can cause mortality of up to 70% hence the work on resistant clones development is underway.

What is important to recognize is that a few diseases that attack Eucalyptus species and their hybrids appear to be present in Southern and Eastern Africa as well (Roux *et al,* 2005) and in their report, cankers caused by species of *Chrysoporthe, Botryosphaeri*a and *Coniothyrium zuluense* on Eucalyptus species are important; as are leaf and shoot diseases caused by species of *Mycosphaerella* and *Cylindrocladium* on *Eucalyptus* spp. Included are root rots caused by *Armillaria* spp. on Eucalyptus, *Pinus* and *Acacia* spp and *Phytophthora* root rots, Diplodia die-back on pines and wilts caused by *Ceratocystis albifundus* on wattle.

What should be worrying here is the increasing acreage of industrial and small scale plantings with Eucalyptus hybrids, namely those of *E. grandis* and *E. camadulensis* (GC) and those of *E. grandis* and *E. urophylla* (GU) in the whole of eastern and southern Africa. This presents large areas with suitable hosts and it is conceivable that new virulent strains of the disease such as the canker causing Chrysoporthe can 'wreak havoc' if suitable preventive measures are not put in place by countries in the two regions.

Diseases and pests of indigenous trees of commercial and semi-commercial value 5Pests. In Africa, one of the few studied pests of indigenous tree species, is the Iroko Gall Fly which is a pest on *Milicia excelsa* (Welw) C. C. Berg commonly known as Iroko in West Africa and Mvuli or Mvule in Eastern Africa (Cobbina and Wagner, 1995; Ugwu and Omoloye, 2014). It is considered the most valuable timber species from all of West, Central and East Africa and despite a high demand for it, its cultivation has been historically constrained across the continent by a psyllid gall bug, *Phytolyma lata* Walker (Scott). The psyllid attacks the buds and young leaves of *Milicia excelsa* plants especially the seedling which later leads to formation of galls on the site of attack and causes forking of the main shoot. In addition, gall formation is followed by saprophytic fungi attack on the apical region of the infested plant after the gall has ruptured to release adult, foliage die-back and formation of multiple leader shoots tend to follow (Cobbinah and Wagner, 1995). Another important pest is a defoliator, known as *Heteronygmia dissimilis*, a lymantrid of African mahogany, *Khaya nyasica* (*K. anthothec*a). Of the two valuable timber species in Africa, the mahogany defoliator has been studied in East Africa, particularly in Tanzania. This should be of interest to Zambia, Zimbabwe, Malawi and Mozambique where the species is grown also in urban areas as an ornamental tree. The larval form of the pest is generally a nocturnal feeder, skeletonizing leaflets while in the early instars and resting on foliage or bark during the day. Of scientific interest to its biological control is a study by Schabel *et al.* (1988) that recorded four species of hymenopterous parasites belonging to four families (*Chalcidae, Encyrtidae, Eurytomidae* and *Ichneu-monidae*), as well as two species of dipterous parasites from the sub-family (Tachinidae) on eggs, prepupae and pupae of *H. dissimilis*. During the rainy season, an entomopathogenic fungus, *Paecilomyces farinosus* was epidemic in pupae of the defoliator. This represents one of the few studies of natural enemies with potential for biological control of an indigenous pest. In Mozambique the occurrence of a species of *Hypsipyla,* a pest that attacks tree species in the Mahogany (Meliacea) family was observed (Bandeira Pers Comm). While not yet confirmed, it could very well be *Hypsipyla robusta* (Moore), the ecology and biology of which has been described by Griffiths (2001). The genus is currently understood as a species complex and its taxonomy is being resolved.

On indigenous fruit trees in Mozambique a survey of pests was conducted by Mausse and Bandeira (2007) to assess the activity of native fruit tree insect pests during the year and their ecological relationships. The naturally occurring indigenous fruits studied in three Districts in the Maputo included *Annona senegalensis*, *Garcinia livingstonii* and *Vangueria infausta*. A native fruit fly, *Ceratitis capitata* (Diptera: Tephritidae) was among the pests identified and was found to have the highest association index with *Spatulipalpia monstrosa* Balinsky (Lepidoptera: Pyralidae), as well as *Carpophilus* sp. (Coleoptera: Nitidulidae) and *Araecerus* sp. (Coleoptera: Curculionidae).The study shows that native species of the feared fruit flies, which attack commercially grown and traded fruits in Southern Africa exist on indigenous fruits and one only hopes that the native species do not cross over to introduced commercial fruit species. On Miombo species a scale insect, *Aspidoproctus glaber* has been observed in Zimbabwe (Mushongahande Pers Comm) and could be very well present in other countries since it has a wide host range among the indigenous tree species (Mushongahande and Mazodze, 1996).

Diseases of selected indigenous tree species of commercial importance. The author observed that there is a general dearth of studies and publications on diseases of indigenous tree species even on the widely used species in the Miombo Ecoregion of southern Africa which covers huge parts of Angola, the DRC, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe. However, an exploratory mycological study in Tanzania which covered the Miombo species of Tanzania published by Nsolomo and Venn (1994) represents the few studies on diseases occurring on native species. In the paper, a variety of leaf spot diseases caused by fungi in the genus Cercospora and an Oidium mildew on *Brachystegia spiciformis*, the most dominant miombo species, is of special interest, as is the leaf spot caused by *Phyllacora brachystegiae*. A sooty mildew *Meliora khayae* on *Khaya nyasica* which causes premature defoliation and leaf spots on *Trichilia emetica* are described. On Strychnos, a popular indigenous fruit in much of the Miombo and the Kalahari Sands Woodlands in Southern Africa a Cercospora leaf blight was recorded. Furthermore a dieback disease caused by *Phomopsis menda* on *Albizzia versicolor,* a fast growing species in the Miombo and riverine areas is also of interest. On *Adonsonia digitata* or baobab, a tree species whose fruits are widely consumed in Southern Africa a mildew, *Leveillula tourica* was described, which is interesting since in Zimbabwe the occurrence of a sooty mold and shoot die back has been observed in recent years (Mushongahande Pers. Comm) in Manica and the Hwange, Victoria Falls areas. In general, studies on the diseases and pests of industrial plantation species have dominated the 'research scene' for obvious economic reasons. However as there is a growing interest in the domestication of indigenous fruits in Southern Africa, there is likely to be more interest in pests and diseases so the work of Nsolomo and Venn (1994) could provide vital clues on possible disease problems.

Impacts of Diseases and Pests on Forest Practice. In the history of forests diseases and pests, their economic impacts has been of great concern to sustainable forest management as was the case when the growing of *P. radiata* was discontinued in East Africa because of Dothistroma needle blight. Even in natural stands, the example of damage that *Phytophthora cinnamoni* caused on natural stands of *Eucalyptus marginata* (Jarrah) in Australia (Von

Broembsen, 1989) was quite significant. In the case of southern Africa as elsewhere particularly East Africa, there is a general agreement that some pests and diseases pose serious economic threats to both industrial and small scale forestry. It is also being appreciated that, the economic losses associated with some pests, such as the Red Gum Lerp Pysllid and Blue Gum Chalcid will disproportionately affect the small scale growers than large scale plantation owners. This is because small scale plantings with little variation in environmental conditions and also based on narrow genetic bases can be wiped out or be severely stunted as to significantly reduce their economic value, whereas large companies with large industrial plantations may be favoured by size and variation in stand conditions than in small woodlots, not to mention their participation in forest product value chains. For diseases such as cankers, weakening of stems can causes breakage, growth loss and the canker wounds in themselves facilitate entry of decay and blue stain fungi both of which degrade wood and lowers its economic quality. In Zimbabwe and Zambia, observations on plantations infested by Red Gum Lerp Psyllid have given indications, though not formally assessed, on potentially significant economic losses that can be incurred due to this rapidly spreading pest. In Zambia, reports of severe stunting of trees in plantations was reported in a particular plantation in the Southern Province of Zambia, causing an estimated mortality of 30%. Further, severe stunting was reported with the implication that trees will either take longer to reach the desired sizes at rotation, or may force premature salvage harvests which would not yield the values expected at planting. For private sector plantations such as those in Mozambique, and some of which are targeting carbon markets, serious infestations will mean that expected rates of carbon accumulation through normal growth will not be attained, reducing volumes of certified emission reductions (CERs) hence less payments.

Despite the observations that have been made on the impacts of pests and diseases, most of those impacts have not been systematically quantified in economic and social terms. This is quite understandable since in a majority of cases, there has been a preoccupation on finding appropriate methods of disease and pest management. An excellent industrial response to pests and diseases is that of the South African Forest Industry which sponsors the Forest and Agricultural Biotechnology Institute (FABI) at the University of Pretoria. This institute runs a forest pathology and biological control laboratories which have been quite useful to the industry. However, research on economic impacts of the pests and diseases does not enjoy the same amount of focus, even though the forest industry will soon demand data on economic losses.

Noting the scarcity on disease and pest impact studies from published literature, a useful example from South Africa, was a study on the economic impact of a post-hail outbreak of a die-back of pines (*P. radiata* and *P. patula*) induced by *Sphaeropsis sapinea* in the Cape Province of South Africa. Damage occurs as direct growth loss, through defoliation, premature salvage cuts and entry of blue stain fungi which degrade wood. The study reported a timber loss through premature harvesting of 28% of volume and 55% of its potential value, both of which are economically significant. As already discussed in an earlier section of this report, in east and southern Africa economic loss caused by cypress aphid (*Cinara cupressivora*) through direct mortality was estimated to be US 41 million and those by the two pine aphids caused damages worth an estimated US $ 2.5 million per year. It is those shocking economic loss figures that triggered resource allocation which initiated a biological control programme, which led to substantial reductions of the cypress aphid (Murphy, 1996).

A useful way of appreciating the sheer scale of impact that a disease or pest can cause to a national industry came from a discussion between the author and the Chief Executive of Forestry South Africa (Mike Peters, Pers. Comm), which represents South Africa's forest industry. According to 2012 / 2013 statistics describing industry performance, the value of round wood sales was an astounding figure of 6.9 billion rand (Forestry South Africa 2014). This consisted of saw and veneer logs, pulpwood, mining timber, poles and others. Of this mix 7.3 million m^3 was softwood and 10.6 million m^3 of hardwood, for a combined total of 17.9 million m^3 of wood. If one considers the entire value chain in the industry, Forestry South Africa estimates that the 6.9 billion rand of round wood sales translates to a value of no less than 27 billion rand after value added processing, which is four times the value of the round wood sold. Bearing in mind the value of round wood sold in South Africa in the 2012 – 2013 period, a pest or a pathogen that causes growth loss of just 5%, would translate into a loss of 5% of the total economic value, which is 1.35 billion rand. This in itself is a significant amount. It is not therefore surprising that the Forest and Agricultural Biodiversity Institute (FABI) is funded by the Forest Industry through Forestry South Africa.

Based on the same reasoning, one can imagine that a stunted eucalyptus stand translates to a 20% growth loss to a farmer to whose tree growing is the single largest source of income. In this regard, Zambia has an interesting story to tell because Zambia's State-owned Plantation Company invested a reported three million US dollars in Eucalyptus plantations to feed a treatment plant for transmission and other poles. In 2015, some of the stands had 30% of its trees stunted with a proportion expected to die as a result of the serious drought. Such growth loss caused by stunting will certainly have economic impacts. While these remain largely speculative, they serve to illustrate the importance of economists working with entomologists and pathologists to estimate economic impacts of infestations and use the results of such studies for policy advocacy.

Based on the above information, one general observation is that impact studies should be given higher priority than is currently the case since the spread of diseases and pests in SADC is definitely cause of concern and forestry practitioners ought to engage policy makers to pay attention and cause countries to put coordinated and concerted efforts to manage them. Impact studies are critical in such a process.

Modalities for regional or transboundary management and control of forest pests and diseases in Southern Africa. Going by the observations already made in the previous sections which have presented and discussed trends in disease and pest populations in southern Africa, it is critical that the SADC Region makes a concerted effort to detect, report and share knowledge, experience and technology in their management and control of forest diseases and pests. At this point it is worth noting that two key pests of Eucalyptus the Red Gum Lerp Pysllid (*G. brimblecombe*i) and the Blue Gum Chalcid (*L. invasa*) have spread rapidly and in a dramatic fashion to four countries outside South Africa where species of Eucalyptus are widely grown, namely Malawi, Mozambique, Zambia and Zimbabwe.

An important observation is also that in the establishment of large industrial plantations in Mozambique and Zambia, seedlings have been imported from overseas and from South Africa, and apparently without any phytosanitary precautions and procedures being followed. This suggests the kind of laxity that is dangerous to the entire region including East Africa. The two regions would be well served to create or simply rejuvenate cross-border and regional mechanisms to control the spread of forest pests and diseases. Fortunately for SADC, an important document, the SADC Sanitary and Phytosanitary (SPS) Annex to the SADC Protocol on Trade of 2008 already exists. The document which has been reviewed separately, and in conjunction with SADC Protocol on Forestry, offers a framework for cross-border collaboration. In addition, and fortuitously for that matter, the Forestry and Agricultural Biotechnology Institute (FABI) hosted by the University of Pretoria and funded by the forest industry of South Africa offers a facility which has trained modern day pathologists and entomologists in both east and southern Africa. As such, the sponsors of FABI would be well served to enable it to interact more widely with southern African countries, provided that some cost sharing arrangement to support the facility can be arranged with South Africa's forestry. In the current disease and pest incidences and spread in southern Africa, 'Regional Disease and Pest Alerts' are necessary and critical and the testing and coordinated release of biological control agents among countries can help build the necessary awareness and technical capacity needed for concerted action. In addition, all the phytosanitary units in countries that are normally housed and run by Departments of Agriculture need to be appraised and trained to deal with forest pests and disease, in addition to the strengthening of national forest protection units.

CONCLUSION AND RECOMMENDATIONS

The planting of popular eucalyptus species and their hybrids (GC and GU) is quite widespread in the southern African region and the movement of live plants between countries is not uncommon. This presents uniform genetic materials for the pests and diseases, an issue that breeders and silviculturalists, should take into account in their planting designs. In connection with this, the spread of pests such as the Red Gum Lerp Psyllid have in the last 12-15 months before November 2015, has been phenomenal based on the four countries that were visited. The countries have realized that they have to take appropriate actions within and between their borders to manage pest and disease problems. The evidence that some countries have allowed the importation of seed and seedlings without adequate quarantine or phytosanitary procedures suggests inadequacies in the application of national phytosanitary policies and procedures and this is in complete disregard of the SADC Protocol of 2008 which was meant to deal with such issues.

A serious pest of pine, the *Sirex* Woodwasp (*Sirex noctilio*) Fabricius, which is associated with a fungal pathogen, *Amylostereum areolatum* (Chaillet) Boiden was a real economic threat to the entire region but has successfully been contained within the boundaries of South Africa using its natural enemy, a parasitic nematode known as *Deladenus siricidicola*. Work on the management control of the wood-wasp remains the best example of a successful biological control story in the contemporary history of forest entomology. This bodes well for research and development on the effective biological control of other pests such as the Blue Gum Chalcid and the Red Gum Lerp Psyllid which are today's serious pests. The trial of biocontrol agents is going on well at FABI and in some instances the agents have spread remarkably fast and colonized plantations far removed from the original centres from which they were released (Bret Hurley Pers. Comm.).

In virtually all countries, plant quarantine falls under departments of Agriculture which have traditionally been concerned with agricultural products which move in large volumes across borders but have little or no experience in dealing with forest pests and diseases. As a result, forest departments in all countries have to proactively engage with national plant quarantine authorities to recognize and incorporate forest pests and diseases in their listings and schedules.

In the current disease and pest incidences and spread in southern Africa, 'Regional Disease and Pest Alerts' are necessary and critical and the testing and coordinated release of biological control agents among countries can help build the necessary awareness and technical capacity needed for concerted action. In addition, all the phytosanitary units in countries that are normally housed and run by Departments of Agriculture need to be appraised and trained to deal with forest pests and disease, in addition to the strengthening of national forest protection units. On a regional scale, the SADC Secretariat should as a matter of urgency, activate the SADC Sanitary and Phytosanitary Protocol of 2008 and through it, constitute and facilitate a regional technical committee on Sanitary and Phytosanitary Issues and a Specialist Working Group on forest pests and diseases. Furthermore, it should formally engage with FABI in South Africa, which is a de factor Centre of Excellence in disease and pest science to work with SADC technical committees and specialist groups and aid the much needed and long overdue collaborative programming and concerted actions.

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STATEMENT OF NO-CONFLICT OF INTEREST
The authors declare that there is no conflict of interest in this paper.

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Status, trends and impacts of forest and tree pests in West and Central Africa

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ABSTRACT
There is considerable drive in many countries of West and Central Africa towards reforestation and rehabilitation initiatives that use trees. However, the occurrence of pests and diseases in Africa is having considerable impact on forest growth and yield and thus reducing profits from forests. Consequently, measures to protect forests from pests and diseases should be an integral part of sustainable forest management. The objective of the study was to evaluate the status and trends of forest and tree pests and disease management in the West and Central African regions with the view to proposing appropriate control measures, including development of protocols for pest and disease surveillance. A combination of literature review and expert surveys conducted in six countries, including Ghana, Nigeria, Niger, Senegal, Gabon and Democratic Republic of Congo were used to gather information on the topic. The results showed that pest problems in the WCA region are generally sporadic. In the humid zone of the sub-region, establishment of plantations of high-value indigenous timber species such as iroko (*Milicia excelsa* and *Milicia regia*) attacked by the gall-forming *Phytolyma lata*, and mahogany (*Khaya* and *Entandrophragma* spp.) attacked by the shoot borer *Hypsipyla robusta*, have been largely avoided. In the Sahel-Savanna zone, termites are the major pests of trees, affecting both indigenous and introduced species. In the mid-1980s, an outbreak of the oriental yellow scale insect *Aonidiella orientalis* (Hemiptera: Diaspididae) affected millions of neem (*Azadirachta indica*) in the countries of the Lake Chad Basin. However, pest trends are generally not that clear in the sub-region. Except for a few cases, endemic pests and disease problems have persisted for decades. A new trend is emerging where exotic species which have been widely planted due to their relative stability to pests now appear to be succumbing to attacks. Recent forest health surveys in Ghana, for example, revealed potentially serious stem canker infections on cedrela (*Cedrela odorata*), and *Amillaria* root diseases on teak (*Tectona grandi*s) in plantations. Also, cases of what appears to be symptoms of blue gum chalcid (*Leptocybe invasa*) attacks have been observed in the region. Enhancing pest surveillance and management in the sub regions are recommended.

Keywords: Central Africa, diseases, pests, Ghana, surveillance, West Africa

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RÉSUMÉ

Dans de nombreux pays d'Afrique de l'Ouest et du Centre, des efforts considérables sont déployés pour reboiser et réhabiliter les forêts. Cependant, la présence de ravageurs et de maladies en Afrique a un impact considérable sur la croissance et le rendement des forêts et réduit ainsi les profits tirés de celles-ci. Par conséquent, les mesures visant à protéger les forêts contre les ravageurs et les maladies devraient faire partie intégrante de la gestion durable des forêts. L'objectif de l'étude était d'évaluer l'état et les tendances des forets et des ravageurs forestiers et la gestion des maladies dans les régions d'Afrique de l'Ouest et du Centre en vue de proposer des mesures de lutte appropriées, y compris l'élaboration de protocoles de surveillance des ravageurs et des maladies. Une analyse documentaire et des enquêtes d'experts menées dans six pays, dont le Ghana, le Nigeria, le Niger, le Sénégal, le Gabon et la République démocratique du Congo, ont été utilisées pour recueillir des informations sur le sujet. Les résultats ont montré que les problèmes de ravageurs dans la région de l'Afrique de l'Ouest et Centrale sont généralement sporadiques. Dans la zone humide de la sous-région, des plantations de bois indigènes de grande valeur telles qu'iroko (Milicia excelsa et Milicia regia) attaquées par le Phytolyma lata et le khaya (Khaya et Entandrophragma spp.) attaqué par Hypsipyla robusta, ont été largement évités. Dans la zone Sahélienne (savane), les termites sont les principaux ravageurs des arbres, affectant à la fois les espèces indigènes et les espèces introduites. Au milieu des années 1980, l'avènement de l'insecte *Aonidiella orientalis* (Hemiptera : Diaspididae) a touché des millions de neem (Azadirachta indica) dans les pays du bassin du lac Tchad. Toutefois, les tendances relatives aux ravageurs ne sont généralement pas aussi claires dans la sous-région. À l'exception de quelques cas, les ravageurs endémiques et les problèmes de pathologie persistent depuis des décennies. Une nouvelle tendance se dessine où des espèces exotiques qui ont été largement plantées en raison de leur stabilité relative aux ravageurs, semblent maintenant succomber aux attaques. De récentes enquêtes sur la santé des forêts au Ghana, par exemple, ont révélé des infections potentiellement graves pour le cedrela (Cedrela odorata) et les maladies des racines sur le teck (Tectona grandis) dans les plantations. De plus, des cas de ce qui semble être des symptômes d'attaques du Leptocybe invasa ont été observés dans la région. Il est recommandé d'améliorer la surveillance et la lutte antiparasitaire dans les sous-régions.

Mots-clés : Afrique centrale, maladies, ravageurs, Ghana, surveillance, Afrique de l'Ouest

INTRODUCTION

Trees and forests constitute an inseparable component of the livelihood of the people in the West and Central African subregions. Forest-dwelling communities, as well as those living further away from forests, have depended directly or indirectly on forests for centuries. Globally, utilisation of tropical forest resources has generally been described as unsustainable, resulting in serious decline in forest area. According to FAO, deforestation rates in tropical Africa are among the highest in the world (FAO, 2010). Major causes of deforestation on the continent include slash and burn agriculture, unsustainable logging practices, illegal mining and urbanisation. Sustainable forest management practices include the application of good silvicultural techniques to utilisation of existing forests, as well as the planting and tending of trees to improve forest cover, often described as afforestation and reforestation.

There is currently a high level of interest in the West and Central African (WCA) region towards afforestation/reforestation (A/R) and restoration initiatives. However, several challenges hamper successful A/R operations on the continent, among which are the impact of pests and diseases. Consequently, measures to protect forests from pests and diseases should be an integral part of forest management programmes. Current global trends, especially climate change and increased trade among nations, have affected the dynamics and spread of pests and diseases across the world (FAO, 2011). Effective management of pests and diseases requires reliable information on the biology and ecology of the pests, as well as their impacts on forest ecosystems and possible methods of control.

Today, exotic species such as eucalypts (*Eucalyptus* spp.), and teak (*Tectona grandis*) dominate planted forests of WCA, but there are strong signals that the 'immunity' of exotic species to pests and diseases is gradually breaking down. In Ghana, for example, popular plantation species like teak and cedrela (*Cedrela odorata)*, which have been widely planted because of their resilience to pests and diseases appear to be succumbing to attacks. The objective of the study was to evaluate the status and trends of forest and tree pest and disease management in the West and Central African regions with the view to proposing appropriate control measures, including development of protocols for pest and disease surveillance.

METHODOLOGY

This study involved six countries of West and Central Africa, namely Ghana, Nigeria, Niger, Senegal, Gabon and the Democratic Republic of Congo (DRC). Two main approaches were used to gather data for the study. First, a review of the literature on forest pests and diseases in the West and Central African (WCA) sub regions was conducted; whereby published literature which included referred journal articles, technical reports, bulletins, books, and various reports mainly from internet sources were reviewed. Information obtained was summarised by country, region, forest zone and type, and pest and disease category. The second phase of information/data gathering involved field visits to six selected countries in the subregions to interview relevant experts (academicians, policy makers, managers, and industrialists) for firsthand information on past and/or current pests and disease challenges in those countries and regions. Four countries in West Africa (Ghana, Nigeria, Niger and Senegal) and two in Central Africa (Gabon and Democratic Republic of Congo) were selected and visited (Fig. 1). In each country, one-on-one interviews were conducted with identified experts using open-ended questionnaires. Prior to the field visit to each country experts/informants were identified through the African Forest Forum's database of experts. The contact person was then requested to identify not less than three and more 10 persons to be interviewed. At least one of the experts was to be in the forest industry; another in forest policy and management and the other in academia, preferably in forest protection.

Additionally, field trips to natural forest stands or plantation estates were undertaken to observe past or current forest pest/disease outbreaks in those countries. The choice of forest or plantation to visit was decided on by the contact person from each country. Criteria for selection was current or past outbreak of pest/ disease and proximity or access to the site. Key information sought during the survey were: existing and/or past forest pest and disease problems; impact of pests on forest management, including other environmental and socioeconomic effects; existing policies and laws on forest health and protection in the country; forest health surveillance programmes; and capacity to implement forest pest and disease management in the country. A total of 34 national experts of relevant expertise and backgrounds were interviewed in the six countries visited. Seven forest plantation estates and one natural forest stand were also visited (Table 1).

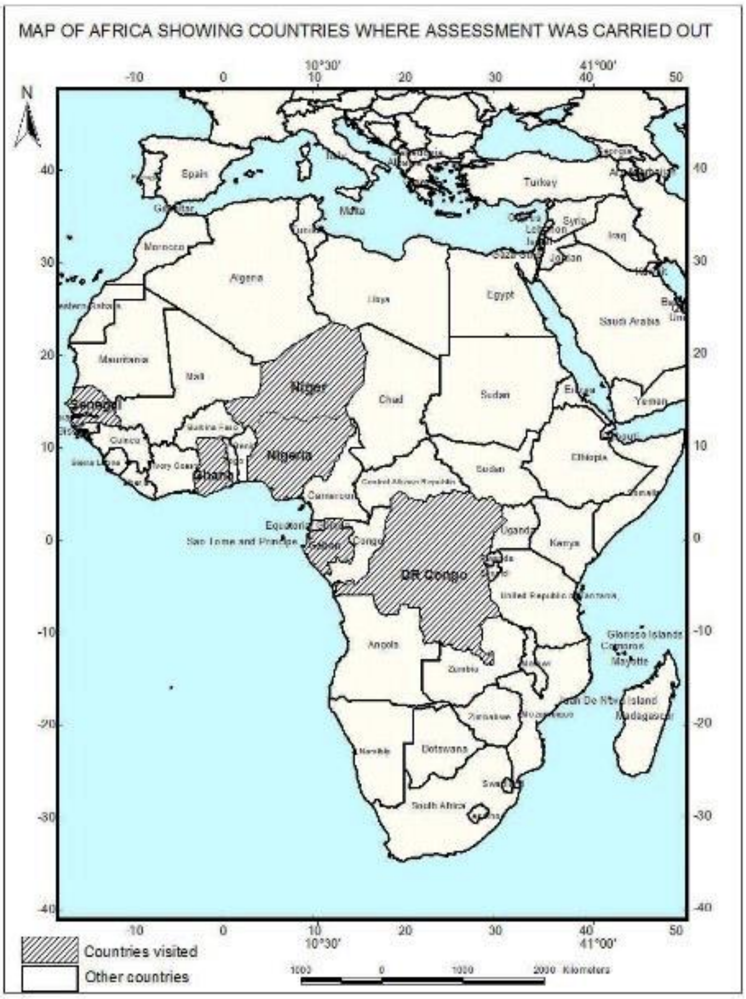

Figure 1. Map of Africa showing countries in West and Central Africa involved in the study

Table 1. Number of experts consulted and forest sites visited per country during the field survey

Country	No. experts consulted	Forest site/ plantation estate visited	Location of forest/ plantation
Ghana	8	• APSD Plantation Estate	Kwame Danso
		• FORM Ghana Plantation Estate	Akumadan
Nigeria	5	• Bisrod Furniture Company (Forest Demonstration Center)	Ijebu-Ode, Ogun State
Niger	4	• Alhaji Eucalyptus Plantation	
Senegal	7	• City Forest	Dakar
		• Casuarina plantation	Dakar Beach
Gabon	6	• CENAREST Research Forest	Libreville
Congo DR	4	• South Kwamouth REDD+ Agroforestry Pilot Project	South Kwamouth

RESULTS AND DISCUSSION

Forest and tree pests and diseases: current trends and drivers. The findings presented include information obtained from the review of literature as well as responses obtained from interviewing the national experts. For clarity, the information has been discussed under three subheadings, namely, insect pests, diseases, and other pests. A review of the literature indicated that a large number of insect pests and diseases of trees and forests exist in the WCA region, especially in West Africa. With the exception of few recorded cases, insect pests and disease pathogens generally did not cause long term problems in natural forest stands of West and Central Africa.

Endemic pests in the humid zone. In the humid tropical areas of WCA where there is high species diversity, outbreaks of pests and diseases rarely occur in natural stands. Insect pests and pathogens may well be present, and may damage or kill a few trees every now and then; however, they rarely reach outbreak status. Most of these potentially serious insects and pathogens have been known for decades, but as long as the host species have not been planted in large-scale plantations, there has never been cause for concern. Indigenous tree species with serious endemic pest problems in the humid zone included, Iroko (*Milicia excelsa* and *M. regia*), African mahogany (*Khaya* and *Entandrophragma* spp), Afrormosia (*Pericopsis elata*), obeche (*Triplochiton scleroxylon*), opepe (*Nauclea diderrichi*i), and *Terminalia ivorensis* (Table 2). Endemic pest problems of these high-value timber species generally account for the persistent failure of indigenous species plantations in the subregion.

Iroko *(Milicia*) suffers severe attacks from the Iroko gall maker *Phytolyma* spp. (Homoptera: Psyllidae) throughout the region and beyond (Wagner *et al.,* 2008). *Phytolyma lata* 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, Cameroon, all the way to Tanzania. All life stages of the tree are susceptible, however, seedlings and actively growing saplings in young plantations are the most affected, often resulting in 100% failure. Another pest of serious regional and global significance is the mahogany shoot borer, *Hypsypyla robusta* (Lepidoptera: Pyralidae). This insect attacks species of the Meliaceae family in Africa, especially African mahoganies *Khaya* and *Entandrophragma)*.

Planting of mahogany is currently a major challenge in the WCA region. Shoot borer attack on mahogany often results in damage and deformation and sometimes death of plants at the nursery and in young plantations. Other endemic pests of considerable importance include *Lamprosema lateritialis* (Lepidoptera: Pyralidae) on *Pericopsis elat*a (Afrormosia), *Orygmophora mediofoveata* (Lepidoptera: Noctuidae) on *Nauclea diderrichii* (Opepe/ Kusia), and *Anafe venata* (Lepidoptera: Notodontidae), on *Triplochiton scleroxylon* (Obeche/ Wawa).

