African Forest Forum

A platform for stakeholders in African forestry

The State of Forestry in Africa: Opportunities and Challenges

About AFF

Established in 2007 as a non-political, non-governmental, objective, independent and not for profit international organization, the African Forest Forum (AFF) is an association of individuals with a commitment to the sustainable management, wise use and conservation of Africa's forest and tree resources for the socio-economic well-being of its peoples and for the stability and improvement of its environment.

AFF exists to voice the concerns of African forestry stakeholders, and to use science, indigenous knowledge, and experience to advocate for the increasing relevance of forests and trees outside forests to peoples' livelihoods, national economies and the stability of the environment.

In this regard, AFF provides independent analysis and advice to national, regional and international institutions and actors on how economic, food security and environmental issues can be addressed through the sustainable management of forests and trees outside forests. Operationally, AFF mobilizes resources to address forestry and related issues that cut across countries and different African sub-regions with a view of enhancing the relevance and contribution of forests and trees outside forests to the livelihoods of the people of Africa and stability of their environment.

Vision

The leading forum that unites all stakeholders in African forestry

Mission

To contribute to the improvement of the livelihoods of the people of Africa and the environment they live in through the sustainable management and use of tree and forest resources on the African continent.

African Forest Forum

A platform for stakeholders in African forestry

The State of Forestry in Africa: Opportunities and Challenges

Correct citation: AFF, 2019. The State of Forestry in Africa: Opportunities and Challenges. African Forest Forum, Nairobi Kenya. 186 pp.

African Forest Forum
P.O. Box 30677-00100, Nairobi GPO KENYA
Tel: 254 20 722 4203 Fax: +254 20 722 4001
E-mail:exec.sec@afforum.org

Website: www.afforum.org
Follow us on Twitter @ africanff
Like us on Facebook / African Forest Forum
Find us on LinkedIn / African Forest Forum (AFF)

ISBN 978-9966-7465-9-7

9 789966 746597

Front cover photos: Dry forest in the Sahel Parklands ©AFF (left); Secondary forest in the southern part of Nigeria ©Larwanou Mahamane/AFF (middle); Harvesting timber in the Vipya forest plantations in Malawi ©Björn Lundgren/AFF (right).

Back cover photo: Secondary forest in the southern part of Nigeria ©Larwanou Mahamane/AFF

Design & Layout: Conrad Mudibo, Ecomedia

Disclaimer

Contents

Preface

Africa is rich in forests and woodlands, as well as trees outside forests. According to FAO (2016) Africa has 624 million hectares (ha) under forests, which comprise 20.6 percent of the continent's land area and 15.6 percent of the world's forest cover. Africa's forest area has declined by about 2.8 million ha between 2010 and 2015 (ibid), a much higher rate that in any other region in the world, and this has been mainly due to deforestation and forest degradation.

The forests are good sanctuaries for wildlife, offer opportunities for beekeeping, support many important ecosystem services and goods, and are home to many genetic resources. They are catchments to many rivers that are essential to the economic development of the continent. They generate considerable biomass that supports an overwhelming majority of Africans with their energy needs, mostly as woodfuel. Furthermore, the natural forest resources are increasingly receiving global attention because of their share in biological diversity, potential for industrial timber exports, capacity for mitigating global climate change, livelihood 'safety nets', and literally support all key pillars of rural development. African forests and trees outside forests also support the bulk of its people to adapt to the adverse effects of climatic change.

Forests and trees support many African national economies by supplying a variety of products and services to rural and urban communities. For example, these resources offer considerable support to agriculture, with much of the agricultural belt lying within the dry forest zone. They serve as a reservoir of land onto which agriculture expands. Most agriculture in Africa is rain-fed and therefore very vulnerable to climate variability that is characterized by frequent droughts and occasional floods, which at times destroy crops and livestock. At such times, rural communities increase their reliance on forests and trees for wild foods including fruits, tubers, fish and bush meat, edible insects, bees wax and honey, as well as traditional medicines. Also, many wildlife game parks are in forested areas, with the primary objective being wildlife management that targets the tourism sector. Most world-renowned wildlife parks and game reserves in Africa are found in these forests and woodlands and provide many countries with considerable incomes from tourism and game hunting.

Forests, and trees outside forests, are therefore at the centre of the socio-economic development and environmental protection of the continent.

Since these resources form an integral part of the livelihood strategies of local communities who live within and/or around them, human impacts in the forests have increased, mainly due to growing demand for agricultural land as well as increased demand for forest products and services, which are consequences of a rising human population and economic development. The pressure has gradually escalated also due to inappropriate land use practices such as shifting cultivation that has been practiced on progressively shorter cycles, slash and burn practice of farm clearing, frequent and uncontrolled bush fires, lack of soil conservation measures, uncontrolled live-stock grazing, and farming on marginal lands. Other major factors include conversion of forest land to non-forest uses such as mining, hydropower, urban centers and agricultural plantations.

In an effort to curb and manage these trends, considerable efforts have been made in the last few decades to empower rural communities and to devolve ownership and management of natural resources to them. It is believed that such devolvement will lead to better management and utilisation of these resources. However, this has not been matched with parallel efforts in terms of enhancing human capacities to take on these additional responsibilities and supplying people and communities with additional physical, financial and other resources to manage the forests sustainably. This is in line with the nature of such efforts in Africa where structural changes have been mainly confined at the macro-organisational level and there is no appreciable change and resources at the meso- and micro-levels.

These shortcomings notwithstanding, and despite the lack of good and sufficient information to support good forest management, there are efforts to manage African forests sustainably, especially those under formal administration. Sustainable forest management (SFM) is a long-term objective for many African countries and is written into most national and regional development plans and strategies. Developing SFM plans for multiple-use forestry is relatively new. Past experience dealt with management plans for sustained timber yield. It is encouraging that African countries are already taking realistic steps to improve management of these resources. The most important steps are in the realm of policy and institutional changes, both within the forest sector, in other related sectors, and the economy as a whole.

The regular review and sharing of information on Africa's forest resources and trees outside forests at the pan-African level, and even in a global context, is increasingly becoming important as Africa moves fast on regional and sub-regional integration, with forestry having considerable trans-boundary linkages. Also, the increasing relevance, at the global level, of international public goods and services that forest resources offer, some of which are critical for human, animal and plant survival on land, have considerably risen the profile of forestry on international, regional and national agendas. In this context, there is both a global and regional drive on how forest and tree resources, within different countries, should be managed and used sustainably, not only for national interests but for the benefit of all.

At both national and global levels there is increasing concern and attention paid to the national issues of deforestation and forest/land degradation that collectively affect the status and development of the forest estate, the provision of forest ecosystem services, support to livelihoods and enhancing national incomes that depend on these resources, and the protection and amelioration of the environment we all live in. While this trend continues to grow, Africa continues to experience increasing human and animal populations, high rates of urbanization, good economic development in many countries with improvements in peoples' welfare. The latter is accompanied with a growing middle class that also comes with different tastes in terms of housing, furniture and food. All these, and other changes, combine to increase demands on a shrinking forest resource base and on increasing trees on farms.

Africa also experiences a gradual change in key players in forestry, largely attributed to macroeconomic policies implemented by many countries, e.g. policies that are market oriented and with the private sector at the centre of national economic growth. National governments are increasingly backing off from commercial forestry investments, like establishing and managing forest plantations, wood processing, marketing and trade, as it used to be in the recent past. These roles are now largely in the domain of the private sector and local communities. The latter are largely facilitated by government extension agents and non-governmental organization (NGOs) in their forestry activities. National governments are now custodians of national forests and formulating related policies and regulations/laws, and guiding, monitoring and reporting on their implementation, as well as managing most of the natural forest resources. Some of these resources have either been transferred (in terms of ownership) to local communities or are managed by them in partnership with governments and, in some cases, with NGOs.

Not much is known about the private sector in African forestry. It is, in most countries, largely informal: it has many dispersed and uncoordinated actors, does not feature in national plans and budgets, lacks a champion for its cause, and does not exist as an entity that can articulate its issues to other players or receive the same from them, and financing remains problematic.

Local communities also have important roles but do not receive much attention in terms of resources for investment and building their capacity to deliver well. Civil society organisations (including NGOs) that support these two players (private sector and local communities) continue to remain on the periphery of national development plans and in allocation and mobilization of resources for their development. So, it is important to constantly evaluate, monitor and share information on how to strengthen these emerging key players in natural forest management and as potential future suppliers of the bulk of industrial roundwood on the continent.

At the global and pan-African levels, there are several key developments and environmental initiatives like the Paris Agreement, Land Degradation Neutrality, Aichi Targets, National Development Contributions (NDCs), SDGs, forest certification and green and blue economy that are important to the forestry sector as well as to trees outside forests. More specific initiatives to forests and trees outside forests include REDD+, CDM, the Bonn Challenge, New York Declaration on Forests, and the International Arrangements on Forests (IAF), to mention a few. At the pan-African level, examples include the African Forest Landscape Restoration Initiative (AFR100), the Comprehensive Africa Agriculture Development Programme (CAADP), AU's Agenda 2063, and a forthcoming Sustainable Forest Management Programme (SFMP) for Africa, also by AU. All these initiatives target sustainable management and use of forest and tree resources. As most of them are now taking root in many African countries, monitoring their mainstreaming into national policies, plans and activities, as well as to report on the same, are key concerns in both global and continental discourses.

Many of these global initiatives come with financial resources from sources such as GEF, GCF and financial institutions like the World Bank, resources that the continent could access and use to improve the sustained availability of goods and services from its forest resources. Further, all these and other similar initiatives combine to profile forest and tree resources on the continent as key for socio-economic development, environmental amelioration and stability, and to human, animal and plant survival, not only on land on the continent but globally as well.

Information generation and sharing the same on the development and use of these resources so as to enhance their roles is therefore very important, not only for the African continent but for the global community as well. FAO has already led the way by producing regular reports on the global state of these resources and on related aspects like trade in forest products. At such high level of aggregation African issues cannot be captured at length and in detail. Hence the launch of this first issue devoted to Africa on "The State of Forestry in Africa: Opportunities and Challenges". This issue provides a broad overview of some of the most pressing concerns in the forestry sector, with the intention that subsequent issues of this publication will dwell on other equally important concerns that could not be accommodated in this issue. AFF plans to produce, with potential partners, such issues once every 2-4 years, resources permitting.

The first chapter explores ways through which SFM can be facilitated to grow on the continent. The actual state of forest resources on the continent is an area that FAO has covered well in its regular publications on the same, so this report does not delve into this. Chapter 2 then looks at how the continent can increase the supply of industrial round wood outside its natural forests by examining the current state, management and supply of germ plasm or planting stock. Following investments in forest and tree establishment in various landscapes is the necessity to protect such investments from pests and diseases, among other vagaries. That is the subject of Chapter 3 that examines the current state, management and control of pests and diseases that afflict forests and tree resources on the continent. Climate change is increasingly bringing another dimension in managing forests and trees outside forests in the sense that a new commercial product, forest carbon, has been introduced to the forestry sector. In addition, climate change is affecting these resources while at the same time these resources affect climate change. This is the focus of Chapter 4. Biofuel development and use on the continent is growing, and this is in tandem with global efforts to develop clean energy through renewable resources. These and other issues are explored in Chapter 5.

The writing of this book would not have been possible without the financial support of the Swedish International Development Cooperation Agency (Sida) and the Swiss Agency for Development and Cooperation (SDC). We are also grateful to the many people and institutions who facilitated this work in various ways.

Godwin Kowero
Executive Secretary, African Forest Forum

Photo: greatapetrust.org

Chapter 1: The role of certification in accelerating sustainable forest management on the continent

Demel Teketay, Marie Mbolo, Severin Kalonga, Ahmin Olivier, Doris Mutta and Godwin Kowero

1.1 Introduction

Forest resources provide multiple benefits and have direct and measurable impacts on people's lives. Forests, trees on farms, and agroforestry systems play important roles in the livelihoods of rural people by providing employment, energy, nutritious foods and a wide range of goods and ecosystem services in most regions of the world (Njuki et al., 2004; Kowero et al., 2009; FAO, 2014). Well managed forests have tremendous potential to contribute to sustainable development and a greener economy (Muthoo, 2012).

Africa is characterised by extremely diverse ecological conditions, ranging from humid forests to deserts and from mountain temperate forests to coastal mangrove swamps.

Superimposed on this ecological diversity are varying degrees of human interaction, which are shaped by political and institutional arrangements, economic conditions, social and cultural settings (FAO, 2003; Barklund and Teketay, 2004).

Africa also harbours the second largest bloc of rainforest after Amazonia, which represents more than 15% (180 million ha) of tropical forests (FSC, 2014a). Over 90% of the 1.2 billion people living in extreme poverty depend on forests for some part of their livelihoods. Forest resources are also a major contributor to the national income of most countries in the continent, notably countries in the Congo Basin Sub-Region (FSC, 2014a). In general, similar to their counterparts elsewhere in the world, African forests have fulfilled and continue to fulfil critical economic, environ-mental, social and cultural functions (Barklund and Teketay, 2004; Njuki et al., 2004; Kowero et al., 2009; FAO, 2014).

The two main global forest challenges, namely deforestation and degradation, appear to be more pronounced in Africa than in other regions. On the surface they would be conceived as loss of forest cover and quality of forests, but in many parts of Africa these challenges are much more serious because they impact on human survival and environmental stability. According to the Millennium Ecosystem Assessment (2005) "deforestation involves the conversion of forests to another land cover type, degradation results when forests remain forests but lose their ability to provide ecosystem services or suffer major changes in species composition due to overexploitation, exotic species invasion, pollution, fires, or other factors." Forest degradation in Africa can be attributed to agriculture expansion by small holder farmers, livestock grazing, collection of fuelwood and making of charcoal (Hosonuma et al., 2012). Deforestation and forest degradation are a result of activities in many sectors in African national economies; they therefore deserve serious attention in terms of political will and action, as well as close coordination of related sectors, in addition to availability of adequate resources to manage the forests sustainably.

Indigenous trees growing in afro-temperate forest in South Africa. Photo: Abu Shakwa/Wikimedia Commons

Sustainable management of the vast and diverse African natural forest resource continues to be a complex issue that is also extremely challenging. Large tracts of natural forests are being treated as open access resources. Further, there is scanty information on the biophysical aspects of the natural forest estate, and even less on the properties and end use of the various tree species. There is much less information on socio-economic and policy aspects related to forest conditions, and responses to the same by users of such resources. In short, there is inadequate information of questionable quality and quantity, to guide rational decision making in planning and managing the resources. The resources should be managed and used in ways that address broader societal goals like to eradicate rural poverty and promote environmental protection.

There are other constraints that continue to make it difficult for the majority of African countries to manage these forests sustainably. Firstly, while forests are increasingly being appreciated, thanks to their role in containing some of the adverse effects of climate change, the forestry sector continues to receive low government priority in terms of political action and resources, and this has worsened because governments are pressurized by economic reforms to reduce public expenditure, and this translates into insufficient budgetary allocations to the sector. On the other hand, in many countries, policy and market failures have promoted the liquidation and degradation of the forest resources, sometimes to finance government expenditure and support livelihoods.

Secondly, many African countries, in their day-to-day struggle to satisfy the most basic needs of their populations (notably food), cannot accommodate the long-term investment and financing periods required for the successful implementation of forest management programmes. The result has been that the forestry sector continues to be subjected to annual cash budgets in many countries. Further, credit is increasingly available at rates of interests that make investments in primary forest production and, to some extent in wood processing, not attractive and profitable. There is, in addition, lack of incentives, in particular to local communities and the private sector, to sustainably manage and use natural forest resources.

Thirdly, forestry institutions in many African countries are weak, again mainly due to economic reforms that have, at times, led to inadequate funding and constrained recruitment of staff for the sector. This then compounds the problem of adequately conserving and managing the continent's forest resources. Fourth, economic reforms required governments, who in many African countries were major investors in industrial round wood production, processing and marketing, to channel these responsibilities to the private sector. However, the private forestry sector in many countries continues to be made up of many small, dispersed and unorganized players, who lack financial and other resources for investment, and who do not form an entity that can express its opinions in any forum. It also does not appear in central government plans, as well as in allocation of national resources. As a result, there has been loss in momentum in building a holistic and cohesive private foresty sector on the continent, and this has hampered a smooth link between primary and secondary forestry production.

In summary, the nexus between rapid population growth, poor agricultural performance, rural poverty, environmental degradation, market and policy failures, and the use of inappropriate technologies provides the basic context within which deforestation and forest degradation are taking place in Africa. This complexity seriously constrains the conception and development of sustainable management practices for these forest resources.

The foregoing notwithstanding, in the last two and half decades several planning frameworks under names such as National Forestry Action Plans, Forestry Master Plans, Forestry Sector Reviews, and National Forest Programmes have been undertaken in many countries in order to improve both planning and management of forest resources. They have led to revisions and/or instituting national forestry policies, legislation and plans. Further, many African governments have participated in numerous forestry related international processes, thereby becoming signatories to various international agreements and conventions, all of which emphasise managing forest resources sustainably. In this regard African countries have underlined their commitment to the sustained production of forest related international public goods and services.

African governments are also embracing new paradigms on both political and economic fronts. There is increasing participation of local communities in decision making. This has gradually been extended to managing natural forest resources. Local communities are becoming more empowered to undertake ownership and management functions from national central governments. On the economic front there is increased private sector participation in the national economies within a larger market oriented framework. This has seen the increasing opening up of the forestry sector to private investment. Industrial plantation management in Africa has not been very challenging because investors could draw upon experiences from other countries.

Further, African governments are increasingly becoming aware of the role of natural forest resources to the broader socio-economic development and environmental stability of their countries. The forests are valued for their habitats for wildlife, beekeeping, unique natural ecosystems and genetic resources. They are catchments to many rivers that are cornerstones of economic development on the continent. The critical functions of the natural forests in protection of soils and watersheds and the conservation of biological diversity have great economic and social implications in Africa. For example, adequate forest cover is a pre-requisite for sustainable agricultural production systems, wildlife management and tourism in many countries.

There is therefore increasing recognition that forests and agriculture are pivots of the rural economy in Africa. Efforts to eradicate poverty cannot be successful unless the roles of trees and forests in the rural economy are fully promoted. Sustainable livelihood, especially in rural areas, is partly dependent on the judicious management of forest resources. In addition, the natural forest resources are increasingly receiving global attention due to their share in biological diversity, potential for industrial timber exports, capacity for mitigating adverse effects of global climate, livelihood 'safety nets', and as levers for rural development.

There is therefore evidence that there have been many changes in forest management and thinking in Africa and globally, and this has facilitated at least the following developments in Africa:

- Decentralisation and devolution of forest administration and increased emphasis on community participation in forest management.
- Changes in forest administration especially through establishment of more autonomous boards, authorities and commissions.
- Increased role for the private sector in forestry production and processing; this has led to privatisation of public-owned commercial enterprises, including forest industries and plantations in many countries.
- Increasing role of civil society – especially national and international non-governmental organisations - in influencing forest resource management, particularly through their advocacy role and also through direct involvement in forestry initiatives in supporting community participation.
- Increasing political will due to concerns about global changes, especially those stemming from demands that forest also in Africa shall provide global public goods and services, and environmental protection, as reflected in various international arrangements including treaties and conventions (Tieguhong and Nair, 2004).

Even with these changes, much of the African natural forests are not under any form of effective forest administration and management. However, some efforts continue to be made within the continent and outside it that aim at accelerating the pace with which these forests could be managed sustainably. At national level forestry/forest policies and legislation emphasize better management and use of the resources. At sub-regional level, the regional economic communities (RECs) have policies specific to the forestry sector, or policies in the larger environment sector that includes forestry, that also advocate for sustainable manage-ment and use of forests. Examples include the

Marketing agricultural produce.
Photo: Charlie Pye-Smith/ICRAF (2014)

"Convergence Plan for the Sustainable Management and Conservation of Forest Ecosystems in West Africa" for ECOWAS countries, the East African Community Forests Management and Protection Act, SADC Protocol on Forestry, and the Convergence Plan of the Central African Forest Commission (COMIFAC). The Great Green Wall of Sahara and Sahel Initiative also targets sound ecosystem management.

At the 23rd Ordinary Session of the African Union Assembly in Malabo, Equatorial Guinea, in June 2014, Heads of State and Government adopted the "Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods". With regard to the forest sector, the same summit, in its Decision 'Assembly/AU/Dec.538 (XXIII)', directed the AU Commission (AUC) in collaboration with African Ministers responsible for forestry and energy to put in place a Framework for Sustainable Forest Management Programme in Africa. This marked the recognition of the importance of SFM at the highest political and governance levels on the continent.

Globally there are many agreements and initiatives that promote and support the development of SFM in individual countries. There are several key developments and environmental initiatives that come from the three Rio conventions (UNFCCC, UNCCD and CBD), in addition to the UNFF International Arrangement on Forests (IAF) and the SDGs that also target managing forest resources sustainably. One notable initiative or approach is ***forest certification*** which holds good potential as a tool to advance SFM on the continent. The rest of this chapter is devoted to forest certification and how it can be promoted on the continent in ways that can accelerate the pace with which African forests are managed sustainably.

1.2 Forest certification in Africa: status, achievements, gaps, challenges and opportunities

Over the years, two main policy approaches have been adopted, i.e. '*top down*' and '*bottom up*' approaches, to manage forest resources by relevant stakeholders and authorities world-wide (Naka et al., 2000). In the top-down approach, fundamentals of policies are formulated at higher levels of government and implemented under the authority of the government. The success of these command and control methods heavily depends on the strength of the governing body. The bottom-up approach relies more on a participatory approach where the public agrees on the need for, and forms of, the policy, and implements it through tradition, cooperative agreement or local rule. However, in modern complex societies, common interests binding the members of smaller communities are lacking, which hinders the success of this approach.

Despite the critical importance of forest resources, which has been re-affirmed empirically, and the agreed international plan to implement the "Four Global Objectives on Forests" developed by UNFF, the rate of deforestation is still alarmingly high in many parts of the world, including Africa (Njuki et al., 2004; Teketay, 2004-2005; Kowero et al., 2009; Chidumayo et al., 2011; FAO, 2014). The various top down and bottom up approaches mentioned above have so far not delivered. As a result, forest resources have been faced with different problems over the last several decades, which prevented them from realizing their potential contribution to economic and social development as well as environmental conservation. The most significant include the reduction of forest area and quality, environmental degradation of forest areas, loss of biodiversity, loss of cultural assets and knowledge, loss of livelihoods of forest-dependent people, and climate change.

These forest problems triggered global concern, especially over the last two decades since, as pressures increased on remaining forest areas, conflicts emerged between stakeholders, i.e. those who live in forests, forest industries, governments and the public at large who depend in different ways on the environmental, social and economic benefits provided by forests. In particular, the 1980s witnessed rapid and severe deforestation and forest degradation, with associated negative environmental, social and economic impacts, especially, in tropical countries. Governments tried, but failed, to solve the problems. This opened room for dialogues among concerned stakeholders with the aim of finding a solution to halt or prevent the prevalent deforestation and forest degradation worldwide (Teketay, 2015; Teketay et al., 2016). Past experiences of ineffectiveness and failures of the 'top down' and 'bottom up' approaches have led to the third approach, namely *certification*, which introduced policy changes through ethical trade and commerce rather than central or local power, and uses market acceptance rather than regulatory compliance as an enforcement mechanism (Naka et al., 2000; Vogt et al., 2000; Perera and Vlosky, 2006; Muthoo, 2012; Teketay, 2015; Teketay et al., 2016).

Certification is a procedure by which a third party provides written assurance/market labelling that a product, process or service conforms to specified standards, on the basis of an audit conducted to agreed procedures (Upton and Bass, 1995; Bass et al., 2001; Nussbaum and Simula, 2005). Forest certification (FC) is, therefore, the process of inspecting particular forests or woodlands to see if they are being managed according to an agreed set of standards. It is a

Natural stand of Miombo woodland in Zambia.
Photo: Forest Department Zambia (Government of Zambia)

soft policy instrument that seeks to use assessments of forest management in relation to a set of predetermined principles and criteria as well as indicators and their means of verifica-tion. The verification of legality, chains of custody, ecolabelling, and trademarks are applied to promote the sustainable management, conservation and development of forests in a holistic manner without compromising the rights, resources or requirements of present and future generations (Muthoo, 2012; Teketay, 2015; Teketay et al., 2016). FC also gives consumers a credible guarantee that the product comes from forests in which their management is environmentally responsible, socially beneficial and economically viable (FSC, 1994; Vogt et al., 2000; Meidinger *et al.*, 2002; Muthoo, 2012; Teketay, 2015; Teketay et al., 2016).

To provide consumers with this credible guarantee, two types of certificates are issued, namely *forest management* (FM) and *chain of custody* (CoC) certificates. These certificates relate to the different origins of forest products, stages of production and the subsequent progress of forest products through the value chain. A FM certificate is awarded to forest managers or owners whose management practices meet the requirements of the standards, while a CoC certificate verifies certified material and products along the production chain and applies to manufacturers, processors and traders of certified forest products. In addition to the FM and CoC certificates, a *Controlled Wood* (CW) certificate is issued by the Forest Stewardship Council (FSC), which is designed to allow organizations to avoid the categories of wood considered unacceptable. Also, other types of certificates have emerged for the verification of the legality of timber and timber products from some African countries.

From the foregoing, it is obvious that FC holds great opportunities through its actual and potential contributions discussed in detail elsewhere. It, therefore, can be a pragmatic instrument for harnessing market forces, public opinion and civil society in support of SFM (Muthoo, 2012; Teketay, 2015; Teketay et al., 2016). However, a recent assessment on the status of FC worldwide (FAO, 2014) revealed that the success so far in the promotion of SFM through the implementation of FC varies across countries and continents. For instance, the total area of certified forests and numbers of FM and CoC certificates issued in Africa by FSC and the Programme for Endorsement of Forest Certification (PEFC) Schemes, the only two international forest certification schemes (FCSs) that have made their footprints in Africa, are much lower than in other regions in the world (Teketay, 2015; Teketay et al., 2016; FSC, 2017; PEFC, 2017;), suggesting that the actual contribution of FC to SFM in Africa thus far is also relatively much lower than in other regions. This indicates that, despite the commendable efforts that have been and are being made to promote and implement FC in Africa (Mbolo, 2014a & b; Kalonga, 2014; Olivier, 2014), its success and contribution to promote SFM have been very limited.

Furthermore, the past and ongoing efforts made to promote FC in Africa, can be characterized as being scattered and uncoordinated. In addition, achievements made so far have not been documented systematically, making the analyses of efforts and achievements made so far, and the identification of gaps, challenges and opportunities associated with the implementation of FC, very difficult.

Therefore, the general objective of the study on which this chapter is based was to assess the status of FC in Africa and identify the associated achievements as well as the requirements to make FC successful in Africa. The specific objectives of the study were to: (i) assess the status of FC and determine the achievements recorded from the various efforts that have been made by different stakeholders to implement FC; (ii) analyze the gaps identified by the different stakeholders, which have limited the success of FC; (iii) identify the challenges encountered during the promotion and implementation of FC; (iv) assess the opportunities associated with FC; and, (v) based on outcomes from specific objectives (i) - (iv), undertake a needs assessment including the necessary actions required to close the gaps, overcome the challenges and exploit the opportunities that can be identified, developed and implemented by relevant stakeholders to make FC more successful in Africa.

1.3 Materials and Methods

The information and results included in this chapter were synthesized from a report entitled “Forest Certification in Africa” (Teketay, 2015), which was the output of a regional project that had four sub-regional components focusing on FC in central Africa (Mbolo, 2014a), eastern and southern Africa (Kalonga, 2014), northern Africa (Mbolo, 2014b) and western Africa (Olivier, 2014). The synthesis study focused not only on the information and results obtained from the four sub-regional studies, but also considered the general information and results generated from the Africa regional study on FC within and outside Africa that were not dealt with by the sub-regional studies. The figures on areas of forests certified, numbers of FM certificates and numbers of CoC certificates issued by FSC and PEFC were updates up to October and September 2017, respectively (FSC, 2017; PEFC, 2017).

Study countries

The countries included in the five study components of the regional project were: (i) Cameroon (CAM), Central African Republic (CAR), Democratic Republic of Congo (DRC), Equatorial Guinea (EG), Gabon (GA) and Republic of Congo (ROC) from the central Africa sub-region (Mbolo, 2014a); (ii) all countries from the eastern and southern Africa sub-region, but with detailed information from Kenya, Madagascar, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (Kalonga, 2014); (iii) Egypt, Morocco and Tunisia from the northern Africa sub-region (Mbolo, 2014b); and, (iv) Benin, Guinea Bissau, Burkina Faso, Cape Verde, Côte d’Ivoire, Gambia, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo in the western Africa sub-region (Olivier, 2014); and (v) countries within and outside Africa with available general information on FC relevant to the stated objectives of the Africa regional study on FC (Teketay, 2015).

Methods

To achieve the stated objectives, different methods were employed. These included: (i) synthesizing findings and information from reports of studies carried out on forest certification in the central, eastern and southern, northern and western Africa sub-regions; (ii) reviewing and synthesizing relevant information from: (a) published documents (books, periodicals, manuals, scientific journals, reports, etc.), (b) unpublished documents, (c) websites of forest certification schemes/systems (FCSs), certified forest companies, countries with certified products as well as those active in FC, organizations offering training on FC and those who were/are active in supporting FC in Africa, and, (d) other internet resources; (iii) consultation with experts and authorities responsible for FC and with certified forest companies; and, (iv) assessment of information gathered from the different sources (i-iii above) to identify needs for the successful implementation of FC in Africa.

Data collection

As much as was feasible, data were collected from the above mentioned sources for each of the four sub-regional studies based on the following pre-prepared topics: (i) status of FC in Africa: (a) FCSs engaged in FC; (b) past and ongoing support provided for FC; (c) availability of fundamental requirements for FC - enabling conditions (appropriate human, financial and physical resources, and technical skills), policy/legislation environment, appropriate institu-tional arrangements as well as markets and marketing structures/information systems for FC; and, (d) perception and engagement of stakeholders in the development of standards on certification; (ii) achievements recorded from implementation of FC: (a) development of FSSs; (b) types and area of forests certified; (c) types and numbers of forest certificates issued; and, (d) types and numbers of certified forest products and/or services; (iii) gaps identified, (iv) challenges observed during the implementation of FC; (v) opportunities associated with FC; and, (vi) needs identified for the successful implementation of FC in Africa.

Data analyses

The data collected for each of the studies were collated, compiled, analysed and synthesised. To assess the strength, weaknesses, opportunities and threats of past and ongoing efforts on FC in Africa, SWOT analyses were undertaken. The strength, weaknesses, opportunities and threats identified through the SWOT analyses were included in the available enabling condi-tions, gaps, opportunities and challenges, respectively. In addition to the SWOT analyses, the actual and potential contributions of FC were identified and analyzed to determine the opportunities that can be realized from the successful implementation of FC in Africa.

1.4 Results

Status of Forest Certification

The status of FC in Africa is described through presentation of past and ongoing efforts made and support provided by the various stakeholders and development partners.

Forest Certification Schemes (FCSs)

Two different groups of FCSs, which are promoting and implementing forest certification in Africa, have emerged over the years. The first group promotes FM, CoC and CW (only by FSC) certification. To this group belong the two *international* FCSs, namley FSC and PEFC. In addition, the African Eco-Labelling Mechanism (AEM) is being developed as an African *regional* certification scheme while two Pan-African FCSs affiliated to PEFC, namely Pan-African Forest Certification (PAFC) Gabon and PAFC Cameroon, are also being developed as *national* FCSs.

The second group promotes the verification of legality of timber and timber products, some in addition to FM, CoC and CW certification. To this group belong Origine et Légalité des Bois (OLB) (Origin and Legality of Timber) developed by Bureau Veritas (BV); Timber Legality and Tracability Verification (TLTV) by Société Générale de Surveillance (SGS), France; Verification of Legal Origin (VLO) and Verification of Legal Compliance (VLC) developed by SmartWood (SW), the Rainforest Alliance's Certification Programme for Forestry; and Forest Law Enforcement Governance and Trade (EU-FLEGT) Action Plan of the European Union (EU) with its two main elements, namely the EU Timber Regulation (EUTR) and Voluntary Partnership Agreements (VPAs) between wood producing countries and the EU. Details of engagement of these FCSs in FC in Africa are presented in the following sections.

Forest Stewardship Council (FSC) is one of the major organizations, which pioneered FC in Africa through promoting certification of various forest types in different countries, recruiting and endorsing FSC National Contact Persons/National Initiatives (NCPs/NIs) to spearhead the process of development of standards and FC in their respective countries, establishing African Regional and Sub-Regional Offices, and building the capacities of countries and stakeholders for responsible forest management (RFM). In addition, FSC has been implementing different projects to familiarize stakeholders, promote and implement FC in the different sub-regions of Africa.

The project implemented by FSC was entitled "*Capacity Building for Sustainable Forest Management and Forest Certification in Africa*" (Boetekees, 2002; Barklund and Teketay, 2004). It was implemented between August 2004 and June 2009, mainly in Cameroon, Gabon, Ghana and Republic of Congo (ROC) through funding from the Danish International Development Agency (DANIDA), the Directorate-General for International Cooperation (DGIS) in Netherlands and Novib (OXFAM-Netherlands). The major achievements of the first FSC project in Africa (Teketay, 2004-2008) are summarized below.

- A legally incorporated FSC Africa Regional Office (FSC-ARO) was established in Ghana with the recruitment of the first FSC Africa Regional Director and a Social Officer (who was based in Yaoundé, Cameroon, to cater for the Congo Basin Countries) as well as bilingual (English and French) Administrative and Finance Officer and Secretary, two security officers and a fully-equipped office.
- Four reports were produced on *"Forest resources, rural communities and prospects of SFM and certification"* in Cameroon, Gabon, Ghana and ROC.
- Several stakeholder training workshops were organized on FC in Cameroon, Côte d'Ivoire, Gabon, Ghana, Kenya, Liberia, Morocco, ROC and Zambia.
- Ten FSC documents, including FSC Principles and Criteria and 18 approved FSC standards, were translated into French and distributed to stakeholders in Francophone Africa.
- 16 FSC NCPs were identified in Burkina Faso, Cameroon, Côte d'Ivoire, Democratic Republic of Congo (DRC), Ethiopia, Gabon, Ghana, Kenya, Morocco, Mozambique, ROC, Senegal, South Africa, Tanzania, Uganda and Zambia, and their applications were processed and endorsed by FSC. FSC-ARO organized the first ever training and meeting of FSC National Initiatives (NIs) in Africa.

- FSC National Offices, furnished with modest office furniture/equipment and modestly funded monthly, were established in Cameroon, Gabon, Ghana and ROC.
- National Working Groups (NWGs) were established in Cameroon, Côte d'Ivoire, Gabon, Ghana, Kenya, Morocco, ROC, South Africa, Tanzania and Zambia to develop national standards and promote FSC FC.
- National forest stewardship standards were developed by NWGs in Cameroon, Côte d'Ivoire, Gabon, Ghana, Kenya, Morocco, Mozambique, ROC, South Africa, Tanzania and Zambia and field-tested by NWGs in Cameroon, Ghana, Morocco and Mozambique.
- The NWG in Ghana and the forest stewardship standard it developed were endorsed by FSC.
- A Sub-Regional Working Group (SRWG) for the Congo Basin, composed of representatives from Cameroon, Central African Republic, DRC, Gabon, ROC and other relevant stakeholders, was established to develop and promote sub-regional forest stewardship standards.
- Draft FSSs for the Congo Basin were developed by comissioning an expert. They were then, discussed and approved, first by the SRWG and subsequently, in April 2012, by FSC as FSC-STD-CB-01-2012-EN Congo Basin Regional Plantations and Natural EN (FSC, 2014b).
- A publication entitled "*Forest certification: a potential tool to promote SFM in Africa"* (Barklund and Teketay, 2004) was prepared for the project "*Lessons Learnt on SFM in Africa*", which was jointly implemented by the Royal Swedish Academy of Agriculture and Forestry (KSLA), African Forest Research Network (AFORNET) at the African Academy of Sciences and FAO.
- FSC-ARO participated in a GEF-supported project entitled "*Improved certification schemes for sustainable tropical forest management*", which involved Cameroon, Brazil and Mexico in 2006. The aim of this project was to develop the tools and incentives to help small forest managers, communities and NTFP collectors in the tropics to identify and protect biodiversity in the forests they manage through certification, while continuing to meet their own management objectives.
- FSC-ARO participated and contributed actively as a member of the "*Regional Expert Group Meeting (REGM) on developing an African Eco-Labelling Scheme*" in 2007.
- FSC-ARO, in partnership with GIZ/GTZ, implemented a Public and Private Sectors Partnership Project in Cameroon (PPP-Cameroon) on "*Adaptation of certification approaches to council forests and other small and medium-sized forest units from permanent estates and improving their access to international market*". The project was instrumental for the development of the Community Small Low Intensity Managed Forest (SLIMF) standard in Cameroon (FSC-STD-CAM-01-2010), which was approved by FSC in December 2010 (FSC, 2014c).
- A website for FSC Africa was designed and uploaded on to FSC website.
- FSC-ARO participated in two sub-regional workshops in 2006, one in Ethiopia and one in Cameroon on "*Lessons and the way forward with SFM in Africa*" organized by the SFM in

Africa Project (Phase II) in partnership with AFORNET and KSLA. A presentation on "*Forest certification and FSC Africa*" was made. The workshop was instrumental in brainstorming for the establishment of the *African Forest Forum (AFF)*.

- The number of FSC members in Africa increased from three in 2004 to 130 in 2008.
- FSC-certified forests increased from about 1.9 million ha in six countries in 2004 to about five million ha in eight countries in 2008-2010 (Blaser et al., 2011).

Unfortunately, with the termination of the project funding, FSC-ARO had to be closed down in June 2009, which also happened to coincide with the global economic melt-down. This led to closure of the national offices established with support from the project and discontinuation of the activities initiated in the different countries.

In August 2010, an FSC-ARO was re-opened in Cameroon with an appointment of the second Africa Regional Director (Hakizumwami, 2011). The major achievements following the re-opening of FSC-ARO are summarized below.

- Awareness was created and capacity was built for key actors (auditors, staff members of logging companies and public administration, local NGOs, individual experts, etc.) on FC to promote responsible forestry.
- Market links were created between producers and buyers (countries and individual companies) for FSC certified timber.
- Frameworks of consultation and dialogue on credible FC were established.
- The Congo Basin Sub-Regional Forest Stewardship Standard, mentioned above, was endorsed by FSC.
- The SLIMF standard, mentioned above, was endorsed for Cameroon by FSC.
- Timber legality verification standards were promoted.