The insects discussed above usually occur on host trees in natural forest stands, however, their presence is hardly noticeable and the 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. However, from the 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 the western African countries of Liberia, Sierra Leone and Guinea, with devastating environmental and socioeconomic effects on forests and agricultural lands.

The impact of the *A. catacoloides* outbreak in the West African subregion was very pronounced. Apart from defoliating the main target tree species known locally as dahoma

(*Piptadeniastrum africanum*), larvae of the insects also damaged coffee trees, coconut palms, plantain and other wild flora. In addition, the outbreak led to the contamination of water by caterpillar excrements and bodies, rendering the water unsafe for consumption. At least 55 localities were affected, and thousands of people were reported to have fled their homes in the affected communities (Sidibe, 2009). This sudden outbreak of *A. catacoloides* 2009 on this scale and magnitude is an example of what could happen in the sub regions at any point in time, given the current fluctuating environmental conditions. It is a wake-up call to policymakers, environmentalists, foresters, investors, plant protectionists and the general population on the need for preparation for imminent pest and disease outbreaks in the two subregions.

Table 2. Major insect pests in the humid forest zone of West and Central Africa

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, Cote 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, Cote d'Ivoire	*Triplochiton scleroxylon*	Sap feeder
Hypsipyla robusta	Lepidoptera: Psyllidae	Ghana, Nigeria, Togo, Cote 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, Cote d'Ivoire,	*Milicia regia*	Gall maker
Phytolyma fusca	Homoptera: Psyllidae	Ghana, Nigeria, Togo, Cameroon	*Milicia excelsa*	Gall maker

Major insect pests of exotic species. In addition to the problems encountered on indigenous species, introduced or exotic species such as *Gmelina arborea* (gmelina), *Cedrela odorata* (cedrela), *Tectona grandis* (teak) and several species of Eucalyptus, which are widely planted in the sub-region often succumb to insect pest attacks. In the humid zone, *G. arborea* suffer severely from attacks by *Achaea* and *Apophylia* species which records show resulted in significant damage in Nigeria (Loupe *et al.,* 2008). Teak and cedrela are perhaps the most commonly planted species in the humid zone of the WCA region, mainly in Ghana, Togo, Nigeria, and Cote d'Ivoire. These two species do not have much 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 during 2004 and 2005 (Bosu and Apetorgbor, 2009). However, no significant economic damage was recorded. The attack is characterized by multiple boring of the stem, reducing the quality of the pole or wood. In heavy infestations, a few trees may be killed. In young plantations, defoliation by the variegated grasshopper *Zonocerus variegatus* can be very visible in plantations in the forest zone; however, attacks appear to have very little impact on plant growth as the trees usually recover over time. Cedrela also suffer attacks from another species of Apate (*A. monachus*) and other bark borers, especially when the trees are under stress. Unlike teak, cedrela usually responds to borer attack by exuding sap which pushes out the invading insects often killing them. This has been observed in various plantations in Ghana, including the Afram Headwaters, Anhwiaso South and Worobong South forest reserves.

Major insect pests of the Savanna and Sahel zones. Pests and disease problems in the forest zone are generally different from those in the dry forest region (savannah and sahel zones). However, incidence of pests in the savannah woodlands are not common, except for perhaps the routine outbreak of the desert locust (*Shistocerca gregaria*) in the Sahel zone that though are major problem on agricultural crops also affects trees. Trees planted for shade, avenue or woodlots are very important in this zone. Common tree species in the savannah often planted for shade include neem (*Azadirachta indica*), *Terminalia mantaly*, *T. catappa*, and *Eucalyptus* spp. Nearly all of these are also commonly planted in towns and cities in the humid zone. *Terminalia mantaly* grows quite vigorously, with nearly evergreen leaves and beautifully spreading canopy, and is almost the tree of choice in cities in WCA. Together with its relative *T. catappa*, these two species rarely suffer attacks from pests and diseases except for occasional infestation by generalist stem and bark borers. In instances where trees are located in ceremonial streets or compounds, damage inflicted by borers become conspicuous and makes the trees unattractive. These may necessitate prompt pest control intervention or outright removal.

The most serious tree pest problem in the Sahel region of recent memory is 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 square kilometers, causing significant damage to neem and other host trees. In Niger and several other countries in the Sahel region, where neem is a very important tree, 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. As a result of serious management efforts in the 1990s the neem scale insect problem is now under control.

Various species of *Eucalyptus* are widely planted in the sub region, among which are *E. camaldulensis, E. territicornis*, and *E. alba.* The objectives for planting include pulp, poles, amenity or wood fuel. Worldwide, *Eucalyptus* are highly susceptible to pests and diseases, and in Africa the blue gum chalcid (BGC) *Leptocybe invasa* is causes havoc 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. In Senegal, the observation was made in a small plot located within the city of Dakar, while 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. A more recent survey conducted in eucalypt plantations in 2018 have confirmed the occurrence of BGC at Agogo and Drobonso in the Ashanti of Ghana (Wondafrash *et al.*, unpublished)

In Senegal it was reported that a filao worm (*Thyridopterix* spp) outbreak was recorded on a plantation of Casuarina established along the beach between Dakar and St. Louis, in 2011 (El Hadji Omar Dieng, DPV Dakar, pers. comm.). The attack affected nearly 1,153 ha of trees and was halted by the application of a broad spectrum insecticide. Again in Senegal, authorities are battling with pest problems on *Acacia senegal* established as part of the Great Green Wall Project. According to Colonel Papa Sarr, Technical Director of the Project in Senegal (pers. comm., 2015), tree mortality of between 2-3% was recorded in the plantation areas in 2015. Though no formal assessment has been carried out it is believed to have been caused by termites. A termite expert at the University of Dakar has indicated that termite-related tree mortality has increased in recent times, affecting species of *Eucalyptus, Casuarina, Balanites, Acacia,* and several other planted trees. He believes the increase is not necessarily the result of climate change, rather he attributes it to increased tree planting and awareness, as the problem has always been there (Ndiaye and pers. Comm., 2015).

Diseases of trees and forests. Diseases affecting trees and forests in WCA include soil-borne diseases, dieback, canker, rots and rusts. Like insect pests attacks, tree diseases are also more prevalent in plantations than in natural forests or woodlands

Damping-off in the nursery is common throughout the subregion whenever the conditions permit. From the literature, root diseases, decline and dieback are the major tree and forest diseases in the sub-region. Among these, dieback of *Ceiba pentandra, Terminalia ivorensis, Gmelina arborea* and *Casuarina equisetifolia* have caused considerable havoc to planted forests (FAO, 1994; Agyeman and Safo, 1997; Apetorgbor and Roux, 2015) (Table 3). Also, host plant dieback associated with attack by the insect *Phytolyma* spp. and *Orygmophora mediofoveata* have been recorded on *Milicia* spp., and *Nauclea diderrichii*, respectively (Table 3). Root diseases and cankers are also gradually becoming serious in planted forests in the sub-region, especially in Ghana.

Of the major tree diseases, dieback of *T. ivorensis*, *G. arborea* and decline of *A. indica* were recorded several decades ago, between 1970 and 1990. The occurrence of dieback on *T. ivorensis* in Ghana and Cote 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 for the establishment of indigenous species plantations. Plantations aged 10-20 years were mostly affected with very high mortalities. Symptoms of attack include branch dieback beginning at the crown apex, chlorotic and wilting foliage, crown thinning and sapwood staining. In Ghana, the imperfect stage of *Endothia* sp. has been associated with the high mortality recorded (Ofosu-Asiedu and Canon, 1976). However, no biotic agents were clearly linked to the disease and the infection has been generally associated with environmental and nutritional stresses. Fortunately, *T. superba* is not affected and is currently planted widely in West Africa.

Dieback of *C. pentandra* is another disease with major impact on regeneration of the host species. It was first observed in Ghana in experimental trials at the Bobiri Forest Reserve in 1996 and is not yet reported in other WCA countries. Unlike dieback of *T. ivorensis*, *Ceiba dieback* affects hosts at nursery stage. It can cause significant damage to seedlings, and can persist throughout the growing stages of the plant. Without proper care and maintenance the likelihood of a 100% mortality at the nursery is high. *Colletotrichum capsici* was the causal agent of the disease (Leaf spot and anthracnose) whereas under favourable conditions, *F. solani* and *L. theobromae* were found to be associated with dieback of stem in the field, however, infected plants of two years old and above often recover from the attack. *Fusarium* sp. and *Lasiodiplodia theobromae* have been associated with the disease (Apetorgbor *et al.,* 2003).

Another species which is susceptible to dieback is *Gmelina arborea*. It is a fast growing 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. According to Gbadegesin *et al.* (1999), 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 high, with infection rates of up to 40% in plantations, while in Cote d'Ivoire and Nigeria, *Armillaria* m*ellea*, *Chaetophoma* sp., *Polyporus* sp., and *Thanatephorus cucumeris* were reported as causal agents.

In addition to outbreak of the neem scale insect in the Lake Chad Basin (LCB) during the mid-1980s, symptoms of decline were also reported, first in Niger and subsequently in the other countries of the LCB. Although symptoms of the decline were initially confused with the scale insect outbreak critical analyses later found it to be different. According to Boa (1992), the most conspicuous symptom of *Azadirahta indica* decline is the loss of older foliage. The foliage loss gives the normally dense crown 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 *Curvulariae ragrostidis* have been recovered from neem with symptoms of decline, they have been shown as secondary pathogens.

Emerging diseases on teak and *cedrela*. Teak and cedrela are two introduced species which have been grown extensively in the high forest zone of West Africa without major concern for pests and diseases. However, a survey of plantations has shown signs of disease infections with potentially serious consequences observed in Ghana (Bosu and Apetorgbor, 2009; Bosu *et al.,* 2015). In 2006, *Armillaria* root rot was observed on teak and *cedrela* plantations located within the Kwamisa, Tano Nimiri, and Mamiri reserves in the Moist Forest zone (Apetorgbor *et al.,* 2013). In several other places, including Anwhiaso, Worobong South, and Afram Headwaters forest reserves, canker of the stem were observed on *Cedrela.* At the Anwhiaso Forest Reserve where the infection was first reported, spread of the disease was halted with sanitation thinning and selective application combination of fungicides and insecticides on infected trees. Consistent monitoring of pest and disease in plantations of teak and cedrela will be needed to ensure the success of plantation development in the sub region.

Mollusc or snail pests. The incidence of snail (*mollusc*) pests in nurseries and newly established plantations appear to be increasing in the WCA region. In Nigeria, at the Bisrop Plantation Estate, it was reportedthat a serious outbreak of a snail pest was experienced in a *Cedrela odorata* plantation, resulting in 100% mortality of the saplings. According to the plantation manager, snails first consumed the leaves on the seedlings and saplings and afterwards attacked the young stems rasping off the bark and ultimately killing the plants. A second round of planting resulted in repeated attacks causing the plantation manager to abandon the planting of *Cedrela.* Somehow, a fire

Table 3. Major diseases of trees and forests in West and Central Africa as of 2018

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 equitosifolia	Dieback	Associated with soil nutrition limitations	Benin	Introduced
Cedrela odorata	Root rot Stem canker	*Armillaria* sp. *Stem borer, Apate terrebrans. Fusarium solani and Lasiodiplodia theobromae are associated opportunistic pathogens*	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, Cote d'Ivoire, Nigeria	Introduced
Terminalia ivorensis	Dieback	No pathogen associated with dieback. Caused by environmental/ nutritional stresses	Ghana, Cote d'Ivoire	Indigenous
Tectona grandis	Root disease	*Armillaria* spp., *Phellinus noxius, Phaeolus manihotis*	Ghana, Nigeria, Cote d'Ivoire, Benin	Introduced

which was set to remove slash from the field and cleanse it for another planting project succeeded in killing nearly all the snails. Following that the few *C. odorata* which survived the fire, re-sprouted without any further damage. In Ghana, FORM Ghana Plantation Estate reported serious problems of snail defoliation of *Khaya ivorensis* seedlings at the nursery, leading to considerable cost to control. Snail pest attack on *K. ivorensis* seedlings has also been reported from the nursery of the Samartex Timber Company at Samreboi, in the Western Region of Ghana.

Impact of pests and diseases on indigenous forest trees. The impact of pests and diseases on forests and trees in the sub-region include partial to total damage or death of seedlings at the nursery, and/or of saplings or young trees during the early stages of plantation establishment. Unlike in Europe and North America, where thousands or sometimes millions of hectares of forests come under severe insect pest and disease attacks, incidences like that are quite rare in tropical Africa. This is largely due to the high diversity of forest stands which reduces susceptibility to attack, and the fact that plantation forestry is not fully developed in the region. Oftentimes, the impact of pests and diseases is hardly noticeable if present in naturally occurring forest stands. However, on few occasions outbreaks in natural stands have had a significant impact on the forests with corresponding socioeconomic impacts on local communities. The outbreak of *A. catacoloides* in West Africa in 2009 is a good example. Otherwise, major effects of forest and tree pests and disease in the sub region have been on planted forests.

One of the most significant effects of forest/tree pests and diseases in the sub-region is the failure of most indigenous species plantations, and the resultant shift towards the planting of in exotic species. Throughout most of the humid zone, attempts to establish plantations of valuable hardwood timbers have failed largely due to endemic pest and disease problems. For example, in spite of huge investments and research efforts over the past two decades to restore Iroko (*Milicia excelsa* and *Milicia regia*) as a major export timber in the region, this has not been realized (Cobbinah and Wagner, 2000). Stakeholders are still apprehensive when it comes to investing in plantations of Iroko because of uncertainties and huge costs that may be associated with managing endemic pests and diseases. Similar cases can be made for species of African mahogany (Opuni-Frimpong *et al.*, 2005).

Traditionally, diseases and pests of trees and forests have had the most impact on indigenous species in the humid forest zone (Wagner *et al.,* 2008)). However, exotic species which were hitherto considered somewhat “immune” are becoming increasingly vulnerable to pest outbreaks due to several reasons. Firstly, increased international trade has been proven to increase the introduction and spread of invasive pests around the world, and some have found their way to Africa. Accidental introduction of native pests and pathogens of introduced species often result in outbreaks, as was the case for the oriental yellow scale insect on neem.

Secondly, widespread planting of certain exotic species often increases the likelihood of native pests adapting to these exotic species. Generalist or polyphagous pests often overcome the physiological barriers of trees, especially during extreme environmental conditions that stress the trees. Under such conditions trees become vulnerable and serious damage or mortalities can occur. Such occurrences are becoming frequent in Ghana, especially with respect to disease incidence on teak. Teak is currently the most widely planted timber species and constitutes at least 70% of planted forests in Ghana (FC, 2013).

Thirdly, the impact of global climate change phenomenon on biological/ecological systems such as host vulnerability/resistance, pathogen biology, as well as pathogen-host interactions have promoted pest problems in the region, as is the case in many other parts of the world. Pests and disease outbreaks of varying intensities continue to be recorded on previously "secure" exotic species such as *Eucalypts, Tectona, Cedrela, Gmelina* and *Azadirachta*.

The approach used to contain the *A. catacoloides* outbreak in West Africa should be documented and improved for future outbreaks in the sub regions. The roles played by the governments of affected countries, the Economic Community of West African States (ECOWAS), International Institute of Tropical Agriculture (IITA), and the involvement of several international research and academic institutions.

Pests and disease impact on exotic trees and forests. In dry areas, termites have a major impact on growth and success of planted trees and forests. In addition to the well-known problem of desert locust outbreaks and its serious effect on agriculture crops, other insects such as Analeptis and Apate species also cause considerable damage to trees. The oriental scale insect outbreak on neem resulted in the death of over one million trees, and covered an area of over one million square kilometers in the Lake Chad Basin countries (Lale, 1988).

Nurseries of Eucalyptus species for large scale plantation establishment in the region easily succumb to disease outbreaks if adequate care is not taken. Complete loss of seedlings in nurseries is not uncommon, often resulting in loss of huge financial investments. In some instances, investors incur huge costs in pesticide purchases, application, and related pest control. For example, a visit to the FORM Ghana Plantation Estates as part of the study revealed that the Company spends approximately GH¢3,000.00 (approximately US$780.00) per week on pesticides to control snail damage on African mahogany seedlings at the nursery stage.. At the African Plantations and Sustainable Development (APSD) Plantation Estate, also in Ghana, it was reported that the Company has a breeding programme in place to ensure that superior clones of *Eucalyptus* are continually being selected for planting, in order to minimise the risk of major pest damage. Such expensive pest management efforts only occur with large scale private investors. Hardly any efforts are made by individuals or small-scale tree growers to manage or control pest problems of planted trees or forests in the sub-region. Oftentimes, the response to a seemingly major pest outbreak by smallholder tree growers is abandonment of the project. Unfortunately, plantation projects by national agencies sometimes face similar fates. Projects are often designed and implemented with no provision for pest monitoring and management or control. Consequently, such national plantation projects fail within few years of initiation, unless no major pest or disease outbreak occurs.

CONCLUSION AND RECOMMENDATIONS

Major insect pests and diseases of forests and trees in West and Central Africa occur on valuable hardwood species in the humid forest zone. These endemic pests become serious and cause significant damage to trees when established in large scale plantations. Widely planted exotic species such as *Tectona grandis* and *Cedrela odorata* and various species of *Eucalyptus* spp. have been grown for many decades without much pest problems in the sub region. However, a new trend is emerging and many of these exotic species are succumbing to pressure by indigenous pathogens. This means accidental introduction of the native pests of these exotic species in the future could worsen the pest problems in the sub region. In their native range, teak for example, suffer severely from defoliation by *Hyblaeapuera* (Lepidoptera:

Hyblaeidae), and *Cedrela* from the other strains of the mahogany shoot borer *Hypsipyla grandella* (Lepidoptera: Pyralidae). So far, *C. odorata* has enjoyed protection from *H. robusta*, but this could all change if *H. grandella* arrives on the continent. With the increased global trade and climate change phenomenon which most experts believe could exacerbate pest and disease problems around the world, WCA countries should take steps to prevent the introduction and spread of pests and diseases.

Countries in the two sub-region have been involved in the global and continental phytosanitary processes and have ratified nearly all international and continental conventions and agreements on phytosanitary measures. However, implementation of the requirements of these measures has been slow, at best. A combination of factors, including lack of institutional and human capacity, logistical/ financial constraints, lack of effective coordination and networking among member countries, absence of national and sub-regional protocols, guidelines, mechanisms for undertaking forest pests surveillance and phytosanitary actions, and focus on phytosanitary measures on pests of agricultural concern have all contributed to the current situation.

Increased pest surveillance and surveys followed by prompt management is required and so the following have been suggested:

i. National governments should develop the laws and legislations required for the implementation of phytosanitary and in particular surveillance systems at national and regional levels;
ii. Member countries should increase the capacity of their national plant protection organisations to make it possible for effective surveillance and control of forest pests and diseases. Additionally, the capacity of the technical staff should be upgraded whiles the necessary tools and equipment should be provided and/or regularly updated;
iii. Stakeholders in the forestry sector should be sensitised about threats of forest pests in the sub-region and the need to include surveillance in their programmes and operations; and
iv. Member countries should develop national protocols and guidelines for the implementation of surveillance programmes. To increase stakeholder appreciation and involvement of the entire process, the drafting, testing and implementation of these protocols should involve all, or as many, relevant national experts and institutions as possible.

Since private investors are interested in putting their money into high value, short-rotation exotic timber species it will be prudent for national governments and institutions in the region to focus more attention to indigenous species that have both socioeconomic, cultural and environmental benefits to the countries and the region. Strategies such as enrichment planting, agroforestry systems, and management of natural regeneration on farms could be more cost effective and culturally acceptable approaches to ensuring sustainable production of many of these susceptible indigenous species.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Status of forest certification in eastern and southern Africa sub-regions

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ABSTRACT
There is a limited awareness and capacity, and hence slow update of forest certification in Africa. The study assessed the status of Forest Certification (FC) in the Eastern and Southern Africa sub-regions. Data on the types of certificates, number and forest areas certified, and past and on-going efforts on FC in the sub-regions of Eastern and Southern Africa were gathered through literature review and stakeholders' consultation. Data were analysed using qualitative methods and A'WOT quantitative analysis, which is a combination of Analytic Hierarchy Process (AHP) and Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses. Results showed that the initiatives for promotion of FC in the sub-regions are empirically apparent but low. The forest covers in the sub-regions were around 225 and 222 million ha for the eastern and southern Africa sub-regions, respectively. For Eastern and Southern Africa, the total area certified was 242,000 ha and 1.563 million ha, respectively. Generally, the FC has not yet taken strong root in the sub-regions due to inadequate financial, physical and human capacities.

Key words: Ecosystem services, forest restoration, green growth, forest standards, forest governance, responsible forestry

RÉSUMÉ
En Afrique, la sensibilisation et les capacités sont limitées, ce qui ralentit la mise à jour de la certification forestière. La présente étude a évalué l'état de la certification forestière (CF) dans les sous-régions de l'Afrique de l'Est et de l'Ouest. Des données sur les types de certifications, le nombre et les superficies forestières certifiées, ainsi que sur les efforts passés et en cours en matière de CF dans les sous-régions de l'Afrique de l'Est et de l'Ouest ont été recueillies au moyen d'une revue de littérature et de la consultation. Les données ont été analysées à l'aide de méthodes qualitatives et d'une analyse quantitative SWOT, qui est une combinaison d'analyses de la hiérarchie analytique (AHP) et de forces, faiblesses, opportunités et menaces. Les résultats ont montré que les initiatives de promotion de la CF dans les sous-régions de l'Afrique sont empiriquement apparentes mais faibles. La couverture forestière dans les sous-régions s'élevait respectivement à 225 et 222 million d'hectares pour les sous-régions de l'Afrique de l'Est et de l'Ouest. Pour l'Afrique de l'Est et de l'Ouest, la superficie totale certifiée était de 242 000 ha et 1,563 million ha, respectivement. En général, la CF n'est pas encore solidement implantée dans les sous-

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régions en raison de capacités financières, physiques et humaines inadéquates.

Mots clés: Services écosystémiques, restauration des forêts, croissance verte, normes forestières, gouvernance forestière, foresterie responsable

INTRODUCTION

Tropical forests provide a variety of valuable ecosystem services, such as biodiversity, carbon sequestration, water source protection and scenic beauty (Sell *et al.,* 2007; Gardner *et al.,* 2009; Sasaki *et al.,* 2011). The forests of Eastern and Southern Africa (EaSA), like in other parts of tropical Africa, are species rich, thereby contributing to local economies by way of timber and Non-Timber Forest Products (NTFPs), as well as numerous ecosystem services (Owino, 2003; Biggs *et al.*, 2008). They also contribute to long-term socio-economic development objectives, and play an important role, specifically in meeting the goal of ensuring environmental sustainability (Sebukeera *et al.,* 2005; Gondo, 2010). However, the capacity of these forests to continue providing ecosystem services is reduced each year by deforestation and forest degradation (Gondo, 2010), owing to uncontrolled human activities, such as logging and fires (FAO, 2006; 2010). Furthermore, a substantial and ongoing loss of forest resources is projected to escalate in Eastern and Southern Africa (Burgess and Clarke, 2000; Nair, 2006; Mwase *et al.,* 2007; Biggs *et al.,* 2008) due to ineffective sustainable forest management (SFM) practices (FAO, 2006; German *et al.,* 2010) related to poor public forest management (FAO, 2010).

The existing forests in the sub-regions still play vital ecological, economic and livelihood roles, and the respective countries have fully realised this fact, and are beginning to strengthen the management of these resources through Sustainable Forest Management practices (Owino, 2003; Gondo, 2010). However, a challenge exists in that the initiatives in place are not effectively and efficiently meeting the primary objectives of Sustainable Forest Management (German *et al.,* 2010; Gondo, 2010). On-going Forest Certification initiatives in the sub-regions could be one of the possible tools to meet this challenge (Barklund and Teketay, 2004) so that forests continue to contribute concurrently and progressively to the vision of green growth and economy (Muthoo, 2012). Forest Certification provides forest owners and managers with independent recognition of their responsible management practices and, hence, premium price for their forest produce (Muthoo, 2012).

Forest Certification (FC) schemes emerged in 1990s as a significant and innovative avenue for standard setting and governance in the Sustainable Forest Management realm (Cashore *et al.,* 2006; Auld *et al.,* 2008). It has been strongly promoted by civil society organisations (UNEP, 2002). It resulted from public disillusionment with the failure of governments and intergovernmental bodies to improve forest management or tackle deforestation effectively, and the lack of discrimination by forest industries about the source of their products (Auld *et al.,* 2008; Marx and Cuypers, 2010). Nussbaum and Simula (2005) described Forest Certification as a process of verifying that a forest management unit (FMU) meets the requirements of a standard for forest management. The purposes of Forest Certification are to: (i) improve the social, environmental and economic quality of forest management, thereby, providing a tool to contribute to the achievement of SFM; and (ii) allow the market to reliably differentiate and purchase products coming from responsibly managed forests and provide the managers of these forests with improved market access for their products (Nussbaum and Simula, 2005).

However, inadequate capacity for Forest Certification at various levels and awareness remain among the challenges facing the promotion of Forest Certification in the sub-regions (Teketay *et al.,* 2016), and hence low uptake of the initiative. This study aimed at assessing the status of Forest Certification in Eastern and Southern African countries with a view to strengthening national capacities for Forest Certification, and to facilitating the development of Forest Certification initiatives in different eco-regions (i.e. forest types). Specifically, the study: (i) identified and analysed key elements and policies for Sustainable Forest Management and Forest Certification; (ii) identified the types and areas of forests certified and/or undergoing the processes of certification; (iii) determined the types and numbers of forest certificates issued and the consequent certified forest products and/or services; and (iv) performed a SWOT analysis of past and on-going efforts on Forest Certification in promoting forest use and trade policy while ensuring forest resources are used in a sustainable manner to meet the economic, ecological, social and cultural requirements of the people who depend on them.

METHODOLOGY

Study Area. The study covered countries in eastern and southern African sub-regions, i.e., Kenya, Madagascar, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (Figure 1). The extent of forest covers in the sub-regions are estimated at about 225 and 222 million ha for eastern and southern Africa, respectively (Table 1).

Review guide. Clear search strings guided by the review questions were used. A set of clear inclusion and exclusion criteria were also used. These included language (English), location (Eastern and Southern Africa) and year of publication (1990 – to date). Moreover, literature for review was searched through Google scholar, Web of Knowledge, CAB Abstract, AGRIS and institutional Websites, e.g., FSC, forest companies.

Forest types considered in the study were miombo woodlands (Figure 2), plantations and other forest types, such as wet and dry forests for

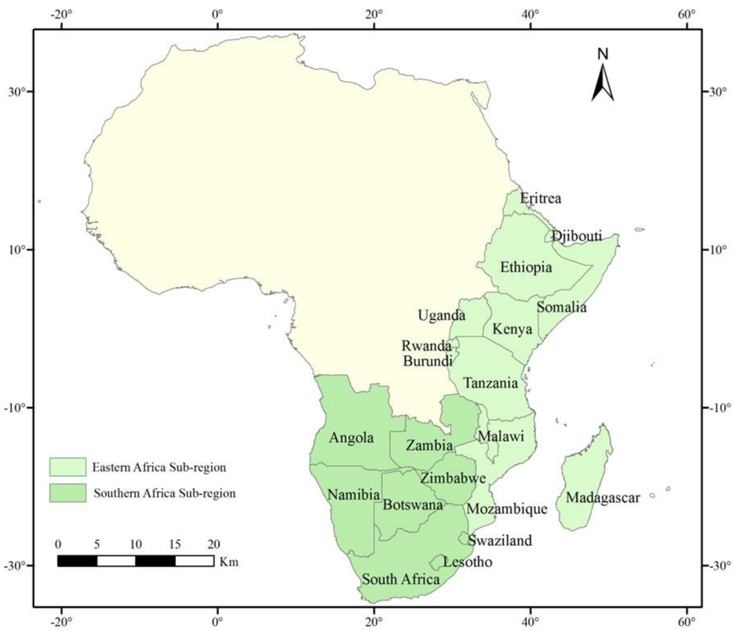

Figure 1. Map showing countries in eastern and southern African included in the study

the respective countries. Generally, vegetation types in all these countries were dominated by woodlands, which were under similar policy and legal frameworks (e.g. forest policy and legislation) for their management, conservation and use.

The study deployed narrative review methodological approach. The type by objective was the status quo review of the Forest Certification literature. Moreover, experts, forest managers and practitioners were interviewed to share their experience and views with regards to Forest Certification in the sub-regions. Results were based on a qualitative rather than a quantitative statistical level.

Data collection. Primary and secondary data and information about the status of Forest Certification in Eastern and Southern Africa were gathered through literature review (journal papers, books, reports and website/databases of Forest Certification schemes and certified companies/entities). Other tools/approaches used were stakeholders' consultation through interviews and meetings via telephone, emails and Skype. Purposively sampling approach was used to identify stakeholders (experts, forest managers/practitioners). They were then invited for interview and were requested to give consent for the interview. The data and information collected from interviews were used for triangulation of the facts from the literature.

Data analyses. Data and information gathered on types of certificates, number and areas certified were analysed using qualitative method. The SWOT analyses were used to identify the internal factors related to strengths and weaknesses, and external factors related to opportunities and threats of past and on-going efforts on Forest Certification in the sub-regions. The SWOT qualitative analysis was followed up with A'WOT quantitative analysis. This is a combination of Analytic Hierarchy Process (AHP) and SWOT analysis to quantify the groups and factors by weighting them (Kurttila *et al.,* 2000; Kajanus *et al.,* 2012). The weightings' scale ranged from 0.00-1.00, whereby 0.00 was lowest score and 1.00 was highest score. The qualitative information gathered from stakeholders interviews were analysed descriptively.

RESULTS AND DISCUSSION

Forest cover, distribution and certified areas in eastern and southern Africa. The extent of forest cover of eastern and southern

Figure 2. Forest Stewardship Council-certified miombo woodlands in Kilwa in Tanzania (Photo by Mpingo Conservation Development Initiative - MCDI).