The FSC-ARO was closed once again in 2012. However, in 2013, an FSC-ARO was re-opened with the appointment of the third FSC Africa Regional Director, this time, in Johannesburg, South Africa, along with two Sub-Regional Coordination Offices for the Congo Basin and East Africa based in Brazaville, Republic of Congo, and Nairobi, Kenya, respectively. The major achievements following the second re-opening of the FSC-ARO are summarized below (Anonymous, 2015).

- FSC East Africa Roundtable Meetings were held in Uganda (2013) and Tanzania (2014).
- FSC Congo Basin Office provided assistance to the Gabon Government to plan a two-day National Workshop.
- Four national meetings have been held in the Congo Basin with the financial support of the Regional Programme for Central Africa of the World Wildlife Fund (WWF-CARPO). Respective stakeholders from Cameroon, ROC, DRC and Gabon are now engaged in the development of National Standards in compliance with version 5 of FSC's Principles and Criteria, and the final version to come of FSC's International Generic Indicators (IGIs).

- The largest contiguous forest concession in the tropics (1.16 million ha), owned by Industrie Forestière d'Ouesso (IFO) - a subsidiary of hardwood company Danzer in ROC, received the FSC FM and CoC certificates at the end of 2014.

Programme for the Endorsement of Forest Certification (PEFC) Schemes supported the establishment of and endorsed PAFC-Gabon and PAFC-Cameroon under the PEFC endorsement process.. However, there is no forest, product or service certified by PAFC Gabon or PAFC Cameroon as yet.

African Eco-Labelling Mechanism (AEM), with its already developed brand known as Ecomark Africa (EMA), is being developed as an African Regional Certification Scheme initially focusing on four priority sectors, namely Agriculture, Fisheries, Forestry and Tourism (Teketay, 2012a & b; UNEP, 2008). The steps and process involved in the evolution of AEM are summarized below:

- The Johannesburg Plan of Implementation that was endorsed by the World Summit on Sustainable Development in 2002 encouraged the development of consumer information tools such as eco-labels.
- The African 10 Year Framework Programme (10-YFP) on sustainable consumption and production (SCP) has been developed as part of the regional follow-up to the Johannesburg Plan of Implementation.
- The 10-YFP was approved by the African Ministerial Conference on the Environment (AMCEN) and its implementation was officially launched in 2006.
- As one of the five priority areas of the 10-YFP, the African Roundtable on Sustainable Consumption and Production (ARSCP), in cooperation with UNEP, identified the development of a continent-wide and cross-sectoral eco-labelling scheme, the African Eco-Labelling Mechanism (AEM), with its brand as Eco Mark Africa (EMA).
- The concept and architecture of AEM was further advanced by African experts and supported by the Marrakech Task Force on Cooperation with Africa, which was facilitated and funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).
- This consultation phase was implemented in close cooperation with the Trade and Industry Department of AUC, the African Organization for Standardization (ARSO), UNEP, UNIDO, the UN Economic Commission for Africa (UNECA), and the Regional Economic Communities (RECs) in Africa.
- In 2006 and 2007, a comprehensive regional assessment was conducted on existing eco-labelling initiatives in the region with the purpose of building upon what is already existing in the region and learning from existing initiatives (Janisch, 2007).
- Organized in collaboration with AUC and UNECA, the first Regional Expert Meeting on Eco-Labelling in Africa was convened in June 2007. Representatives of the Consumers

Information Network (CIN), the South African Cleaner Production Center, FSC, the African Organic Farming Foundation,IUCN, Clongen Laboratories, the NEPAD Secretariat, the Agro Eco Uganda Branch and UNEP reviewed the outcome of the regional assessment and made recommendations on how to develop the regional eco-labelling mechanism.

- Consultations were held through the Regional Working Group on Eco-Labelling. The summary outcome of the assessment and the regional meeting was printed as a booklet and distributed to different forums as a basis for consultation with the aim of ensuring the political buy-in from the relevant inter-governmental institutions and forums, including AUC, the African Committee on Sustainable Development (ACSD) and ARSO.
- The 5th African Roundtable on Sustainable Consumption and Production (ARSCP-5) called for a continued political commitment for the effective implementation of the programme. As a follow-up to the Regional Expert Meeting and the consultation processes, a preliminary paper on the *'Structure and Function of an AEM'* was prepared in 2007. Facilitated by UNEP, the paper was further developed and finally endorsed as the *Strategy Document of the AEM*.
- In 2009, the Executive Board of AEM was formed (see point 1 beloiw).
- Through a consultative process, AEM's eco-label, named Eco Mark Africa (EMA), was developed, and through its EMA label, the AEM aims at promoting intra-African and international trade and enabling African economies to adapt and contribute to the mitigation of climate change.
- The AEM has developed sustainability standards, through consultative processes, for recognizing and branding sustainably produced African products and services from agriculture, fisheries, forestry and tourism, which have been selected on the basis of their economic importance for Africa as well as their contribution to global greenhouse gas (GHG) emissions. The four standards have been endorsed by the Executive Board of AEM in 2013 (AEM, 2014). At a later stage, the scope of the AEM shall be expanded to additional sectors.
- The organizational structure of AEM builds on existing capacities and structures within the region in order to effectively respond to African needs and priorities within the context of global trade and environment regimes. It includes:

    1. an Executive Board composed of AUC (Chairperson), ARSO, ARSCP, eight RECs, African Business Community (ABC), Consumer International (CI), UNECA, UNEP, UNIDO and BMU/GIZ, as well as the Executive Manager of AEM (Secretary).
    2. a Technical Board composed of representatives of ARSO (Chairperson), ARSCP, Chairs of the four Sector Working Groups and three relevant technical institutions, including AFF (responsible, mainly, for the evaluation of the conformity assessment of producers and the equivalence assessment of standards systems submitting to the EMA benchmarking process);
    3. AEM Secretariat based in Nairobi, Kenya (operative body of the AEM, coordinating the development and revision of standards, steering marketing and capacity building activities, acquiring political support, promoting certification, label management and service provision, etc.); and,

4. four Sectoral Technical Working Groups, one each for the agriculture, fisheries, forestry and tourism priority sectors (responsible for spearheading the development, field testing and getting the AEM standards approved) and a Marketing Panel (responsible for developing and assisting in the promotion of the AEM marketing strategy).

- AEM is currently being elaborated with regard to the types of certificates to be issued as well as its accreditation programme and steps required for certification. No forest has been certified through the AEM FCS as yet.

Pan-African Forest Certification (PAFC) Gabon is a Pan-African national FCS, which has already been endorsed by PEFC. A brief summary of its development is presented below:

- The process of development of PAFC Gabon as PEFC-affiliated national FCS started in the mid-1990s (TERRA, 2008).
- In 2004, a workshop entitled "PAFC Gabon, the opportunity for world promotion of the Pan-Africa certification and ATO/ITTO Principles, Criteria and Indicators (PCIs)" was held in Libreville. This workshop opened the way for the creation and institutionalization of an associate structure called "*PAFC Gabon*" destined to be the Gabonese instrument of support for the national certification PAFC Gabon.
- PAFC Gabon is designated "*Pan-African Forest Certification Association of Gabon*", and its bylaws were submitted to the Gabonese Interior and Decentralization Minister in December 2004.
- Different experts worked during the course of 2005 on the expansion of a technical document defining the rules and procedures of PAFC certification in Gabon. This document, called "*The Gabonese Scheme for Forest Certification*" was submitted to the PAFC General Assembly for advice and approval in June 2005. The Scheme was then validated during the national workshop, which took place in 2006 in Libreville, reuniting all stakeholders in SFM and the protection of the environment.
- In October 2004, PAFC Gabon submitted its candidature to become the Gabonese member of the PEFC Council. It was accepted following the General Assembly of the PEFC Council in Chile (October 2004).
- This international recognition of PAFC Gabon by the PEFC was in accordance with the wishes of the Ministers of the ATO. The recognition process by the PEFC Council began in April 2006.
- Form International, a consultancy firm, was appointed by the PEFC Council and assessed the Gabonese FCS. They produced a report in 2007 listing the main points that needed to be corrected in the scheme.
- The PAFC Gabon General Assemblies held in April and September 2008 ratified the changes to the Gabonese FCS so that it fully complies with the requirements of the PEFC Council.
- PAFC Gabon joined PEFC in 2004, and in April 2009, its scheme became the first in Africa to meet PEFC's sustainability benchmark requirements (PEFC, 2015a, b). Based on the

requirements of PEFC, PAFC Gabon has been re-endorsed by PEFC in November 2014, which is valid until November 2019.

- Though more than 10 years have elapsed since its endorsement, no forest has been certified through the PAFC Gabon FCS as yet.

Pan-African Forest Certification (PAFC) Cameroon is the second Pan-African PEFC-affiliated national FCSs, which was created in October 2007. PAFC Cameroon (Cameroonian Association of the Pan-African Forestry Certification) is currently in the process of developing its FCS and aims to develop, promote and implement FCS adapted for Cameroon based on the ATO-ITTO PCIs.

Organizations verifying legality of timber and timber products.

Different organizations are engaged in verifying the legality of timber and timber products originating in central and western Africa sub-regions. Engagements of these organizations are presented briefly below.

Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan was developed by EU in 2003, which provides a number of measures to exclude illegal timber from markets, improve the supply of legal timber and increase the demand for wood products from legal sources. The two main elements of this action plan are the *EU Timber Regulation (EUTR)* and *Voluntary Partnership Agreements (VPAs)* between wood producing countries and the EU. Since then:

- Cameroon started the negotiation of the VPA with the EU in 2003. It was signed and ratified in 2010 and 2011. Cameroon is developing the systems needed to control, verify and license legal timber.
- Central African Republic signed the VPA with the EU, and is developing the systems needed to control, verify and license legal timber. It will use these systems for timber and timber products exported not only to the EU, but also to other destinations worldwide.
- DRC and Gabon are negotiating their VPAs with the EU.
- ROC has ratified a VPA with the EU, and is developing the systems needed to control, verify and license legal timber. It will use these systems to cover timber and timber products exported not only to the EU, but also to other destinations worldwide. The systems will also apply to timber and timber products sold within the country.

Legal Verification System of Bureau Veritas (BV) has developed the OLB system, an international system based on a complete and strict legality requirement for traceability adapted to forest enterprises and simple and effective wood tracking CoC, to heed client requests for an official and third-party certification on the legality of their timber. This is an exclusive service of certification by BV. OLB is based on a certificate for operators/forest managers and a certificate of CoC for industrialists and traders. The legality certificate is based on compliance with the certification standard by forest companies. This document presents the provisions to meet compliance with the laws regarding the management and exploitation of wood, employment and security of persons, and respect for the environment. It also addresses the issue of traceability of the wood in the company until the sale or primary processing. The certification of companies processing and trading wood is based on the CoC standard. This document presents the provisions to meet the right to use the OLB mark on products of companies. BV has certified a total area of 628,212 ha of natural forests in two companies in Côte d'Ivoire through its OLB system.

SGS Timber-Traceability-and-Legality Verification System (TTLV) was developed to improve traceability and forest management with technology. Using technology to trace the movement of timber and monitor financial flow has transformed transparency in the forest sector. Ensuring efficient control on timber movements guarantees the legality of exported or locally distributed timber, and enhanced traceability ensures that the supply chain data is 100% accurate from the forest to the point of export. By using technology to enhance forest management, timber can be traced, tracked and eventually certified. The significant presence of SGS in the global forest sector gives it insight into how regular auditing, continuous monitoring and independent verification of a company's wood production can enhance supply chains and sustainability.

VLO and VLC of the Rainforest Alliance (RA) SmartWood (SW). The Rainforest Alliance (RA) has developed standards and procedures for independent third-party verification that wood has been harvested and/or traded legally. RA's standards verify the legality of the wood at the forest level and ensure the traceability of legal timber at all points in the supply chain (CoC). RA offers forest product companies voluntary independent third-party verification of legal status for the sources of raw material used in their products. It originally developed its legality verification programme as a progressive, two-tiered system in which companies began with Verification of Legal Origin (VLO) and moved to Verification of Legal Compliance (VLC). VLO verifies that timber comes from a source that the harvester has a documented legal right to harvest, pursuant to the laws and regulations of the government of the jurisdiction. Suppliers of VLO timber must follow and maintain documented CoC systems. VLC ensures that the administrative requirements of permitting, planning, taxes or fees, and harvesting, as well as a broad range of applicable and relevant laws and regulations related to forestry have been met. The difference between "legal origin" and "legal compliance" is important. Legal origin verification signifies that a company has met the administrative requirements of permitting, planning, taxes or fees, and harvesting in defined areas only. Legal compliance encompasses a broad range of laws on environmental protection, wildlife, water and soil conservation, harvesting codes and practices, worker health and safety, and fairness to communities.

Certification Bodies (CBs) engaged in Forest Certification. The following CBs have been engaged in FC in Africa: (i) BV (both FSC- and PEFC-accredited); (ii) Scientific Certification Systems (SCS) - doing business as SCS Global Services (both FSC- and PEFC-accredited); (iii) SW (FSC-accredited); (iv) SGS (both FSC- and PEFC-accredited); (v) Quality Assurance Training (QAT) (PEFC-accredited); and, (vi) Woodmark Soil Association (WSA) (both FSC- and PEFC-certified).

Support provded for Forest Certification in Africa

In table 1 below, past and ongoing support for FC in Africa is listed. Such support include capacity building/training, standard development and funding.

Table 1. Types of support for FC in Africa and their spread among institutions

Institutions*	Support		
	Capacity Building/Training	Standard Development	Funding
FSC	✓	✓	✓
SSC – Forestry	✓	-	-
AB Training/CMO	✓	-	-
Bureau Veritas (BV)	✓	✓	-
Smartwood (SW)	✓	-	-
CES	✓	✓	-
BWWI	✓	-	-
GIZ and IAC	✓	-	-
COMIFAC	✓	-	-
FSC and GTZ	✓	-	-
HCEFLCD, SDA, WWF, UNDP and USA PC	✓	-	-
GCDF	✓	-	-
ATO and ITTO	-	✓	-
ATO, ITTO and CIFOR	-	✓	-
FSC, GTZ and UNDP	-	✓	-
WWF	-	-	✓
FSC Denmark	-	-	✓
COMIFAC and FSC	-	-	✓
ECOFORAF	-	-	✓
BMU			

* FSC = Forest Stewardship Council; SSC-Forestry = Svensk SkogsCertifiering AB; CMO = Center for the Modernization of Operations; CES = Centre d'Excellence Sociale; BWWI = Building and Wood Workers International; GTZ = Gesellschaft für Internationale Zusammenarbeit; IAC = International Agricultural Center; COMIFAC = Commission des Forêts d'Afrique Centrale; HCEFLCD = Haut Commissariat aux Eaux et Forêts et à la Lutte contre la Désertification; SDA = Social Development Agency; WWF = World Wide Fund for Nature; UNDP = United Nations Development Programme (UNDP); USA PC = US Peace Corps; GCDF = Group Chèque Déjeuner France; ATO = African Timber Organization; ITTO = International Timber Trade Organization; CIFOR = Center for International Forestry Research; ECOFORAF = Support for Ecocertification of Forest Concessions in Central Africa; ✓ = Yes; - = No information (source: Teketay, 2015).

Availability of fundamental requirements for Forest Certification

The successful promotion and implementation of RFM at the country level in Africa, through FC as a market tool, entails the availability and accessibility of fundamental requirements, the major ones being enabling conditions, such as adequate human, financial and physical resources, technical capability/skills and marketing structures/information systems for certified forest products/services as well as enabling policy/legislation environment and appropriate institutional arrangements. The spread of these fundamental requirements for FC in Africa is summarized below.

Enabling conditions. The major bottleneck in the promotion and implementation of FC in Africa is either the inadequacy or the complete lack of the enabling conditions for FC mentioned above. For instance, the enabling capacities required to implement FC effectively and efficiently, i.e. sufficient human, financial and physical resources, and technical capability/skills, by the various actors engaged along the entire value chain of the forest sector, are very far from being adequate. Nevertheless, some encouraging conditions exist on the ground while promising initiatives are emerging in the different sub-regions of Africa as summarized below:

- FC is an internationally recognised, independently verified procedure for ensuring that forests are sustainably managed, social issues are adequately considered, benefits are equitably shared and forest ecosystem services are not compromised.
- Availability of price premiums for some certified forest products.
- The existence of certified forests and products from Africa (see details under Achievements below) provides concrete evidence that FC and RFM/SFM can be realities and accomplished successfully in Africa. This can be considered as a capacity as it can increase confidence in stakeholders, thereby, moving FC and RFM/SFM forward..
- Signature of VPA by some countries with the EU is creating favorable conditions for FC.
- Though still very few, the national and sub-regional FSSs (see details under Achievements below) , which have been developed in a few countries in Africa and endorsed by FSC, PEFC and AEM, form capacities that could be scaled-up and -out to promote credible FC and RFM/SFM.
- The increasing political will of governments, e.g. in the Central African Sub-Region (CASR), which own all the forests, for FC as well as the efforts being made by ATO/ITTO, COMIFAC and bilateral cooperation, the Conference of the Ecosystems of the Dense Humid Forests of Central Africa (CEFDHAC) and the Programme Sectoriel Forêts Environnement (PSFE) specific to Cameroon, to promote and support FC and RFM/SFM.
- Though not adequate, the presence of policy and legal frameworks that support FC.
- Increased revenue to governments as more taxes are paid due to good forest governance as a result of FC.
- Though not adequate as yet, the presence and operations of FSC Africa Regional and Sub-Regional Offices, in Johannesburg and Brazaville, respectively, FSC National Representative and

Focal Point in ROC and Uganda, respectively, National Offices of PAFC in Gabon and Cameroon as well as several NWGs affiliated to FSC, PEFC, ATO/ITTO in different African countries, are emerging capacities, which are and will be very instrumental to accelerating the process of FC and RFM/SFM in the continent.

- Existence of awareness of FC and well-trained staff in the forest sector in some countries.
- Although the exact number is not well known, there are experts trained in forest certification, including for auditing/assessment of forest resources for certification, in several countries.
- The Réseau des Institutions de Formation Forestière et Environnementale d'Afrique Centrale (RIFFEAC) made up of all institutions providing training in forestry and environmental issues is a good example to cultivate the human resources required to promote FC and RFM/SFM in CASR. RIFFEAC is a group of twenty-one training institutions in CASR, which aims at developing the skills and the necessary structures for joint and sustainable management of environmental and forest resources.
- The Professional Masters Programme on Forest Certification and Auditing developed by the Department of Plant Biology, Faculty of Science, the University of Yaounde I in Cameroon since 2005 has been instrumental in producing professionals to promote FC.
- Though few, a number of short-term training programmes have been and are being implemented to increase the number of qualified professionals in FC, including FM certification auditors. Examples are training programmes implemented by FSC, SSC-Forestry, AB Training/CMO, SW, BV and CES.
- Increasing development of policy tools and institutional frameworks for the promotion of SFM in northern Africa sub-region (NASR).
- Establishment of a NWG in Morocco affiliated to FSC in 2008 after a large public consultation and a final election of its members. Although it has not been endorsed by FSC, its members have received training on FC by the first FSC African Regional Office and could be used as experts to spread the process in the NASR.
- Availability of legal civil society organisations, such as Associação pela Gestão Responsável das Florestas em Moçambique (AGREF) and Tanzania Association for Forest Management and Products (TAFMP).
- Expansion of existing markets and the creation of many new European markets for North African forest products, including markets for caps and construction equipment made up of cork, according to the growing demand from industrialized countries. This has resulted in the attractiveness of the investment partners and financing of forest projects by potential donors. The flow of forest products from NASR to these markets requires international recognition of RFM, therefore, FC.
- FC is being used by governments in Africa, e.g. Cameroon, as a communication tool to demonstrate progress towards SFM.