Africa in September 2015 was 224,967,000

and 222,344,000 ha, respectively (Table 1). However, The FSC-certified areas for eastern and southern Africa were 242,000 and 1,563,000 ha, respectively.

At sub-regional level, the Forest Certification initiatives started in 2002 in Eastern Africa (Owino, 2003), and in 2007 in Southern Africa with the objective to facilitate, analyse and document a process by which stakeholders would formulate and agree on a regional capacity building strategy for Forest Certification promotion. Unfortunately, the regional initiatives did not bear any promising fruits due to inadequate capacity, i.e., inadequate financial, physical and human resources, resulting in slow adoption and implementation of Forest Certification . However, there had been some successful Forest Certification initiatives at the level of individual countries since the late 1990s in the sub-regions, which have been mainly driven and supported by private forest companies (Cashore *et al.,* 2006). The southern Africa sub-region is leading in terms of forest certification because there are more forest companies compared to in eastern Africa (Table 1).

Table 1. The extent of forest cover, distribution and certified areas in eastern and southern Africa (in 1000 ha) by September 2015

Country	Forest cover	Distribution			Certified area
		Primary forests	Other naturally regenerated forests	Planted forests	
Burundi	468	156	120	192	0
Djibouti	226	0	226	0	0
Eritrea	9,013	0	9,013	0	0
Ethiopia	53,131	0	53,131	0	0
Kenya	13,778	0	13,581	197	0
Madagascar	26,939	3,036	23,488	415	0
Malawi	3,147	844	1,938	365	0
Mozambique	52,361	0	52,299	62	60
Rwanda	541	7	161	373	0
Somalia	6,363	0	6,360	3	0
Tanzania	54,044	0	53,804	240	143
Uganda	4,956	0	4,905	51	39
Total-East Africa	***224,967***	***4,043***	***219,026***	***1,898***	***242***
Angola	57,856	0	57,728	128	0
Botswana	45,631	0	45,631	0	0
Lesotho	145	0	135	10	0
Namibia	15,026	0	15,026	0	138
South Africa	33,799	947	31,089	1,763	1,301
Swaziland	1,082	0	942	140	125
Zambia	54,743	0	54,681	62	0
Zimbabwe	14,062	801	13,153	108	0
Total-Southern Africa	***222,344***	***1,748***	***218,385***	***2,211***	***1,563***

Source: FAO, 2015; FSC, 2015

Key elements and policies for SFM and Forest Certification in the sub-regions. The FSC is the only Forest Certification scheme operational in the sub-regions. The concept of Forest Certification has not yet taken strong root in all the countries of eastern and southern Africa. The status of Forest Certification initiatives observed in the sub-regions is due to individual country's efforts, which were mainly driven by private forest companies and Environmental Non-Governmental Organisations (ENGOs).

All the countries in the two sub-regions have sectoral policy and legal frameworks and institutional arrangements, which are pro-SFM. These provide an enabling environment for Forest Certification adoption and implementation in the sub-regions despite the fact that the institutions do not explicitly deal with Forest Certification legally, except Namibia, South Africa and Uganda. However, there is inadequate and unethical implementation of policy and legal frameworks for SFM, due to weak forest law enforcement and governance (FLEG), suggesting that weak FLEG was another impediment to effective adoption and implementation of Forest Certification in the sub-regions. This could be attributed to the voluntary nature of Forest Certification and the lack of legal support for Forest Certification (Mickels-Kokwe and Kokwe, 2013) in most of the countries.

There was a positive perception towards Forest Certification in the respective countries because the stakeholders and governments were involved and/or plan to implement SFM practices to manage their forests responsibly. The construction and furniture industries, as well as government ministries, departments or agencies were willing to buy timber from certified forests, in particular through the adaptation of public procurement policies geared towards purchasing certified forest products and ecosystem services. Stakeholders from countries like Tanzania indicated that there was on-going dialogue with the government to review the procurement procedures to accommodate the sourcing of certified forest products.

Types and areas of forests certified. The total areas of FSC-certified forests in eastern and southern African showed or reflected a situation of stagnation or decline (Figures 3 - 5). In Kenya, the first forest operation of FSC was certified in 2005 (Figure 3) for a community-based agroforestry project, but the certificate was not renewed, evidently on cost grounds; and at the time of this study, there was no forest that was FSC-certified. However, there was an on-going certification process for a charcoal project by Wild Living Resources.

In Madagascar, the first forest operation was FSC-certified in 2010, and there was no operation undergoing the process of certification. In Mozambique, the first forest operation was FSC-certified in 2006, and there were some operations undergoing the process of certification with Niassa Green Resources (Figure 3).

Since the first certificate issued in 1999 in Namibia, the trend of Forest Management certified area has since been fluctuating, and in recent years it has declined, though it was still above other countries in the two sub-regions, except South Africa. In Namibia there were no forests/ operations undergoing certification. The Forest Certification under the FSC system in South Africa has gone a long way, more than in other countries in both sub-regions, with the first FSC certificate having been issued in 1997. Since then, the trend of Forest Management certified area increased in South Africa more than in the other countries in the sub-regions, until 2010. Thereafter, it has been declining, though it was still above all other countries. By the time of this study, there was no forest

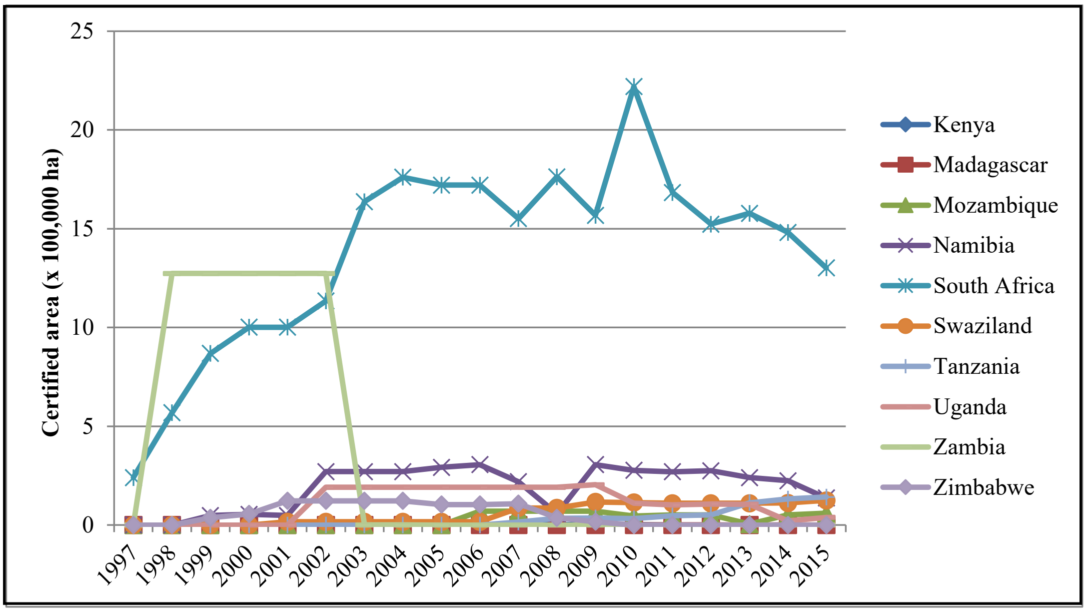

Figure 3. Forest Certified areas in eastern and southern Africa (1997 - 2015) (source: FSC, 2015)

certification going on in the country. South Africa was also distinctive in that the certification process was concentrated in plantations rather than natural forests.

In Swaziland, the first forest operation of FSC was certified in 2001, but there was no further forest certification operations going on at the time of the study (Figure 3). In the case of Tanzania, since the first certificate in 2007, there has been a rise in FM certified area, particularly during the last three years. In fact by the time of this study, it was above all the other countries in the eastern Africa sub-region (Figure 3). There were several operations undergoing the process of certification then. There were on-going initiatives with the New Forests Company (Tanzania) Ltd. The MCDI was expected to certify 7,600 ha more community natural forests in Kilwa before the end of 2015. The MCDI had plans to expand the scope of their operations outside Kilwa and Rufiji Districts. Two more districts, Tunduru in Ruvuma Region and Liwale in Lindi Region, were expected to be covered in this expansion. Community forests of about 100,000 ha were to be FSC-certified in Tunduru before 2017; while some initial preparations were on-going to certify about 78,000 ha in Liwale, depending on the availability of funds.

The Forest Certification in Uganda had gone a long way, and it was the first country to have an FM certificate in the eastern Africa sub-region (Figure 3). The Uganda Wildlife Authority obtained a FM FSC certificate for the Mt. Elgon National Park and Kibale National Park under the Forests Absorbing Carbon Dioxide Emissions (FACE) Project in 2002. This was an early example of the use of FM certification for certifying ecosystem services and it was achieved using existing local FM standards. There were also other operations undergoing the certification process in Uganda then. There was an initiative for piloting the MAP process with financial support from the FSC International Smallholder Fund. Three private owners of small natural forests on Lake Victoria islands in Kalangala District were identified for the pilot scheme. The National Forestry Authority (NFA) was also in the process of certifying Kalinzu Central Forest Reserves (CFR), one of its tropical forests.

Zambia was the second country to be FSC-certified in 1998 after South Africa in the southern Africa sub-region, and in fact initially had more area certified than South Africa, but there were no forests/operations undergoing certification in Zambia then. In Zimbabwe, the first forest operation was FSC-certified in 1999, but there were no forests/operations undergoing certification at the time of this study.

Types and numbers of forest certificates and certified forest products issued. There were a total of nine and 28 FM certificates in eastern and southern Africa, respectively (Figure 4), with a few operations undergoing the certification process in Kenya, Mozambique, Tanzania and Uganda.

There were a total of two and 107 FSC CoC certificates in eastern and southern Africa, respectively (Figure 5). Kenya was the first country in the eastern sub-region to obtain a CoC certificate in 2005 (Figure 5). However by the time of the study, the country had no CoC certificate. Since its first certificate, Kenya was the country with highest number of CoC certificates than any other countries in the sub-region up to 2011, although the number of certificates was relatively few. Since the first CoC certificate in 2010 in Madagascar, the number has increased and, thereafter, remained constant up to 2013, and declined thereafter. Mozambique received its first CoC certificate in 2011, which has been maintained to-date (Figure 5).

Namibia had three CoC certificates. Since its first CoC certificate in 2005, the number has remained relatively constant, but above the other countries in the two sub-regions, except in South Africa (Figure 5). South Africa was the first country in the southern sub-region to obtain a CoC certificate in 1997. By the time of this study, the country had 104 CoC certificates (Figure 5). Since receiving its first certificate,

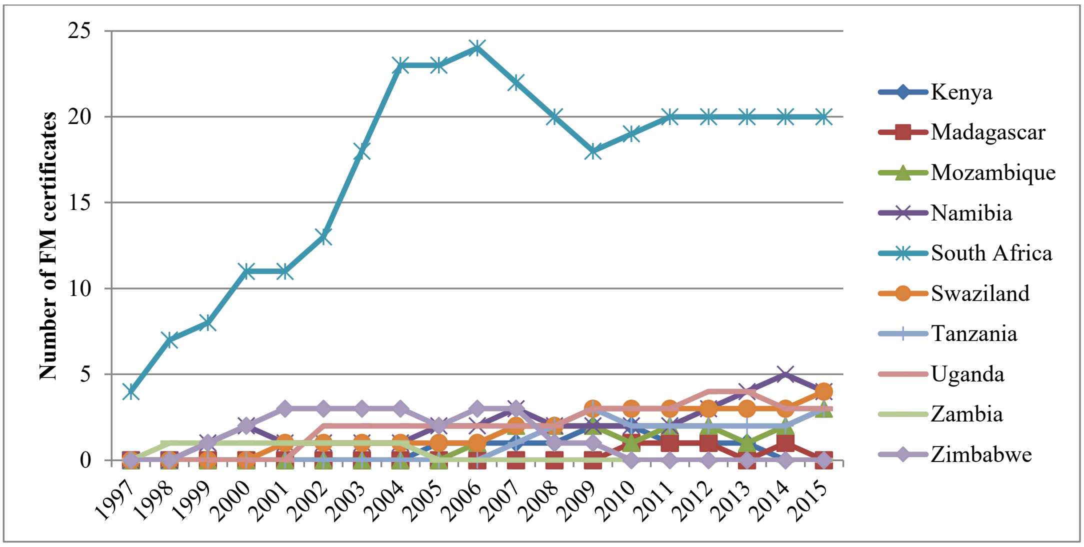

Figure 4. Number of FM certificates in Eastern and Southern Africa (1997 - 2015) (source: FSC, 2015).

South Africa remained the country with the highest number of CoC certificates in the two sub-regions.

In Tanzania, there was just one CoC certificate and the number of such certificates has been fluctuating, but increased a little above the other countries in the eastern Africa sub-region for some years; though it eventually declined (Figure 5). Uganda has not obtained any CoC certificate so far. Swaziland, Zambia and Zimbabwe no longer have any CoC certificates. Since the first certificate in 2001 in Swaziland, the number of CoC certificates has been relatively constant with a slight increase in 2007, thereafter, it declined to the current state. In Zambia, since the first certificate in 1998, the number of CoC certificates had been constant up to 2004, thereafter, the number diminished to zero. Zimbabwe received its first CoC certificate in 1999 with the number of CoC certificates fluctuating over the years up to 2009, but it also declined to zero. There was no certificate yet for ecosystem services (e.g. Carbon, Biodiversity, Watershed, Ecotourism, etc.) anywhere in the sub-regions.

SWOT analyses of Forest Cerfication in the sub-regions. Figure 6 summarises the suggested reasons for the current low development of Forest certification in the sub-region, including barriers to and benefits of FM certification. The weightings of the SWOT factors (see Figure 6) by A'WOT application showed the highest weight for inadequate appropriate capacity as a weakness for Forest Certification adoption/ promotion and implementation in the sub-regions (human, physical and financial resources), i.e., no locally-based accreditation and certification bodies, and standards, among all other factors. The increased costs of FM and production had the least weight as a threat for Forest Certification adoption/promotion and implementation in the sub-regions. The weightings of the SWOT groups showed weaknesses to be predominant followed by opportunities. Strengths and threats

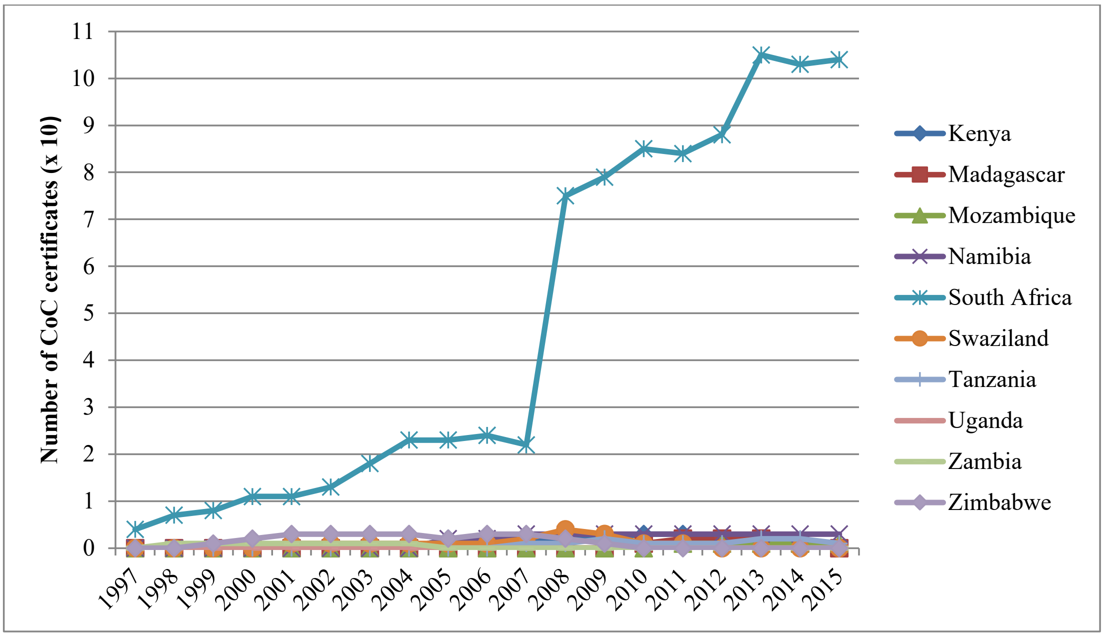

Figure 5. Number of CoC certificates in Eastern and Southern Africa (1997 - 2015) (source: FSC, 2015)

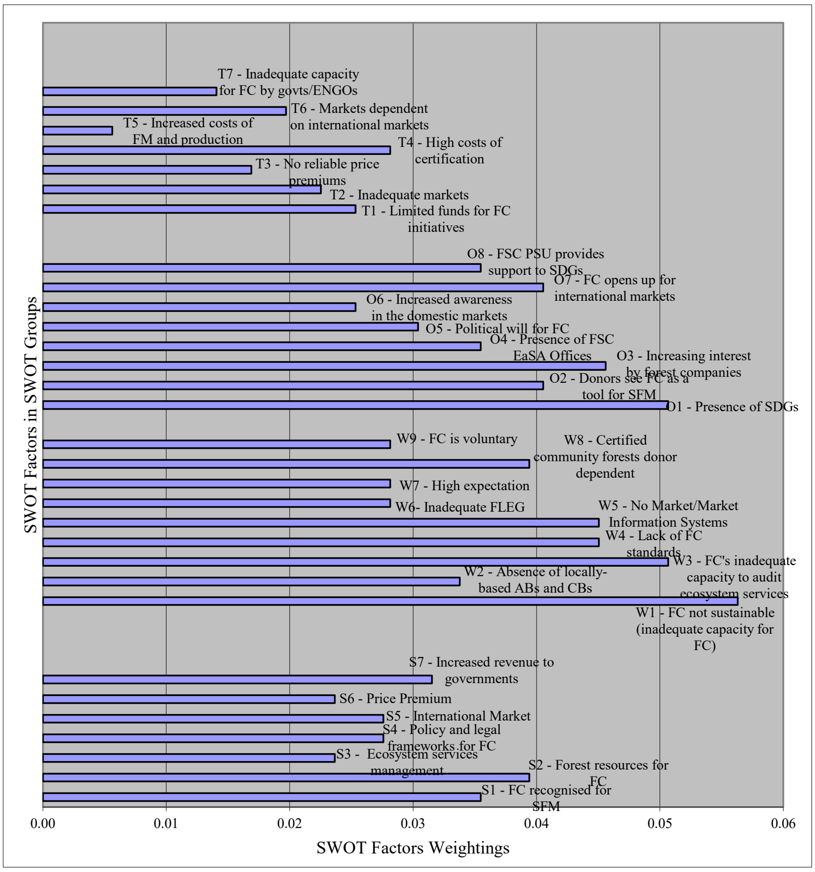

Figure 6. Graphical interpretation of the results of pairwise comparisons of SWOT groups and factors for SWOT analyses of past and on-going efforts of forest certification in the sub-regions. (Note: the higher the value means the higher weight given to the SWOT factor and vice versa).

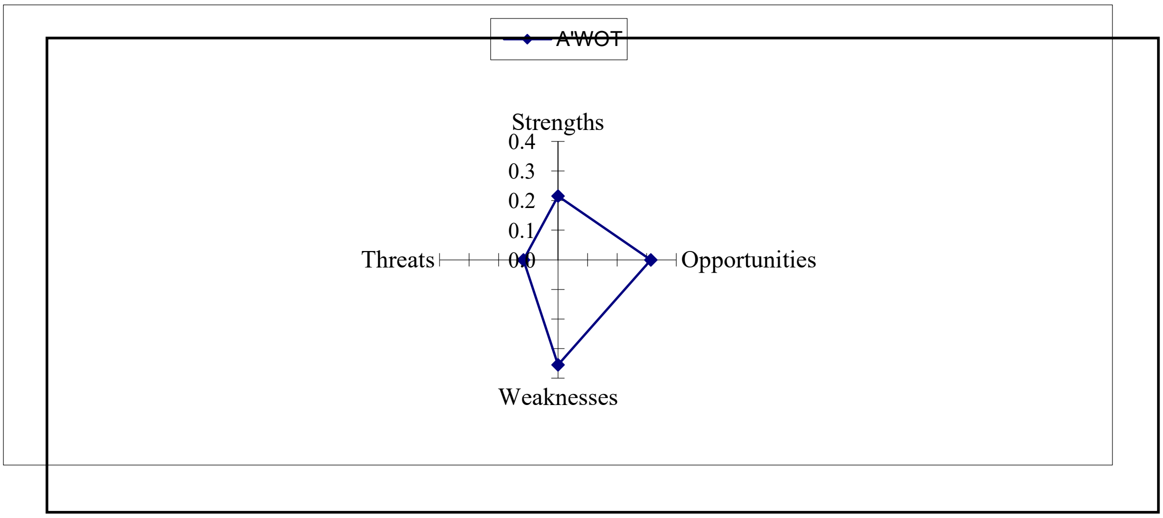

Figure 7. Relative importance of SWOT groups in an A'WOT application to SWOT analyses of past and on-going efforts of forest certification in the eastern and southern Africa sub-regions.

were the least (Figure 7).
The past efforts on Forest Certification in the sub-regions have brought some positive social benefits to stakeholders. For instance, stakeholders revealed that there was a general trend across countries in improved communication between forest companies/ entities and their rural neighbours through outreach programmes, as well as their workers through employment. There were improved working conditions, including signing of work contracts, transparent collective bargaining and higher remuneration above the minimum government rates, and provision of health insurance and safety at the work place. Furthermore, through outreach programmes, certified companies/entities work with their neighbours on community-based projects, such as infrastructure development, including rural roads construction, schools, health centres and water supply in the sub-regions. All these observations corroborate with literature that forest certification improves workers' conditions and welfare (see e.g., Karmann and Smith, 2009; Cerutti *et al.,* 2014; Kalonga and Kulindwa, 2017).

The Forest Certification enables businesses and consumers to make informed choices about the forest products they buy, and drive positive change by engaging the power of market dynamics, i.e., supply and demand (FSC, 2012). However, the availability of certified forest products markets and market information was limited in the sub-regions and this affected certified forest products businesses in the sub-regions. Similarly, Purbawiyatna and Simula (2008) reported that consistent information on production and trade data on certified products and markets was unavailable worldwide, particularly in the two sub-regions. This in turn was due to the lack of markets but the availability of certified products itself constrained market development. In addition, marketing structures and information systems for certified forest products were largely absent in the two sub-regions. This implies that there was inadequate consumers' awareness and preference for certified forest products in the sub-regions. This was attributed to the fact that customers were uninformed about and could not differentiate between certified and non-certified forest products in the market. The absence of Forest Stewardship Council National Offices further limited the ability to promote certification and certified products locally. However, consumers in the sub-regions normally opted for low priced products.

In the international markets where certified forest products have reliable markets (Cashore *et al.*, 2006), there were still limited marketing information systems linking the owners of forest resources, primary producers and the traders in these markets (Kalonga *et al.,* 2014). There were significantly more markets established in Europe and America (Ham, 2006; Njovu, 2006; Dieckmann and Muduva, 2010; Mickels-Kokwe and Kokwe, 2013). However, these markets were dominated by a few buyers (through closed marketing structures), who were aware of what certified forest products are, hence they tend to control the market, resulting in no effective competition, and do not pay premium prices to producers (Kalonga *et al.,* 2014). The Forest Certification market information systems are of paramount importance to stakeholders because they provide a reliable source of information on the markets, which recognise and promote responsible forest management and reward it accordingly (FSC, 2012). This implies that market information systems for certified forest products/services in the sub-regions could inform producers and consumer groups of the economic, environmental and social benefits that Forest Certification brings (Karmann and Smith, 2009).

Despite the marketing constraints, stakeholders viewed Forest Certification as a useful management tool that can guide them in their day-to-day operations. At the same time, Forest Certification had brought a keen awareness of the social issues related to forestry, i.e., existence of better communication mechanisms between foresters, their rural neighbours and employees (Ham, 2006). This illustrates that Forest Certification focuses not only on ecological aspects of harvesting for timber production but also includes social and economic issues (Duchelle *et al.,* 2014). Also Forest Certification works towards ensuring that economic and social benefits of well-managed forests are shared equitably throughout the value chain of forest products (FSC, 2007; Kalonga *et al.,* 2014). Moreover, the social positive impacts of Forest Stewardship Council include material benefits for workers such as good working conditions, employment of local workers with higher wages and improved workers' training (Cerutti *et al.,* 2014; Kalonga *et al.,* 2014). At community level, benefits include community-based projects, such as infrastructure development, including rural roads construction, schools, health centres and water supply in the sub-regions. This finding was also reported by Kalonga *et al.* (2014) in a study about benefits that communities derive from certified forests.

The environmental benefits and the potential for related economic gains have increased importance in Forest Management, not only in the context of preserving high conservation values such as wildlife and endangered species in general but more and more in the mitigation of climate change effects and the protection of water resources. Forest Stewardship Council had a unit dedicated to the certification of ecosystem services and was launching a scheme for the payment for forest ecosystem services, particularly for carbon sequestration and water sources (FSC, 2015b). These have the potential for generating new income revenues for local populations.

The Forest Certification initiatives, among others, enable greater market security (international markets in particular) and higher prices for forest products to forest owners, managers and timber dealers (Njovu, 2006; Quaedvlieg *et al.,* 2014). These act as market incentives (e.g. the opportunity for premium prices) and drivers of certification (Meijaard *et al.,* 2014). Such markets could provide reliable income to forest owners/managers and local suppliers in addition to providing opportunities for expansion (Njovu, 2006). However, the perceived market advantage of obtaining Forest Certification did not materialise to the degree that some certificate holders expected in the sub-regions. This corroborates the findings by Kalonga *et al.* (2014). From a market perspective, certification should lead to a premium price, which could pay for the incremental cost of good stewardship by forest managers, and for the certification costs (Meijaard *et al.,* 2014). However, certificate holders were not receiving premium prices for their forest products. These observations were also confirmed by Kalonga *et al.* (2014).

One of the biggest barriers to Forest Certification was the initial cost, especially for smallholder private owners and communities (Cashore *et al.,* 2006). Certification typically increases management costs by 5% -20% without clear financial returns (Wong, 2005). Costs are a combination of the direct costs of registration and audit and indirect costs related to additional management inputs to prepare for audit. Nevertheless, the costs of forest management and production were perceived as the least threat in the implementation of Forest Certification in the sub-regions, and some of the initial costs could be reduced through the application of the FSC International Smallholder Fund, the SLIMF standard and MAP.

CONCLUSIONS

The initiatives for strengthening SFM employing Forest Certification through the adoption and implementation of its best practices in eastern and southern Africa sub-regions were apparent but low. The Forest Certification acted as a market-driven management and conservation tool. The adoption and promotion of Forest Certification in the sub-regions would contribute to the wise use of forest resources, which would in turn, promote conservation values at the same time enhancing restoration of degraded forests and the socio-economic wellbeing of people who depend on forests. The sub-regions have good enabling policies and legal frameworks for the implementation of responsible forest management. Thus, it should not be unduly difficult to certify more forests.

RECOMMENDATIONS

Much more work still needs to be done in terms of capacity building to make Forest Certification a norm in the management and governance of forests, and certainly, a lot more work is needed in relation to smallholder private natural forests and community forests. Market development is also a priority both in terms of access to market information and the promotion of the benefits of forest certification and certified products and services.

To ensure that there is an effective and efficient adoption and implementation of Forest Certification in the sub-regions, the development of frameworks and policies for SFM and Forest Certification should capitalise on the existing opportunities to address the prevailing weaknesses and hence, enhance the strengths to overcome the threats.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Prospects for public private partnership in Nigerian forestry sector

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ABSTRACT
The failure of the classically structured resource management institutions in most African countries has continued to precipitate an inclination of governments and other stakeholders to consider public-private partnership in forest management and governance on the continent. In spite of its importance, information on public-private partnership in the forestry sector in most of Sub-Saharan Africa is inadequate. Therefore, this study examined the prospects for public-private partnerships in forestry in Nigeria with a view to harnessing its potentials towards contributing to sustainable development of the forest sector. Data were collected through desk research, field visits, and interview schedule. Three interrelated processes involving collecting, organizing and analyzing information were followed. A SWOT analysis was also undertaken. Findings show that primary forest production is still essentially a government concern in all parts of Nigeria. However, private ownership is also fast becoming a significant form of control, especially in the south-west zone. The secondary forest production segment is private sector-led. The production activities in the segment range from small to medium to large scales. There are gender-specific inequalities and capacity utilization is also generally low (barely 50.0%). The private forestry sector contributes significantly to income, employment, wood energy, food, medicine and housing. Identified facilitating factors for public-private partnership include huge employment and income opportunities; large foreign and domestic markets, and; provisions for participatory and sustainable forest management in the National Forest Policy, among others. Overall, and given the right policy environment, there is a positive perception among respondents on the desirability of public-private partnership in the development of the forestry sector in the country.

Keywords: Forest management, forest policy, governance, Nigeria, public-private partnership

RÉSUMÉ
L'échec des institutions de gestion des ressources classiquement structurées dans la plupart des pays africains a continué à inciter les gouvernements et autres parties prenantes à envisager un partenariat public-privé pour la gestion et la gouvernance des forêts sur le continent. Malgré son importance, les informations sur les partenariats public-privé dans le secteur forestier dans la plupart des pays d'Afrique subsaharienne sont insuffisantes. Par conséquent, cette étude a examiné les perspectives de partenariats forestiers public-privé dans le secteur forestier au Nigéria en vue d'exploiter son potentiel pour contribuer au développement durable du secteur forestier. Les données ont été collectées par le biais de recherches documentaires, de visites de terrain et d'interviews. Trois processus inter-reliés impliquant la collecte, l'organisation et l'analyse des données ont été réalisés ainsi qu'une analyse SWOT. Les résultats montrent que

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la production forestière primaire reste essentiellement une préoccupation gouvernementale dans toutes les régions du Nigéria. Cependant, la propriété privée est de plus en plus en train de devenir une forme de contrôle importante, en particulier dans la partie Sud-Ouest du pays. La production forestière secondaire est aux mains du secteur privé. Les activités de production de ce secteur se situent à petites, moyennes et grandes échelles. Il existe des inégalités spécifiques aux sexes et l'utilisation des capacités existantes est généralement faible (environ 50,0%). Le secteur forestier privé contribue de manière significative aux revenus, à l'emploi, au bois-énergie, à l'alimentation, à la médecine et au logement. Les facteurs de facilitation identifiés pour les partenariats public-privé incluent d'énormes possibilités d'emploi et de revenus; de grands marchés étrangers et nationaux et des dispositions pour la gestion forestière participative et durable dans la politique forestière nationale, entre autres. Globalement, et compte tenu du cadre politique approprié, les enquêtés ont une perception positive de l'opportunité d'un partenariat public-privé pour le développement du secteur forestier dans le pays.