- Government institutions are becoming increasingly open to the involvement of civil society in forest management and monitoring.
- Capital investment by private companies for SFM is increasing, and there is increasing interest in FC by a number of major logging companies.
- Donor agencies interested in the forest sector are considering FC as a positive tool for the promotion of SFM.
- Increased awareness in the domestic markets, mainly in South Africa and Uganda, for forest products originating from well-managed forests.
- Foresters have started to see FC as a useful management tool that can guide them in their day-to-day operations, i.e. FC provides foresters with a way of measuring performance of their own activities, with the reward being a certificate to prove that they are maintaining sustainable levels of forest management.
- In Mali, for example, the actors in the mining sector have become aware of the damage caused to the environment by the exercise of their business and are committed to change or modify their practices and significantly contribute to the rehabilitation of damaged sites; this committment had been taken during the awareness workshop on SFM in the country in which they participated.
- Involvement of other economic sectors (agriculture, mining, infrastructure, etc.) during the process of developing standards for SFM or FC in Côte d'Ivoire has led to the awareness of the stakeholders for the development of standards for sustainable agriculture.
- National ATO/ITTO standards/PCIs and audit manual for SFM of African natural forests strengthen forest policies and legislation in ATO/ITTO member countries and form a good bases to help companies make decision on FC.

Enabling policy/legislation environment. Many countries in Africa have mentioned sustain-able development and SFM in their constitutions and/or environmental/forest policies/ legisla-tion without making any specific reference to FC, while others, e.g. Namibia, Uganda and South Africa, have made reference to FC as a tool to promote SFM in their policies, strategies, programmes, etc.

According to the recent report on "*State of the World's Forests*" (FAO, 2014):

- all countries, including in Africa, that have revised their national forest programmes (NFPs) or forest policies since 2007 have included SFM as a policy goal;
- since 2007, at least 37 countries worldwide, 10 of which are African, have passed and promoted new policies promoting SFM and aiming at socioeconomic development,;
- at least six countries, one from Africa, have reported having further elaborated criteria and indicators as a way of operationalizing SFM, supporting policy development, monitoring and reporting;

- by 2013, Cameroon, CAR, Ghana, Liberia and ROC were implementing a VPA; and,
- Côte d'Ivoire and Uganda have begun incorporating legality assurance system elements, such as tracking and verification in their NFPs or policies.

Despite the above encouraging initiatives and efforts, the policy/legislation environment in many African countries remains largely unconducive for implementing FC and RFM/SFM

Wood harvest in the evergreen forest of Ghana.
Photo: Enoch Gbénato Achigan-Dako

Appropriate institutional arrangements. Apart from the official representation of the FCSs and the encouraging initiatives taken to establish NWGs on FC in some countries discussed above, there are no institutional arrangements put in place to cater specifically for FC by countries in Africa. Exceptions are Ghana and Liberia, which have been reported as putting effort in improving their organizational frameworks and information systems to track legally harvested timber through value-added chains and improved market transparency (FAO, 2014).

Markets and market structures/information systems. Apart from the web-based market information provided by FSC and PEFC, there are no adequate African market structures/information systems for certified forest products/services originating from all the sub-regions in Africa that can inform producers and consumer groups of the economic, environmental and social benefits that FC brings. In the international markets, where certified forest products have reliable markets, there are still limited marketing information systems linking the forest owners/operators and primary producers and the traders in these markets. Despite several calls for separate production and trade data on certified products, consistent information on markets for certified products is still inadequately available worldwide, particularly for Africa.

There are potential prospects of local/national, sub-regional, regional and international markets. Stakeholders are willing to buy timber from certified forests. Despite the fact that some big companies, government ministries, departments or agencies indicated that they were willing to buy their timber from certified forests, more awareness raising about certified forest products is still needed. In addition, some of the stakeholders in the construction and furniture industries indicated that it is difficult to state the extent to which they would procure timber from certified forests, and that their decisions would depend on the market dynamics. This means that there are training and promotional needs to forest products consumer groups on the value of certified forest products so that they influence the market accordingly by changing their preference.

Perception and engagement of stakeholders on Forest Certification

Central and Western Africa Sub-Regions. In the 1990s, driven by environmental NGOs, e.g. WWF, GreenPeace, Friends of the Earth, Fern, etc., that were promoting the boycott of tropical timber in general and African timber in particular in the international markets, FC was perceived by governments in the central and western Africa sub-regions as a process aimed, ultimately, at boycotting African timber and to be under the domination of those activist environmental NGOs. However, after the Brazzaville conference held in 2005, FC is now perceived as a tool to: (i) enhance SFM by obliging forest companies to respect laws and regulations in force, so giving advantage to the governments in the monitoring of this aspect of SFM; (ii) communicate worldwide efforts made by governments towards sustainable forestry and conservation of biodiversity; and, (iii) sell timber in international markets. Currently, the governments of Cameroon and ROC are implementing the accreditation of private FC schemes to enable forest enterprises to access the EU market by respecting the EUTR. However, some governments are still complaining that FC is too much driven by European and International NGOs while others do not show any interest.

Similar to the initial attitude of governments, forest companies perceived FC as a means used to boycott tropical and African timber in the international markets. However, nowadays, some realise that FC enables them to keep their customers, access new market niches or credits, and communicate their progress towards sustainable/responsible forestry. However, all of them find the costs of FC to be exorbitant, especially the implementation of social issues, e.g. construction of roads, schools, hospitals and support to local communities required as part of their corporate social responsibilities implicit with FC. Forest companies also consider FSC's FSSs and certification procedures as being too complex and, hence, difficult to implement.

Likewise, forest workers and trade unions initially perceived FC as a process leading to more work for forest workers to enable the forest companies increase their profits through the sale of their certified products without sharing the benefits with their workers. However, currently, they consider FC, mainly FSC certification, as "a saviour", i.e. a tool that enhances the well-being of the forest worker, and a process that obliges the forest companies to respect the labour code and apply the conventions of the International Labour Organization (ILO) in the forest sector.

For civil society, FC is the only efficient tool that will ensure sustainable management of tropical forests in general and African forests in particular. Their reasons for supporting and promoting FC are many, i.e.: (i) reducing illegal logging; (ii) reducing corruption in the forest sector; (iii) enabling the effective participation of local communities and indigenous people in forest management; (iv) enabling the sharing of benefits from SFM; (v) enabling the respect of laws and regulations in force by forest companies; and, (vi) introduction of transparency in the forest sector. Still, civil societies feel that FC is being undermined by CBs biased towards increasing their own benefits rather than enhancing the credible assessment of RFM/SFM.

Decidious forest in Northern Benin. Photo: AFF

For the CBs, FC is a tool that will enhance the responsible management of tropical forests in general and African forests in particular. Nevertheless, they reported that the standards of FSC or PEFC are too complex and become more complex every day. The standards comprise too many complex concepts that lead to increased costs of FC in their implementation.

In terms of the engagement of stakeholders in FC, as part of the development of the FSC national standard by the NWG in Ghana, the government was very active. Traditional chiefs also played a leading role in view of their impact on land tenure and property of the country. A particular opening was made for women to boost their participation in the process. In Côte d'Ivoire, where the process of developing the national FSC standard was initiated, the involvement of various stakeholders, including the government was significant. For the development of standards, both for the FSC and ITTO, the government and other stakeholders have taken a very active part. This was accomplished through the multi-stakeholder-based NWGs in which all stakeholders were engaged.

With regard to the development of ATO/ITTO standards, the process begins with the creation or activation of a NWG in each country through a strong awareness creation and mapping of stakeholders involved in forest management. A stakeholder workshop is organized to inform the different actors of the initiation of the process. From this moment, the parties choose their representatives to serve in the NWG. Once the NWG is in place, it starts the process of developing such standards.

Eastern and Southern Africa Sub-Region. Stakeholders and governments in the E/S Africa sub-regions are involved and/or plan to implement SFM practices to: (i) manage their forests sustainably and, hence, contribute to improvement of the economic returns of their forests and the livelihoods of the communities; (ii) market forest products to increase sales and prices of these products; (iii) instill good governance, which aims at stopping corruption and promoting public awareness about the need for SFM; (iv) promote self-esteem, as part of those contributing to forest conservation efforts and promoting corporate social responsibility; and, (v) access green loans and financial mechanisms, through international networks with financial institutions like the World Bank and, hence, increase the chances of attracting operational funds for SFM, through employing FC as a management tool. These responses indicated that there is a positive perception towards FC in the sub-regions, and that FC provides various advantages that attract or would attract more participation of stakeholders and governments in the sub-regions. Nevertheless, despite the fact that FC gives assurance that forest management activities are environmentally appropriate, socially beneficial and economically viable, the stakeholders did not appreciate the voluntary regulatory role FC has in contributing to responsible management of forest resources.

Governments have been and continue to be involved in the FC processes, including the development of standards informally through instituting policy and legal frameworks, which create enabling environments for FC adoption. Moreover, as stated above, Namibia, South Africa and Uganda have formally recognised FC as a tool for SFM in their legal frameworks. Stakeholders' identification and analyses processes have been in place in Kenya, South Africa, Mozambique, Tanzania and Uganda. The engagement process brought together, and continues to bring together, interested and affected parties from respective governments, private sectors, civil society and community-based organisations into the development of FSSs and FC. Collectively, they nominate people to stand on their behalf for the FC standards development process.

Northern Africa Sub-Region. In NASR, stakeholders believe that FC is a tool useful for the improvement of forest planning and management, providing a transparent and credible dialogue between all interested parties in the public and private sectors, both nationally and locally. In this sub-region, mainly in Morocco, the contributions and commitment of these various stakeholders, including the Government, in the development of FC and standards are identified in terms of:

- initiation of multi-actor partnerships for reflection and development of participative management, multi-functional and self-financing models for the forests of the Middle Atlas, focusing on continuity, good governance and monitoring of certification approaches in the management of forest areas;
- facilitation and funding from international organizations for the development of pilot FSC certification initiatives in the countries;
- consultation and participation of local stakeholders and partners in the development and revision process of national standards, affiliated to FSC; in Morocco [mapping of stakeholders, develop-ment of national standards, establishment of FC structure (NWG) and governance mechanisms and field testing of standards];
- technical support to the NWG in the national standards development process;
- political support of the Government in the process of initiation, development and evaluation of the national standard;
- technical support of national, sub-regional and international expertise for the development of the national standards;
- scientific research to determine the potential social and environmental impacts of FSC certification; and,
- communication and information on the FC process.

Achievements recorded in the implementation of Forest Certification

The major achievements recorded in the implementation of FC in Africa include the develop-ment and endorsement of FSSs, and the recording of types and area of forests certified, numbers of FM and CoC certificates issued and types of certified forest products.

Development and endorsement of Forest Stewardship Standards (FSSs)

The following national FSSs have been developed in Africa and endorsed by FSC (FSC, 2014c):

- Cameroon (FSC-STD-CAM-01-2012: Natural and Plantations) - follows the requirements of FSC-STD-60-002 "Structure and content of forest stewardship standards" to improve consistency and transparency in certification decisions between different CBs in the Congo Basin region and thereby to enhance the credibility of the FSC certification scheme in the region as a whole.
- Cameroon (FSC-STD-CAM-01-2010, SLIMF) - covers diversified vegetation types and eco-systems, including forests, savannas and steppes, distributed throughout the country.
- Central African Republic (CAR) (FSC-STD-CAR-01-2012, Natural and Plantations) - follows the requirements of FSC-STD-60-002 "Structure and content of forest stewardship standards" to improve consistency and transparency in certification decisions between different CBs in the Congo Basin region and thereby to enhance the credibility of the FSC certification scheme in the region as a whole.
- Democratic Republic of Congo (DRC) (FSC-STD-DRC-01-2012: Natural and Plantations) - applicable to all forest operations seeking FSC certification within the Congo Basin. The standard applies to the management of natural forests and plantations, managed by large forest enterprises for timber production. Specific indicators for each of the above forest types will be adapted at national level. The standard also takes into account small and low intensity managed operation (Community forests and NTFP management) in the Congo Basin region. These shall meet the international definition of SLIMF in order to qualify to use these indicators.
- Gabon (FSC-STD-GAB-01-2012: Natural and Plantations) - applicable to all forest operations seeking FSC certification within the Congo Basin. The standard applies to the management of natural forests and plantations, managed by large forest enterprises for timber production. Specific indicators for each of the above forest types will be adapted at national level. The standard also takes into account small and low intensity managed operation (Community forests and NTFP management) in the Congo Basin region. These shall meet the international definition of SLIMF in order to qualify to use these indicators.
- Republic of Congo (ROC) (FSC-STD-ROC-01-2012: Natural and Plantations) - sets out the required elements against which FSC accredited CBs shall evaluate FM practices within ROC.

- Ghana (FSC-STD-GHA-01-2012, Natural and Plantations) - follows the requirements of FSC-STD-20-002 Structure and content of forest stewardship standards (November 2004) to improve consistency and transparency in certification decisions between different certification bodies in Ghana and in different parts of the world, and thereby to enhance the credibility of the FSC certification scheme as a whole.

One among other major achievements of FSC in Africa is the *very first regional FSS in the history of FSC* (FSC, 2014b) (FSC-STD-CB-01-2012, Sub-Regional Standard), that was approved in 2012 for countries in the Congo Basin, namely Cameroon, CAR, DRC, ROC, Equatorial Guinea and Gabon. As indicated above, the AEM has also developed a pan-African FSS (ARS AES 3-2014 Forestry - Sustainability and Eco-Labelling - Requirements), which has been approved by the AEM Executive Board in 2013. PAFC Gabon has also developed a national PEFC-endorsed standard for FM and CoC certification.

Types and area of forest certified

So far, forests in Africa have been certified with FM certificates through only the FSC FCS. The types of certified forests in Africa include natural as well as semi-natural forests, exotic hard and soft-wood plantations, and miombo woodlands/forests (community natural forests).

Table 2. Global FSC-certified forest areas by region

Region	No. of Countries	Forest Management Certificates				Chain of Custody Cerificates		
		Area Certified (1000 ha)	% of Total Area	No. of Certificates	% of Total No. of Certificates	No. of Coun-tries	No. of Certi-ficates	% of Total No. of Certificates
Africa	12	7,685	3.9	51	3.4	18	194	0.6
Asia	13	8,471	4.3	231	15.3	29	10,019	30.3
Europe	32	94,389	48.2	686	45.3	41	17,466	52.7
S. America/ Caribbean	19	13,592	6.9	259	17.1	24	1,485	4.5
North America	3	68,947	35.2	246	16.3	3	3,537	10.7
Oceania	5	2,665	1.4	41	2.7	5	419	1.3
Total	**84**	**195,749**	**100.00**	**1,514**	**100**	**120**	**33,120**	**100**

Source: FSC (2017).

As of October 2017, the total area of forests certified by FSC in Africa was c. 7.7 million ha, representing only 3.9% of the total area of FSC-certified forests worldwide of c. 195.7 million ha in 12 countries (14.3% of all countries with FSC-certified forests worldwide) (Tables 2 & 3) (FSC, 2017) and 2.5% of the total area of PEFC-certified forests worldwide of c. 304.2 million ha (Table 4) (PEFC, 2017). The area of certified forests (with FM certification) in Africa represent only 1.5% of the total area of forests certified worldwide by both FSC and PEFC (c. 500 million ha), the two FCSs that have their footprints in Africa. Within Africa, ROC (32.3%), Gabon (26.6%) and South

Africa (18.4%) had the three largest areas of FSC-certified forests while Madagascar (0.02%) had the lowest area of FSC-certified forests (Table 3). In terms of numbers of certificates, South Africa had the highest (20 = 39.2%) while Madagascar and Sierra Leone had the lowest (one each = 0.02%) numbers of FSC FM certificates in Africa.

The only FSC-certified operations in WASR are those in Ghana, and the types of forest certified were a teak plantation and natural forest covering 1,675 and 1,298 ha, respectively. In addition, BV has certified a total area of 628,212 ha of natural forests through its OLB system in Cameroon. The legality of a total of 2,115,231 ha of forests has been verified through the OLB system of BV in Cameroon so far. In Gabon, 832,305 ha of forests have been verified through the OLB system of BV up to 2013. As no certificate was renewed, the trend of OLB certification in Gabon has been rather downwards. In 2013, the VLC certificate had been issued to six forest companies in Cameroon covering a total area of 685,351 ha. A single eucalypt plantation of 20,270 ha has been FSC-certified with FM certificate in 2008 in Morocco. This certificate has not been renewed, and since then, no more forest area has been certified by FSC or PEFC in the NASR.

Table 3. FSC-certified forest areas and numbers of forest management (FM) certificates in Africa

Country	**Area Certified (ha)**		**Number of FM Certificates**	
	Total (1000 ha)	**Proportion (%)**	**Total**	**Proportion (%)**
Cameroon	1,130	14.7	4	7.9
Gabon	2,043	26.6	3	5.9
Ghana	11,5	0.2	2	3.9
Madagascar	1,3	0.02	1	2.0
Mozambique	50,8	0.7	2	3.9
Namibia	231	3.0	5	9.8
Republic of Congo	2,479	32.3	4	7.8
Sierra Leone	3,1	0.04	1	2.0
South Africa	1,417	18.4	20	39.2
Swaziland	124	1.6	4	7.8
Tanzania	154	2.0	2	3.9
Uganda	40,9	0.5	3	5.9
Total	**7,685**	**100**	**51**	**100**

Source: FSC (2017).

Numbers of certificates issued

Up to October 2017, the total number of FM certificates issued in Africa by FSC was 51 (3.4% of total FM certificates issued by FSC worldwide), in 12 countries (14.3% of all countries with FSC FM certificates worldwide) (Tables 2 & 3) (FSC, 2017). The total number of CoC certificates issued in Africa by FSC was 194 (0.6% of total CoC certificates issued by FSC worldwide), in 18 countries (15% of all countries with FSC CoC certificates worldwide) (Tables 2 & 5) (FSC, 2017). Within Africa, South Africa (58.8%), Egypt (13.9%), and Cameroon and Gabon (each with 5.2%) had the three highest numbers of CoC certificates while five countries (each with 0.5%) have the lowest numbers of CoC certificates (Table 5). It is worth noting that all of FM and CoC certificates in Africa have been issued by FSC (FSC, 2017) except 10 PEFC CoC certificates issued in Egypt (one), Morocco (three), South Africa (five) and Tunisia (one) (Table 4 & 5) (PEFC, 2017).

Table 4. Global PEFC certified forest areas by region

Region	Forest Management Certificates			Chain of Custody Certificates		
	No. of Countries	Area Certified (1000 ha)	% of Total Area Certified	No. of Countries	No. of Certificates	% of Total No. of Certificates
Africa	0	0	0	4	10	0.1
Asia	4	13,998	4.6	19	1 101	9.8
Central/ South America	4	5,623	1.85	9	138	1.2
Europe	23	95,874	31.52	34	9 339	82.9
North America	2	164,440	54.06	3	451	4
Oceania	2	24,266	7.98	3	223	2.0
Total	**35**	**304,202**	**100**	**46**	**11 262**	**100**

Source: PEFC (2017).

Types of certified forest products

The types of certified forest products in Africa are mainly logs, lumber, plywood and carpets. Other are wooden products, which include paper products, household toilet and towel paper, tissue paper and cosmetic wipes; kitchen accessories like cutting boards; furniture for children's rooms, bedrooms or living rooms; outdoor furniture for gardens or terraces; wood for construction and gardens; many tools with a fist or a wooden handle; bags for market, and grilling accessories, like -grill or charcoal pliers.

Table 5. Chain of custody (CoC) certificates in Africa

Country	Chain of Custody Certificates			
W	WFSC		PEFC	
	Numbers	Proportion (%)	Numbers	Proportion (%)
Algeria	1	0.5	-	-
Cameroon	10	5.2	-	-
Egypt	27	13.9	1	10
Gabon	10	5.2	-	-
Ghana	6	3.1	-	-
Kenya	1	0.5	-	-
Madagascar	1	0.5	-	-
Mauritius	1	0.5	-	-
Morocco	4	2.1	3	30
Mozambique	2	1.0	-	-
Namibia	3	1.6	-	-
Republic of Congo	3	1.6	-	-
Seychelles	3	1.6	-	-
South Africa	114	58.8	5	50
Swaziland	2	1.0	-	-
Tanzania	1	0.5	-	-
Tunisia	4	2.1	1	10
Zimbabwe	1	0.5	-	-
Total	**194**	**100**	**10**	**100**

Source: FSC (2017); PEFC (2017).

Gaps

The gaps identified as being responsible for the limited success of FC in Africa are summarized below:

- Inadequate/lack of fundamental requirements (enabling conditions and policy/legislation environ-ment as well as appropriate institutional arrangements) for the promotion and implementation of FC (discussed above).
- Lack of national or sub-regional FSSs in many African countries or sub-regions other than the Congo Basin.
- Lack of African-based accreditation bodies for FC.
- Inadequate number of African-based certification bodies and auditors for FC.
- Inadequate public education and awareness on FC.

- Inadequate and unethical implementation of policy and legal framework for SFM (inadequate political will, corruption and tax evasion).
- Low level of information available to stakeholders in laws and regulations governing SFM in general and FC in particular.
- Unavailability of adequate statistical data on African forest resources and the associated wood economy.
- Low level of domestic wood processing.
- Extractive character of the African forest sector with a small proportion of income reinvested in productive activities, such as processing.
- Absence of or inadequate certification of NTFPs.
- FC has inadequate capacity on how to audit and certify ecosystem services (e.g. carbon sequestration, biodiversity conservation and water catchment protection, among others).

Challenges

The challenges identified as being responsible for the limited success of FC in Africa are summarized below.

- FC initiatives not sustainable due to inadequate appropriate capacity for FC (human, physical and financial resources).
- No Market and Market Information Systems in place for certified forest products.
- Inadequate and unethical implementation of policy and legal frameworks (e.g. FLEGT).
- FC initiatives for smallholder private and community forests are dependent on donor funding.
- With no government involvement allowed by the FSC statutes, there is inadequate government participation in FC. In turn, this causes limited FC of public forests, restricting impact of FC since in many African countries, forests are owned and/or managed by governments and/or agencies of governments.
- While individual certification works well for most medium- and large-sized enterprises, it can be a major challenge for small enterprises, whether these are small forest owners or small-scale producers of wood products since they do not have the economies of scale that their larger competitors have.
- Certified forest products from Africa represent a very small proportion of certified forest products in global markets.
- Demotivation of forest operators due to the complexity of FC's standards and procedures.
- Processes of FC are voluntary and market-oriented with no legal requirements.
- Lack of awareness on FC in some countries.

- Restructuring of FSC that led to the abolition of FSC national initiatives and disbanding the established FSC affiliated NWGs.
- FSC members do not receive the benefits of their membership rights, such as benefiting from training, getting support from FSC for national level activities or attending international meetings or workshops in relation to FC; this may discourage the FSC members from their active participation in the promotion of FC.
- Ignorance of consumers on certified forest products in the markets.
- Limited funds for FC initiatives.
- Inadequate market for certified forest products (local, sub-regional, regional and international markets).
- Expectation of a price premium for certified forest products that is not yet apparent, except for a few niche products and markets. In the absence of a price premium, the costs of certification serve principally not only as a barrier to markets wishing to source certified products but also demotivate forest managers to certify their forests.
- High costs of FC, especially for smallholder private owners and communities.
- FC processes perceived as coming from outside of Africa, and perception of some stakeholders that FC is aimed at boycotting African timber in international markets and is under the domination of activist environmental NGOs.
- Existence of a large market and alternatives for non-certified products.
- VPA signed or under negotiation with the EU leading to a decline in interest for private certification.
- Bad campaigns on the credibility of certificates.
- Domestic market of wood (not demanding in terms of certification) increasingly growing
- Risk of bad publicity for companies in case of withdrawal of the certificate despite the huge resources involved in certification.
- Recurring droughts, which amplify the phenomenon of desertification of woodlands in NASR.
- Difficulty for small scale operations to be certified due to the intensive levels of administration and management required from mostly illiterate forest managers.
- Some FC criteria are above the national standards for forest management, contributing towards resistance of forest managers to certify their operation.
- Weak national forestry institutions, especially for the implementation of forest regulations and enforcement of forest laws.
- Political instability, e.g. DRC, CAR, South Sudan, leading to insecurity that hampers the promotion and implementation of SFM and FC.

- Illegal logging compromising the possibilities of promotion of FC and SFM.
- Inadequate basic information about forest resources and forestry in Africa.
- Poor roads and other infrastructure systems in Africa making FC costly to set up and maintain.
- Corruption, both in public and private forest operations, undermining the possibilities to fight illegal forestry and encourage FC and SFM.
- Most training activities on FC are more theoretical than practical.
- Despites the various efforts being made by different countries and stakeholders to promote FC and SFM, deforestation still continues unabated.
- Heavy burden that forest operators, at least in the Congo Basin, are confronted with if they need to process more than one certificate from various schemes for the same forest area, e.g. FM/CoC, OLB, TTLV, VLC and VLO, operated by CBs. The multiplication of all these FCSs has led to a war of trademarks and a need for clarification to the consumers.
- Fluctuations of the total area of forests certified and the numbers of certificates (FM and CoC) in Africa over the years owing to either suspension or failure by the forest companies to renew their certificates.
- Weakness of the EUTR, reflected in illegally sourced wood still being imported into Europe, despite the entry into force of the EUTR in the importing countries.
- Difficulties in implementing social requirements related to the SFM and FC.

4.5. Opportunities

The opportunities that could be created as a result of promotion and implementation of FC in Africa have been identified and categorized as economic, social, environmental, and cross-cutting (i.e. cutting across economic, environmental and social dimensions) as summarized below.

Economic opportunities

- Greater access to premium timber markets, where they exist.
- Medium-term gains in efficiency and productivity.
- Protection of market share and increased marketing opportunities through product differentiation.
- Reduction of environmental risk, resulting in better access to financial markets for loans, right issues, insurance, etc.
- Improved image in ‘green’ conscious markets and with employees.
- Better commercial advantage of timber companies over competitors, e.g. preferential access to new customers or increased market share or better prices through direct sales or niche

marketing.

- Reduction of the number of intermediaries and, thereby, increased proportion of the final sale price awarded to the forest owner by improving the efficiency and transparency of the supply chain.
- Improved product supply prospects.
- Improved management control/system, including internal mechanisms of planning, monitoring, evaluation and reporting.
- Economic benefit for local communities.
- Higher recovery of national revenues where forest revenues are being avoided.
- Promotion of multiple benefits, e.g. non-timber forest products and ecosystem services.

Environmental opportunities

- Environmental conservation and maintenance, and enhancement of biodiversity.
- Great potential to promote payments for ecosystem/environmental services.
- Provision of a mechanism for companies to reduce environmental risk and negative commercial effects that high environmental risk increasingly involves.
- Improve company influence on government and politicy
- Increase credibility of companies with environmental groups.
- Influencing the health and viability of World Heritage Sites adjacent to certified forests.
- Conservation, maintenance and enhancement of High Conservation Value Forests.
- Protect rare, threatened or endangered species and/or their habitats.
- Minimizing the movement of invasive species.
- Prevent or contain forest fires.

Social opportunities

- Improved health, safety, rights and living conditions of employees in forest companies and their families.
- Protection of sites of special cultural, ecological, economic and religious significance to local communities.
- More inclusive and better governed institutions for negotiations between local populations and logging companies.

- Financial or in-kind support to local communities for many purposes, including consultation, capacity-building and economic development.
- Better managed and more effective benefit-sharing mechanisms.
- Formal agreements between forest companies and local communities, leading to verification that their interests and concerns are incorporated into the management plan of the certified forests.
- Innovative ways of dealing with problems related to infringement of customary uses.
- Increased stakeholder involvement in RFM and promotion of new institutional roles in relation to governments.
- Balancing the objectives of forest owners, other stakeholders and society.
- Bringing together industry, environmental and local communities in an unprecedented way.
- Reduced social conflict in and around certified forests.
- Securing land tenure and usufruct rights (in certified community forests).
- Greater protection of NTFPs.
- Poverty alleviation.

Cross-cutting opportunities

- Promotion of RFM more generally through dialogue between the private sector, government bodies, NGOs and civil society.
- Creating a climate of change for policy and legislative reform.
- Incentive to harmonize forest management standards between countries.
- Enhanced capacity for RFM.
- Enhanced effectiveness and efficiency of forest managers.
- Development of new skills and capacities for stakeholders and organizations involved in forestry.
- Contribution to foresters' professional development.
- Gaps identification, leading to more relevant forest research and allocation of research resources.
- Enhancing better public reporting as a result of the provision of independent statements on forest condition and status: the principle of third party verification.

Needs identified for the successful implementation of Forest Certification

Outcomes of the needs assessment undertaken on availability and accessibility of fundamental requirements for FC at national, sub-regional, Africa and international levels can be categorized into human, financial and physical resources, technical capability/skills, enabling policy/legislation environment, appropriate institutional arrangements, marketing and marketing structures/ information systems as well as support in standard development, which are summarized below.

Human resources

- Increased number of qualified auditors for each country.
- Qualified internal auditors in forest companies for FM and CoC certification processes, i.e. for the preparation of external audits as well as coaching and training staff members and overseeing the work regularly.
- Trained stakeholders in the technical development of national standards for sustainable forestry and cetification management.
- Raising awareness on advantages and disadvantages of FC, its potential role as a policy instrument for RFM and related market requirements.
- Assessment and integration of social needs, including access to resources, workers' needs and rights, and community development.

Financial resources

- In order to have SFM initiatives that employ FC as a tool, there is need to have financial institutions at national or sub-regional levels to support such initiatives to complement efforts of private companies and environmental NGOs. The Tanzania Forest Fund (TFF) is an example of such a financial institution.
- Establish well-coordinated funding mechanisms to support stakeholders at all levels in the forest sector in the development and promotion of FC. The good examples of WWF's GFTN and ITTO should be scaled-up and initiatives are required to set-up similar mechanisms to support volunteer companies to go for FC.
- Partnerships should be encouraged between major distributors of certified products and producers to support them financially through better prices or direct subsidies.
- Efforts of African RECs - COMIFAC, EAC, ECOWAS and SADC - to promote SFM and FC should be supported by donor agencies.

Physical resources

- NIs/NWGs/SDGs that would be responsible for the development of FSSs and promotion of FC should be established with national offices adequately staffed, furnished and equipped.
- Moreover, the physical presence of FCSs, demonstrated by the presence of fully staffed, equipped, furnished and operational offices, is needed in Africa to promote FC.

Technical capability/skills

- Developing and implementing a training programme on FC targeting various stakeholders at all levels, including government employees.
- Build technical capacity of stakeholders in the areas of:
  - ✓ forest certification schemes/systems;
  - ✓ techniques of forest management, including development of forest management plans;
  - ✓ geographic data and assessment systems, e.g. Geographical Information System and Remote Sensing;
  - ✓ traditional knowledge and socio-cultural services associated with forest resources;
  - ✓ undertaking studies on the economic potential of forest areas;
  - ✓ restoration of forest resources, including reforestation of targeted areas;
  - ✓ conflict management;
  - ✓ valorization of forest products and services, starting with medicinal and aromatic plants and, thereafter, ecosystem services;
  - ✓ techniques of Reduced Impact Logging;
  - ✓ identification of high conservation values in managed forests;
  - ✓ establishment and management of forest products traceability systems (CoC);
  - ✓ forest auditing techniques;
  - ✓ Building capacities of producers (farmers, communities, concessionaires and governments), small- and medium-sized enterprises, regulators (public extension systems), assessors/auditors, certification bodies, accreditation bodies, timber companies, wood and NTFP industry, rural/urban development banks, etc. to implement RFM and comply with related standards. Forest owners, managers and field staff to understand and implement the requirements of responsible forest management, including adequate training and support.
- Build capacity for conducting internal audits and establishing an effective external audit process.

- Knowledge and skills/techniques necessary to understand the forest resource, including forest dynamics, standing volume, growth and yield, what responsible or sustainable forest management entails, including management planning, harvesting, silviculture and road building.
- Provide training on environmental protection, conservation planning and identification, protection and monitoring of endangered species and forests of high conservation value.

Enabling policy/legislation environment

- Mainstreaming FC as a tool for promoting SFM in existing policy and legal frameworks of African countries, as has been done in Namibian, South African and Ugandan forest policy and legislation.
- Strengthen capacities and mechanisms for forest law enforcement and governance (FLEG).
- Revision of forest/environmental policies and laws to provide more support to FC, forest companies and all other stakeholders in FC.
- Put in place public procurement policies that clearly support/prioritize procurement of certified forest products.
- Capacity for developing certification standards and procedures.
- Strengthen the capacity of policy makers through training and sensitization on FC.
- Strong, committed leadership: sufficient numbers of well-trained supporters of responsible management in government, NGOs, companies and support agencies.

Appropriate institutional arrangements

- Establishment of forest certification structures adequately covering Africa, viz. regional and sub-regional offices, national offices/representatives/focal points, African-Based (preferably also African-owned) certification bodies, SDGs/NWGs, etc. and build the capacities of existing ones.
- The groups responsible for promoting certification, such as SDGs/NWGs should be established in countries with a clear legal status and recognition by Forest Administration authorities and the different FCSs, and with the necessary support to operate effectively and efficiently
- Supporting African-based interested entities to become CBs for FC.
- Provide public institutions responsible for forest management in Africa with adequate staff members empowered with the necessary physical and financial resources as well as technical capabilities so that they can shoulder their responsibilities during the process of FC.

- Institutionalising courses on FC in higher learning institutions at national levels could bridge the knowledge gap in FC.
- Development and strengthening of public-private-partnerships among various stakeholders, which are instrumental to promote FC.

Marketing structures/information systems

- Develop and maintain markets and market structures/information systems that link African forest owners/operators, primary producers and traders to the different actual and potential sub-regional, regional and international markets of certified forest products/services, which recognise, promote and reward RFM.

Need for support in standard development

Studies carried out in the different sub-regions of Africa indicate that there are initiatives of FC and/or FSS development in some African countries, e.g.: (i) Cameroon, CAR, Gabon, DRC and ROC in CASR; (ii) Kenya, Madagascar, Mozambique, Tanzania and Uganda in EASR; (iii) Namibia, South Africa, Swaziland, Zambia and Zimbabwe in SASR; (iv) Egypt, Morocco and Tunisia in NASR; and, (v) Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo in WASR.

The processes involved in the development of FSSs are very complex and require appropriate technical skills as well as longer periods for completion. As a result, the decision to develop the national FSSs should be taken by the stakeholders in the countries. In other words, the development of national FSSs should be demand-driven. Hence, interested parties and development partners that are willing to support the development and implementation of national FSSs should approach and work with the national stakeholders and in close collaboration with national, regional and international FCSs, namely FSC, PEFC, AEM, PAFC Gabon and Cameroon as well as those that are engaged in the verification of legality of timber, e.g. BV, SGS, SW and EU.

Blue monkey *(Cercopithecus mitis stuhlmanni)*, Kakamega Forest, Kenya. Photo: Charles J Sharp via Wikimedia Commons

1.5 Discussion

Forest and woodland resources in Africa play critical roles in providing goods and services necessary for the well-being of all, including human beings, animals, micro-organisms, and the physical environment. However, as in other tropical regions, various factors have affected these resources in Africa (Teketay, 2004-2005; Njuki et al., 2004; Kowero et al., 2009). The factors range from demographic to institutional, climatic, societal and political factors. Because of the complexity of these factors, it has been difficult to achieve SFM in Africa. As the problems of deforestation and forest degradation continue unabated, public concern for the environment, in general, and forest and woodland resources, in particular, has grown markedly during the last decades, both in developed and developing countries. As a result, environmental issues are becoming more important in global economic and trade policies.

The emergence of FC, a process that attempts to provide an indicator of how well a product is environmentally appropriate, socially beneficial and economically viable, is a contemporary example of a market-driven mechanism, giving consumers the opportunity to use their purchasing power to promote environmentally friendly and socially beneficial products (FSC, 1994; Vogt et al., 2000; Perera and Vlosky, 2006; Muthoo, 2012; Teketay, 2015; Teketay et al., 2016). In addition, SFM systems supported by FC conform with the green economy paradigm because they appropriately balance the social, economic and environmental dimensions of development. FM and the associated CoC certification are developing into a prerequisite for public procurement and market access, and have become associated with ethical trade and social responsibility (Muthoo, 2012). FC can help ensure the provision of forest biomass as a renewable carbon-neutral energy source and as a substitute for carbon-intensive building materials, such as steel and cement, thereby lowering the carbon footprint and contributing to the alleviation of climate change and generally contributing to a greener economy. Moreover, FC can also help ensure that forests are not only well-managed, but also properly valued by markets.

The idea and practice of ensuring stakeholders with economic, environmental and social concerns, sometimes with conflicting interests, to sit together around a table to discuss and agree on how best to manage forest resources, which characterizes FC, is among the excellent and innovative initiatives developed. However, such an initiative alone is not enough to bring about the intended impact, namely RFM/SFM. The successful promotion and implementation of RFM/SFM globally and in Africa, through FC as a market tool, involves tackling the prevalent problems facing forest resources. These include inadequate or lack of enabling human, financial and physical resources; unconducive policy/legislative environments, market and institutional failures, inadequate tenure, increasing human and animal populations and their demands – leading to increased deforestation, forest degradation and fragmentation. These, as well as inappropriate infrastructure, technology and skills, require policy decisions to be made at national and international levels (Upton and Bass, 1995).

The policy requirements at the national level to ensure RFM/SFM (Upton and Bass, 1995; Nussbaum and Bass, 2005; Muthoo, 2012) include: (i) establishing multi-stakeholder involvement with more appropriate roles in decisions on forests; (ii) appropriate policy and legislation with policy instruments that provide secure tenure and rights over forest resources as well as effective incentives for RFM/SFM; (iii) managing forest resources, which should cover the legal classification of production forests (natural and plantations), protection forests (for biodiversity, cultural and watershed conservation) and mixed land use categories; (iv) building capacity to meet current and changing needs; (v) improving the financial environment of forest conservation and management; (vi) improving forest information, monitoring, valuation and research; and, (vii) ensuring domestication and country-level coordination of international forest initiatives.