Mots clé : Gestion forestière, politique forestière, gouvernance, Nigéria, partenariat public-privé.

INTRODUCTION

Nigeria's forests estate is mostly owned, controlled and supervised by the public sector. The State control of land and forest resources was a concept introduced and imposed during the colonial era even where and when other traditional resource use and customary ownership systems already existed (Bada, 1998). However, the current economic climate in Nigeria is such that government funding alone cannot adequately drive the satisfactory and sustainable development of the forest sector. Besides, given the gloomy picture that characterizes the country's forestry sector at the moment, there is an urgent need for innovative funding and management arrangements. Technical, commercial, institutional and policy innovation are also required to accelerate the development and delivery of large-scale reforestation and afforestation programmes in the country. Sustainable forest management requires that management ensures utilization that meets present demand for forest products and services and also ensures that future generations' ability to have the products and services is not compromised. It is also widely agreed that financing of sustainable forest management (SFM) requires mobilization of significant incremental financial resources and diversification of financing sources (Castrén *et al.,* 2014). For this goal to be achieved, the public and private sectors involved in forestry practices must collaborate.

The collaboration of the public and private sectors in what is termed Public-Private Partnership is a contractual agreement between a public agency and a private company or consortia of companies (Jorgensen, 2006). Through the agreements, the skills and assets of the public and private sector are shared in delivering a service or facility. In addition to the sharing of resources, each party may share the potential risks and benefits associated with delivery of the service and facility. The public-private partnership arrangements are specifically developed to suit the needs and circumstances of an individual project. A public- private partnership arrangement may be funded and operated through a partnership of government and one or more private sector companies. They are typically medium to long term arrangements whereby some of the service obligations of the public sector are provided by the private sector or vice versa, with clear agreement on shared objectives for delivery of public infrastructure and/ or public services.

There is a relatively long history around the world about joint public/private investments in other sectors, mainly for large infrastructure projects, with well-developed guidelines and risk sharing criteria. Public-private partnerships in the delivery of public services have become a phenomenon which is spreading across the globe and generating great interest. The concept has gained increasing attention, particularly since the 2002 UN World Summit on Sustainable Development in Johannesburg, where the need for collaborative alliance was highlighted (Jorgennsen, 2006; Sathaye *et al.,* 2007). According to the World Bank (2015), it is crucial to mobilize private sector investments in high-quality sustainable infrastructure in order to ensure easy access to markets and basic services that will boost trade and productivity, provide jobs and improve people's lives.

In spite of its importance, public-private partnership is less developed in natural resources management. Information in the forestry sector in most of Sub-Saharan Africa is inadequate. There is need for disaggregated data analysis to help fill the information gap. Studies are required to support the emergence of organized private sector for sustainable forest management and enhanced livelihoods in the Sub-Saharan Africa region. Therefore, this study examined the prospects for public-private partnerships in forestry in Nigeria with a view to harnessing its potentials towards contributing to sustainable development of the forest sector.

RESEARCH APPROACH

The study was carried out in the three main agro-ecological zones of Nigeria namely: High/ Moist Forest, Savanna and Sahel (Figure 1).

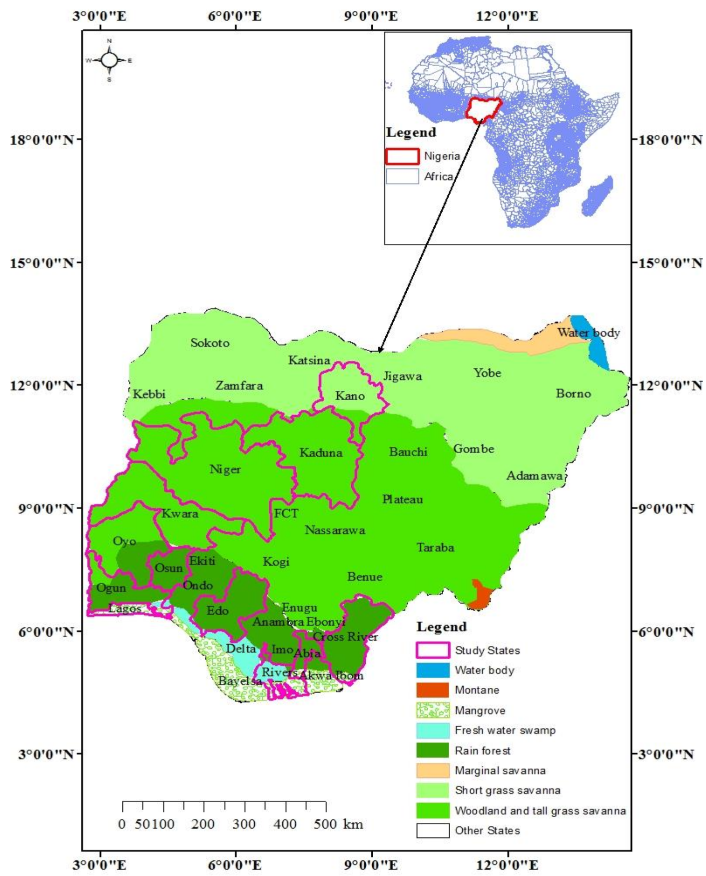

Figure 1. Agro-ecological map of Nigeria showing the study States

The following States were covered physically through visits: Lagos, Ogun, Oyo, Osun, Edo, Abia, Rivers, Cross Rivers, Niger, Kaduna, Kano and Kwara. The States were further stratified by agro-ecological as well as geo-political settings. Within these settings, study localities were selected across primary forest production and secondary forest production (wood processing, marketing and trade) including Small and Medium Enterprises. The methodology used consisted of desk research, field visits, and interview schedule.

From the desk research, we collected relevant documents about public-private partnerships on the internet and in the library. Several literatures that covered various aspects of forestry in the country were explored. The information accessed were on forest types, tree species preferences, types of timber andnon-timber forest products, primary and secondary production, technology adoption, recovery efficiency, key actors, and potential opportunities for public-private partnerships in the forest sector. Three interrelated processes involving collecting, organizing and analyzing information were followed.

The field visit enabled the team to have direct information on activities in selected forest industries and businesses. Forest sites, factories, timber yards, furniture making sheds, wooden pole treatment plants, saw mills and pulp and paper production plants were visited. The visits yielded information that supported various aspects of the study.

The interview guide involved a checklist of questions prepared and forwarded to forestry stakeholders in the country. Participants included forest officers, saw millers, tree growers, wooden pole manufacturers, woodworks sector operators and researchers. The stakeholders were consulted through visits, emails and phone discussions. Information were obtained about the employment opportunities, policies, regulations and other factors facilitating and/or constraining the development of forest products industry. Also, gender specific inequalities/ opportunities in the forest sector were examined.

The data collected were essentially qualitative and they were subjected to critical interpretation. The projections of supply and were analysed demand of key forest products in the country covered. A SWOT analysis was also undertaken. The unavailability of recent data in some areas was a major limitation. In this case, expert estimates were used in absence of accurate information.

RESULTS AND DISCUSSION

Key actors in primary and secondary forest production. Primary forest production is essentially a government concern in all parts of Nigeria. The largest proportion of timber in use is extracted from reserved natural forests and other public plantations. By virtue of the National Forest Policy of Nigeria, 2006, and the Land Use Act of 1978, the ownership of the forest reserves is vested in the State governors who hold them in trust for the people. Thus, approval of the governor or his/her delegated authority (usually the State's Director of Forestry) is required for the extraction/withdrawal of timber from forest reserves. This is the situation in all the six geo-political zones of the country (north-east, north-central, north-west, south-west, south-south and south-east).

Nevertheless, private ownership is fast becoming a dominant form of ownership for primary forest production in south-west zone of the country. Some of the notable partakers in this regard are Obasanjo Farms (1,300.0 ha), Evergreen Tree Plantations (1,200.0 ha), Heritage Plantations (50 ha), Afe Babalola Forest Plantation (500 ha), and Bola Odebiyi Ventures (4 ha), among others. There are also pockets of private plantation owners in the south-east and south-south zones. Within the north-central zone, the University of Ilorin has established over 600 hectares of Teak plantation in the last eight years. Some of the participants in the interview guide within the zone also indicated owning private forest estates. In contrast, private forest estates ownership was found to be very low within the north-west zone. For all the zones, the sizes of the private forest estates (which are largely mono-crop plantations) were generally small, such that the largest proportions of timber extraction are still being carried out in government forest reserves.

The secondary forest production segment in Nigeria is dominated by private individuals. Government involvement at this level is virtually non-existent and this is the same for public-private ownership. The production activities in the secondary forest production sector range from small to medium to large scales. Small scale production is by far the largest employer of labour and income provider within the segment. The activities identified in secondary forest production in the country include:saw milling, pulp and paper production, production of wooden transmission poles, match production, furniture and joinery moulding. Others are production of rattan furniture, wood carvings, chew-sticks, fuelwood, charcoal and non-wood forest products.

Tree **species raised and managed in primary forest production.** Timber species extraction in government forest reserves is influenced mainly by climatic and utility preferences. For instance, in the south-west zone, the five most important timber species included *Afzelia africana* (Red Apa), which was the most preferred among the respondents. This species, found largely in the natural forest, is widely sought after because of the beauty and durability of its wood. It is, however, currently endangered in many parts of the country as there are tremendous pressures on its germplasm in the natural forest; and it is very rare in plantations. The other species are: *Milicia excelsa* (Iroko), *Khaya* spp (Mahogany), *Gmelina arborea* and *Mansonia altisima*. These are also very popular among users. Unfortunately, some of them (e.g. *Milicia excelsa* and *Mansonia altissima*) are equally not raised in plantations in the country. They still occur largely as wild stands in remnants of rainforest, farmlands and other protected areas such as campuses of higher institutions and sacred groves in the southern part of the country.

Gmelina arborea exists in large scale plantations in virtually all parts of the country. The plantations were established in the late 1970s up to the mid-1980s. The original goal of establishment was to supply raw materials to pulp and paper mills at Oku Iboku (south-south), Jebba (north-central) and Iwopin (south-west). Unfortunately, the plantations outgrew the pulping age before the mills could take off and they momentarily became a burden to the States owning them. It was only at the beginning of 1990s that wood processors discovered that Gmelina wood was quite good for various uses including: furniture, roofing, doors, as well as window and door frames. This sudden discovery coupled with dwindling supplies of some favourite species such as *Khaya, Terminalia, Mansonia, Milicia* and *Nauclea* from the forest reserves and free areas have now put the species under pressures. Unfortunately, there is no commensurate planting to cope up with the high rate of exploitation. *Tectona grandis* (teak) also faces similar threat. As a matter of fact, its own case is worse off because of the great export demand pressure for its wood. For instance, FAO (2014) reported that the average annual volume of teakwood exported from Nigeria to India alone between 2005 and 2014 was 212,590,000 m^3.

In the northern part of the country (covering north-east, north-central and north-west), some of the most preferred species were: *Khaya senegalensis, Terminalia ivorensis, Diospyros mespiliformis, Piliostigma reticulatum, Gmelina arborea*, and *Eucalyptus camaldulensis*. The commonest tree species found in plantations in the area included: *Eucalyptus* spp; *Azardirachta indica* and *Khaya senegalensis*. These were planted in shelter belts and city avenues as well as road sides. Unfortunately, management regimes for these plantations are near zero. There are no records of past and current yields, growth rate, standing volume or silvicultural treatments. Many of the shelter belts have been devastated by years of uncontrolled exploitation for poles and firewood. At the same time, smallholder woodlots that abound on private farms were established mainly for the supply of poles and firewood. The average plantation size ranged between 0.5 to 2.0 hectares. Around Wudil, in Kano State, small scale Jatropha farms were also encountered. It was observed that some of these farms were being replaced with arable crops such as millet and sorghum. Farmers claimed that there was no market for the Jatropha crops.

Generally, primary forest production in Nigeria is characterized by unplanned and uncoordinated timber extraction and over-harvesting, while the principles of sustainable forest management are not applied in most cases. There is little or no information on age distribution, stand volume and timber yield. There are no concrete plans for sustainable management of the forest estates. The public forests are the worse hit by this menace. In virtually all the zones, there have been no records of inventory, growth monitoring, harvests and regenerations in the last twenty years. In some of the private forest plantations, the stands were found in age series ranging between two and thirty years. But in others, only one or two age classes were recorded. This has implication for sustainability as the harvesting of mono-specific and even-aged stands has left a wide gap in supply trends. The consequence of this is that the country now depends on wood importation from neighbouring countries of Cameroon, Benin Republic, Togo and Ghana.

Industry types in forest production. Industry types in forest production in Nigeria can be classified as small, medium and large scales. Small scale production usually involves between one and five workers including the business owner. They obtain their raw materials from suppliers from remote villages sometimes far away as in the case of rattan canes which are obtained from suppliers mainly from the south-south zone. Although, this sector employs only very few people per firm, the number of individual jobs created by the segment may be up to 500,000 persons.

Furniture and sawmilling are medium scale secondary forest industry types which also contribute greatly to income and employment generation in the country. This is in line with the submission of Ogunwusi (2012), who observed that these industry types contributed greatly to employment.There are over 1000 sawmills located in big and small towns around the south-west zone, with concentration around Ijebu Ode, Ijebu Igbo (Ogun State); Ikire, Ile-Ife (Osun State); Ondo and Ore (Ondo State) and Ebute Meta (Lagos State). These sawmills supply Oko Baba Plank market in Lagos (the biggest timber market in Nigeria) and Bodija Plank market in Ibadan (another notable plank market in the zone). Both markets serve as the major distribution centers for planks to other parts of Nigeria, particularly, the less timber-endowed Northern region. Over two million participants are engaged in both formal and informal employment in this sector. Table 1 shows a generalized structure of timber/timber product market in the country.

Currently, there are few large-scale concerns in the secondary forest industry and they are found mostly in the south-west zone of the country. These include: the agglomeration of hundreds of small firms at Oko Baba in Ebute-Meta, Western Wood Processing Industry at Akure and BISROD Furniture, Ijebu Ode.

Chain-sawmilling which involves *in-situ* timber conversion has also evolved as an important activity of the wood-based industry in the country. Over 70.0% of the planks in the timber markets in south-west and north-central parts of Nigeria during this study were found to have been produced from chain-sawmilling.This is in spite of the extant law, which allows for it only in some special circumstances because of its perceived wastefulness. This activity, however, generates a lot of rural employment ranging from tree finders, chain-saw operators, loaders, transporters and sellers. These activities cut across genders, although it has contributed also to illegal logging in all parts of the country.

There were several secondary forest industry types in the country in the early 1970s up to the end of 1980s. Table 2 shows a list of wood processing units in the country as at 1989. Unfortunately, many of these units have folded up as a result of poor power supply, high equipment cost and shortage of raw materials (Timber). The plywood, paper products and particleboard producing segments of the forest industry are virtually no longer in operation.

The value chain within the forest industry typically involves the resource base (natural and plantation forests) controlled by the States' Forestry Departments, to timber logging, dominated by forest concessionaires/timber contractors, up to the chain-saw operators and the timber haulage operators, then to the saw mills. At the other end of the continuum are the plank sellers and marketers down to the furniture

Table 1. Structure of timber/timber product market in Nigeria

Resources form	Market structure	Sellers	Buyers
Standing timber	Monopoly	Government	Licensed timber contractors, concessionaires/permittees
Round logs/lumber converters	Oligopoly	Licensed timber contractors, permittees	Sawmillers and other primary
Planks/flitches makers/joinery etc.	Oligopoly	Primary converters, plank sellers	Secondary converters/furniture

Table 2. Some wood-based processing units and their locations in Nigeria as at 1989

S/N	Name	Location
1	Nigeria Paper Mill	Jebba, Kwara State
2	Nigerian Newsprint Manufacturing Company	Oku-Iboku, Akwa Ibom State
3	Nigerian National Paper Mill Company	Iwopin, Ogun State
4	African Timber and Plywood	Sapele, Delta State
5	SAFA Splints Limited	Ibadan, Oyo State
6	Piedmont Plywood (Nigeria) Limited	Benin City, Edo State
7	Seromwood Industry Limited	Calabar, Cross River State
8	Calabar Veneer and Plywood Company	Calabar, Cross River State
9	Nigerian Romania Wood Industries Limited	Akure, Ondo State
10	Ekiti Lumber Production Company	Ikere-Ekiti, Ekiti State
11	Ethiope River Sawmill Limited	New Benin, Benin City, Edo State
12	Epe Plywood Industries Limited	Epe, Lagos State
13	Nigerian Wood Preservation Industries Limited	Ikorodu, Lagos State
14	Nigerian Hardwood Company Limited	Abraka, Delta State
15	Woghiren Wood Treatment Factory Forestry Road,	Benin, Edo State
16	Yinka Morenike Plywood and Wood work	Ise Ekiti, Ekiti State
17	Nigerian Hard woods	Burutu, via Warri, Delta State
18	Agatapa Wood Treatment Industry, Abagana	Anambra State
19	Bendel Wood Treatment Factory	Ekenwa Road, Benin-City, Edo State
20	New Nigeria Timber Company Limited	Makurdi, Benue State

Source: Forestry Association of Nigeria (FAN), 1989 makers and the artisans involved in carpentry and joinery works. Basically, conversion and processing efficiency is a major issue along the chain, with recovery being as low as forty percent (40.0%) in many cases.

The rattan furniture value chain is not as long as what is described above, since the resource involved is completely different. The typical rattan furniture value chain progresses from cane harvesting in the forest reserves, to Maryland, Lagos Cane Village (which is a major depot for harvested rattan in the country), then to the respective cane weavers in the various States.

The most profitable product lines in the timber trade are the hardwoods cut into various dimensions such 1" x 12" and 2" x 12". On the other hand, soft woods are considered least profitable. For those in the furniture business, upholstery chairs are considered as the most profitable product line, while the least is bed making. In the rattan segment of the industry, furniture items (especially rattan chairs and tables) are regarded as the most profitable line of product, while gift items (souvenirs) and flower vases are considered the least profitable. Human resource requirements include mainly technical, skilled and unskilled labour. There is also an expanding managerial and supervisory cadre within the segment.

The product lines for sawn-wood identified in the different zones include logging; sawnwood; planks; furniture and saw doctoring. Capacity utilization in all the cases was about 60.0% and below. The factors identified for the low productivity were shortage of raw materials, poor power supply and general economic downturn which led to low market patronage for the products. The high cost of diesel fuel (automotive gas oil) to power generators for processing was also identified as a limiting factor. Average production capacity was about 10m^3 per shift (per day), while log conversion efficiency through flitching at stump was between 36.0-48.0%. Many of the logs processed are 1.524m (5ft) girth and below. About 90.0% of the sawmillers obtained supplies from government-owned forest reserves and free areas (farms and farm fallows). Wood supplies from privately-owned forest were insignificant. Semi processed round logs were transported via water ways from Edo, Delta, Rivers, Bayelsa and Akwa Ibom States in the south-south zone via rafts to Oko Baba at Ebute Meta, Lagos. Firewood, charcoal and other non-wood forest products are largely from private farms and communal lands. There was evidence of movement of charcoal from Kwara State in the north-central zone to cities in the south-west, particularly, Ibadan and Lagos. Oke-Ogun Area of Oyo State is another major source of charcoal production and supply to Ibadan, Lagos and other locations in the northern part of Nigeria. The most common enterprise encountered in the northern region was fuelwood business which constituted over 52.4% of encounter rate.

Gender group representation in forest production. Primary forest production activities are male-dominated. The furniture and saw milling segment at the secondary forest production level are also male-controlled. The female gender is involved mainly in the marketing aspects. The collection, marketing and utilization of fuelwood are dominated by the female gender. Other areas of women's involvement in forestry activities include mangrove exploitation, including non-timber forest products collection, utilization and trade. Generally, women engagement in forest industry activities is limited in the more hazardous activities like timber exploitation. Men undertake difficult jobs such as tree climbing, routing, felling, hauling, loading, sawing, climbing and beekeeping. On the other hand, women mostly deal with the processing and marketing of products. This is similar to the finding of Eneji *et al.* (2015) that the male gender was engaged more in timber extraction while female exploited more of NTFPs. The implication of this is that both genders are active users of forest resources. It also supports the findings that men control the more tangible forest resource which is timber (Agarwal, 2009; Aguilar *et al.,* 2011 and FAO, 2015).

Women are also involved in sawn wood/ plank trade, small scale cottage processing of non-timber forest products such as *Irvingia gabonensis* (bush mango), *Massularia acuminata* (chew-stick), baskets and bag-weaving and firewood marketing. They are also engaged in tending, weeding, transplanting and nursery management. They visit the forest and sawmills for fuel wood, roots and barks, off-cuts and wood wastes for domestic cooking and sometimes for commercial purposes. Medicinal plant collection, utilization and marketing are other important activities where the women folks dominate the business. These were found in all the locations visited. About 90.0% of the actors in the medicinal plant trade were females ranging from 17 to 76 years of age.

There is obvious gender-specific inequalities in the forest product industry in Nigeria. The arduous nature of forestry activities, particularly at the primary level and the general lack of incentives to enhance the participation of the female group within the sector are key issues that need to be addressed. The main factors responsible for male dominance in the sector is cultural restriction and poor access to resources by women. In some parts of Nigeria, women do not have right to land and its resources. So, access to land by inheritance is rare. This could serve as a hindrance for female investment in primary forest production. Land tenure system, and in some cases, tree tenure are major factors which inhibit the equal participation of all stakeholders and groups in forestry activities in many parts of Nigeria. Although, the Land Use Decree (later the Land Use Act) vests ownership of land in the government, with the State government holding it in trust for the people, access to land is very tendentious due to a combination of factors, major among which are cultural, political, economic and bureaucracy.

Trends in wood products production in Nigeria. There are few reliable records of production estimates for wood and non-wood forest products in Nigeria. However, Popoola (1998) and the FAO (2010 and 2014) carried out studies in thisregard. Table 3 presents the account of FAO (2010) for industrial round wood and woodfuel removals between 1990 and 2005.

The value of the industrial round and woodfuel removals in Nigeria were US$124 million and US$456 million, respectively (FAO, 2010). This underscores the importance of woodfuel in the supply of domestic cooking energy in the country. It also calls for concern about the need to direct deliberate efforts at establishment of plantations of fuelwood species both at the level of government and the private practitioners. It presents an opportunity for Public-Private collaboration in forest production. Organizations such as the British-America Tobacco Company (BAT) already have private woodlots for fuelwood production. Government may collaborate with such organizations by providing them with incentives such as easy access to land, tax rebates and technical support. Tables 4 and 5 present the summary of forecast of consumption trend for major timber and non-timber forest products in Nigeria from 2000 to 2020.

Fuelwood and Charcoal. Fuelwood consumption is expected to decline in both absolute and per capita terms. This reflects the well-established and universal trend for more efficient and convenient fuels to replace fuelwood as living standards improve. However, with the declining GNP per capita and the unavailability of alternative domestic fuels, this trend may not hold as more and more people may be compelled to turn to fuel wood over time. With Goal 8 of the SDGs focusing on affordable and clean energy, this may be abated.

Table 3. Trends in production of wood products in Nigeria (1990-2005)

Industrial Round wood Total volume ('1000m³ over bark)				Woodfuel Total volume ('1000m³ over bark)			
1990	2000	2005	% from forest in 2005	1990	2000	2005	% from Forest in 2005
9,321	10,831	10,831	100	59,095	68, 172	70,427	100

Source: FAO State of the World's Forests (2010)

Table 4. Trend in consumption of timber and non-timber forest products in Nigeria (2000-2020)

Year	News Print ('1000m³)	Printing and Writing Paper ('1000m³)	Sawn wood ('1000m³)	Plywood ('1000m³)	Poles and Pilling ('1000m³)	Fuelwood and Charcoal ('1000m³)
2000	71.39	8.46	87.08	219.2	2,236.77	84,546.2
2010	139.22	17.68	192.73	379.67	2,900.73	93,120.33
2020	295.97	40.15	453.23	686.59	3,809.26	100,523.46

Source: Popoola (1998)

Table 5. Forecast of decades and cumulative rates of changes (%) in wood product consumption in Nigeria

	2000		2010		2020			
	Total consumption	Per capita consumption	Total consumption	Per capita consumption	Total consumption	Per capita consumption	Cumulative total consumption	Per capita consumption
Fuelwood and charcoal	0	0	10.14	-17.57	7.95	-19.67	18.89	-37.24
Poles, pilings and posts	0	0	30.46	-1.56	30.57	-2.12	70.35	-3.65
Plywood	0	0	73.27	31.05	83.21	36.95	217.45	79.46
Sawnwood	0	0	66.99	25.98	75.02	30.79	192.26	64.77
Particle board	0	0	121.21	66.45	139.3	76.19	420.48	193.26
Newsprint	0	0	95.01	47.02	112.6	58.81	314.58	133.49
Printing and writing paper	0	0	108.98	57.82	127.1	69.83	374.59	168.03
Paper and paperboard	0	0	88.19	42.14	99.89	49.48	276.17	112.46
Other Wood products	0	0	13.04	-15.3	12.88	-15.97	27.29	-28.82

Source: Popoola (1998)

Poles, pilings and posts. The predicted change indicates slight increases by 2020 in terms of total consumption. However, the per capita consumption over the same period will decline. Again, this is in line with established and apriori trend for consumption of unprocessed forest products.

Plywood. On absolute and per capita terms there will be an increase in demand for plywood over the next 10 years. Cumulative rate of change in demand will be as high as 217.45%. This is higher than cumulative rate of change in demand for sawn wood. Again, this confirms the established trends for processed forest products. Additionally, it indicates the technical advantages of the more highly processed materials in view of the expected advances in technology of utilization over time. Again, it is expected that with technological advancement, and with declining wood outputs from forests, plywood will be produced in larger quantities. This expansion in panel product market will represent an incursion into the sawnwood market. The danger here is that Nigeria may end up committing scare resources on importation of this refined forest product, unless if urgent steps are taken to improve the state of technology in the production of homemade plywood.

Sawnwood. For a long time to come, sawn wood will remain the most highly demanded semi-processed wood product in Nigeria. This is a reflection of the high positive income elasticity of sawnwood consumption against the backdrop of the low range of GNP per capita. It is the most widely distributed wood product in Nigeria, partly as a result of the wide range of technology (from crude to refined) that is adopted in its conversion and utilization. It also has high range of utilization (building construction, furniture, scaffolding, packaging etc).

Particleboard. In absolute terms, the demand for particleboard is not high, but it will grow in importance over time. There will be a steady growth in total and per capita consumption. The cumulative rate of change is predicted to be 420.48% by the year 2020. This calls for policy thrust in the development of the industry in Nigeria. As earlier stated, capacity utilization in this segment of the forest industry has declined as a result of the downturn in the macro-economy and the power supply situation.

Paper and other paper products. The relationships between the expected rates of growth in the consumption of Newsprint, printing paper /minting paper and paper/paperboard are evident. They all indicate positive growth rates both in absolute and per capita terms over the next 10 to 20 years. During the period, it is expected that there will be an increase in literacy, public education programmes, and enrolment at all levels of educational institutions and health standards to warrant the expansion of the market for paper and other paper products. The predicted high rate of increase is a reflection of the high positive income elasticity for per capita consumption of all grades of paper over the low range of GNP per capita. However, the upsurge in the use of electronic devices in communication and storage of information/documents may serve as a limiting factor to this rise, but this may not be so significant.

Contributions of private forest sector activities to local livelihoods and national economy. The private forestry sector contributes significantly to income, employment, wood energy, food, medicine and housing in Nigeria. Unfortunately, most of these contributions remain undocumented. The contributions of two subsectors: furniture, and pulp and paper between 1990 and 2011were captured in the National Accounts of ECOWAS (www.ecostat.org) and reported by FAO (2014). These two subsectors which are operated mainly by the private sector contributed significantly to

Table 6. Contributions of furniture and pulp and paper industries to livelihoods and national economy in Nigeria

Employment	1990 (000)	1995 (000)	2000 (000)	2001 (000)	2002 (000)	2003 (000)	2004 (000)	2005 (000)	2006 (000)	2007 (000)	2008 (000)	2009 (000)	2010 (000)	2011 (000)
Pulp and Paper industry	8	11	11	11	11	11	11	11	11	11	11	11	11	11
Furniture industry	127	85	158	206	223	133	195	195	195	195	195	195	195	195
Gross Value added (Furniture Industry) in million USD at 2011 prices and Exchange rate	878	438	1,051	1,403	1,185	883	886	886	886	886	886	886	886	886
Gross Value Added (Pulp and Paper Industry) in million USD at 2011 prices and Exchange rate	173	66	72	72	72	72	72	72	72	72	76	76	76	72

Source: FAO (2014)

Table 7. Contributions of the formal forestry sector to employment and GDP in Nigeria in 2011

Employment					Gross Value added			
Round wood production	Wood processing	Pulp and paper	Total forestry sector	Percentage of total labour force	Round wood production	Wood processing (Million USD)	Pulp and paper (Million USD)	Total forestry sector (Million USD)
30000	33000	11000	44000	0.1	906	14	72	992

Source: Annex 101 FAO State of the World Forests (2014) employment and income generation. According to the FAO (2011 and 2014), by far, the furniture segment of the forest industry contributes more in terms of employment and Gross Value added, while wood processing generally, generates higher employment than the pulp and paper segment (Tables 6 and 7).There is huge market for furniture and pulp and paper products within the West African Sub-region. This potential could be tapped into through public private collaboration.

Factors facilitating and constraining the development of the forest products industry. Table 8 shows a SWOT analysis of factors facilitating and/or constraining the development of the forest products industry in the country. The facilitating factors are: huge employment and income opportunities; large foreign and domestic markets, and, provisions for participatory and sustainable forest management in the National Forest Policy, among others. On the other hand, constraints against development of the sector include: underdeveloped infrastructure; low degree of industrialization; weak linkages to the industry and service sectors; and corruption, among others.

The forest sector represents a huge source of employment in Nigeria. Thousands of young men and women are employed at all stages along the value chain of the wood-based industry of the sector. At the resource base, workers are employed as forest labour in silvicultural, maintenance and harvesting operations. Table 9 presents a summary of employment opportunities in the secondary forest industry in the south-west (the hub of the forest industry in Nigeria) at both professional and technical levels. At the professional level, vacancy ranged between 33.0% and 71.0%, while it ranged between 45.0% and 85.0% at the technical level of employment. Great potentials exist in the forest industry for employment generation, provided issues such as power supply and regular supplies of raw materials are addressed.

Table 8. SWOT analyses of factors facilitating and constraining the development of the forest products industry

Strengths	Weaknesses
• Huge employment and income opportunities in the sector. • Large foreign and domestic markets. • Adequate provisions for participatory and sustainable forest management in the National Forest Policy. • Many people depend on forests and forests resources for their livelihoods. • Large and wellspread natural forests and plantations in some of the states.	• Low productivity. • Low ownership by strategic actors as lands and forests are owned by States. • Dominance of small-scale producers. • Low technology use. • Low investment-low income trap • Extant National Forest Policy (which is near obsolete) yet to be backed by any law.
Opportunities	Threats
• Productivity improvement potential. • Empowerment of youth and vulnerable groups' capabilities. • Strengthening of forest laws in favour of better forest management. • Livelihood security and resilience building.	• Underdeveloped infrastructure. • Low degree of industrialization. • Weak linkages to the industry and service sectors. • Low competitiveness. • Inadequate capacities • Inability of state apparatus to check corruption.

Table 9. Potentials of forest industries for employment generation in south-west Nigeria

Personnel type	Number of professionals required	Number of professionals recruited	Vacancy percentage	Number of technical staff required	Number of technical staff recruited	Vacancy percentage
Skilled	201	79	39.00	49	28	57.10
Managerial	73	52	71.00	14	12	85.70
Supervisory	195	65	33.00	10	6	60.00
Unskilled	241	141	59.00	196	90	45.90
Gender	105	54	51.00	40	20	50.00

Source: Field Survey, 2015 as updated in 2018

Overall, employment and income generation, productivity improvement potential, enhancement of gender, youth and vulnerable groups' capabilities, livelihood security and resilience building, leadership and governance are fairly high within the forest products industry in the country. However, forest production is still generally characterised by low productivity; the dominance of small-scale producers; low technology use and the reliance on human labour. The inability of State apparatus to check corruption has indeed taken its toll on forestry development in the country. Recent studies have also highlighted the implications of corruption on marketing and trade in forest products on the African continent as a whole (Chupezi *et al.,* 2015; Popoola, 2015).There is a positive perception among respondents on the desirability of public-private partnership in the development of the forest products industry. This hinges on the ability of such partnership to help regulate forestry activities, particularly the issue of illegal logging as well as ensuring strict compliance with all laid down rules and regulations that will engender conservation, sustainable forest management and optimum utilization of forest resources.

CONCLUSION

Primary forest production is essentially a government concern in all parts of Nigeria. However, there is a bourgeoning of private ownership of forest estates for primary forest production in some parts of the country. Although capacity utilization is declining, the forest sector still serves as a huge source of employment openings. Opportunities for public-private collaboration in forest production exist, as the private forest sector already contributes significantly to income, employment, wood energy, food, medicine and housing. There is a huge market for the furniture and pulp and paper products in the Nigeria and the West African sub-region. A positive perception on the desirability of public-private partnership in the development of the forest products industry in Nigeria exist. This is hinged on the ability of such partnership to help regulate forestry activities, particularly the issue of illegal logging as well as ensuring strict compliance with all laid down rules and regulations that will engender conservation and optimum utilization of forest resources. The identified constraints in the sector are surmountable with the right policies and mindset.

RECOMMENDATIONS

Arising from findings of this study, the following recommendations are proposed for promoting public-private partnership in the Nigerian forest sector for sustainable livelihood:

i. Encourage private forest estates ownership by facilitating access to land, and other incentives such as tree seedlings;

ii. Facilitate access to resources and remove barriers to effective gender participation;

iii. Ensure adequate data collection and information on tree species raised/managed and encourage formulation of sustainable management plan;

iv. Encourage the establishment of plantation of indigenous and preferred tree species, with deliberate efforts at establishment of plantations of fuelwood species both at the level of government and the private practitioners;

v. Remove constraints to full realization of forest industry potentials through provision of adequate power supply and other infrastructure;

vi. Encourage value addition and innovation within the forest sector by improving the state of technology in the production of homemade plywood, particle board, paper and paper products among others;

vii. Engender innovative financing mechanism that will make access to funding of forestry projects attractive.

viii. Update the extant forest policy and also back it with enabling laws.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Forest Law Enforcement, Governance and Trade (FLEGT): A Mechanism for Forest Resources Management in sub-Saharan Africa

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ABSTRACT

The forestry sector plays an important role in the livelihoods of many communities and economic development of many sub-Saharan Africa. This is especially true in the West, Central and Eastern Africa countries with considerable forest cover. However, these forests are undergoing significant changes, mainly due to high rates of deforestation and degradation. In addition, the level of forest protection, formal effective management and governance of forest resources in the region is still very low. This study therefore, sought to analyse the current status of Forest Law Enforcement, Governance and Trade (FLEGT) in Democratic Republic of Congo (DRC), Uganda and Kenya with a view to guiding interventions for facilitating capacity building for FLEGT in Africa. Data were obtained on the status of FLEGT in East and Central Africa, and the drivers of illegal logging and timber trade. The data were analysed using descriptive statistics. The study revealed that between 2000 and 2005, the estimated forest cover loss was about 4 million hectares per year; with the Sudan, Zambia and the Democratic Republic of Congo accounting for almost 44 % of Africa's forest cover reduction. Out of the total 650 million hectares of forests in Africa, only 32.5 million hectares (5%) are formally protected. Forest loss and degradation are partly caused by changes in policies and limited capacity to prevent forest encroachments. Logging and timber trade were poorly regulated, with limited administration capacity characterised by lack of regulatory systems, especially at the permit issuing. There was poor staffing by forest agencies to cover the vast areas in the field and to validate whether the concessionaires abide by the quantities and standards of what was applied for. The chain of custody procedure was too cumbersome and difficult to comply with, especially given the demands for bribes along different processes and there was rampant illegal logging and timber trade. There was generally lack of compliance with chain of custody procedure due to bribery along different processes, resulting into rampant illegal logging and timber trade. There are many cases of timber harvesting from designated national parks or forest reserves without going through proper authorization process. The cases of illegal logging and timber trade had been challenged in courts of law without success on legal grounds because of limited proof of criminality from forest agencies. The study recommends the need to devote more effort in promoting and solidifying Forest Law Enforcement, Governance and Trade through reviewing and synthesizing policies and legislations in order to enhance harmonisation and collaboration with other mainstream law enforcement structures and institutions of government, including the police, prosecutors and judiciary.

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Keywords: Deforestation, degradation, East and Central Africa, effective forest management, enforcement of forest law, forest governance, forest trade, illegal timber trade, illegal logging

RÉSUMÉ
Le secteur forestier joue un rôle important dans les moyens de subsistance de nombreuses communautés et le développement économique de nombreux pays d'Afrique subsaharienne. Ceci est particulièrement vrai pour les pays d'Afrique occidentale, centrale et orientale dotés d'un couvert forestier considérable. Cependant, ces forêts subissent des changements importants, dus principalement aux taux élevés de déforestation et de dégradation. En outre, le niveau de protection des forêts, de gestion efficace et de gouvernance des ressources forestières dans la région est encore très faible. Cette étude visait donc à analyser l'état actuel de l'application des Législations Forestières, de la Gouvernance et des Échanges Commerciaux (LFGEC) en République Démocratique du Congo (RDC), en Ouganda et au Kenya, en vue de guider les interventions visant à faciliter le renforcement des capacités pour le LFGEC en Afrique. Des données ont été obtenues sur le statut des LFGEC en Afrique orientale et centrale et sur les facteurs de l'exploitation illégale du bois et du commerce du bois. Les données ont été analysées à l'aide de statistiques descriptives. L'étude a révélé qu'entre 2000 et 2005, la perte du couvert forestier estimé était d'environ 4 millions d'hectares par an et le Soudan, la Zambie et la République Démocratique du Congo représentent près de 44% de la perte du couvert forestier de l'Afrique. Sur les 650 millions d'hectares de forêts que compte l'Afrique, seulement 32,5 millions d'hectares (5%) sont officiellement protégés. La perte et la dégradation des forêts sont en partie dues aux changements de politiques et à la capacité limitée d'empêcher les empiétements sur les espaces forestiers. L'exploitation forestière et le commerce du bois étaient mal réglementés, avec une capacité de gestion administrative limitée caractérisée par l'absence de systèmes de réglementation, en particulier lors de la délivrance des permis. Les agences forestières ne disposaient pas des effectifs suffisants pour couvrir les vastes étendues sur le terrain et pour vérifier si les concessionnaires respectaient les quantités et les normes de ce qui était demandé. La procédure de la chaîne de contrôle était trop lourde et difficile à respecter, en particulier compte tenu des demandes de pots-de-vin lors de différents processus et de la généralisation de l'exploitation et du commerce illégal du bois. Il y avait généralement un manque de respect de la procédure de la chaîne de contrôle en raison de différents processus corruption, ce qui a entraîné une généralisation de l'exploitation forestière illégale et du commerce du bois. Il existe de nombreux cas de collecte de bois dans des parcs nationaux ou des réserves forestières sans passer par un processus approprié d'autorisation. Les cas d'abattage illégal et de commerce de bois ont été contestés devant les tribunaux, sans succès pour des raisons juridiques, en raison de l'absence de preuves de la criminalité d'agences forestières. L'étude recommande de consacrer plus d'efforts à la promotion et à la consolidation de l'application des lois forestières, de la gouvernance et du commerce en revisitant et en synthétisant les politiques et les législations afin de renforcer l'harmonisation et la collaboration avec les autres structures et institutions gouvernementales chargées de l'application des lois, y compris la police, les procureurs et le système judiciaire.

Mots clés : Déforestation, dégradation, Afrique de l'Est et du Centre, gestion forestière efficace, application de la législation forestière, gouvernance forestière, commerce forestier, commerce illégal de bois, exploitation forestière illégale

INTRODUCTION

Estimates by FAO (2015) indicate that the "closed forest" of the world has a total area of about 3.999 billion hectares that declined by 3% between 1990 and 2015. Conversely, forests and woodlands in Africa cover an area of about 650 million hectares; about 21.8% of Africa's total land area, representing about 17% of the world's forest area. Sub-Saharan African forests and woodlands form an important part of the African forests, which are undergoing significant changes mainly due to the high rates of deforestation and degradation. Forests of sub-Saharan Africa are extremely diverse; with fascinating ecosystems such as the 180 million hectares of rainforests in the Congo Basin region and 270 million hectares of Miombo woodlands (Katerere *et al.,* 2009). Compared to the natural forests, the whole of Africa has only 8 million hectares of forest plantation, accounting for 4.3% of the global total. Moreover, the major plantation forests are found in South Africa and Sudan.

The forestry sector in Sub-Saharan Africa plays an important role in the livelihoods of many communities and in the economic development of many countries especially in Western, Central and Eastern Africa, where there is still considerable forest cover. For example, as indicated in Figure 1, eight countries - Angola, Cameroon, Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Guinea-Bissau and Seychelles, which comprise about 16% of Africa's land area accounting for 43% of the total African forests, have more than 50% of their land area under forests (Katerere *et al.,* 2009). The Congo basin in Central Africa is home to the world's second largest continuous block of tropical rain forest. Forests are key sources of livelihoods, through provision of different products in form of food, fibre and construction materials and they provide valuable ecosystem services. The role of forests amidst the current climate change challenges is invaluable, given that they bind carbon dioxide and store it; a phenomenon referred to as Green

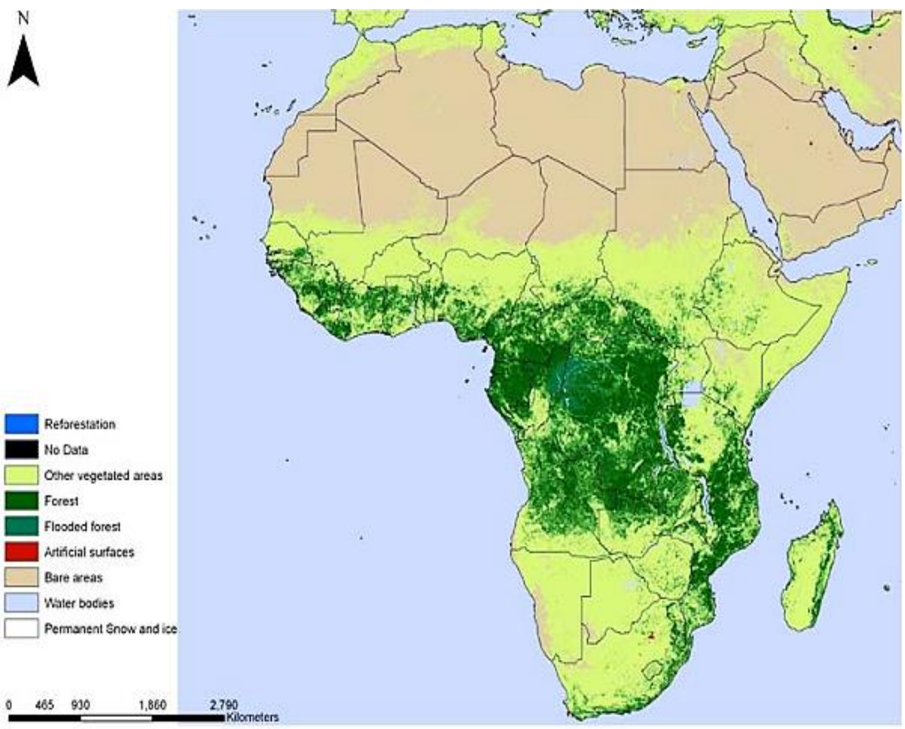

Figure 1. Forest and Woodland cover in Africa

carbon and hence the forests are appreciated to play a vital role of ultimately helping to mitigate climate change effects. The different socio-economic characteristics have resulted in an inevitable situation of varied use and abuse of the forests, largely due to anthropogenic factors (Agustino *et al.,* 2011).

In view of the above, this study aimed at analysing the status of Forest Law Enforcement, Governance and Trade (FLEGT) in Sub-Saharan Africa with a view to guiding interventions for facilitating capacity building for FLEGT. The study presents opportunities for forest protection and more economic growth, allowing the use of national, regional and international FLEGT processes and approaches to control illegal logging and timber trade. It draws lessons from previous studies and field work carried out in selected countries and proposes recommendations that can be used to facilitate development of capacity for enhanced FLEGT in sub-Saharan Africa.

METHODOLOGY

Study Area. The study areas were Democratic Republic of Congo (DRC), Uganda and Kenya in sub-Saharan Africa.

Data collection and procedure. Literature and available data were examined to review the status of trade in forest products and services in Africa. Literature was also reviewed on illegal logging, including reported estimates of the volumes and values of harvested timber, alleged to be from illegal sources and traded internationally. The review included an economic analysis to measure competitiveness and impacts related to legally suspicious material in the global timber market. Interviews were conducted with stakeholders from selected countries along the timber trade value chain that included DRC, Uganda and Kenya. Reports from government and non-government institutions were used to estimate the extent of illicit activities in one or more countries. These were supplemented with data collected from stakeholders on trade in forest products from illegal operations. Information on the trade in timber and other forest products were collected from the Forest Authorities and agencies in DRC, Uganda and Kenya. The data included statistics of timber harvesting permits issued, amount of timber harvested and cleared, for both local consumption and export. Data were also collected from the Customs Agencies and border posts in DRC, Uganda and Kenya. A special focus was paid to timber transiting from DRC through Mpondwe border post, which links DRC to Uganda; Malaba border post that links Uganda to Kenya and Kenya's Port of Mombasa. Interviews were conducted with officials from government forestry agencies and law enforcement institutions, such as the police. Information collected also included law enforcement efforts aimed at controlling illegal logging and timber trade in the respective countries. At the border posts, data were collected on timber trade; concerning estimates of frequency and size of timber trucks passing through the transit routes and other aspects.

RESULTS

Status of FLEGT in East and Central Africa. Results revealed that between 2000 and 2005, the forest cover loss was about 4 million hectares per year; with the Sudan, Zambia and the Democratic Republic of Congo accounting for almost 44 % of Africa's forest cover reduction. Out of the total 650 million hectares of forests in Africa, only 32.5 million hectares (5%) were formally protected. An underlying cause of forest loss and degradation is a result of changes in policies and limited capacity to prevent forest encroachments.

Some of the factors that have been attributed to the decline of forest cover in Africa include increased wood fuel collection; clearing of forests for agriculture; illegal and poorly regulated timber extraction; civil and political conflicts and increasing urbanisation. Changes in policies and limited capacity to prevent forest encroachments were reported as factors contributing to forest loss and degradation. It is believed that one of the most sustainable approaches for enhancing effective management and monitoring the use of forest products is building of local capacity and also expanding and developing forest plantations.

The reports note that most of the exports are characterized by speculative behavior, which has implications on governance in the industry. For example, China is one of the leading donors to the region in areas related to infrastructure development, and political and military aid, which limits the strictness that can be imposed on likely illegalities that may be carried out during timber logging and trade. Reports from the Global Timber Network indicate that China is currently one of the principal destinations for tropical timber from Africa (Figures 2, 3 and 4); with China's imports accounting for much of Africa region's exports.

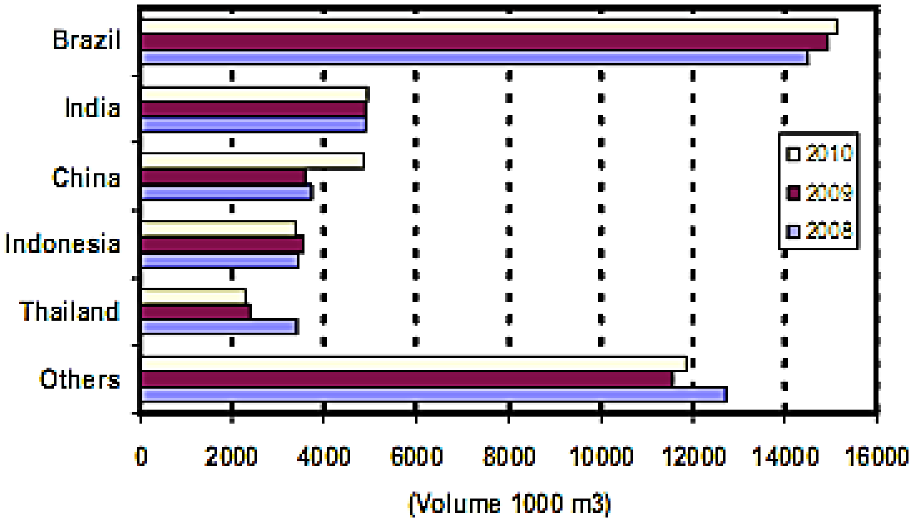

Figure 2. Major Tropical Sawn wood consumers

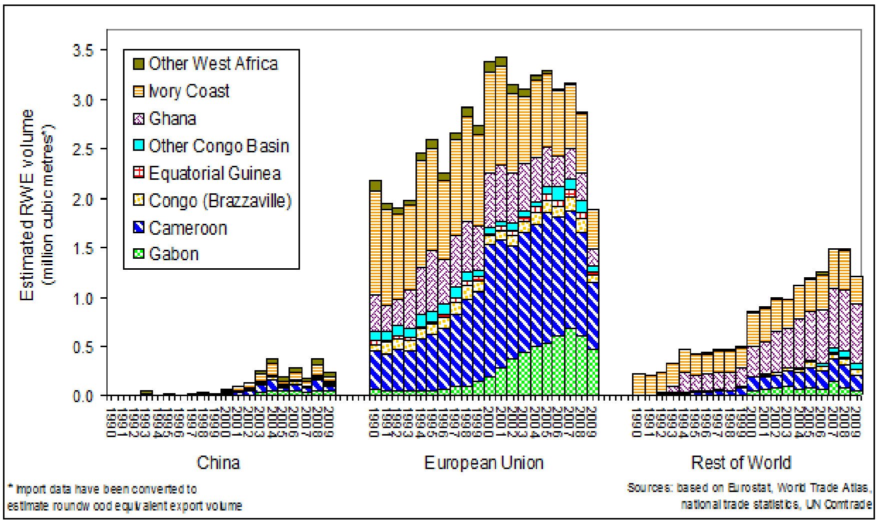

Figure 3. West Africa and the Congo Basin - exports of timber* other than logs to China, the EU and elsewhere

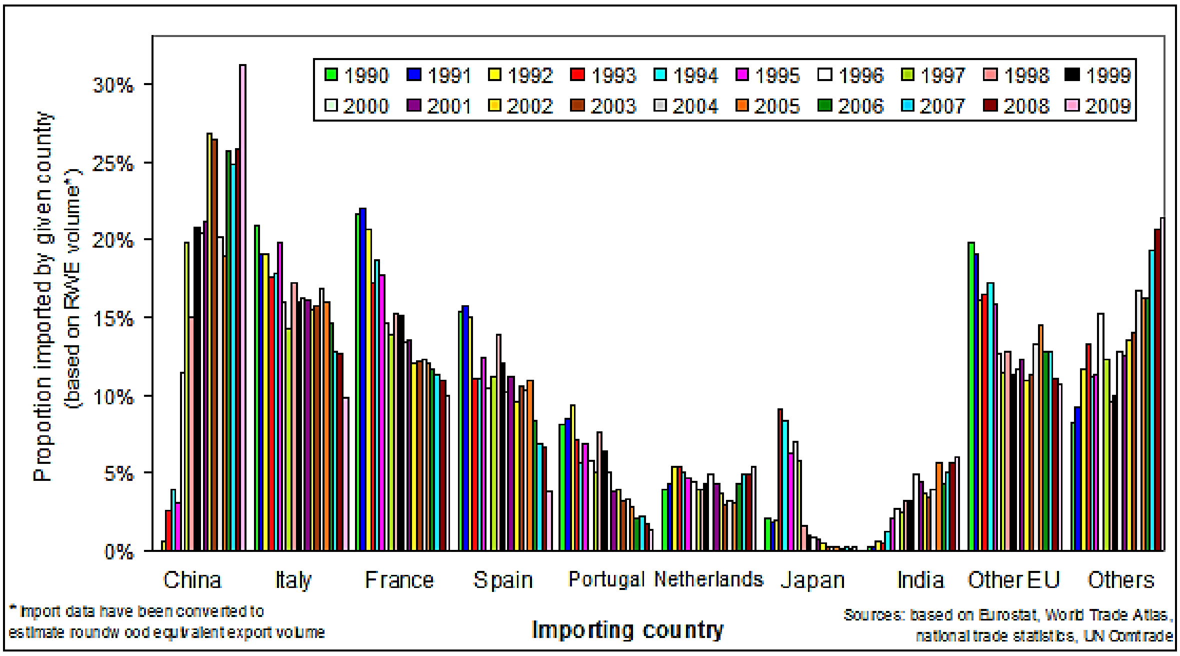

Figure 4. The share of particular destination countries in the tropical timber exports of West Africa and the Congo Basin

Drivers of illegal logging and timber trade. From interactions with different actors, it was revealed that most logging and trade within DRC (estimated at 50% within the sampled area) was illegal. However, responses from the timber harvesters indicated that they were indifferent about the illegality. Most respondents indicated that they were reluctantly willing to abide by local procedures, including payments to local chiefs and various administrative levels. The results indicated that most of the depletion and degradation of forest resources and landscapes, in many sub-Saharan countries, were mainly due to illegal logging and unsustainable practices. Even after harvesting the timber, trade processes and related procedures along the value chain of forest products were mauled by poor governance and corruption, which lead to illegalities and affected benefits from the forests; indirectly leading to more deforestation and forest degradation. The major factors identified during this study as drivers of illegal logging and timber trade in sub-Saharan Africa were: limited awareness about the timber trade policies; unclear or poorly enforced forest harvesting regulations; weak political institutions; poverty and corruption; weak enforcement of sovereign laws and regulations; and inadequate natural resources planning and monitoring (Figure 5).

Tenure of forest ownership and chain of custody. According to the forest management laws in DRC, natural forests are owned by chiefs, on behalf of the government and local community. The authorisation procedures therefore, involve both the local chief and the forestry authorities. The procedure for authorisation, harvesting and clearing of the timber up to the border posts involve application for initial authorisation from the area Chief; payment of estimated authority fees to the Community Chiefs and issuance of authorisation to harvest given to the Timber Harvester. After the payment and authorisation by the Local Chief, the harvester reports to the Officer in charge of Forestry and Environment, who measures and ascertains the area and tree species to be harvested. Thereafter, authorisation and issue of license is made for the Licensee to start harvesting operations for timber (Figure 6).

Harvesting, mainly using power saws, involves at least two people. The trees are transported from the forest to the nearest motorable road and each piece of timber costs about US$ 10 to transport from the forest to the motorable road side. The Forest Officer processes a timber movement permit valid for use from the motorable road side to the nearest border post. The timber movement permits costs US$ 400 for every 15 tonnes of timber, irrespective of the species; though there is a system of categorization in four classes, which is always ignored. For timber that is expected to be sold within DRC, it is displayed in the timber yard at the border post for marketing.

The timber for export is stamped at the border post with a hammer, indicating the exit border point, before issuing of an export permit. An export permit costs US$ 1,800; for every 15 tonnes of timber. Until recently, transactions for issuing of export permits were made in Beni, far from the border post. Due to the delays caused by first travelling to Beni for permits, authorisation was also allowed from the Governor in Beni to issue export permits at border posts.

For new transactions, a letter of credit is issued by the customs agency in form of an invoice for payment at the nearest bank in Uganda

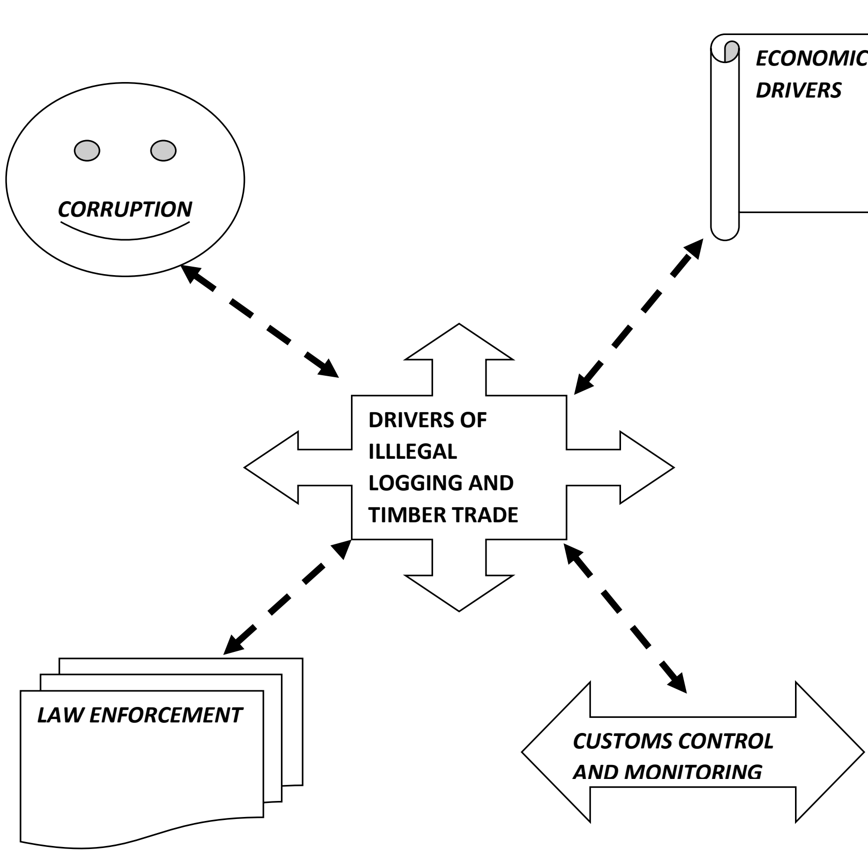

Figure 5. Drivers of illegal logging and timber trade in Sub-Saharan Africa

and payment is later transmitted to Kinshasha. Daily records are kept for all exports; including vehicle number, exporter, volume of timber, and destination. The data are entered in the DRC Revenue Agency Information Management System (IMS); which is controlled from the headquarters in Kinshasa. Changes in the entered data can only be made with authority from the Kinshasa headquarters.

At the Uganda Mpondwe border post, the following clearing process was described (Figure 7):

- √ After receiving the lorries/ trailers from DRC, a validation exercise is carried out by Uganda Revenue Authority (URA), to check the completeness of DRC customs documentation and phyto-sanitary certificates. However, the documents are in French;
- √ Daily records are made of the cleared timber and are entered in the URA database (SIDON);
- √ The entered data are sorted according to any required queries and can only be changed with authority from the URA Commissioner for Customs;
- √ The Clearing agent then fills in the IM8 form, applying for verification from URA and taxation;
- √ URA ascertains the type and quantity of timber, and determines the value for taxes;
- √ For transit timber, a site account is made and a T1 form is prepared on the basis of IM8 and the container is locked with a URA seal. This in essence bonds the transit timber, using the Clearing Agent's bank guarantee, which will be deducted, in the event of the declared timber not crossing the transit point committed on the form;
- √ The bond is cleared after validating that the seal has not been tampered with at the exit border post;
- √ URA taxes timber at a rate of US$ 130 per cubic metre for class one and US$ 51 per cubic metre for class 2 timber; according to the indicative tax values of 2012 and
- √ Data for exports in Uganda are entered in ASYCUDA Information Management System (IMS), using the new version of ASYCUDA world.

All EAC countries use the same version of IMS and are linked for the ease of management. However, the IMS used in DRC (SIDON) is not the same as EAC but has similar templates and coding.