The international policy requirements include support for national processes, such as financial and technical assistance for capacity strengthening and skills development: sharing informa-tion, research and technology: harmonization of standards, etc., and dealing with global forest issues, e.g. developing and harmonizing FSSs and payment for environmental/ecosystem services (PES) schemes (Upton and Bass, 1995; Nussbaum and Bass, 2005; Muthoo, 2012).

The assessment of the status of FC in Africa revealed that two international (FSC and PEFC), one regional (AEM) and two national (PAFC, Gabon and Cameroon) FCSs are currently engaged in FC in Africa. However, only FSC, which has issued all the FM certificates and all but 10 of the CoC certificates, is fully developed; the other FCSs are at the initial stages of development. AEM had a good start in its development, but is currently surrounded with problems, mainly funding, that are challenging even its existence and continuation as a credible regional FCSs/Eco-Labelling scheme. The development of PAFC Gabon as the national FCS started in 2004, but it became endorsed as the first PEFC-affiliated FCS only in 2014, indicating that its process of development has been exceptionally long. As a result, not even a single forest operation has been certified by PAFC Gabon so far. PAFC Cameroon, which is at an initial stage of development, is passing through the same processes as PAFC Gabon to get endorsed by PEFC as a PEFC-affiliated national FCS. Though it is difficult to predict the exact period required for PAFC Cameroon to be endorsed by PEFC, it can be speculated that the process might take as long a period as observed in the case of PAFC Gabon. From the foregoing, it is clear that FSC will, for a long time, continue to be the leading FCS in Africa.

Despite FSC's commendable efforts and achievements in promoting and implementing FC in Africa, the facts that: (i) its past two regional offices established in Ghana and Cameroon had to be closed down, necessitating a third one to be opened recently; (ii) its decision to restructure the organizational set-up, leading to the abolishment of NCPs/NIs in 14 out of 16 African countries was associated with abandoning/disbanding of the FSC-affiliated NWGs, including those which were relatively strong, e.g. Cameroon, Gabon, Ghana and ROC; and, (iii) less attention is given to FSC members in Africa, all suggest that FSC has had and continues to have problems of developing deep organizational roots in the region. The above facts not only affected initiated/planned activities, as well as regional and national organiza-tional setting-up of FSC by the past regional offices and FSC-affiliated NWGs, but also caused the demotivation of FSC members in Africa. The major causes of these problems were the dependence of FSC on unsustainble projects funded by donors/development partners, and the lack of organizational system/procedure to dedicate funding from the central treasury to cover, at least, operational costs or bridge gaps created when donors pulled out from funding projects run by the regional/national offices.

In addition to the FCSs, a number of organizations have provided, and continue to provide, commendable support, in the areas of capacity building/training, development of regional, sub-regional and national FSSs as well as funding, which has been instrumental in promoting and implementing FC in Africa. The costs and benefits of certification, including a low, or no, price premium for certified products, can be interpreted by stakeholders from varying perspectives. If there is no net financial benefit, the up-take of FC will be correspondingly slow, although other factors, such as the marketing of a green/ethical image may be at play. The potential profitability of certified products will influence marketing strategies, entre-preneur- and stewardship of forest custodians, communities and companies (Muthoo, 2012).

One of the initial pre-requisites of FC is the development of FSSs, which is a multi-faceted process involving custodians of the forest and related resources, owners, workers and managers, local communities and societies, retailers and consumers, producers and processors, business, and civil-society organizations. Harmonized FSSs are required to bring synergy between the various stakeholders and their diverse expectations regarding economic return, the environment and social justice. As a result, there has been increasing interest in developing national FSSs in Africa although the achievements so far are limited. As stated above, this implies that there is a need to strengthen institutions, policies and legislation to reduce the gap between current standards of forest management and certification require-ments, so that FC delivers due rewards to forest stewards, especially in recognition of their contribution to RFM/SFM, forest law enforcement and legality (Muthoo, 2012).

Stakeholder engagement is crucial to the success of any FCS. It is only through participation of all interested parties that a system can ensure that all information and knowledge are applied, experiences and best practices are integrated, conflicts avoided, and stakeholder expectations are met (PEFC, 2014). The motives and interests of the various stakeholders in FC are rarely fully mutually reinforcing. There are many potential conflicts: for example between local communities, traders and consumers, between those who incur costs and those who receive benefits, and between big and small operators, North and South, and global and national FCSs. Therefore, FC has to take into account all these, sometimes, divergent values, interests and goals. Engaging local small-scale stakeholders is also essential if FC is to be a mechanism for improving equity (Muthoo, 2012).

The results from the assessment of perceptions of stakeholders revealed that at the initial stages of the promotion and implementation of FC in Africa, the various stakeholders perceived FC differently depending on their vested stake as well as perceived risks and benefits. Also, most stakeholders considered FC as originating from and imposed on them by the Global North to block entrance of timber and other forest products into the international markets. However, the suspicions and unwarranted worries have subsided through time, thanks to the crucial and pioneering past and ongoing efforts of FCSs, especially FSC, and other stakeholders. As a result, most stakeholders are currently appreciating FC and, hence, actively engaged in supporting, promoting and implementing FC.

The legality of timber production and trade is “an essential pre-requisite” for achieving SFM (van Dam and Savenije, 2011; Muthoo, 2012). Hence, as described earlier, different organiza-tions, viz. EU, BV, SGS and SW - through their various plans/programmes, i.e. the FLEGT Action Plan (EUTR and VPAs), OLB, TTLV and VLO-VLC, respectively, have been engaged in verifying the legality of timber and timber products originating from Africa, especially in central and western Africa sub-regions. Nevertheless, illegal logging is still rampant in Africa, including the Congo Basin, mainly because of the availability of national, sub-regional, regional and international markets for illegally-sourced timber and timber products. This has also been identified as one of the major threats limiting/discouraging the expansion of certified forests and forest products in the region (see under 3.4). Illegal logging has been reported to generate illicit earnings of 10-15 billion USD annually, including the huge underpayment of royalties and taxes (Goncalves *et al.*, 2012; Muthoo, 2012). This estimate does not capture the enormous environmental and societal costs associated with illegal logging. This stifles sustainable development and distorts the marketplace, dis-couraging legitimate forest enterprises from investing in good forest management and undermining attempts to achieve FC and RFM/SFM.

Evergreen forest in southwestern forest in Ghana. Photo: Enoch Gbénato Achigan-Dako

In spite of the encouraging efforts made to promote and implement FC by various organizations, the total number of national (seven), sub-regional (one) and regional (one) FSSs endorsed (by FSC, PEFC and AEM) are only 9 while the areas of forests certified (with FM certification) in Africa represent only 3.9% of the total area of FSC-certified forests worldwide and about 1.5% when compared with the total areas of forests certified globally by both FSC and PEFC. The total numbers of FM and CoC certificates issued in Africa by FSC are 3.4% and 0.6% of the global total, respectively. Furthermore, the total area of certified forests and the numbers of certificates (FM and CoC) have been observed to fluctuate over the years since the beginning of FC in Africa. This is owing to either suspension of certificates by the CBs as a result of violation of compliance with the FSSs or failure to renew their certificates by forest companies for reasons previously discussed. For instance, as no certifi-cate was renewed, the trend of the OLB certification in Gabon has been rather downwards. This indicates demotivation or lack of interest from economic operators. Similarly, in CAR, one company had a total of 195,500 ha certified through the OLB system of BV in 2006. However, this certificate has not been renewed. In 2010, Société de Développement des Forêts (SODEFOR), a logging company in DRC, was certified through the VLC by SW. The certifi-cate was withdrawn a few months later due to a complaint by Greenpeace (Mbolo, 2014a).

The apparently slow progress and limited success of FC in Africa could be attributed to inadequate, or lack of, fundamental requirements, i.e. enabling conditions and policy/ legisla-tion environment, appropriate institutional arrangements as well as market and marketing/ information systems, compared with the ideal requirements discussed above, as well as the numerous gaps and challenges identified. In agreement with these findings, Peña-Claros et al. (2009) and Muthoo (2012) have reported that despite considerable potential to expand the area of certified forest in the Global South, there are many obstacles, including limited domestic demand for certified products, the incompatibility of certification standards with local legal frameworks, weak governance, and barriers to adoption by small landholders and forest communities, especially those without clear title or tenure. Moreover, the cost and lack of know-how related to FC as well as the big gap between existing management and what is required for FC are huge hurdles for private and public forest custodians in many tropical countries. Addressing these problems warrants international recognition and investment to strengthen capacity and promote better management. As alluded to earlier on, Muthoo (2012) has also emphasized that the international development partners should consider increasing investment for promoting FC while, at the national level, public- and private-sector organiza-tions could contribute to and help deliver such investment.

The limited achievements recorded so far coupled with the numerous gaps and challenges identified as associated with the promotion and implementation of FC in Africa, suggest the critical need for measures to make FC more attractive and less costly (Ghazoul, 2011; Gullison, 2003; Muthoo, 2012). These measures include group certification (Nassbaum, 2002; Nassbaum and Simula, 2005), certification of non-timber/wood forest products (NTFPs/ NWFPs) from which millions of poor people derive their livelihoods (Yadav et al., 2007; Muthoo, 2012), small or low-intensity managed forest (SLIMF) certification (FSC, 2005a, 2009), phased approach (Nassbaum and Simula, 2005), also known as SmartSteps (Rainforest Alliance, 2007), modular approach

(FSC, 2005b, 2013) and FC for ecosystem services (Nassbaum and Simula, 2005; Teketay et al., 2016).

While concerned stakeholders are understandably worried about the slow progress and limited success observed in FC in Africa, the assessment of the economic, environmental, social and cross-cutting opportunities that could be realized if and when FC is successully promoted and implemented revealed very promising and appealing outcomes (see details under 3.5). The general contents of several of these opportunities concur with those reported by Muthoo (2012), which are summarized below. Thus, FC can:

- be an effective tool for promoting sustainable livelihoods, safeguarding the biodiversity of ecosystems, combating climate change and reducing C emissions through avoided deforestation and forest degradation (REDD+);
- serve as a backstop for the verification and monitoring of projects on REDD+ and PES, which would translate into opportunities for new resources for conservation and restoration of forests;
- be used as a tool in REDD+-related strategies and PES to address climate change and to benefit local forest stewards;
- unite stakeholders in a quest for an inclusive green economy;
- address fair trade, the need to balance social, cultural, economic and environmental dimensions of development, and environmental concerns for the biodiversity- and C-rich forests in the South;
- backstop efforts to erode persistent poverty, which is both a cause and a consequence of deforestation and forest degradation; and,
- assure the health and RFM/SMF, which can, in turn, contribute to goals of the multilateral environmental agreements, poverty alleviation and green growth.

1.6 Conclusions and recommendations

Two main policy approaches have been adopted, i.e. ‘top down’ and ‘bottom up’, to manage forest resources by relevant stakeholders and authorities globally and in Africa. In the top-down approach, fundamentals of policies are formulated at higher levels of government and implemented under the authority of the government. The bottom-up approach, on the other hand, relies more on a participatory approach where the public agrees on the need for and forms of the policy, and implements it through tradition, cooperative agreement or local rule. However, past experiences of the ineffectiveness and failures of both approaches have led to the third approach, namely FC, which introduced policy changes through commercial rather than central or local power and uses market acceptance rather than regulatory compliance as an enforcement mechanism (Naka et al., 2000; Perera and Volsky, 2006; Teketay, 2015).

Concerned about the accelerating deforestation, environmental degradation and social exclusion, a group of timber users, traders and representatives of environmental and human rights organizations met in California in 1990. This diverse group highlighted the need for a system that could credibly identify well-managed forests as the sources of responsibly produced wood products. The concept FSC and the name were coined at this meeting. Therefore, FC started with the establishment of FSC in 1993 with a definitive set of Principles and Criteria as well as the Statutes agreed and approved by the votes of the Founding Members in 1994 (FSC, 2014d). Following the establishment of FSC, several international, regional and national FCSs proliferated.

In Africa, two different groups of FCSs have emerged over the years, which are promoting and implementing forest certification. The first group promotes FM, CoC and CW (only by FSC) certification. To this group belong the two *international* FCSs, namely FSC and PEFC. In addition, the African Eco-Labelling Mechanism (AEM) is being developed as an African *regional* certification scheme while two Pan-African FCSs affiliated to PEFC, namely Pan-African Forest Certification (PAFC) Gabon and Cameroon, are also being developped as *national* FCSs. The second group promotes verification of the legality of timber and timber products, some in addition to FM, CoC and CW certification. To this group belong BV, SGS, SW and EU.

A total of nine FSSs, composed of seven national, one sub-regional and one regional FSSs, have been developed and endorsed in Africa. Forests in Africa have been certified with FM certificates through only the FSC FCS. The types of certified forests in Africa include natural as well as semi-natural forests, exotic hard and soft-wood plantations, and miombo wood-lands/forests (community natural forests).

Up to October (FSC) and September (PEFC) 2017, the total area of forests certified by FSC in Africa is c. 7,7 million ha, representing only 3.9% of the total area of FSC-certified forests worldwide (c. 195,7 million ha) in 12 countries (14.3% of all countries with FSC-certified forests worldwide) and 2.5% of the total area of PEFC-certified forests worldwide (c. 304,2 million ha). The areas of certified forests (with FM certification) in Africa represent only 1.5% when compared with the total areas of forests certified worldwide by both FSC and PEFC (c. 500 million ha). During the same period, the total number of FM certificates issued in Africa by FSC were 51 (3.4% of total FM certificates issued by FSC) in 12 countries. The total number of CoC certificates issued in Africa by FSC are 194 (0.6% of the total CoC certificates issued by FSC) in 18 countries while PEFC issued 10 CoC certificates (0.1% of the total CoC certificates issued by PEFC) in four African countries. Different types of forest products have been certified in Africa.

The above figures suggest that the area of forests certified in Africa and, hence, brought under RFM/SFM is relatively very small compared with the available large expanse of forest resources in the region that qualify for FC and the area of forests certified worldwide. This has been attributed to the numerous gaps, challenges and, hence, various needs identified. On the other hand, the outcomes, which could be realized if and when FC is implemented successfully, hold promising and attractive economic, environmental, social and cross-cutting opportunities.

In general, the outcomes of the assessment of availability and accessibility of fundamental requirements, the large numbers of existing gaps and challenges identified as being responsible for the limited success on FC as well as needs identified to close the gaps, address the challenges and exploit the opportunities, all point towards the fact that ensuring RFM/ SFM, through the use of FC as a voluntary market tool in Africa requires huge coordinated efforts by all concerned stakeholders at national, sub-regional, regional and international levels. One of these efforts is the need for developing appropriate demand-driven and tailor-made *capacity building programmes* (CBPs) aimed at enhancing/creating the required capacities in terms of human, physical and financial resources, and technical capability/skills. Such programmes should also address the shortcomings of the policy/legislation environment, appropriate institutional arrangements as well as deficiencies in markets and marketing structures/information systems for the successful promotion and implementation of FC. Among the many possible CBPs are *Training Programmes* (TPs) on the various aspects of FC in Africa, such as the one already developed by the African Forest Forum (AFF). The CBPs should target actors at various levels along the value chain of the forest sector.

It is, therefore, strongly recommended that the relevant stakeholders should come together and jointly develop/design and implement a strategy that should contain, among others, support programmes, e.g. the CBPs and TPs mentioned above. Such programmes will guarantee closing the numerous gaps identified, and overcoming the many challenges recognized. Ongoing efforts should be supported while ensuring the effective and efficient exploitation of economic, environmental, social and cross-cutting opportunities in order to fulfil the various needs identified for the successful implementation of FC in Africa.

Acknowledgements

We would like to gratefully acknowledge the AFF Secretariat, for supporting the preparation of this chapter through commissioning the four sub-regional and regional studies. Our sincere thanks also go to Prof. Larwanou Mahamane and Ms. Barbara Owuor for their kind assistance during the studies. Mr. Paul Oponga (FSC East Africa Sub-Regional Office), Ms. Christine Kalui and Mrs. Diana A. Ocheng (AEM Secretariat), Mr. Michal Brink (CMO), Mr. Assefa Tigneh and Dr. Humphrey Ngibuini are acknowledged for providing useful information and the valuable discussions on various aspects of forest certification in Africa. All other individuals and organizations that have contributed to the studies directly or through the information obtained from their publications and websites are also gratefully acknowledged.

Vitellaria paradoxa (shea tree, karité), eastern Burkina Faso. Photo: Marco Schimidt/Wikimedia

Chapter 2: Tree germplasm in Africa: status, opportunities and challenges

Crispen T. Marunda, Marie Louie Avana-Tienctheu, Heriel P. Msanga

2.1 Introduction

Reviews of tree germplasm supply in Central and Western Africa (Avana-Tientcheu, 2016), Eastern Africa (Msanga, 2016) and Southern Africa (Marunda, 2016) have shown a decreasing trend in investments in tree breeding research and seed production systems in many countries in Africa resulting in shortages in the supply of high quality tree planting stock. A new wave of tree planting to meet demand for wood and environmental services has brought into sharper focus a widening gap between production and demand of tree germplasm of high genetic and physiological quality in many regions of Africa. In this regard, the African Forest Forum (AFF) has generated baseline information on the status of tree germplasm improvement, production, supply and demand in Africa. The reviews highlighted the inadequacy of current seed production and management practices and identified gaps experienced in the provision of quality tree germplasm that constrain optimal forestry production at both plantation and farm forestry levels. The increasing demand of tree germplasm, the threats posed by pest and diseases to trees, climate change and demand of new species (for example agroforestry species) to meet the many and varied demands of small-scale farmers places tree germplasm production and deployment at the core of sustainable forest management in many countries in Africa.

The production and supply of high quality tree germplasm in many countries in Africa has been a central aspect of large-scale tree planting programmes and more recently for small-holder farmers for agroforestry species. Over the decades, tree germplasm of genera such as *Eucalyptus, Pinus, Acacia*, *Tectona grandis* and many others have been imported and tested for adaptability in many regions of Africa and have become the priority species for tree planting. Traditional species and provenance trials have been the hallmark feature for forestry research and development and this process led to the introduction of a range of species to meet the demand for wood, non-timber products (NTFPs) and environmental services (Koskela, 2014). Through tree improvement programmes, productivity has been increased by 10 to more than 60 % depending on the targeted products (wood, fruit, leaves, resins) and species (FAO, 2014). Hybrid breeding, mainly for pines and eucalypts, has been adopted in many countries, particularly in South Africa, to produce trees with superior productive capabilities and resistance to pest and diseases.

Whilst many countries in Africa still depend on exotic species for commercial forest plantations, there are signs of decreasing investment in research and development of these species resulting in shortages of good tree planting stock and increasing reliance on importing original germplasm from source countries. Planting un-tested seedlots or provenances could result in sub-optimal productivity. The growing of trees requires deep and extensive knowledge of choice of species, site-species matching, development and deployment of good tree germplasm to stakeholders. More often than not, many tree planting projects have used ordinary run-of-the-mill seed resulting in poor tree survival and growth. As tree growing has expanded from commercial plantations to community and small-holder tree plantings, the demand for new species has increased and new deployment strategies are needed to guarantee success.

The adoption of agroforestry as an alternate tree planting technology in many regions of Africa has seen an increase in the demand of a range of tree species to supply various products and environmental services. The supply of germplasm for most of the agroforestry species has been supported by international organisations such as the World Agroforestry Centre (WAC). For most of the agroforestry tree species, only limited tested or improved seed sources are available (Koskela *et al.*, 2014). Nyoka *et al.* (2014) reported that some of the agroforestry germplasm supply systems in Africa do not efficiently meet farmers' demands and environmental expectations in terms of productivity, species and genetic diversity. The demand for a wide range of species makes it difficult for targeted and sustained research efforts and most governments in Africa still rely on donor support for research, development and deployment of agroforestry tree germplasm.