It is apparent that the role of the Forest Officer, who is expected to provide technical guidance on the type of timber and appropriate taxes, is not clearly spelt out and is often ignored by the customs officials. It was reported that the Forest Officer or Ranger comes in to witness and verify the timber quality and quantity and collects a tax of 1% that is remitted to the relevant local government authority (Kasese District Forestry Services for Mpondwe). He/she then stamps the timber with a field hammer and issues movement permits to the timber, using the 2000 statutory instrument rates. Enforcement officers interviewed (Customs Officers, Forest Officers, and Police) admitted that some leakages occur along the porous border, where people ferry timber on bicycles and motor cycles. Though some cases of confiscation were reported, it was difficult to estimate quantities lost through such leakages. Figure 8 shows the export procedures of wood from Mombasa to final destination.

DISCUSSION

The forest cover in the study area was reducing at an alarming rate as a result of deforestation and forest degradation. Even where the forests were managed as protected areas, a number of challenges related to poor law enforcement and governance were reported. Some of the factors that have been attributed to the decline of forest cover in Africa include increased wood fuel collection; clearing of forests for agriculture;

illegal and poorly regulated timber extraction; civil and political conflicts and increasing urbanisation. FAO (2015) alluded to the fact that Sub-Saharan African forests and woodlands form an important part of the African forests, which are undergoing significant changes mainly due to the high rates of deforestation and degradation.

Previous studies by Katerere *et al.,* 2009; Nellemann, 2010 and Kakuru 2012 indicated that illegal logging and timber trade thrive most in areas with poor forest governance;

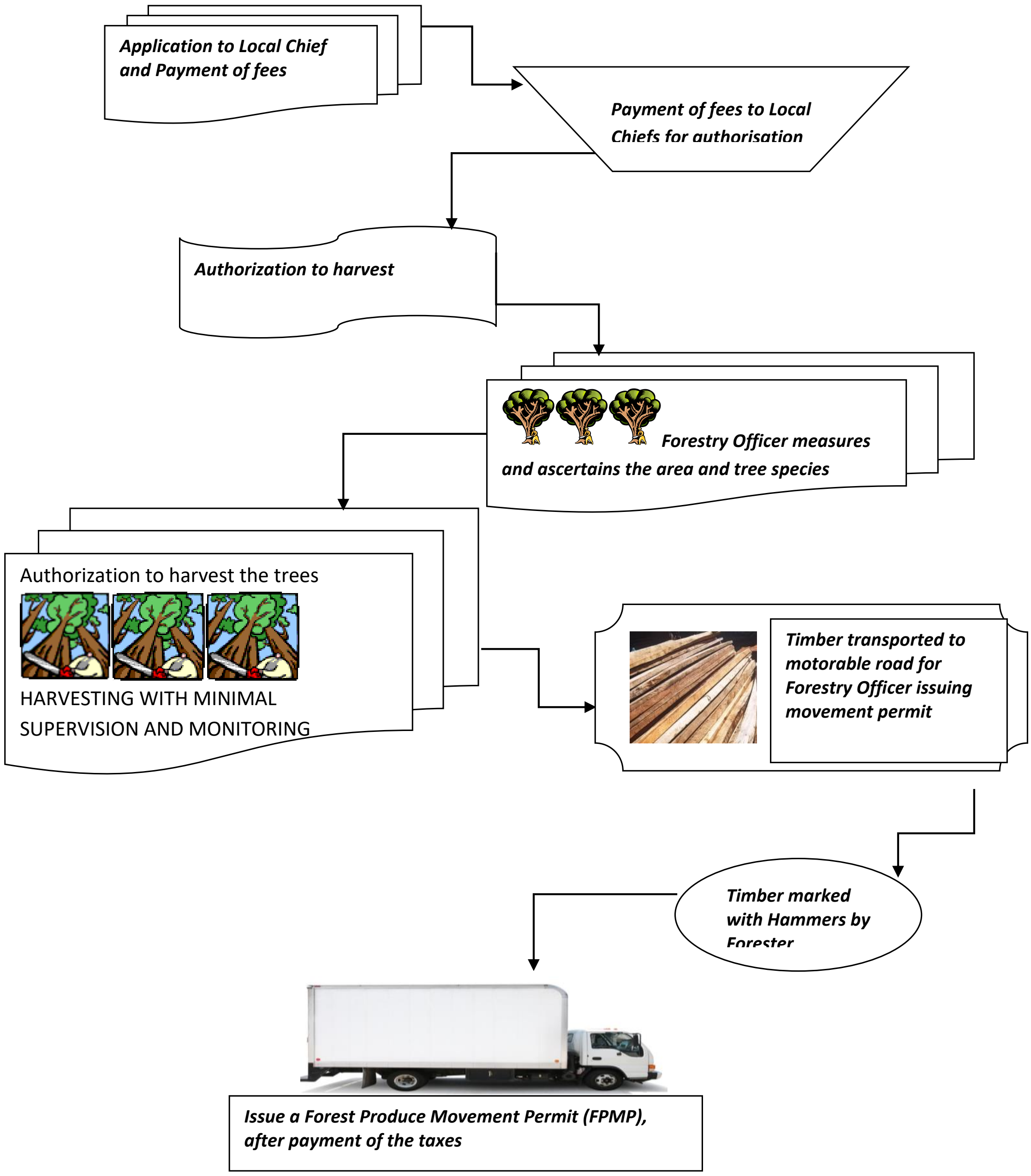

Figure 6. Prescribed chain of custody during assessment and offer of licenses

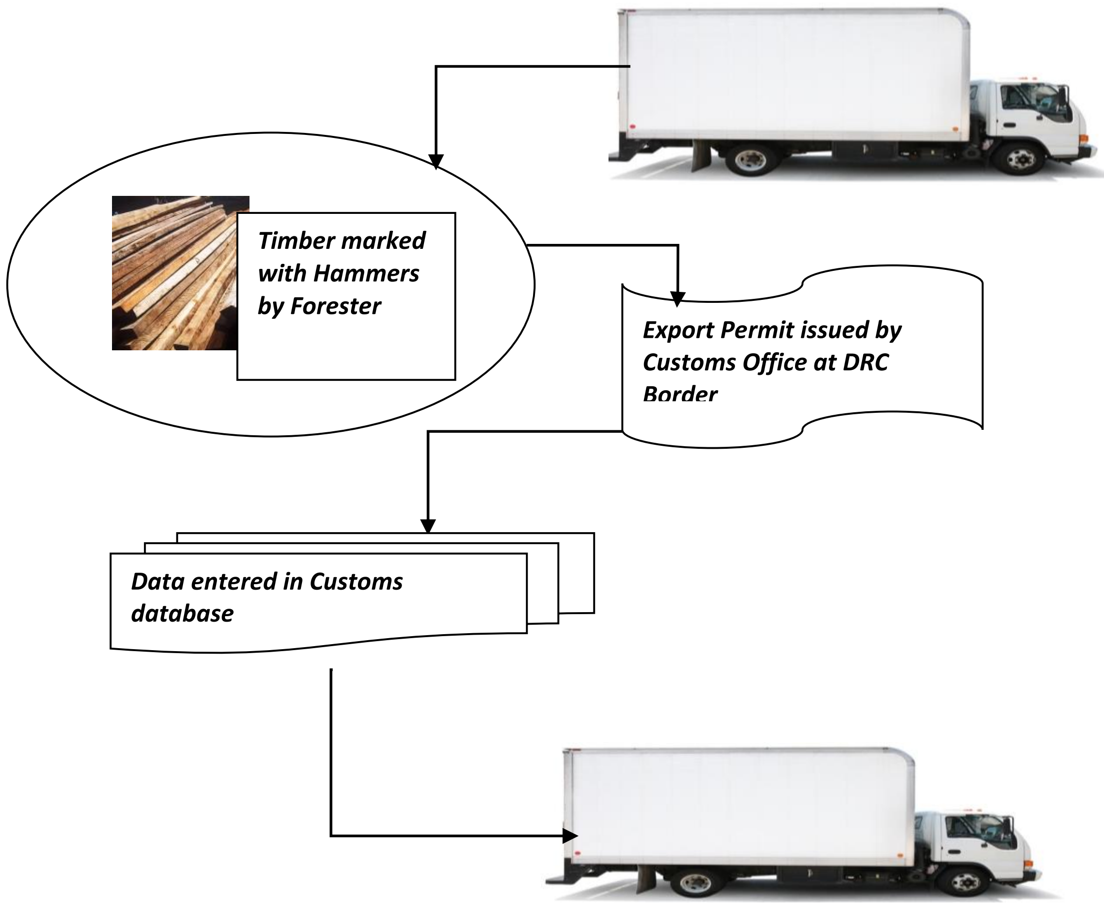

Figure 7. Chain of custody at the DRC Border

where transparency and law enforcement are weak, and are prone to foster corruption. Sub-Saharan Africa has all those characteristics and is indeed one of the regions that has experienced and faced severe impacts of illegal logging and trade in timber. Illegal logging and timber trade undermine sustainable forest management and development in most of the countries, since most of the economies therein are dependent on natural resources. Within the sub-Saharan Africa, a number of challenges, some of them related to poor governance, facilitate the unhindered plundering of forest resources. Incomes from illegal logging and timber trade fuel conflicts between different groups and amongst communities neighbouring forests. Forest products can be sold into international commodity markets to raise money to pay for wars. Conflicts that have involved timber in one of these ways range from small-scale, low-intensity violence at the community-level to full scale civil wars. The use of forests for different products such as timber, poles and charcoal has been linked to the provision of financing dissidents involved in bloody national and regional conflicts (UNSC, 2001). Notable examples include the Khmer Rouge forces in Cambodia, DRC rebels, and the Sudanese Peoples Liberation Army (SPLA). China's role in importing illegal timber can be partly attributed to its policy that puts a ban and tightened illegal harvesting of indigenous wood from their natural forests. This has affected the global timber trade dynamics by satisfying its timber demands using its increased purchasing power from the strong economy and this ultimately makes China the main importer of illegally harvested logs that feed a growing demand in wood products. China is also indirectly acting as a hub of illegal timber trafficking, where logs imported from Sub-Saharan African countries are processed into finished manufactured products. The wooden products are then exported to European countries, the US, and Japan; countries that claim to condemn the illegally obtained timber. The Chinese finished products are also exported to a number of other countries, where there is limited legislation to counter imports of illegally harvested timber. This can easily be considered as a sign of impunity, at a time when a red flag is raised for countries that seem to defy FLEGT principles.

However, INTERPOL's proactive interventions in illegal logging and timber trade indicated that timber trafficking criminals involved can

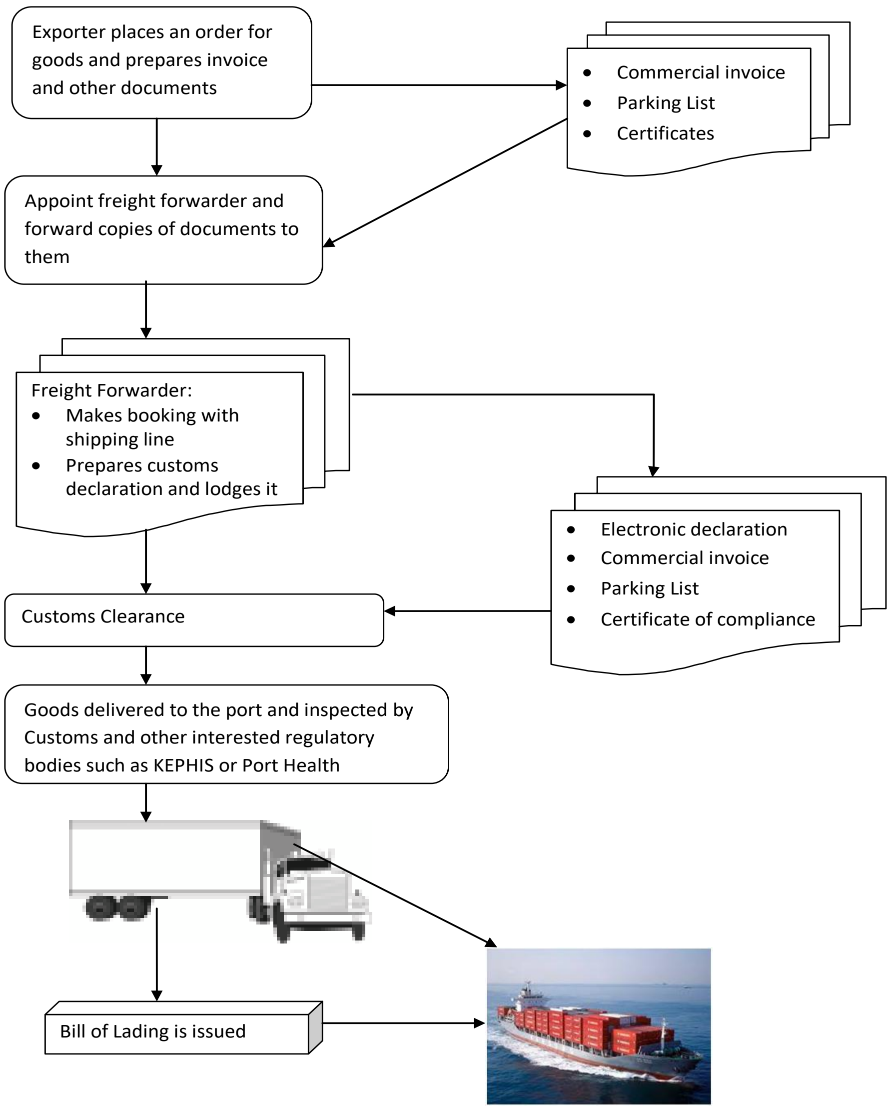

Figure 8. Timber export procedures in Mombasa
Adapted from: Government of Kenya, 2005

be charged and convicted for other crimes punishable under criminal laws such as conspiracy, smuggling, issuing false statements and money laundering. The study found out that FLEGT processes have achieved some positive developments in strengthening legitimate timber logging and trade by making it much easier to track and verify certified timber from sustainably managed forests. Regional and international networks aimed at jointly addressing forest law enforcement and governance have been put in place such as use of the Harmonized Commodity Description and Coding System, commonly referred to as "Harmonized System" "HS". The study recommends that efforts should be devoted to promoting and solidifying Forest Law Enforcement, Governance and Trade through the harmonisation and collaboration with other mainstream law enforcement structures and institutions of government including the police, prosecutors and judiciary. The study also recommends the need to review and synthesise the policies, legislation and regulations in sub-Saharan Africa related to illegal logging and trade for use in capacity building.

Katerere *et al.* (2009), Nellemann (2010) and Kakuru (2012) showed that illegal timber trade leads to unsustainable forest management and degradation thus negatively affecting local economies and forest dependent communities. The vice exacerbates forest management costs and accentuates market distortions for forest produces. Markets for forest products are regulated by factors that play a role in bringing together buyers and sellers. Trade development in the forest products and recently the services suffers from significant uncertainties due to unpredictability of the demand and supply for forest products and are significantly affected by illegalities. Illegal timber trade distorts the prices and markets with negative implication on local economies and employment ratios. This is one of the reasons contributing to the increasing illegal logging and trade in forest products in Eastern Africa, with its own market distortions. The markets for illegal timber increase the forest exploitation rate, with implications on climate change concerns. In the event of market and price distortions, consumers could end up paying a high price with implication in poverty levels in some countries, if wood takes a large share of their disposable incomes. Distortions are further exacerbated by limited cooperation and uncoordinated national, regional and international laws and regulations about competition and trade in forest products.

CONCLUSION AND RECOMMENDATIONS

This study set out to analyse the current status of Forest Law Enforcement, Governance and Trade in Sub-Saharan Africa, to guide interventions for facilitating building of capacity for FLEGT. The status of illegal logging and timber trade, FLEGT challenges, opportunities, constraints, achievements and market failures are presented. Sub-Saharan Africa countries have weak forestry policies, some of which have not addressed issues of illegal forest trade, especially where they occur beyond their borders. The existing forest legislations are either incomplete or fragmented with responsibilities spread among many institutions. African Forest Forum (AFF) should use the success and experiences of the Regional Economic Commissions (RECs) to lobby for an Africa level platform for addressing the bottlenecks to timber trade. Examples of actions that should be considered may include harmonizing trade policies, such as requiring common documents for cross-border clearance of cargo, vehicles and business people, removing unnecessary duplication of programmes, harmonizing investment codes and factor mobility and promoting a legitimate unification of the sub-regional markets. The study on the status of Forest Law Enforcement Governance and Trade in the forest sector in Sub-Saharan Africa has proposed a number of recommendations for consideration by actors:

- Forest cover is a measure of Sustainable Forest Management (SFM). Capacity enhancement for participatory monitoring, assessing and reporting on forest area and forest area change in these countries is essential;

- There is a need to review and synthesise policies, legislation and regulations in sub-Saharan Africa related to illegal logging and trade and the FLEGT process so as to inform policy review;
- Based on the review, develop training modules and materials to be used during FLEGT training, targeted at different categories of actors along the timber trade value chain such as harvesting concessionaires, traders, customs agents and law enforcement and legal officers;
- Training and sensitisation on FLEGT targeted at articulating roles and responsibilities of different categories of actors along the timber trade value chain, such as harvesting concessionaires, traders, customs agents and law enforcement officers, and legal officers is required;
- There is also need to improve the timber trade governance system by removing and or minimizing bureaucratic processes, which contribute significantly to forest crime and difficulties in law enforcement;
- Sub-Saharan Africa countries need to take appropriate steps to stabilise and strengthen their forest sector administration, through improved governance, such as reducing political interference and corruption. This may require strengthening the capacity for good forest governance, law enforcement, trade and forest administrations and ensuring that the forest management institutions are adequately staffed and equipped with skills of monitoring illegal logging and timber trade;
- Project proposal development for joint interventions to be implemented by different actors along the timber trade value chain and for strengthening market information systems should be guided by country needs. The priority areas of focus are improving market transparency, market access and trade development, standards, grading rules, quality control system and development of a market information system on timber trade;
- A regional level programme that can strengthen the forest certification process, involving a wide consultation process with many stakeholders under the leadership of RECs is recommended. The programme should put in place measures for certification of government owned forests, small scale forest owners and tree growers;
- Improved approaches to the FLEGT systems should be developed, with a mechanism that actively encompasses major importing countries like China. Efforts should be made to develop schemes to track multiple cross border movement of timber. This requires mechanisms for tracking the movement of timber through several stages of harvesting, transport and processing, including, movement across international borders. Efforts should also be made to strengthen this process by including provisions that can be based on other existing international trade related agreements;
- There is need to strengthen the chain of custody, increase the levels of information, education and communication, to improve transparency, as a strategy to improve governance; harmonise customs procedures and interactions among neighbouring border posts, facilitate regular interactions and collaboration between Customs authorities, Police Officers and Forest Authorities, promote timber procurement standards for government and donor contracts to ensure that only sustainably harvested timber is used, adopt standards in the different Regional Economic Commissions, to discourage and ultimately prohibit the use of illegal timber in the region and empower the law enforcement officers to be able to arrest culprits and impound illegal timber.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Promoting African integration through trade in forest products: Cameroon's perspective

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ABSTRACT
Intra-African trade has been highly promoted as a sustainable growth pathway for African economies. However, intra-African trade of forest products and its contribution to boosting the African integration agenda is not well covered in literature and promotional strategies are not well-known. This paper provides information that can be used to promote intra-African trade in forest products through an assessment of wood products traded between Cameroon and countries within the five African sub-regions. Cameroon's national trade in forest products for the period 2009 to 2014 was analysed to establish export trends in major wood products to various continents, in addition to highlighting intra-African trade in the five African sub-regions. Results showed that from 2009 to 2014, exports of wood products from Cameroon amounted to 7,281,710 m^3, and was made up of five products categories, namely: logs (48%), sawnwood (47%), veneers (2.8%), and plywood and parquets (<2%). Of this trade, the share of intra-African trade was logs (2%), sawnwood (7.4%), veneers (11%) and plywood (29.7%); all of which represented about 5.3% for all wood products. This trade was among 22 African countries on the continent, with significant differences in inter-regional distribution ($P<0.05$). The top three logs importing African countries were Morocco (89.5%), Algeria (5.6%), Tunisia (2.1%) and Senegal, Tanzania, Nigeria and South Africa together (3%), respectively. The top five sawnwood importers were Senegal (51.9%), Libya (25.7%), Tunisia (11.2%), Morocco (3.5%) and Mauritius (2.6%). The top five veneers African importers were Senegal (31%), Tunisia (21%), Egypt (12%), Morocco (10%) and Gabon (9.7%); while eight other African countries imported the remaining 18%. The top five plywood importers included Senegal (64.4%), Equatorial Guinea (13.5%), Gabon (5.6%), Democratic Republic of Congo (4.8%) and Tunisia (3.9%). This paper demonstrates Cameroon's efforts in fostering trade in wood products with 22 other African countries that are spread in all five sub-regions of the continent. Evidence from trends in trade in wood products between Cameroon and other African countries shows that Cameroon is already contributing to the promotion of intra-African trade and by extension regional integration on the continent.

Key words: African sub-regions, Cameroon, Intra-African trade, Regional Economic Commissions, timber trade

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RÉSUMÉ

Le commerce intra-africain a été hautement promu en tant que voie de croissance durable pour les économies africaines. Cependant, le commerce intra-africain des produits forestiers et sa contribution au renforcement de l'agenda d'intégration de l'Afrique ne sont pas bien couverts par la littérature ainsi que les stratégies de promotion ne sont pas bien connues. Ce document fournit des informations pouvant être utilisées pour promouvoir le commerce intra-africain de produits forestiers grâce à une évaluation des produits en bois commercialisés entre le Cameroun et les pays des cinq sous-régions africaines. Les résultats ont montré qu'entre 2009 et 2014, les exportations de produits en bois du Cameroun s'élevaient à 7 281 710 m3 et étaient réparties en cinq catégories de produits, à savoir: grumes (48%), bois de sciages (47%), placages (2,8%), planches de contreplaqués et parquets (<2%). La part de ce commerce intra-africain était composée de grumes (2%), de bois de sciages (7,4%), de placages (11%) et de contreplaqués (29,7%); ce qui représente environ 5,3% de l'ensemble des produits du bois. Ce commerce concernait 22 pays du continent africains, avec des différences importantes dans la répartition interrégionale (p <0,05). Les trois principaux pays africains importateurs de grumes étaient le Maroc (89,5%), l'Algérie (5,6%), la Tunisie (2,1%) et l'ensemble Sénégal, Tanzanie, Nigeria et Afrique du Sud (3%). Les cinq principaux importateurs de sciages étaient le Sénégal (51,9%), la Libye (25,7%), la Tunisie (11,2%), le Maroc (3,5%) et la Mauritanie (2,6%). Les cinq principaux importateurs africains étaient le Sénégal (31%), la Tunisie (21%), l'Égypte (12%), le Maroc (10%) et le Gabon (9,7%); tandis que huit autres pays africains importaient les 18% restants. Les cinq principaux importateurs de contreplaqués sont le Sénégal (64,4%), la Guinée équatoriale (13,5%), le Gabon (5,6%), la République Démocratique du Congo (4,8%) et la Tunisie (3,9%). Cet article démontre les efforts du Cameroun pour promouvoir le commerce des produits du bois avec 22 autres pays africains répartis dans les cinq sous-régions du continent. Les tendances des échanges de produits ligneux entre le Cameroun et d'autres pays africains montrent que le Cameroun contribue déjà à la promotion du commerce intra-africain et, par extension, à l'intégration régionale sur le continent.

Mots clés : Sous-région africaine, Cameroun, commerce intra-africain, commissions économiques régionales, commerce du bois

INTRODUCTION

The need for African integration has been captured in the Organisation for African Unity (OAU) Charter, the Monrovia Declaration, the Lagos Plan of Action, the Abuja Treaty, the African Union Constitutive Act and the New Economic Partnership for African Development (NEPAD) (AUC, 2015a, 2014). Africa's Integration Vision is elaborated in the Abuja Treaty, which established the African Economic Community (AEC) in 1991. The Treaty, which came into force in 1994 and will continue over a transition period of 40 years (1994-2028), provides for the establishment of a continent-wide economic cooperation with pioneer eight Regional Economic Commissions (RECs) as building blocks (OAU, 1991). There are at least 14 RECs in Africa that are officially or unofficially recognised by the African Union (AU), some of which overlap in membership (Barka, 2012). The RECs are the pillars of the AEC that are recognised by the African Union with mandates to be progressively strengthened into a coherent pan-African economic institution (UNECA, 2010; Oppong, 2011; Tumuhimbise, 2013). This envisages a continent where there is free movement of people, goods and services, rights of establishment, free circulation of goods, free movement of capital, free movement of labour, among others (Tumuhimbise, 2013; AUC, 2015 a&b). These visions are tied to two of the four main objectives for setting up the AEC: (a) to promote economic, social and cultural development and the integration of African economies in order to increase economic self-reliance and promote an endogenous and self-sustained development; and (b) to establish on a continental scale, a framework for the development, mobilisation and utilisation of the human and material resources of Africa in order to achieve a self-reliant development (OAU, 1991). Fifty four (54) African countries are signatories to AEC, including Cameroon. In managing its forests, Cameroon is also a signatory to the African Convention on the Conservation of Nature and Natural Resources with the triple objectives of enhancing environmental protection; fostering the conservation and sustainable use of natural resources; and harmonising and coordinating policies in view of achieving ecologically rational, economically sound and socially acceptable development policies and programmes (AUC, 2003). The aforementioned treaties, conventions and institutional frameworks demonstrate and confirm the great desire of Cameroon and other African countries to integrate their economies towards the enhancement of mutual growth and development.

Added to the above, the concept of 'African solutions to African problems' has become a compelling maxim of the African Union (AU) with a clarion call that resonates equally among governments and civil society on the continent (Nathan 2013). The maxim applies to a wide range of issues, including development, education and health, but it is used most often in relation to peace and security (Ayittey, 2010). Also, the concept of 'African solutions' evokes a sense of self-reliance, responsibility, pride, ownership and indigeneity and calls on African countries to come together and work in partnership with the international community to address problems inherent on the African continent. This means that Africa as a continent must endeavour to be a full partner in addressing African problems although, not in isolation from the international community (Ayittey, 2010). In complement to the above concepts is that 'Africa must feed Africa', a concept promoted by the African Development Bank that will require unlocking the potentials of Africa to diversify African economies (Adesina, 2015).

Enakele (2015) emphasises that the key to unlocking Africa's true economic potential is an Africa that trades with itself. Africa cannot rely on the rest of the world to deliver on the trade agreements and preferences, policies, strategies and indeed investments required for growth (AUC, 2015 a&b). This could partially be achieved through regional trade in goods and services, albeit impending shortcomings (Geda and Kibret, 2001; Daya *et al.,* 2006). However, for all commodities of trade value, intra-continental trade is still limited in Africa at 10-13% compared to other continents like Europe (72%), Asia (52%), North America (48%), and South and Central America (26%) (Hartzenberg, 2011; WTO, 2011). However, these global figures tend to obscure the realities of intra-continental trade on specified types of products from specific countries (UNECA, 2010; UNCTAD, 2013). Such information, and at the country level, may help shape the implementation of regional policies, treaties and conventions for effective African integration through trade.

With the population of Africa expected to rise to 2.5 billion by 2050 and to 4 billion by the turn of the century (Adesina, 2015), the questions the forestry sector should ask itself could include: How will Africa meet the wood products needs of this growing population? Will Africa simply depend on ever increasing wood products imports? Is such a scenario unacceptable? How much does Africa spend annually on importing wood products? By simply turning African into a relatively wood products self-sufficient continent, the many billions of foreign currencies spent on importing can be spent on other domestic needs without recourse to expensive international capital markets. With this understanding, many authors believe that Africa's economic success depends on the ability of the continent's nations to trade with one another (Mwai, 2016).

As a case study on how Africa can increase trade in itself, this paper focuses on four wood products categories from Cameroon that were exported to other African countries over a period of six years (2009-2014). This paper therefore, relies on only one aspect of trade: exports of wood products; however, there are several other aspects to consider in trade. For example, the paper does not try to analyse policy implications of regional timber trade in Africa (Njinkeu and Fosso. 2006; Chipeta and Kowero, 2015) or the constraints to intra-African trade (Daya *et al.,* 2006) or the dynamics of intra-regional trade (Zannou, 2010; Ebaidalla and Yahia, 2014; Shuaibu, 2015); but rather attempts to demonstrate the magnitude and extent to which wood products from Cameroon are traded with other African countries within the five African sub-regions (Eastern, Central, Northern, Southern and Western); indicative to boosting African integration. In this light, this paper will contribute to a better understanding of intra-African trade in forest products exported from Cameroon and provide empirical evidence that wood products value chains could be strengthened and/or properly developed to ensure continuous and improved interactions and trade among African countries.

STUDY METHODS

Cameroon and the forestry sector. Cameroon is a lower middle-income country with a population of 21.7 million people. It is situated in Central Africa and it shares its border with five countries namely Nigeria, Chad, Central African Republic, Equatorial Guinea and Gabon. Cameroon is endowed with significant natural resources, including oil and gas, high value timber species for logs, sawnwood, veneers and plywood, non-timber forest products, minerals, and agricultural products such as coffee, cotton, cocoa, maize, cassava (World Bank, 2015). Cameroon has for the first time embarked on the formulation of a long-term development vision, which projects the image of the country up to 2035. In that context, the main issue concerning the implementation of the Growth and Employment Strategy Paper - GESP (2010-2020) is focused on growth acceleration, the creation of formal jobs and poverty reduction (GESP, 2009).

The dense humid forest represents about 36.2% of the national territory (including water and land totalling 475,440 km^2). The total surface area of Cameroon's forests is 23,035,630 ha representing 48.73% of the national territory (Alemagi, 2011). Production forests are exploited and managed under four forest management models and partnerships arrangements, representing varying proportions of total forests; namely

(a) forest concessions/forest management units - 30.64% (government in partnership with private sector);
(b) community forests - 8.04% (government in partnership with communities);
(c) council forests - 6.71% (government in partnership with local councils); and
(d) sale of standing volumes - 1.65% (government in partnership with the private sector).

Indeed, the four production management models or partnership arrangements cover 47.04% of Cameroonian forests or 23% of the national territory (Tieguhong, 2016a). There are 111 forest management units in Cameroon covering a total of 7,058,958 ha out of which 66% (5,071,000 ha) are managed concessions and 34% (2,393,061 ha) are certified (de Wasseige *et al.,* 2015).