Natural forests and planted trees provide sustenance to many millions of people in Africa, particularly the vulnerable, women and children. The endowment value of forests and woodlands in Africa is enormous, and can be used to promote a wide range of livelihood opportunities, including increased income and enhanced livelihood security (Sebukera *et al.,* 2006). The forest genetic resources (FGR) in these forests are the heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific or societal value (FAO, 2014). The FGR in natural forests play a crucial role in maintaining the status and diversity of forests, and human activities such as expansion of agricultural lands, harvesting trees for timber, and collection of fruits continue to affect and shape the diversity of the species.

This chapter is based on the extensive report by Marunda *et al.* (2017) and describes the status of tree germplasm in Africa focusing on resources for tree planting, and the utilization and conservation of natural tree genetic resources. Eucalypts, pines, acacias and teak remain the dominant species for plantation establishment. A critical concern is whether the current assemblage of exotic germplasm is robust and broad enough to meet the increasing demand of wood and pulp, has resistant to pests and diseases and is adaptable to climate change given the decline in forest research and development budgets across Africa. The privatization of commercial forestry research in most countries has resulted in most governments being unable to account for and manage forest genetic resources, resulting in many small scale growers having limited access to good tree germplasm.

A number of multipurpose tree species (MPTs) are planted or retained in farming landscapes. The genetic improvement of agroforestry tree species is still fraught with uncertainties of scaling up investments given the perceived demand (driven by donor projects) or lack thereof. Forest genetic resources in native forests are threatened by agricultural expansion, are continuously being modified by forest management practices and some are conserved *in-situ*. With the later, the key question is whether the forest genetic resources are comprehensively and adequately reserved. The chapter highlights the constraints that many government agencies, private sector and NGOs are facing in supplying tree germplasm, and gives the perspectives of the end-users of the resources. Successful tree germplasm management is also dependent on the acquisition and importation of exotic tree germplasm from source countries and the exportation of improved germplasm and indigenous tree seed to other countries. The international regulations on movement of germplasm are discussed and how these can affect tree germplasm management in Africa. This chapter also covers the emerging opportunities provided by the new wave of tree planting going on in Africa, the reconfigured view of forests for environmental provisioning (e.g. climate change mitigation) and the forecasted increase in demand for wood and NTFPs. These trends drive the demand for germplasm and create opportunities for increased investment in the supply of high quality germplasm. The chapter is divided into four sections describing the forests in Africa, the status of the main genetic resources, constraints and opportunities.

2.2 Forests in Africa

To understand the importance of investments in tree germplasm production and management for the sustenance of Africa's forests, we need to understand the scale of forest resources in Africa. The total land area under forests in Africa is 624 million ha. There are 125 million ha of primary forests, 165 million ha of production forests, 16 million ha of planted forests, 133 million ha of multiple use forests and the rest is set aside for biodiversity conservation, habitat for wildlife and provision for environmental services (FAO, 2015). About 140 million ha are under some form of forest management plan.

Natural forests

The distribution of forests and woodlands in Africa varies from one sub-region to the other, with Northern Africa dominated by the Sahara Desert and having the least forest cover while Central Africa is dominated by the Congo basin forest ecosystem, which is the second largest forest in the world. Eastern Africa forests and woodlands are widespread and include high altitude forests, medium altitude moist evergreen forest and semi-deciduous forests. Southern Africa is dominated by forests and woodland types which include large tracts of tropical rain forests found in parts of Angola and the Congo basin, afromontane forests, Zambezi teak forests, Miombo woodlands found north of the Limpopo River, Mopane woodlands and the Cape Floristic Centre forests found along the south-western coastline of Africa (see Sebukera *et al.*, 2006).

For natural forests, management has largely been based on encouraging natural regeneration (Maisharou *et al.,* 2015; Kamwenda, 1999; Ghazi *et al.,* 2005; Sawadogo *et al.,* 2011; Sendzimir *et al.,* 2011; Gabou and Maisharou, 2014; Luoga *et al.,* 2004; Chidumayo, 1997). The management of natural woodlands and forests based on selective and clear-cut systems followed by natural or artificial regeneration can impact population structure and mating patterns and hence the conservation status of tree genetic resources (Ratnam, 2014). Other natural influences, such as climate change, are believed to be impacting on the forest genetic resources (Alfaro *et al.,* 2014). In this regard, tree germplasm collected or conserved in these natural forests becomes important for regeneration of the forests and long-term conservation.

Plantation forests

The development of 16 million ha of plantation forests in Africa was largely based on the importation and testing of exotic tree germplasm such as *Eucalyptus, Pinus, Acacia* and *Tectona grandis*. Large scale establishment of industrial forest plantations started at different times during the early 1900s, e.g. in East and North Eastern Africa (Chamshama, 2011), West and Central Africa (Harris, 1993) and in South Africa the first commercial plantation of eucalypts was established in 1876 (Nordin, 1984, cited in Chamshama and Nwonwu, 2004). The first extensive plantings of industrial tree crops in Africa occurred during the period 1900-1945, mostly in countries with little utilisable natural forest 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). Plantation development was motivated by the realisation that the indigenous forests with very slow growth and difficulty in propagation would not meet future wood needs. Most species planted for plantations were exotics, mainly Eucalypts (hardwoods), Pines (softwoods), *Hevea* (rubber), Acacias (gum Arabic and fuelwood), *Tectona* (hardwood) and a few others (Table 1). Planted forests are now an important component of the forest landscape in Africa with southern Africa having the largest area of plantation forests. The successful establishment of commercial plantations in Africa have generally been driven by the private sector encouraged and supported by governments and international finance (Jacovelli, 2014).

1.5 year old *E. grandis* in Lichinga, Mozambique. Photo: C. Marunda, 2014

Table 1. Commonly planted species in Africa by percentage and area planted

Species	Area (%) (Chamshama and Nwonwu, 2004)	Area (ha) (Pandey, 1992)
Eucalypts	22.4	790 000
Pines	20.5	610 000
Hevea	7.1	-
Acacia	4.3	250 000
Tectona	2.6	140 000
Others	-	120 000

Agroforest systems

Zomer *et al.* (2009) describe agroforestry as the inclusion of trees within farming systems and has been a traditional land-use developed by subsistence farmers throughout most of the world. Agroforestry practices have been widely adopted in Africa (Sanchez, 1995). Domestication and commercialisation of IFT has been promoted in most African countries through the leadership of the World Agroforestry Centre (WAC) in partnership with government agencies, NGOs and farmer groups. Agroforestry systems are grouped based on products and services as follows: fodder production (e.g. Franzel and Wambugu, 2007, Wambugu *et al.,* 2011), soil fertility improvement (e.g. Sanchez *et al.,* 1997; Ajayi *et al.,* 2001), indigenous fruit trees (e.g. Akinnifesi *et al.,* 2006) and woodlots for fuelwood (e.g. Rural Afforestation Programme in Zimbabwe; World Bank; 1991; Jagger and Pender, 2008). It is difficult to estimate the area under agroforestry systems. Agroforestry, if defined by tree cover of greater than 10% on agricultural land is wide-spread in Africa covering over close to 1.8 million km^2 of agricultural land (Zomer *et al.,* 2009).

Declining forest areas

The Forest Resource Assessment by FAO in 2015 showed that the forest area in all regions of Africa declined between 1990 and 2015 (Table 2) (FAO, 2015). African countries with the highest rates of deforestation include Nigeria (409 600 ha yr-1), Tanzania (372 000 ha yr^{-1}), Zimbabwe (312 000 ha yr^{-1}), Democratic Republic of Congo (311 400 ha yr^{-1}), Cameroon (220 000 ha yr^{-1}) and Zambia (166 600 ha yr^{-1}).

Table 2. Trends in forest area from 1990 to 2015 by sub-regions in Africa (1000 ha) (FAO, 2015).

Sub-region	1990	2000	2005	2010	2015
East-Southern Africa	319,785	300,273	291,712	282,519	274,886
West–Central Africa	346,581	332,407	325,746	318,708	313,000

The reasons for increased rates of deforestation include low rates of tree planting, increasing demand for wood products and expansion of agricultural land. The implication of this negative change is that African countries need to increase investment in sustainable forest management (SFM) which will include increasing rates of reforestation and afforestation. The loss of natural forest and ecosystems also has implications on the quality of forest genetic resources. To reverse these trends, Africa will need to invest in SFM and one key strategy will be to invest in tree germplasm production and deployment to ensure timely availability of good planting stock.

2.3 Status of germplasm resources in Africa

Successful plantation establishment and regeneration of indigenous forest is underpinned by good forest germplasm management. For plantations and woodlots, the choice of species for planting depends on expected end-products, survival and growth of the species. Growth and survival are fundamental to successful plantations, regardless of the production objective (Teulières *et al.*. 2007). The early introductions of exotic species provided the tree stands from which superior trees were selected and the seed used to establish plantations. The need to import seed from different provenances was recognised in the 1900s, and many species/ provenances of eucalypts and acacias where imported from Australia, pines from North, Central and South America, and *Tectona grandis* from South and Southeast Asia. Most of the countries in Africa have conducted basic species and provenance trials for exotic species and have now assembled a wide range of provenance trials and seed orchards.

For indigenous species, germplasm management has mainly focused on the collection of seed for research and general planting. For example, the World Agroforestry Centre supported a number of countries to collect germplasm of indigenous fruit trees for research purposes (Akinnifesi *et al.,* 2006). A number commercial species such as *Khaya*, *Entandrophragma*, *Melicia, Terminalia* and *Triplochiton* species have been established in plantations from seed collected in natural forests. Some countries have participated in projects to conserve biological resources *ex situ* especially for those species threatened with extinction through partnership with the Millennium Seed Bank Project (for example, the Seed for Life Project in Kenya). The next section describes the status of tree germplasm resources and supply systems in Africa.

Eucalypts germplasm in Africa

The most widely planted species in Africa falls under the *Eucalyptus* genus, which are also 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 most frequently planted: *Eucalyptus camaldulensis, E. dunnii, E. globulus, E. grandis, E. nitens, E. pellita, E. saligna, E. tereticornis* and *E. urophylla* (Harwood, 2011). Most of these species have been tested and deployed for operational tree plantings in many parts of Africa. They are planted mainly for pulp-wood, transmission poles, fencing post, construction timber and firewood on a short-term rotation and coppice management basis.

Huge investments have been made in the evaluation and development of eucalypt genetic resources. Table 3 lists some of the common species planted in Africa. Other Eucalypt species tested include *E. pilularis, E. microtheca, E. citriodora, E. maculata* and *E. decaisneanai*. In South Africa, new temperate eucalypt species are being tried in cold and frost-prone areas, including: *E. bagjensis, E. bethami, E. macurthii* and *E. henryii* (Mondi Forest and SAPPI, 2014, Annual reports).

Table 3. List of the commonly planted eucalypt species in Africa (source Marunda et al., 2017).

Species	Regions/countries introduced	Selected countries
E. camaldulensis	CA, EA, SA, WA	All
E. citriodora	SA	South Africa, Zimbabwe
E. cloeziana	SA	Zimbabwe
E. grandis	EA, SA, WA	All countries
E. globulus	SA	Malawi, Ethiopia, South Africa
E. dunni	SA	South Africa, Zimbabwe
E. microtheca	SA	Zimbabwe
E. nitens	SA	South Africa, Zimbabwe
E. pellita	SA	Mozambique, South Africa
E. saligna	SA	Malawi, South Africa, Zimbabwe
E. robusta	SA	Madagascar, Mozambique
E. tereticornis	SA, EA, WA	Mozambique, Zimbabwe,
E. urophylla	SA, EA	Mozambique, South Africa, Zimbabwe

EA (Eastern Africa), CA (Central Africa), SA (Southern Africa), WA (Western Africa)

Hybrids and eucalypt clonal forestry

Controlled pollination, or manipulated/artificial hybridization, has been used for the generation of eucalypt inter-specific hybrids for tree improvement (Eldridge *et al.,* 1993) and has been used in the development of eucalypts for clonal forestry in South Africa, Congo and recently in Eastern Africa. The hybrids are adapted to intermediate climatic and environmental conditions that are in-between the pure species and the new hybrids. Hybrids also combine favourable and complementary traits such as volume, stem form and drought tolerance. Examples of inter-specific hybrids are given in Table 4.

Table 4. Common inter-specific hybrids of eucalypt species planted in Africa.

Hybrids	Target environment	Examples	References
grandis x nitens	Frost prone sites	South Africa	ICFR (2015)
grandis x urophylla	Tropical and sub-tropical humid areas	Mozambique, Tanzania, Angola, Uganda, Kenya	Kilimo Trust, (2011), Gouma *et al.* (1995)
grandis x camaldulensis	Drought prone areas	Zimbabwe, Zambia, Nigeria	Madhibha *et al.* (2013) McComb and Jackson (1969)
grandis x tereticornis	Drought prone areas	Zimbabwe, Mozambique	Madhibha *et al.* (2013)

Clonal propagation in Africa has evolved from its inception in the 1970s when the French in the Congo and the Australians first began trialling root cuttings as a method for clonal propagation of eucalypt species. The Republic of Congo is now well known for the development of a high performing *Eucalyptus* hybrids used in forest plantations (Marien and Peltier, 2010) and has ex-situ conservation of the hybrids (Gouma *et al.,* 1995). Interspecific hybrids of *Eucalyptus* spp. have been developed and the germplasm (clonal material) deployed to commercial companies, e.g. in Angola, Kenya, Mozambique, Rwanda, South Africa and Uganda. In countries with a tropical to sub-tropical climate (e.g. Uganda, Kenya, Congo, DRC, Mozambique and Angola), *grandis (G)* x *urophylla (U)* hybrids have been introduced for growing on warm moist sites. In countries such as South Africa, investments to develop hybrid germplasm to extend the planting of eucalypts into colder environments is ongoing, whilst in other countries *grandis (G)* x *camaldulensis (C)* hybrids have been introduced for drier areas (e.g. Zimbabwe and Zambia) with limited success. In East Africa, clones of Eucalypts (GxU, GxT, GxC,) have been developed with support from Mondi, Gatsby Charitable Foundation and Tree BioTechnology Projects in Tanzania and Kenya (Msanga, 2016; Ngamau *et al.,* 2004).

Whilst clonal forestry has increased productivity and resistance to pests and diseases in countries (e.g. South Africa) which have invested heavily in the technology, some countries with low level of investment might find clonal forestry expensive, as costs per plant might be higher than seedlings (e.g. Griffin, 2014). Clones might also be susceptible to diseases and whole blocks of plantations might be wiped out; e.g. in Zimbabwe and Zambia *grandis x camaldulensis* clones succumbed to pests and clonal plantings failed. Inter-specific hybrids tend to be more vulnerable than the pure parental species to pests and diseases (Harwood, 2011). Countries with well-established clonal forestry programmes need to continuously test the performance of hybrids in different conditions to make sure they are adaptable and resistant to pests and diseases. In East Africa, where eucalypt clonal forestry has been promoted (e.g. through the Sawlog Production Grant Scheme in Uganda, Tree Biotechnology programmes in Kenya and Tanzania), there are increasing concerns that small-scale tree growers are collecting seed from clonal trees (due to their superior phenotype) for raising seedlings. This is resulting in poorly performing plantations and woodlots (Cheibowo, personal communication, 2016). There is need to raise awareness and regulate seed collection and distribution to ensure use of good seed. It is worth noting that “monoclonal blocks are impressive if they work, but are equally impressive if they don’t” (Henson, 2011).

Eucalypt germplasm supply and demand

From the regional reports, it appears that seed of eucalypt species is readily available although there are localised shortages. For example, the seed centre in Zimbabwe is failing to supply seed of *E. camaldulensis, E. grandis* and *E. tereticornis* for planting woodlots to supply wood for curing tobacco (Dzingai Rukuni, personal communication, 2017). The decline in the production of seed has been attributed to lack of funding for research and development leading to abandonment of research trials and seed orchards, some of which have been cut for firewood. Other species, such as *E. nitens,* are shy seed producers and seed production cannot meet demand. Inconsistent flower and seed production is a major hindrance to the genetic improvement and commercial seed production of *E. nitens* in South Africa (Swain and Gardner, 2003). The selection of sites for the establishment of orchards for commercial seed production and breeding of this species still presents a major challenge.

Seeds of most of the *Eucalyptus* spp. are available, but concerns for genetic and physiological quality were reported in some countries. 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 and expand afforestation into new eco-zones (e.g. frost prone and cold environments), to increase resistance to new pests and diseases (e.g. Blue gum chalcid, red gum lerp and bronze bug on *Eucalyptus* spp. in Southern Africa), and mitigate the potential impacts of climate change by importing provenances from the extreme ends of natural distribution of some species.

Most eucalypt species planted in Africa are managed on coppice rotation (5-20 years), and it is only when the old moribund stumps are removed that new seed sources are planted. This cycle, if not managed carefully, might lead to the planting of inferior planting stock or in the case of trials, de-stumping might result in the loss or depletion of the original genetic diversity. The need for enrichment collection was mentioned in many countries and it is recommended that countries should engage with the Australian Tree Seed Centre (ATSC) – a seed centre under the Commonwealth Scientific and Industrial Research Organisation (CSIRO) - to acquire more seed from a diverse range of provenances.

The critical questions for eucalypt genetic resources in Africa are;

- whether the genetic pool held in Africa is broad and resilient enough to face the new challenges of climate change, new diseases and pests (Psyllid, chalcid and bronze bugs in many parts of Africa);
- are the *Eucalyptus* genetic resources robust enough to be further improved for yield and wood properties since national economies are growing and the demand of wood is projected to increase;
- do African countries need to re-invigorate their *Eucalyptus* gene pool through new importation from Australia or other original sources;
- do countries need to engage in inter-specific hybridization to create new clones adaptable to new climatic conditions, resistant to pest and diseases and superior in performance to pure species and how cost-effective is vegetative clonal forestry compared to seedlings?

Pine germplasm in Africa

Tropical pine species from Mexico and Central America are being used in plantations all over the world (Dvorak, 2000). In Africa, *Pinus* species are the second most widely planted species in environments ranging from cool-high rainfall high altitude areas to low-lying high-rainfall areas. *P. patula* was the first species to be introduced in South Africa from collections made in Mexico in the early 1900s. These early plantings served as a source of genetic material for other countries in southern Africa for many years (Butterfield, 1990; Poynton, 1977). Several species, mostly originating from the American or Asian tropics and subtropics, are now widely cultivated and planted. These include *P. caribaea, P. elliottii P. greggii*, *P. kesiya, P. maximinoi, P. patula, P, oocarpa, P.radiata* and *P. tecunumanii*. *P. kesiya* is a tropical pine from Asia widely planted in Madagascar and Zambia. In West Africa, Nigeria established trials of the following species: *P. caribaea, P. oocarpa, P. khasya (kesiya)* and *P. merkusii* as part of a series of species introduction trials in the 1960s (Otegbeye, 1991).

Pines are popular because there is a wide range of species suitable for varying growing conditions; they flourish in dry, poor soil and degraded sites; the volume production of some of the species can be very high; they are robust pioneer species well suited for reforestation and for simple silviculture (monocultures and clear-felling) and for their wood qualities and uniform coniferous wood valued for production of lumber, chemical pulp, paper, particleboard, etc. (Lamprecht, 1990).