In this paper, exports of wood products between Cameroon and countries within the five African sub-continental regions are tracked and explained. To show the regional spread of wood products exports from Cameroon to other African countries, partner countries were divided according to the United Nations sub-regional blocks of Africa (Favada, 2009, Chipeta and Kowero. 2015); namely Eastern, Central, Northern, Southern and Western. Three factors explain the selection of Cameroon for this study (i) geographically centralised country in Africa, (ii) endowed with forest resources, and (iii) signatory to Africa Economic Commission of the African Union.

Trade data were sourced from various databases, including national trade statistics from the Commerce du bois du Cameroun (COMCAM) (2009-2014). Desk review of relevant reports, policy documents, information from various websites and scientific articles were carried out to substantiate and complement findings. In terms of data analysis, descriptive statistics in terms of proportions in percentages as well as analysis of variance (ANOVA) to see the variation in regional distribution were employed. The statistical data analysed cover only wood products exported through the Douala seaport. What goes through other seaports, the porous borders of the country via roads and navigable rivers were not reported. This reveals a weakness in the data reported, as well as a recommendation on the need to improve trade data collection to capture other exit points for intra-African trade. Further, the recorded data were on legal exports, notwithstanding the fact that there could be considerable unrecorded legal and illegal exports of forest products. In this paper, only certain categories of primary (logs) and secondary forest production (sawnwood, veneers and plywood) were considered. Logs were considered as primary forest production while sawnwood, veneers and plywood were considered as secondary forest production. Trade information on fibreboards, particle boards, paper and paper boards as well as secondary processed wood products (SPWPs) such as wood furniture, mouldings, builder wood and cane and bamboo products were patchy and not analysed. Based on the results, the extent to which Cameroon trades on the four specified wood products with other African countries was captured, demonstrating albeit in a limited way, the avenues available for boosting regional integration through trade in forest products.

RESULTS AND DISCUSSION

Five main primary and secondary wood products categories exist in Cameroon, and these are logs, sawnwood, veneers, plywood and parquets. From 2009 to 2014, a total of 7,281,710 m^3 of these products, in varying proportions, were produced and exported to various countries in the world.

Intra-African trade. From 2009 to 2014, the total intra-African trade on wood products from Cameroon was 5.33% of global total export volume, which was equivalent to 388,450 m^3 (Table 1). Further analysis of the exported volume of wood products indicates that this was made up of sawnwood (65.6%), logs (18.7%), plywood (9.7%) and veneers (6.0%). Over the same period, Cameroon formally traded with 22 African countries: five countries in Northern Africa (Morocco, Tunisia, Libya, Egypt and Algeria), six in West Africa (Senegal, Gambia, Nigeria, Ghana, Togo and Côte d'Ivoire), five in Central Africa (Gabon, Equatorial Guinea, Republic of Congo, Democratic Republic of Congo and Central African Republic) four in Eastern Africa (Comoros, Kenya, Seychelles and Tanzania), and two in Southern Africa

(Mauritius and South Africa) (Figure 1).

In terms of actual wood volumes imported from Cameroon into these African sub- regions during the same period, significant differences exist in the sub-regional distributions (P=0.048; calculated F =3.047; Critical F=3.007). Northern Africa led with 193715 m^3 (50%), followed by Western Africa 43%, Central Africa 4%, Southern Africa 3% and Eastern Africa 0.4%. This variation is associated with the quantity of different wood product categories, for instance, over 97% of logs go to Northern Africa (Table 1).

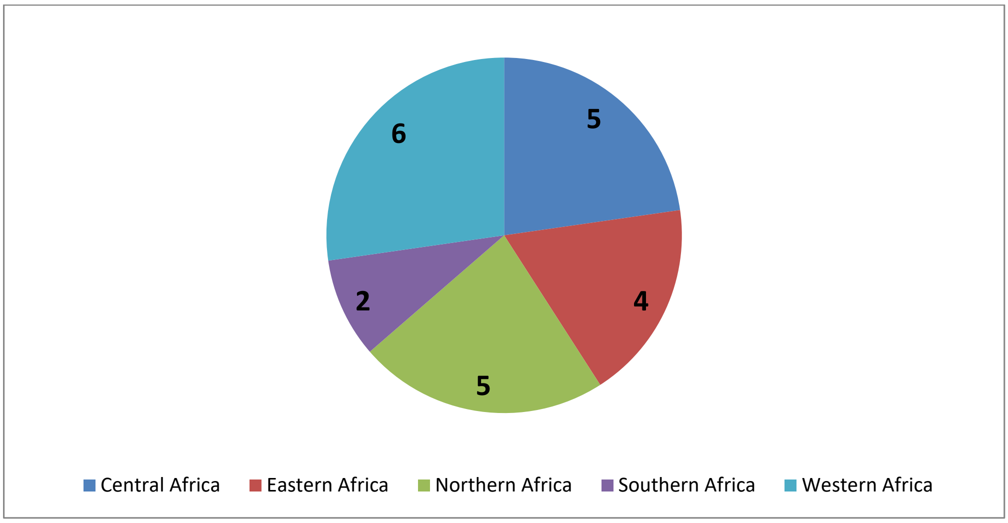
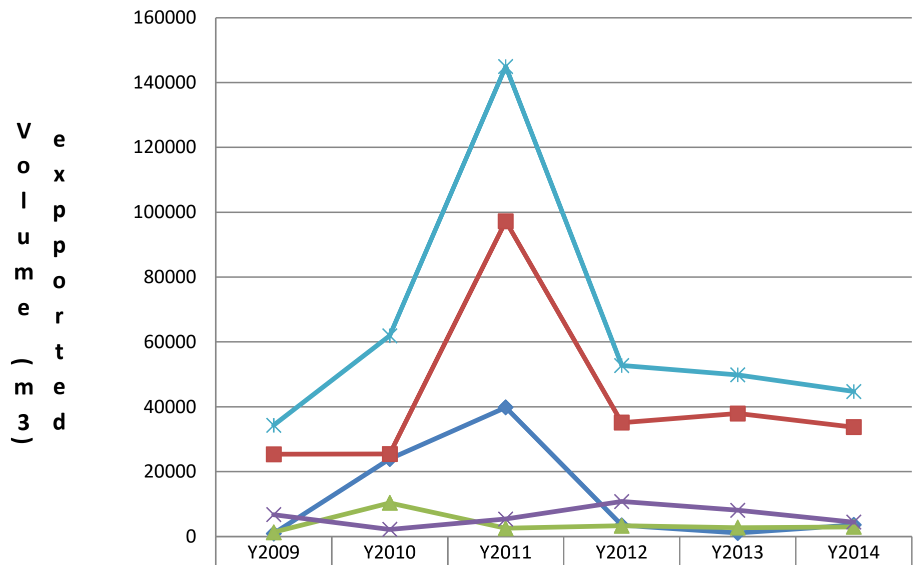


Figure 1. Regional spread of Cameroon's wood products exports to African sub-regions (number of countries per sub-region). Source: COMCAM

Table 1. Wood products exports from Cameroon to African sub-regions in 2009-2014 (Units: m^3 and %)

African sub-region	Number of countries	Logs m^3 (%)	Sawnwood m^3 (%)	Veneers m^3 (%)	Plywood m^3 (%)	Total m^3 (%)
Central Africa	5	0 (0)	560.52 (0.22)	4792.09 (20.62)	9015.45 (23.92)	14368.06 (3.70)
Eastern Africa	4	625.56 (0.86)	484.08 (0.19)	409.02 (1.76)	79.15 (0.21)	1597.81 (0.41)
Northern Africa	5	70696 (97.19)	109428.01 (42.95)	9795.66 (42.15)	3795.38 (10.07)	193715.05 (49.86)
Southern Africa	2	14.55 (0.02)	10598.85 (4.16)	976.08 (4.2)	222.37 (0.59)	11811.85 (3.04)
Western Africa	6 22	1403.9 (1.93)	133759.5 (52.5)	7267.15 (31.27)	24577.65 (65.21)	167008.2 (42.99)
Total		72740.01 (18.72)	254830.96 (65.59)	23240 (5.98)	37690 (9.70)	388500.97 (100.00)

The trends in the exports of these wood products are shown in Figure 2



	Y2009	Y2010	Y2011	Y2012	Y2013	Y2014
Logs (m3)	912	23891	39806	3479	1067	3585
Sawnwood ((m3)	25360	25424	97206	35126	37927	33737
Veneers (m3)	1288	10378	2542	3315	2739	2978
Plywood (m3)	6745	2206	5401	10807	8103	4428
Total (m3)	34305	61899	144955	52727	49836	44728

Figure 2: Trends in the export of different wood categories (2009-2014). Source: COMCAM

The trends show that wood exports from Cameroon dropped considerably for all product categories with the exception of plywood between 2011 and 2012 due to increased exports to China (Tieguhong *et al.*, 2015). However, these total volumes do not indicate the final country destination of the products. Further analyses in the following sections show exports to different countries within Africa by product type, thus highlighting the extent of intra-African trade on logs, sawnwood, plywood and veneers between Cameroon and the rest of Africa.

Intra-African wood flows from Cameroon

Logs. From 2009 to 2014, about 3 499 560 m^3 of logs were exported from Cameroon to different continents of the world with the share to other African countries respresenting 2% (Tieguhong *et al.*, 2015). The intra-African trade share of 72740 m^3 went to seven African countries, with over 97% going to Morocco, Algeria and Tunisia. The remaining 3% were exported to Tanzania, Nigeria and South Africa (Figure 3).

Sawnwood. Between 2009 and 2014, about 3.45 million m^3 of sawnwood were exported from Cameroon with intra-African trade shareof 7.4%, equivalent to 254823 m^3. Out of this volume, 94.9% was imported by five countries: Senegal (51.9%), Libya (25.7%), Tunisia (11.2%), Morocco (3.5%) and Mauritius (2.6%). Another 13 African countries imported relatively smaller quantities of sawnwood from Cameroon during the same period (Tieguhong, 2016a) (Figure 4).

Veneers. Out of the 203,799 m^3 of veneers exported from Cameroon between 2009 and 2014, 11% or 23,240 m^3 went to 13 other African countries with the top five countries importing 82%. The top five countries included: Senegal (31%), Tunisia (21%), Egypt (12%), Morocco (10%) and Gabon 9.7% (Tieguhong, 2016a) (Figure 5).

Plywood. From 2009 to 2014, 86 011 m^3 of plywood was exported from Cameroon with intra-Africa share of 29.7%. This intra-African share totalling 37,690 m^3 went to 14 countries, with top five countries importing over 92% of the plywood: Senegal (64.4%), Equatorial Guinea (13.5%), Gabon (5.6%), Congo (4.8%) and Tunisia (3.9%) (Tieguhong, 2016a) (Figure 6).

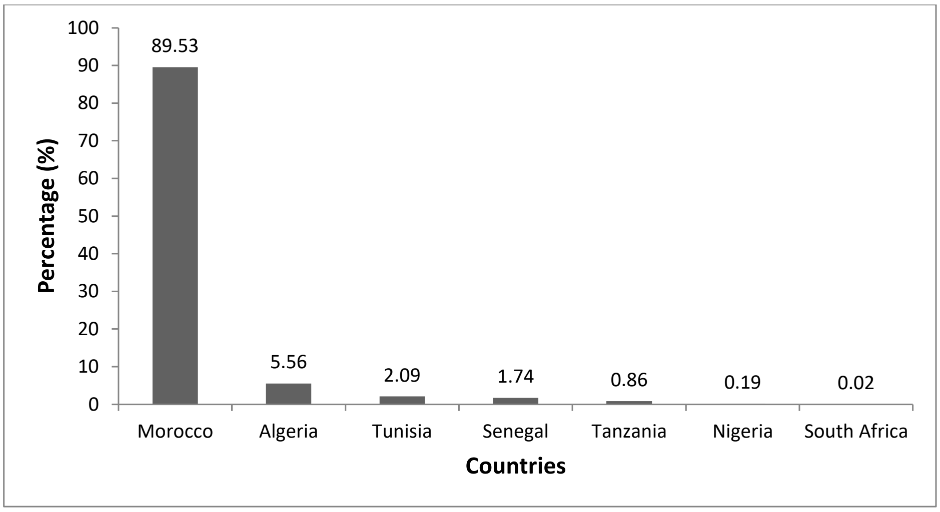


Figure 3. Tree log exports to African countries (m^3) from Cameroon during 2009-2014 period. Source: COMCAM

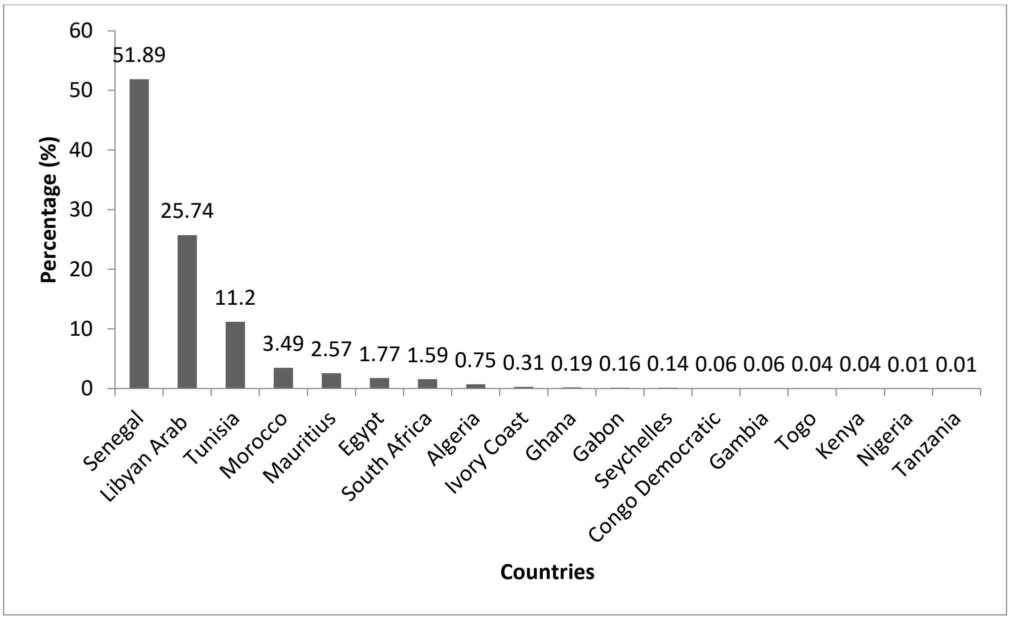


Figure 4. Sawnwood export to countries in the African continent (m^3) from Cameroon during 2009-2014 period. Source: COMCAM

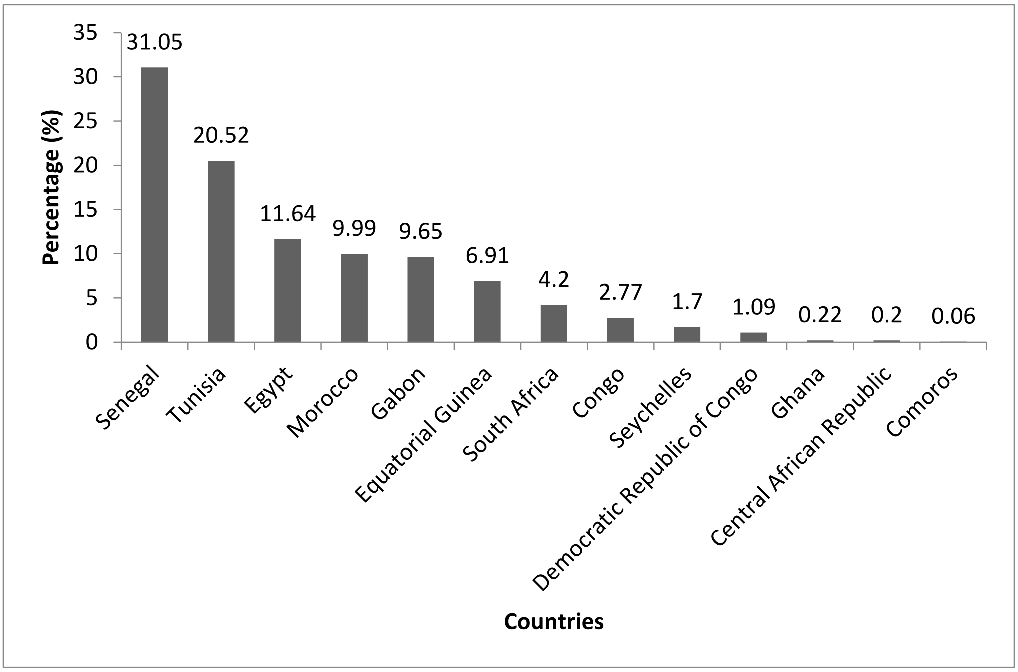


Figure 5. Veneer exports to African countries (m³) from Cameroon during2009-2014 period. Source: COMCAM

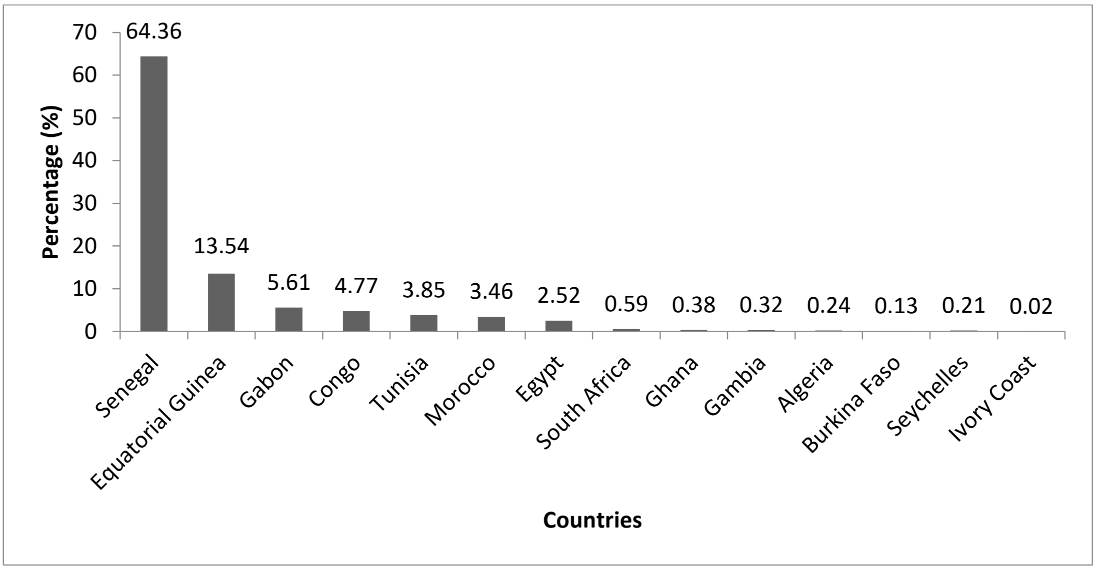


Figure 6. Plywood exports to countries in Africa (m³) from Cameroon during 2009-2014 period. Source: COMCAM

Potential for integration of Africa through trade. It is widely recognised in literature that intra-African trade has enormous potentials to create employment, catalyse investments, foster economic growth, reduce poverty and enhance food and energy security in Africa (Adesina, 2015; Enakele, 2015). The key ingredient to achieving these being regional integration (Ayittey, 2010; UNECA, 2010; Nathan, 2013; UNCTAD, 2013; AUC, 2015 a&b). With respect to the forestry sector, an understanding of the dynamics of various forest product types at the country level could help inform the implementation of regional policies, treaties and conventions for effective African integration through trade. Therefore, generating data to fill gaps in knowledge on intra-African trade in wood products is seen as an important contribution to guide policy makers in formulating policies and strategies to encourage such trade by the forest-endowed countries with those that are less endowed (AfDB, 2018; Traore and Tieguhong, 2018). This is in accordance with the promotion of the integration of Africa's maxim as stipulated in the African Continental Free Trade Agreement (AfCFTA) signed in Kigali in March 2018 and the Action Plan on Boosting Intra-Africa Trade (BIAT) endorsed by the African Union General Assembly in 2012 (Stuart, 2018).

Despite this recognition, many authors pinpoint that the African continent continues to trade very little with itself (7.5 to13%) compared to other continents (Hartzenberg, 2011), requiring more strategic studies that generate recommendations to advance the regional cooperation and integration agenda (UNECA, 2010; UNCTAD, 2013; AUC, 2015 a&b).

Despite the wide geographical spread of forest products from Cameroon, to 22 other African countries, the low proportion of intra-Africa share at only 5.3% suggests that much still has to be done to increase the volume of trade among African countries. Some authors suggest that the poor intra-African trade could be linked to inadequate technologies to process wood products at competitive prices to meet the demand of African economies (Chipeta and Kowero, 2015; AfDB, 2018).

Promotion of intra-African trade in forest products. There is a growing political commitment and recognition by African leaders that economic diversification is needed to create jobs and sustain growth in Africa (AfDB, 2018; Traore and Tieguhong, 2018). By reason of its geographical position and the fact that there has been an increase in income and in the size of the middleclass in Africa over the past decade suggest a potential and ready market for regional trade in goods and services. This provides avenues for galvanising and improving financial, economic, infrastructure and technological efforts in overcoming obstacles at the continental level to practically promote and achieve the desired level of African integration (Adesina, 2015; Chipeta and Kowero, 2015). Therefore, boosting intra-African trade in all its ramifications is seen by the African Union and other development partners as one of the key opportunistic pillars to achieving the lofty objectives of regional integration as inscribed it the Abuja Treaty and the Kigali Declaration (Stuart, 2018). Moreover, by enhancing regional trade African countries will overcome the burden associated with exporting to distant markets (UNCTAD, 2013). For instance, a 2016 evaluation conducted by Trade Mark East Africa on the impact of non-Tarrif Barriers to trade in East Africa indicated that removal of key barriers had contributed to over 14% reduction in time taken to import goods from each East African country. It resulted in the reduction in the cost of transporting a 40-foot container from Mombasa to Kigali from US$ 6500 in 2011 to US$ 4800 by 2016. Evaluators estimated savings of about US$7 million on the Mombassa-Kigali route alone (Mwai, 2016).

Intra-African wood products exports from Cameroon. Based on official statistics, the total intra-African trade in all commodities reached $130.1 billion in 2011, representing only about 11.3% of African trade with the world (UNCTAD, 2013). However, the intra-African wood exports share of 5.3% from Cameroon to the rest of Africa does not include indirect and informal cross-border trade of Cameroonian wood products to countries such as Chad, Niger and Sudan (Koffi, 2005; Cerutti and Lescuyer, 2011; Eba'aAtyi, 2016). This was because there were no reliable statistics on this trade; a considerable part of it being illegal. For instance, estimates indicate that Chad alone imports about 150,000 m^3 of sawn wood from Cameroon annually, which when converted to roundwood equivalents makes for the second highest volume of wood exported from Cameroon to any single country in the world after China (Eba'aAtyi, 2016). In only six months, Eba'a Atyi (2016) estimated that about 27,000 m^3 of informal sawnwood were exported from the Southwest and Northwest Regions of Cameroon to Nigeria, which is more than double the 12,000 m^3 estimated by Cerutti and Lescuyer (2011). The increase may be explained by the improvement in infrastructure (roads and others), the increase in demand on the Nigerian side and a more peaceful situation in the region (Eba'a Atyi, 2016). Other reasons for such an increase include overall quadrupling of annual GDP growth rate (3.4 to 13.8%) in Chad between 2009 and 2015 and, a significant increase in urban populations and real estate investments (Geda and Kibret, 2001). By adding the informal cross-border trade of wood products to official figures, the intra-African trade share in total trade would increase appreciably. For instance, elsewhere in the Southern African Development Community (SADC) area, informal cross-border trade could amount to US$17.6 billion per year, representing 30 to 40% of total intra-SADC trade. Ugandan informal exports to the Democratic Republic of the Congo, Kenya, Rwanda, the Sudan and Tanzania represented $224 million or 83% of its total recorded trade to these countries in 2006 (UNCTAD, 2013).

Based on the above findings, UNCTAD (2013) concluded that substantial and thriving informal trade in Africa was an indication that intra-African trade was not as low as official statistics suggest. In this regard, improvements will require the simplification of customs procedures, multi-country strategies to fight against corruption should be put in place to facilitate legal trade, reduce transaction cost related to trade and encourage official registration of trade transactions.

It is not only Cameroon that exports wood products to other African countries, many other forest-endowed African countries do the same. For example, over the study period, the Democratic Republic of Congo (DRC) exported wood products to 11 countries (Mbangilwa, 2015) and the Republic of Congo to 21 other African countries (SCPFE, 2015; Koubouana, 2016). Such trade is in alignment with the Abuja Treaty on the establishment of African Economic Community (AEC) that was signed, ratified and/or deposited by all the countries. For instance, of the 54-Member States of the AU; 30 have signed, 9 have ratified/acceded and 9 have deposited the instruments of ratification of the Charter on Statistics (AUC, 2009). These efforts are also aligned with the objectives of the more recent African Continental Free Trade Agreement (AfCFTA) and the Action Plan on Boosting Intra-Africa Trade (BIAT) that promote the integration of Africa (Stuart, 2018).

It would appear that African countries trade among themselves in more processed wood than in logs, whereas Africa exports considerable volumes of logs to outside the continent and less so to other African countries. This has two implications: by increasing intra-African trade, we encourage more wood processing from

Africa and less trade in logs. Also, such trade in processed products make African countries earn much more from exports. This can be illustrated by the following example from the Democratic Republic of Congo.

In 2011, the DRC exported 192,760 m^3 of wood products, out of which 6,226 m^3 (3.23%) was traded with 11 other African countries. The country earned US$70,642,869 from these exports, out of which the export share earnings from African countries was US$3,404,986, equivalent to 4.82% of global exports value (Mbangilwa, 2015). The implication is that DRC earned an average of US$547/$m^3$ on exporting to other African countries and US$360.5/$m^3$ on exporting to countries outside Africa, suggesting that DRC gains about 52% more earnings by exporting to other African countries as compared to exporting to non-Africa countries. This can be explained as follows: most timber exports to countries outside Africa were largely on roundwood and sawnwood which were not highly priced and therefore, not very profitable to DRC as well as to other African countries. For instance, according to Tieguhong (2016b), calculations of volume/value indices for exported roundwood, sawnwood, plywood and veneers from Cameroon were US$ 283, 499, 548 and 1,318 m^3 respectively. This means that Cameroon gets far less when roundwood is exported than when exporting veneers, giving the wood conversion factor of between 40 and 60% in Cameroon. Such a trade scenario is very bad for Cameroon because roundwood and sawnwood still account for over 95% of timber exported from Cameroon (Tieguhong, 2016a).

For three wood products (sawnwood, plywood and veneers) that are customarily produced in most timber producing African countries, the aggregate import and export values with countries outside Africa in 2014 for all African countries were US$ 3.3 billion and US$ 409.7 million, respectively, giving a trade deficit of about US$ 2.9 billion for the continent (Table 4).

The deficit will even be higher for secondary processed wood products (SPWP) such as wood furniture, builder wood, mouldings, cane and bamboo products and other SPWP that are produced and exported from Africa but are also imported in large quantities. For example, from 2006 to 2013, Cameroon was a net importer of wood furniture, builder wood and cane and bamboo products with a negative trade balance (trade deficit) of over US$ 19 million (Tieguhong 2016a).

Building regional integration on wood products trade. Forest products remain very strategic resource in ensuring regional trade and integration in Africa because nature has

Table 4. Value of trade in sawnwood, veneers and plywood in Africa in 2014

African Region	Sawnwood (US$) * 1000		Veneers (US$) * 1000		Plywood (US$) * 1000		Trade balance (Export-import) *1000 US$
	Export	Import	Export	Import	Export	Import	
Eastern	21459	45438	871	5845	6813,22	89534	-111674
Central	1285	1014	179790	2005	45775	42804	181027
Northern	3033	2330942	1356	108730	9696	423725	-2849312
Southern	8839	40550	6962	16048	3369	66409	-103837
Western	2984	6726	87817	3286	29655	119997	-9553
Africa	37600	2424670	276796	135914	95308,22	742469	-2893349

Source: Authors' calculations from http://faostat3.fao.org/download/F/FO/E made it that some parts are forest endowed and others are forest deficient. For instance, most of the countries (Morocco, Tunisia, Egypt, Libya, Chad, etc.) that import significant volumes of wood from Cameroon have less than 10% of their land area under forest cover. Also the 12 least forested countries in Africa (Algeria, Burundi, Comoros, Djibouti, Egypt, Ethiopia, Lesotho, Libya, Mauritania, Niger, Tunisia, Western Sahara) with total African forest cover of just about 1.5% but account for over 26% of the African population (Nair and Tieguhong, 2004). This indicates that the wood needs of many people in these countries must come from elsewhere and probably from more forest endowed countries such as Cameroon under well-developed intra-African trade arrangements or from other continents at higher costs.

Ghana appears to be taking the lead in ensuring intra-African as well as intra-REC trade in wood products. For instance, in 2015, the major markets for Ghana's wood products were Asia (59%), Africa (19%) and Europe (15%) (ITTO, 2016a). For all wood products exported, African markets accounted for 67,950 m^3 valued at Euro 26.93 million with the Economic Community of West African States (ECOWAS) countries accounting for the largest share (82%) of the sales to African countries. Togo, Nigeria, Niger, Senegal, Burkina Faso and Benin were the major ECOWAS countries that traded with Ghana and 2015 imports by these countries increased to about 10% compared to 2014 (ITTO, 2016a). The promotion of African integration through trade in wood exports requires that countries overcome several obstacles such as poor state of road, railway and trade infrastructure, lack of coordination of macro policies, divergent legal/regulatory frameworks and multiplicity of inconvertible currencies (Chipeta and Kowero, 2015; Erling *et al.,* 2016; AfDB, 2018).

CONCLUSION

This paper provides guiding information on Cameroon trade with other African countries with focus on wood products. The geographic spread of wood products exports from Cameroon to 22 other African countries in all the five African sub-regions provide strong evidence of integration, albeit low trade volumes. It could be argued that this study, together with similar one, can facilitate development of national and regional policies that can enhance intra-regional trade transforming illegal trade to legal trade in these products, and promoting the integration of markets. In this light, the importance of ensuring that policy decisions are backed by data (trends, trade flows in volume and values and by product categories) cannot be overemphasized. Along the same lines, some recent authors (Chipeta and Kowero, 2015; Erling *et al.,* 2016) buttress that Africa needs to cultivate a conducive environment for sustainable production and effective marketing systems that include favourable policies and infrastructure for legalizing such trade, and in ways that its actors can be better organized and regulated.

Such decisions can lead to improving the wood-based industry as well as promoting intra-African trade in wood products that cumulatively will contribute to creating a continental economy that strengthens each member country and ultimately create a prosperous and industrialised Africa that is in line with the African Union Agenda 2063.

RECOMMENDATIONS

In order to promote and substantially increase the potential benefits of intra-African trade in wood products, Cameroon and other African countries' efforts should be geared at policy interventions that could increase the share of wood products imported by the less forest-endowed African countries. These interventions could, among others, include:

- setting up a joint system for better collection and processing of timber trade statistics between customs, trade and forestry administrations;
- harmonizing the legal and regulatory frameworks for timber trade with other forest-endowed African countries;
- promoting the implementation of tenets of AfCFTA and BIAT on trade facilitation and free movement of goods and people for regional integration;
- establishing networks with African wood importing countries for better understanding on existing and future intra-African trade opportunities.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Forest sector contribution to a green economy in different West African climatic zones: Evidence, limits and actions needed

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ABSTRACT
Green economy is associated with low carbon, resource efficient and socially inclusive use of natural resources, including forestry. This review assesses forest sector contribution to green economy among francophone countries in west and part of central Africa. Data were collected through desk study and field visits in Gabon, Niger and Benin. The forestry sector is already playing a leading role in the implementation of green economy principles. Forests and trees absorb CO_2 emissions, provide resources to local populations, and protect communities from increasingly erratic weather. In this regard, studied countries have developed plans and programmes such as afforestation, reforestation and forest management plans aimed at improving forest cover and sustainable use of forest and tree resources. There is a good engagement of the local communities on how to increase the benefits they get from forest resources in a sustainable manner. However, none of the countries is involved in REDD+. Benin has expressed interest to be involved in the REDD+ process, while Gabon was opposed to this mechanism due to market uncertainties. It is recommended to strengthen policy reforms and knowledge, and technology transfer to enhance the contribution of forestry sector to green economy.

Keywords: Africa, Carbon, Forestry, REDD+, Resources, review, Sustainability

RÉSUMÉ
L'économie verte est associée à une utilisation faible en carbone, efficace et socialement inclusive des ressources naturelles, y compris la foresterie. Cette revue évalue la contribution du secteur forestier à l'économie verte au sein des pays francophones de l'Ouest et d'une partie de l'Afrique centrale. Les données ont été recueillies au moyen d'études documentaires et de visites sur le terrain au Gabon, au Niger et au Bénin. Le secteur forestier joue déjà un rôle de premier plan dans la mise en œuvre des principes de l'économie verte. Les forêts et les arbres absorbent les émissions de CO2, fournissent des ressources aux populations locales et protègent les communautés des conditions météorologiques de plus en plus irrégulières. À cet égard, les pays étudiés ont élaboré des plans et des programmes tels que le boisement, le reboisement et les plans de gestion forestière visant à améliorer la couverture forestière et l'utilisation durable des ressources forestières. Les communautés locales participent activement à accroître de façon durable

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les avantages qu'elles tirent des ressources forestières. Cependant, aucun des pays n'est impliqué dans le mécanisme REDD+. Le Bénin s'est dit intéressé à participer au processus REDD+, tandis que le Gabon s'est opposé à ce mécanisme en raison des incertitudes du marché. Il est recommandé de renforcer les réformes et les connaissances en matière de politiques, ainsi que le transfert de technologies afin d'accroître la contribution du secteur forestier à l'économie verte.

Mots-clés : Afrique, Carbone, Sylviculture, REDD+, Ressources, revue, Durabilité

INTRODUCTION

Forests generate income and provide employment to over a billion people throughout the world, especially in developing countries. In its 2014 report on the state of the world's forests, the FAO estimated that about 840 million people (12% of the world's population), collect from forests wood fuel and charcoal for their own use (FAO, 2014). More closely, in less developed countries, forest products play important roles during crop failure period (Shackleton and Shackleton, 2004; Vodouhê *et al.,* 2009). In africa for example, about 150 million people live in homes where forest products are the main materials used for walls, roofs, floors (FAO, 2014).

However, despite the important role played by forest to people's well-being, deforestation and forest degradation continue at an alarming rate (FAO, 2011). To address forest loss, numerous policies and measures have been developed by countries to sustainably promote forest management, improve human well-being through the enhancement of food security, poverty alleviation and social inequality reduction. Thus, green economy has emerged in the recent years as a means to successful contribution to nation's economic development policies, gender and natural resources sustainable use.

The green economy concept was first used in 1989 by a group of leading environmental economists in a United Kingdom report (Pearce *et al.,* 1989). The aim was to advice the United Kingdom government to focus on the implications of sustainable development for the measurement of economic progress and the appraisal of projects and policies. They reported on the necessity to support environmental policy while the sequels extended this message to the problems of the global economy - climate change, ozone depletion, tropical deforestation, and resource loss in the developing world (Allen and Clouth, 2012). In response to the multiple global crisis in 2008 the United Nations Environment Programme (UNEP) championed the idea of "green stimulus packages" and identified specific areas where large-scale public investment could kick-start a "green economy" (Atkisson, 2012).

To date, there is no universal definition of the green economy concept and different topics were used to refer to the same concept. The organisation for Economic Cooperation and Development (OECD) uses the term "green growth" as opposed to the "green economy" to refer to the same concept, with a greater focus on integrating environmental and social factors into the concept of economic growth (Sustainable Prosperity, 2012). The term "clean economy" is also being used to refer to the same concept in literature. Green economy definition generally refers to the transition of the current economy towards one that supports "the development and use of products and services that promote environmental protection and/or

REDD+: Reducing Emissions from deforestation and forest degradation through forest carbon stocks conservation, sustainable forests management and forest carbon stocks enhancement.

energy security" (State of Washington, 2009). The green economy has social, environmental and economic aspects and must be considered in the context of sustainable development (Webb and Esakin, 2011).

The UNEP definition is largely adopted while a number of non-government organizations and partnerships have also developed their definitions of the concept. The UNEP defined the green economy as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low carbon, resource efficient and socially inclusive" (UNEP, 2012). This definition presents the necessary social, environment and economic integration to get sustainability.

The OECD defines green growth as "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies". On the other hand, ECO Canada stresses humanity attention on actor's intention. It defines the green economy as the aggregate of all activities operating with the primary intention of reducing conventional levels of resource consumption, harmful emissions, and minimizing all forms of environmental impact (ECO-Canada, 2010). According to Eco Canada, the green economy includes the inputs, activities, outputs and outcomes as they relate to the production of green products and services.

Looking at each of the green economy definitions above, there are different economic, environmental and social aspects considered (Webb and Esakin, 2011), entailing different parameters to measure the green economy. For the purpose of this review, we used green economy in line with the UNEP vision. Therefore, green economy in this paper is typically understood as an economic system that is compatible with the natural environment, environmentally friendly, ecological, and socially just. Thus, green economy can be thought of as one which is low carbon, resource efficient and socially inclusive (UNEP, 2012).

However, to date in West Africa, there is a gap of data on how forest sector could contribute to green countries' economy. Little is known on actions developed at country level to combine nation's economic development policies, gender and sustainable us of natural resources.

This study therefore sought to identify and analyse key elements within the forest sector that contribute to green economy of three French-speaking African countries (Benin, Gabon, and Niger). It also evaluated various parameters that characterise land use and land use change with the aim of understanding their management in ways that leave little negative impacts on the ecological and social systems as well as improving livelihoods.

METHODOLOGY

Study area. The present work was carried out through desk study and field visits in Benin, Gabon and Niger (Fig. 1). These three countries experience different climatic and demographic conditions. Therefore, the study has the advantage to assess forest contribution to green economy in countries with high climatic and vegetation variation. Indeed, Niger is a Sahelian country with about 540 mm of rainfall, while Gabon situated in equatorial zone receives 3 000 mm of rainfall per year. The climatic conditions in Benin fall in between these two extremes. According to country statistics, Gabon shows the best development indicator in opposite to Niger, one of the poorest African countries. These countries offer the possibility to assess forest contribution to green economy objectives in areas with different forest cover and climatic conditions. Gabon is covered in its central part by closed moist and semi-deciduous forests while Benin is largely covered by savannah

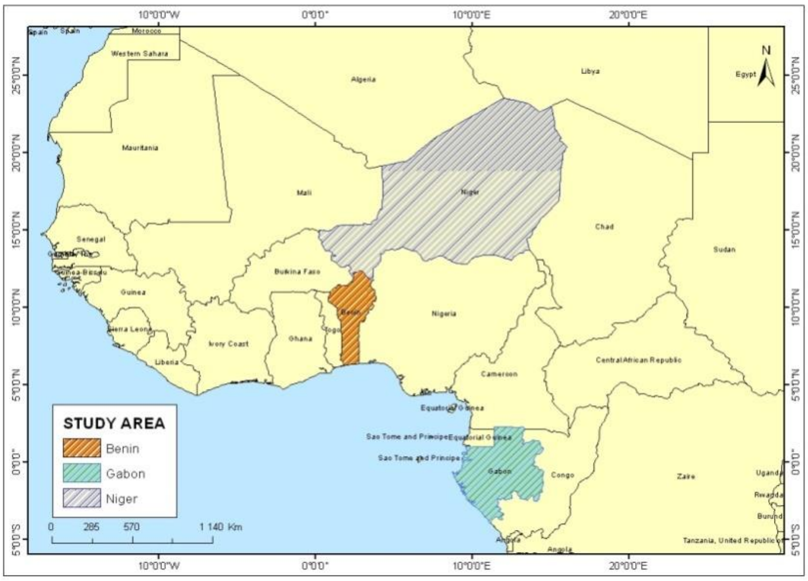

Figure 1. Tree countries covered by study

vegetation. Niger, a Sahelian country, has the lowest forest cover amongst the three countries studied.

Description of forest sector in selected countries. Although Benin has moderate forest cover (4 561 000 ha; 41% of country land area), the forest sector plays an important role in people's well-being especially in rural area. In 2011, it contributed USD 307 million to the national economy (4.6% of Gross Domestic Products) and 219 000 persons were directly employed by the forest sector in the country (FAO, 2014). Forest in Benin is mainly natural forest with limited planted area. The natural forest areas are concentrated mostly within protected areas throughout the country. According to FAO data, about 2.7 million hectares (19 % of the country) are located within national parks (843 000 ha), wildlife reserves (420 000 ha) and reserved forests (1 436 500 ha). The planted forest areas are mostly covered by teak (*Tectona grandis*), an economically important forest species in the country mainly in the southern part (Aoudji, *et al.,* 2012). Thus, flora census carried out in 2008 showed that planted forest (223 521 ha; 1.8% of country land area) were dominated by exotic species such as teak and acacia (80 000 ha), oil palm (90 000 ha), cashew and other afforestation species (PNGDRN, 2008). Despite its moderated cover, forest sector has a great potential to contribute to green economy objective and some actions were developed to harness this potential.

Gabon is one of African countries reporting the highest percentage of their land area covered by forest, about 85% cover (FAO, 2011). Forest resources are very important in the country's economy where wood products represent 60% of exported goods (Gumbo, 2010; FAO, 2011). Indeed, in 2008, the country produced 534 000 m^3 of woodfuel and exported, respectively, 2 178 000 and 62 000 m^3 of roundwood and sawnwood (FAO, 2011). The country has three major forest types: (i) evergreen rainforest occurring in the west, which has been heavily harvested, degraded and in some areas reduced to secondary forest characterized by the abundance of *Aucoumeakl aineana* and *Dacryodes buettneri;* (ii) the central Gabonese forest, covering most of the country, with many of the same tree species found throughout (*Canarium schweinfurthii, Lophiraelata, Entandrophragma, Khaya* spp and *Triplochitons cleroxylon*); and (iii) a semi-deciduous forest type occurring in the northeast, characterized by a predominance of Maranthaceae (rattan) in the sub-layer and by a dominance of trees such as *Terminalia superba*, and *Millettia laurentii* (STFM, 2005). So far 7,000 to 75,000 species have been identified and about 11% were endemic species (Sosef and Florence , 2007). The large part of Gabon forest is natural. Planted forests cover only about 25,000 hectares.

Among the three countries involved in this study, Niger has the lowest percentage of its land area (1%) covered by forest (FAO, 2011). Niger is a Sahelian country and the natural forest area covers about 600 000 ha of the country's land (CBD, 2014). Its flora contained 2,761 species in 2013 (CBD, 2014) compared to 2, 274 species in 1998 (Saadou, 1998), and is the main source of wood energy. Wood energy sector is the most developed in the forest sector and its commercialization earned about 11 billion CFA francs to forest dwellers communities in 2010 (CBD, 2014). Indeed, forest sector plays an important role in people's wellbeing providing food, fodder and medicinal plants. In Niger, formerly forested lands are plagued with soil loss and desertification. The Sahara Desert, which already covers two-thirds of the country, is expanding at a rate of 200,000 hectares annually. In an effort to slow the progress of the desert, the government planted more than 60 million trees between 1985 and 1997.

Data collection and analysis. Data were collected through desk study and field visits in selected countries. In each country, asystematic review on green economy concept was carried out through internet. International, regional or national institutions working in forest sectors websites were visited to collect data on forest sector contribution to green country economy. Especially, FAO and World Bank websites were visited for statistics on forest sector in each selected country. At regional and national levels, reports were collected from forests institutions, ministries in charge of forest sectors, and forest projects trough institutional websites.

Three field visits were organised within each country (Benin, Gabon and Niger) where formal and informal interviews were carried out with key actors (forest sector responsible persons, project and protected areas managers, forest sector technicians) involved in activities linking with green economy. Key contact persons were selected based on their knowledge and their institution's potential role in greening the forest sector. In total, 20 contact persons were selected to provide information during field visits in the three selected countries, i.e., 7 in Benin, 5 in Gabon and 8 in Niger. This was done through desk study where representative institutions involved in forest management were identified in each country. In cases where none or limited data were available, the key persons selected per country above were contacted to provide information.

For each country, a questionnaire was addressed to key contacts identified. Subsequently, appointments were made with each of them followed by face to face interviews during the field visits. Before travelling to each selected country, an official email explaining the aim of the mission was sent to contact person within institution in charge of forest sector and the appointment was made with them. Permission letter were requested for and obtained where needed. A questionnaire study was carried out to collect data on forest cover, planted forest areas, forest areas removed, country legislation in forest sector, forest management policies, sustainability in forest resources use, biodiversity conservation, forest potential in

REDD+ initiatives and number of employments in the forest sector. These statistics were summed up at country level to reveal forest potential to green country economy.

RESULTS AND DISCUSSION

Forest legislation and green economy objectives. For reach green economy objectives many actions were developed in each selected country to improve forest management policies.

Benin defined its forestry policy in 1994 based on the 93-009 law relating to forests which was accompanied by priority actions plans. The current management policy aims at allocating to local collectives the authority to manage forest resources under their responsibilities. Management under the current policy attempts to give local populations more control on the management plans. The current vision of Benin forestry policy on the horizon 2025 is: "A green Benin where forestry resources are sustainably managed for ecological, socio-economic and cultural needs and contribution to poverty reduction, food security and climate change mitigation" (MEHU, 2012). Thus, the current forest management vision is in line with green economy principles. Ongoing management strategies take into consideration the need of communities and allow effective local control and management through access and benefit-sharing. Through these strategies, the country has improved its forest management and increased local communities' awareness to support forest sustainable use.

In Gabon, authorities have attempted to increase and optimise the forest sector's contribution to economic and social development. The country updated its forest code (Law No 16/01 of 2001) to improve forest governance and management. The main goals of the 2001 forest code are to foster: (i) the sustainable development of forests; (ii) the industrialisation of the Gabonese timber sector; (iii) the sustainable conservation of natural resources, and (iv) greater local stakeholder involvement in the management of Gabon's natural resources. Thus, Gabon's current forest legislation aims to increase and optimise the contribution of the forestry sector to economic and social development and to promote a more diversified and efficient wood industry through a significant reduction in the export of logs and an increase in the local processing of wood products. This strategy is a good option to green the country economy. By promoting local processing, forest sector responsible goal is to more involve local people in forest good use by increasing their benefits through employments. Therefore, the current legislation also promotes the development of new forest harvesting rules, the introduction of means to monitor forest harvesting, the reform of timber licences to ensure wood supplies to local industries, the imposition of a progressive transformation tax on local forest production, and, finally, the progressive reduction of log exports from 75% of production in 1996 to 50% by the year 2005 (STFM, 2005). To green its economy, Gabon has adopted a national-level legislation supporting investment promotion and the establishment or enhancement of forest funds. Since 2007, the country has introduced taxes from timber or other sales revenues dedicated to re-investment for longer-term benefit such as roads or forest-management planning (FAO, 2014).

Based on green economy principles, the forest sector responsible in Niger developed strategies for forest resources sustainable use and significantly reduced environmental risks and ecological scarcities. To achieve this goal, they continuously work to revise the forestry legislation in a way to involve more local communities. Thus, the revision of the country's forestry resources juridical framework gives more prerogatives to communities in the context of decentralisation.

Through the law 2004-040 of 8 June 2004, local communities have authority to organise their forest management plan, carry out their own forestry inventory, and impose taxes on NTFPs use. Thus, taxes on woods carriage earned about US$ 2 672 871 (Nyare Essima *et al.,* 2012). Taxes on NTFPs are still in discussion while for example community levy in one of the country's municipality earned about US$ 57 814 during a two-year experimentation. This initiative aims at allowing local communities to use part of the money realized to finance community infrastructures. The main objective was to contribute to the country's sustainable development and poverty reduction through the management of biological diversity.

The three countries have signed many international conventions, laws, action plans and developed very good legislation to maintain and increase forest cover but their implementation remain limited. If all regulation strategies developed were well implemented, these countries' forest sectors could play even greater roles in green economy.

Climate change effects mitigation as principle to green countries' economy. In Benin, the carbon stock in living forest biomass was about 263 million tonnes in 2010, i.e., about 58 tons ha^{-1} (FAO, 2011). To increase forest contribution to climate change effects mitigation, many national policies have been developed and implemented at the national level. Thus, to ensure sustainable forest products uses, conservation actions were developed under different projects carried out throughout the country. Many afforestation, tree planting, local communities support and sensitisation actions were developed under a project PGFTR (Programme de Gestion des Forêts et Terroirs Riverains: Forests and Riparian Area Management Program) implemented from 2003 to 2013. The implementation of a project called Communal Forest Management from 2005 to 2011 helped to develop community forests managed by local authorities with high implementation of local communities. To reduce people dependence on forests for fire wood harvest, Benin government in collaboration with African Development Funds (AFD) carried out the second stage of the Fire-Woods Project from 2002 to 2011. Under this project, 2,515.214 ha of village and private forest are promoted and 2, 231.65 ha of state plantations were established. To better control fuel woods harvest, the project established about 86 rural fuel wood markets in 2009. These markets specificity were to involve market actors in classified forest conservation especially in the area where charcoal production is an important economic activity. These constitute a major new approach in participatory forestry management and the local income generation for poverty reduction in Benin. Since 2010, Benin has supported the implementation of the National Action Programme for climate change Mitigation (PANA: Programme d'Action National d'Adaptation aux changements climatiques). These actions aim at reinforcing forest sustainable conservation in the country.

In Gabon, the most forested country covered by the study, the carbon stock in living forest biomass was about 2 710 million tons in 2010, i.e., about 123 tonnes ha^{-1} (FAO, 2011) and the county experienced less than 1% change in its carbon stock from 1990 to 2010. Based on these results and knowing the importance of forests to the country economy, there is a need to develop strategies for their sustainability. To reach this objective, many national policies have been developed and implemented to increase the forest potential to stock carbon in living forest biomass. Apart from afforestation policy implemented by Gabon authorities, wood exploitation was regulated by developing many laws. Indeed, Gabon has a rich potential for additional carbon sequestration and greenhouse gas (GHG) reduction. The country's commitment to natural resources development led to the signing in 1998 of the UN Framework Agreement on Climate Change and the ratification in December 2005 of the Kyoto Protocol. A National Council on Climate Change was established in 2010 to draw up a National Climate Plan.

In the case of Niger, despite its limited vegetation cover, forest lands are continuously removed for agriculture, fire woods and urbanization. Therefore, forest capacity to stock carbon is still decreasing. An assessment of climate change in 2009 revealed that land use change and forestry contributed 55.6% to the gas emission followed by agriculture/ feeding (34.60%), energy (8.51%), wastes (1.21%) and industries 0.06% (PNCC, 2013). Thus, classified forest areas are continuously degraded. The carbon stock in living forest biomass was about 37 million tonnes in 2010, i.e., 31 tonnes ha^{-1} (FAO, 2011). To maintain and increase forest contribution to mitigation of climate change effects, the Niger government and NGO developed and implemented at the national level many environmental actions. Much afforestation, tree planting, local communities' support and sensitisation actions were developed under different projects in collaboration with international organisations and development banks such as the Danish International Development Agency (DANIDA), African Development Bank (AfDB) and European Union (UE). For example DANIDA has assisted the Niger government to carry out projects called "Projet Énergie II (1990-1996)" and "Projet Energie Domestique (1999-2003)". The African Development Bank (AfDB) has supported financially the country from 2000 to 2006 to carry out the Natural Forest Management. From 2006 to 2011, the Global Environment Fund (GEF) funded through United Nations Development Programme (UNDP) the project called Projet de Cogestion des RessourcesNaturelles de l'Aïr et Ténéré (COGERAT). This project's objective was to reinforce Aïr and Ténéré natural reserve surrounding communities' role in natural resources management within these reserves. To support the country to develop strategies to face climate change, UNDP-Japan funded the "Project Appui à l'Adaptation aux Changements Climatiques" to reinforce the country partnership and sectorial network development.

REDD+ mechanism and a green economy in selected countries. REDD+ activities such as afforestation, reforestation and sustainable forest management in low-income countries could lead to more income gains in the formal and informal forest sector. But for different reasons, none of the countries covered by this review was participating in the REDD+ programmes and activities. Benin and Niger are not opposed to the mechanism but Gabon despite its great forest potential and its selection as one of the 37 countries from Asia, Africa, Latin and Central America into the readiness mechanism based on its readiness plan idea notes (R-PINs), is not ready to integrate REDD+ mechanism if the carbon market will be established as defined currently. Readiness mechanism is one of the two separate mechanisms supporting Forest Carbon Partnership Facility (FCPF). This is a World Bank program whose goal is to assist developing countries in their efforts to reduce emissions from deforestation and forest degradation (REDD) by providing value to standing forests. Gabon Republic shows low deforestation and degradation rate and this puts the country in good situation for REDD+ and carbon finance mechanism in Africa. This is a good indicator to green country economy but the current carbon market development is not compatible with the country development objectives according to forest authorities.

Benin is already partner of CASCADE

(Créditscarbonepourl'agriculture,lasylviculture, la conservation et l'actioncontre la deforestation) project and expressed its interest to be involved in FCPF in 2014 . This allowed the country to develop institutional expertise and increased actors' capacities in commercial plantation development, community afforestation, biocarburant production with a view to create new opportunities for participating in millennium development programme (MDP) and voluntary carbon market. For Niger Republic, there is no data available on the country's intention to be involved in FCPF. The country is not also listed as participant in the CASCADE project which allowed involved country to develop institutional expertise and increased actors' capacities in commercial plantation development, community afforestation, bio-carburant producing in view to create new opportunities for participating in millennium development program and voluntary carbon market. However, the country is not opposed to REDD+ mechanism because there are some actions currently being developed for the country involvement.

Limits and policy actions needed. The forestry sector in the study countries has a potential to contribute to green economy, however, there exists some challenges hindering effective contribution to green economy. For example, the forest capacity of Benin and Niger to stock carbon is decreasing due to deforestation and forest degradation as a result of inadequate regulatory mechanisms. Indeed, in Benin, despite the protection strategies developed, forest areas are still being destroyed for agriculture, wood extraction, grazing and hunting. According to FAO data, 38.3% of GHG emissions in the country came from land-use change and forestry in 2011. Between 2000 and 2010, the country lost an average of 50 000 ha of forest per year (1% annual deforestation rate). The vegetation has been considerably modified by human activities and large areas of high-canopy forest have been cleared (FAO, 2011). Currently, most of the country's land area is covered by savannah, either resulting from the regeneration of cleared forests, or made up of natural Sudanian-type stands. In Benin, although the general policy as elaborated in many action plans and law encourage the environment conservation, their implementation remains limited. For example, concerning Nagoya protocol which promotes equitable sharing of advantages got from genetic resources use (APA), Benin has not implemented its own juridical system of APA even though there exist texts of law linking with protection and natural resources management in its national legislation.

In case of Niger, as a Sahelian country, it is facing degradation of its productive potential as a result of a globally unfavourable climatic situation, especially over the last two decades, and a fast growing land pressure, generated by a high population growth (3.3%) (CEDC, 2004). In addition to these unfavourable climatic consequences, the balance between human beings and nature is broken as a result of pressures exercised on the environment by people and livestock and a bad management of fragile ecosystems in arid zones that generate a gradual desertification process (CEDC, 2004). As in Benin, this desertification process especially results from the deforestation operated to develop agriculture and provide firewood in increasing quantities. The country has relevant juridical framework in the environment domain with about 317 texts of law from 283 at national level and 34 at international level (PNEDD, 1997). Despite this juridical arsenal and the institutional existent disposition, there is a need to point out the non-operational status of certain texts, the low consideration to conservation and sustainable use of biological diversity in the country's economy, the low consideration in the national legislation of the disposition of article 15 of the biological diversity convention "just and equity sharing of advantages got from genetic resources" and the insufficient disposition allowing researches and valorisation of traditional knowledge about biological diversity uses affecting forestry sector contribution to green economy.

With very low demographic pressure Gabon experienced low change in its forest cover. Woods logging is the most important forest activity in the country and this hides the potential role that could be played by other forests goods and services. Thus, with its opposition to REDD+ mechanism, the country will not benefit from the carbon market establishment which would have been a big opportunity to earn money to improve its habitants' wellbeing and increase their awareness about forest and its biodiversity conservation. Indeed, an estimation of deforestation reduction will allow the country to earn about US$ 2 to 33 billion per year but Gabon authorities think that the REDD objectives could not be reached only by funding actions. To obtain this fund the country will experience no deforestation but this will be very difficult considering the forest cover in the country. Gabon has 85% of its land covered by forest and it is difficult to see the country development without deforestation. For example, they have to increase their agricultural production to meet food security demands and this objective will be difficult to realise at the same time with the zero deforestation rate.

From the green economy perspectives some urgent actions are needed to reverse all of these weaknesses. In Benin and Niger, to contribute to mitigation of climate change effects, there is a need to develop actions to reduce forests degradation. Knowing that forest lands are mainly cleared for agriculture purpose, there is a need to promote intensive agriculture production. In some protected areas in Benin (Pendjari National Park and W park), some actions are currently being implemented by involving local communities in organic production. Organic agriculture is knownt to be less extensive and more profitable where the market is available. In this regard, to limit wood logging more effective afforestation programs are needed in countries such as Benin and Niger. Moreover, despite their non-member countries status, the REDD+ (reducing emissions from deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks in developing countries) mechanisms implementation would be very important for them. The introduction of schemes of payments for environmental services may be one option to be developed in order to help promote and better value other eco systemic services available through the forest sector.

CONCLUSION AND RECOMMENDATIONS

In each of the selected countries (Benin, Gabon and Niger), many actions were undertaken in support of green economy. The forest sector is already playing a leading role in green economy implementation. From the equatorial to Sahelian zone, the responsible forest sector has developed a number of programs to maintain forest cover or to afforest new lands. Currently, the Benin, Gabon and Niger forest cover is estimated at 27,765,000 ha and their carbon stocking capacity 3 010 million tons in 2010. These represents a high potential to fit green economy objectives. But apart from Gabon, the two other countries experience a relatively high deforestation rate. The main deforestation causes are agriculture, wood extraction, grazing, hunting and urbanization.

All of the three countries have developed good legislation to maintain and increase forest cover, but their implementation remain limited. If all regulation strategies developed were well implemented, these countries' forest sector would fit green economy principles. Gabon situated in equatorial zone of Africa has the highest percentage of is land area covered by forest followed by Benin and Niger in that descending order. With its large forest cover area, forest sector plays an important role to green Gabon's economy by contributing to national economy (woods exploitation mainly and NTFPs use) and stocking carbon in living biomass. Thus, with its very low deforestation rate, the country could benefit from the establishment of carbon market but its authorities are not agreeable to market access conditions. Indeed, to benefit from the carbon funds, the country has obligation to maintain its deforestation rate to zero. Although Gabon deforestation rate is already less than 1% per year, the country sees its integration to carbon market as a limitation to the socioeconomic development of the country. According to FAO, (2011), only 15% of the country area is not covered by forest and they have to increase their agricultural production to meet their population food needs and this may not be done without removing some forest areas. On the other hand, Benin has expressed its interest to be involved in Forest Carbon Partnership Facility. This represents the beginning of the country's integration into the REDD+ country members. It will probably benefit from its first REDD+ fund in 2020. This is a great opportunity for the country to benefit from its conservation effort. Concerning Niger, the country is not listed as REDD+ country and there is no data available on the country ambition to be involve in Forest Carbon Partnership Facility.

Globally, although the green economy concept is still in its infancy stage in countries covered by this review, actions already developed in forest sector comprise the beginnings of the concept implementation. However, for a well established green economy, there is a need to fill some gaps relative to knowledge about forest conservation mechanisms, interest to be involved in REDD+ mechanisms and development of different actions to involve local staff into green economy development process. Indeed, with the growing international interest in green economy, there is a need to:

- sensitize country staff about the benefits of green economy for sustainable development;
- implement effectively countries' policies and legal frameworks for better integration of local communities into forest management strategies for improved livelihoods ;
- develop more afforestation programmes with the view to increase the countries forest covers especially in Benin and Niger;
- provide a special place for REDD+, as a strong catalyst for the green economy;
- enhance efforts on conservation and sustainable use of biological diversity especially NTFPs; and,
- strengthen the national capacities on different concepts and facets of green economy through social and environmental policy making and how they can integrate with national priorities.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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