Table 5 below shows that *P. caribaea* and *P. oocarpa* are widely planted in Africa, but do not necessarily occupy the largest plantation areas. These species grow well along low-lying coastal areas. Unconfirmed reports appear to suggest that there is a local shortage of seed of these species. For example, in Mozambique, private companies establishing plantations of the species in the northern part of the country are importing untested seed for plantation expansion. P. *maximinoi* and *P. tecunumanii* were recently introduced in Southern Africa and are slowly replacing *P. patula* as preferred species in South Africa (Dvorak and Shaw, 1992), Rwanda (Mugungu and van Wyk, 2003) and Zimbabwe (Gapare *et a1.,* 2001; Nyoka *et al.,* 2010). Recently, the Central American Coniferous Resources (CAMCORE) has been partnering with countries such as Kenya, Mozambique, Tanzania, Uganda, South Africa and Zimbabwe to import new genetic material of selected *Pinus* spp. for enriching diversity of existing genetic resources. Other pine species were distributed by CAMCORE to its member organizations (mainly private companies) as part of a series of international provenance and progeny trials and developments of *ex-situ* conservation stands (Dvorak *et al.,* 1996).

Table 5. List of commonly planted pine species in Africa. See http://www.cabi.org/isc/datasheet

Species	Regions	Countries with records of species trials or plantations
P. caribaea	WA, CA, EA, SA	Burundi, Cameroon, Congo, DRC, Gambia, Ghana, Guinea, Kenya, Nigeria, Madagascar, Malawi, Mauritius, Mozambique, Liberia, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Zambia, Zimbabwe
P. elliottii	SA, EA	Burundi, Madagascar, Mauritius, South Africa, Tanzania, Rëunion, Zimbabwe
P. greggii	SA	South Africa, Zimbabwe
P. kesiya	SA	Nigeria, Madagascar, South Africa, Zambia, Zimbabwe
P. maximinoi	SA	Mozambique, Tanzania, South Africa, Zimbabwe
P. merkusii	WA	Nigeria
P. oocarpa	CA, WA, EA, SA	W/CA: all countries on the coast from Sierra Leone to Angola; EA: Ethiopia, Kenya, Tanzania, Uganda; SA: Malawi, South Africa, Mozambique, Zambia, Zimbabwe
P. patula	SA, EA	Ethiopia, Kenya, Malawi, Mozambique, South Africa, Swaziland, Tanzania, Rwanda, Zimbabwe
P. taeda	SA	South Africa, Zimbabwe
P. tecunumanii	SA. EA	South Africa, Malawi, Mozambique, Tanzania, Zimbabwe
P. radiata		S. Africa,

Hybrids and pine clonal forestry

In South Africa, a number of hybrids are being tested in cooperation with CAMCORE (Table 6). Some of the popular hybrids include *P. elliottii* x *P. caribaea* and *P. patula* x *P*. *tecunumanii* which have consistently shown good growth and form (CAMCORE 2013). The hybrids were created to improve resistance to diseases such as the pitch canker in *P. patula*, and to increase productivity (fiber gain). The development of clonal forestry for pines has been developed in cooperation with CAMCORE.

Table 6. Some of the hybrids planted or being evaluated in South Africa (CAMCORE, 2013).

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. maximinoi* *P. taeda* *P. greggii*	*P. patula*	*P. oocarpa*	*P. maximinoi*	*P. tecunumanii*

Pine seed production

Demand for seed for *P. maximinoi* and *P. tecunumanii* outstrips supply in Southern Africa (e.g. Mozambique and Zimbabwe) (Nyoka and Tongoona, 1998; Gapare *et al.,* 2001), and even world-wide (Koskela *et al.,* 2014). The two species have been planted in a number of countries in Southern Africa and the existing plantations and trials could be used to follow flowering and seed production patterns to determine the landscapes most suitable for establishing seed orchards or seed production areas. The other species whose seeds are difficult to acquire in Mozambique are *P. caribaea* and *P. oocarpa* (Kachale, personal communication 2014). The shortages are due to the fact that the species are shy seed-producers under certain climatic and ecological conditions and more research on flowering fecundity needs to be done to identify suitable conditions for good seed production.

Countries with a history of planting pines on a large scale (e.g. South Africa) reported sufficient supply of most pine species. This has been made possible because the private sector has invested in tree germplasm to meet own demand and sell excess seed. Zimbabwe used to be self-sufficient in pine seed supply and the largest exporter of pine seeds. However, over the past years local shortages are common as investments in tree breeding and seed supply have gone down in the country (Tembani *et al.,* 2014). Some of the clonal seed orchards are too old and have lost vigour resulting in decreased yields (e.g. for *P. elliottii* and *P. taeda*). The same situation applies to countries like Malawi and Zambia where seed production areas have been neglected for a long time.

Other exotic species

Other tree species planted as plantations include *Tectona grandis* (teak) accounting for 2.6 % of the plantation forests in Africa (AFORNET, 2005). While natural teak forests are found only in India, Laos, Myanmar and Thailand, more than 75 % of the global supply comes from plantations. The documentation of the origin (seed sources) of these species in Africa is poor and most of the collections are now referred to as local land races. Vehaegen *et al.* (2010) showed that nearly 95% of teak landraces in Benin, Cameroon, Côte d'Ivoire, Tanzania, Togo and Senegal came from North India, and 96% of Ghanaian teak appeared to be very closely linked to Central Laos.

The other species, *Gmelina arborea,* was introduced in West Africa in 1888 (Akachuku, 1984) and to-date there are over 130 000 ha of plantation under this species. A number of countries participated in an international breeding trial with seed samples coming from Ghana (Forest Products Research Institute), Tanzania (Forest Research Institute), Malawi (Forest Research Institute) and Cote d'Ivoire (*Centre Technique Forestier Tropical*) (Lauridsen and Kjaer, 2002). The largest plantations are found in Nigeria, Kenya, Ethiopia, Sierra Leone, Ghana, Ivory Coast and Cameroon and are mainly grown for pulp-wood and fuelwood. It is also grown in countries such as Malawi, Tanzania and Zambia in small woodlots to provide energy (e.g. for curing tobacco in Malawi).

Seed production for T. grandis and G. arborea

Seed supply is a major limiting factor in planting efforts for *T. grandis*. In Nigeria, for example, availability of quality seeds is a major constraint as the current stands are generally of poor form, especially the bole height, and fruiting appears very early (age 3) resulting in reduced height growth and more branching (Kwame Asomoah Adams, personal communication, 2016).Tanzania provided large amounts of seeds for plantations in EA, and later in WA Africa from seed sources in Kihuhwi, Bigwa and Mtibwa (Msanga, personal communication, 2016). It is well known that teak seed germination is poor and sporadic as a result of its dormancy behaviour. Vegetative propagation is also used to propagate the species. For example, in Côte d'Ivoire, the Society for the Development of Forests (SODEFOR) and CIRAD developed a mass micro-propagation technique for the production of millions of vitro-plants from improved clones of teak (Bouvet, 2011).

For *G. arborea* seed is currently collected from local landraces although in most cases the origin of the seed is unknown and may be based on a very narrow genetic base. Seeds are recalcitrant and are prone to fungal infection and are difficult to store as they quickly lose germination capacity. Most seed centres reported on the need to improve the storage of the species. A solution to the problem of recalcitrant seed is to raise seedlings for distribution, but that would mean extra costs to the seed centres.

Germplasm for Agroforestry systems

Many farm landscapes in Africa contain a range of planted and retained forest trees (Dawson *et al.,* 2013). A numbers of species are planted for improving soil fertility, fodder banks, woodlots (broadly referred to as multi-purpose tree species-MPTS). Research on the domestication of indigenous fruit trees (IFT) has become a core component of agroforestry. The lack of tree seeds, seedlings and other planting materials (tree germplasm) has long been recognised as a major constraint to the scaling up of agroforestry innovations (Kindt *et al.,* 2006). On-going attention is being paid to the genetic improvement of trees in the agroforestry systems and this effort has largely been led by international organisations and NGOs. A large number of MPTS has been assembled by the World Agroforestry Centre and a comprehensive list of indigenous fruit tree species has been identified and prioritised for all the regions in Africa. The following sections describe the status of agroforestry germplasm in Africa.

Multi-purpose tree germplasm (fodder, soil improvement and fuelwood)

Exotic MPTS and agroforestry species have a fairly recent history in the region. WAC spearheaded the research on MPTS for fodder, soil improvement and fuelwood production. Most of the species used in agroforestry are exotic leguminous species and the main ones include *Acacia crassicapa, Azadirachta indica, Calliandra calothyrsus, Glyricidia* spp.*, Leucaena leucocephala, Senna siamea, Sesbania sesban* and *Tephrosia vogellii* for the Eastern and Southern African regions. For West and Central Africa, common species include *Acacia auriculiformis, Albizzia lebbeck, Flemingia congesta, Gliricidia sepium, Leucaena leucocephala* and *Piliostigma malarborium*. A small range of indigenous species are also grown in agroforestry systems and the species depend on the region. The most commonly mentioned species is *Faidherbia albida* (*Acacia albida*) with Niger having over 5 million ha of the species. It has been collected throughout its geographical range in Africa and tested across many sites (Barnes *et al.,* 1996). Gradually the species is becoming the default species for planting in farming systems in the sub-tropical parts of Africa. WAC has led the tree improvement programmes of selected species and most of the research outputs are targeted for the densely populated regions of EA, SA and W/CA.

Many countries in Africa face shortages of fuelwood, and a number of species have been planted to supply fuelwood to meet energy demand for cooking, brick curing and in some countries, like Malawi and Zimbabwe, wood energy for curing flue-cured tobacco. In Southern Africa, like all other regions of Africa, *E. camaldulensis* and *E. tereticornis* are the major species demanded for fuelwood. In Eastern Africa, planting of woodlots is widespread in high potential areas with the most commonly planted species including *Eucalyptus* spp., *Markhamia lutea*, *Casuarina equstifolia*, *Senna spectabilis*, and *Melia azederach* (Buyinza and Wambede, 2008). Some dry-zone Australian acacias, such as *Acacia crassicarpa*, *A. jurifera*, *A. leptocarpa* and *A. auriculiformis,* have been tried in many dry areas of Africa (Cossalter, 1987) with limited success due to poor coppicing ability and low wood density of some of the species (e.g. Tembani *et al.,* 2014)

Germplasm production of MPTS

Problems were reported in the supply chain of agroforestry germplasm with seed still being collected by farmers and on rare cases by national tree seed centres from home-gardens, demonstration plots, and trials initiated through donor funded programmes. Reviews by Nyoka *et al.* (2014) found that some of the germplasm supply systems in Africa do not efficiently meet farmers' demands and expectations in terms of productivity, species and genetic diversity. Most seed centres in Africa, except in Malawi, reported that they did not collect or distribute agroforestry tree seeds. The perception reported by most seed centres is that putting in place a strategy to collect agroforestry seed is difficult and costly since priorities for end-users keep changing. The fact that most of the demand for such species is driven by donor projects creates a level of uncertainty, and Forestry Departments tend to favour long-term research funded from government fiscal allocation. In countries where there is a strong demand (Malawi), the seed business has attracted several stakeholders and there is no control or capacity to monitor the quality of the seeds. There is need to set some standards and improve the capacity by governments to monitor seed quality. Sustainability of planting agroforestry species beyond the tenure and involvement of international organisations need to be evaluated since the perception that the activities are donor driven is quite common and in-grained.

Seed deployment has been reported to be through three channels, *viz*. central government through NTSC, NGOs through donor funded projects and farmer to farmer exchanges. There is still a perception amongst national developmental practitioners and farmers that agroforestry is a donor driven process, and this negates local initiatives and can be a barrier to uptake of the agroforestry technologies. In some countries, such as Zambia, it was indicated that long-term strategic planning for improving agroforestry tree species and the supply of genetic resources is difficult because of changing priorities, changing end-products and uses, and the short-term nature of funding.

Indigenous fruit trees (IFT)

Domestication and commercialisation of IFT has been promoted in most African countries through the leadership of WAC in partnership with government agencies, NGOs and farmer groups. The programmes aim to promote the domestication and improvement of IFT with economic potentials as new cash or novel crops, and to provide incentives to subsistence farmers to grow such trees that contribute towards achieving poverty reduction, enhancement of food and nutritional security (Awodoyin *et al.,* 2015). Domestication of IFT has been done in a participatory way in all 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 suggesting that seed-lots held by research organisations are of good genetic make-up (Tchoundjeu *et al.,* 2006).

Research on the domestication of local fruit trees started recently through projects concentrating on some of the most important indigenous species in Africa. In the last couple of years, new concepts and approaches have been developed, case studies have been produced and the potential and feasibility of their domestication and commercialization has been explored (Akinnifesi et al., 2007; Jusu and Cuni-Sanchez, 2016). Priority lists of species have been agreed upon by national, regional and international research organisation (e.g., WAC). The list (Table 7) has been developed using the approach described by Franzel et al. (1996) which constituted a combination of focus-group data, field observations, market surveys and ranking exercises to determine which IFTs have highest potential for domestication and commercialisation. IFTs have so far been grown around homestead as shade trees, nurse trees, in community protected sacred forests, wild and volunteer stands on farms, market squares, village lands and forest areas.

Table 7. Priority indigenous fruit trees for domestication in sub-Sahara Africa.

Species	References
West Africa (Sahel region)	
Adansonia digitata; Parkia biglobosa; Tamarindus indica; Vitellaria paradoxa; Ziziphus mauritiania	Raebild *et al.* (2011)
Central Africa	
Irvingia gabonensis; Dacryodes edulis; Ricinodendron heudelotti; Chrysophylum albidum; Garcinia cola	Tchoundjeu *et al.* (2006)
Parinari excels; Cola lateritia; Pentaclethra macrophylla; Heritiera utilis; Bussea occidentalis	Jusu and Cuni-Sanchez (2016) - list for Sierra Leone
East Africa	
Adansonia digitata; Carissa edulis; Parinari curatellifolia; Sclerocarya birrea; Tamarindus indica; Ziziphus mauritiana; Balanites aegyptica; Berchemia discolour; Borassus aethiopium; Cordeauxia edulis; Strychnos cocculoides; Vangueria madagascarienses	Teklehaimanot (2005)
Southern Africa	
Uapaca kirkiana; Strychnos cocculoides; Parinari curatelifolia; Ziziphus mauritiana; Adansonia digitate; Sclerocarya birrea	Akinnifesi *et al.* (2006)

Germplasm supply for IFT species

The analyses of tree germplasm supply in Africa has shown that collection of seed/fruit has been limited to supply the demand for tree improvement by international organisation (e.g. WAC) and conservation by national tree seed centres. For communities, collections target the fruit for consumption or processing into other products (e.g. baobab for powder), *V. paradoxa* for shea butter rather than collection for seed or tree germplasm. The challenge to widespread adoption of IFT is the unavailability of high quality planting stock of high priority species. Caradang *et al.* (2007) observed that activity on IFT is constrained by availability of planting stock, distance to seed/fruit sources (often remote as the trees near villages are harvested first), lack of propagation techniques and lack of awareness among the farmers. In many parts of Africa, exotic fruit trees are deployed as improved planting stock in the form of potted seedlings from commercial nurseries. This tradition might give guidelines for the future development of IFTs. Deployment of improved grafted material might offer a solution to the limited availability and improve domestication uptake. The widespread uptake of IFT is slow and there is need to change research and deployment strategies and community/household attitudes toward IFT from depending on wild sources to engaging in domestication processes.

Tree germplasm for most species is still scarce with national tree seed centres still not able to supply seed. A few nurseries have reported the supply of IFT seedlings. A small number of IFT species are scarcely grown deliberately by the farmers, who most times depended on wildings they came across for transplanting and regeneration of their selected local fruit trees. Knowledge and technical know-how of propagation and nursery management of the IFT are more or less lacking and there is need to identify new technologies to promote the propagation of the priority species. Unlike other species, IFT require vegetative propagation (grafting, air-layering, marcotting) to advance the time to fruit production, e.g. for *Ziziphus mauritiana* (Kalinganire and Koné, 2010). More research is needed to expand knowledge to other useful species within the region. Seedlings rather than seed could be the best way to deploy improved planting stock of IFT to farmers. Efficient vegetative propagation based on simple horticultural techniques was shown to be possible for most IFT species (Tchoundjeu *et al.,* 1998).

Seed germination tests in a germination room, TTSA, Morogoro, Tanzania Photo © Heriel Msanga/AFF

Indigenous commercial species

Commercial indigenous tree species have been the main source of timber in countries rich in natural forests, e.g. in W and C Africa. Special hardwood timbers are also harvested in countries with dry forests, e.g. Zambia and Mozambique. Due to their superior wood qualities and the need for conserving natural populations, most African countries are supporting programmes to plant indigenous commercial species. Some species which were previously not commercially harvested are now being exploited due to new markets. For example, *Pterocarpus chrysothrix* (Mukula) is now threatened with over-cutting due to increasing demand from China (Kawanda, undated)

A few species and provenance trials have been established. For example, in Gabon a trial of 13 provenances for *Aucoumea klaineana* from the species natural distribution range, was planted in 1967 in the M'Voum Reserve. More recently, provenance trials for *Baillonella toxisperma* (Moabi)*, Distemonanthus benthamianus* (Movingui), *Erythrophleum suaveolens* and *E. ivorense*

(Tali) collected from different populations across the climatic regions in Cameroon, Gabon and Republic of the Congo, were established in forest gaps in Cameroon and Gabon (FAO 2014a, cited in Avana-Tientcheu, 2016).

Planting of commercial indigenous timber species is more wide-spread in W/CA than in other regions of Africa. This is mainly because the species are commonly harvested for timber and there are concerns of over-exploitation of the species. The main seed sources for indigenous tree species are natural forests because they have not been tested in provenance trials. In general, bulk seeds collected from natural stands and from remnant trees scattered in farmlands constitute the major source of material for establishing plantations and woodlots. Therefore, seed supply for most of the indigenous tree species is grossly inadequate and the use of genetically superior planting stock is uncommon. A list of the common species is given in Table 8 above. Technologies for the production of high quality seedlings include selection of plus trees or pest resistant individuals and adaptation of conventional vegetative propagation techniques for mass production. In most countries in W/CA, the main technologies for the production of high quality seedlings are vegetative propagation techniques, especially for tree species that have poor and difficult seed production (Avana-Tientcheu, 2016).

Table 8. List of common indigenous commercial species for planting

Species	Common Names	Potential uses	Regions
Khaya ivorensis, K. grandifolia, K. angolensis	African Mahogany	Plywood, Veneer, Boards, Furniture	CA, WA, EA, SA
Terminalia superba	Ofram Veneer/Frake/Limba	Plywood, Furniture	WA
Pycanthus angolensis	Otie Plywood/Ilomba	Veneer, Boards, Furniture	WA
Canarium schweinfurthii	Bediwonua Plywood/Aiélé	Veneer, Boards, Furniture	WA
Dalbergia sissoo, D. retusa	Rosewood Furniture	Veneer, Plywood	WA, EA
Tieghemella heckelii	Makore Plywood	Veneer, Boards, Furniture	WA
Pterygota macrocarpa	Koto Plywood	Veneer, Boards, Furniture	WA
Triplochiton scleroxylon	Wawa Plywood/Ayous	Boards, Particle Board	WA, CA
Entandrophragma angolensis	Edinam Plywood/Tiama	Veneer, Boards, Furniture	WA, CA, SA
E. cylindricum	Sapeli Plywood	Veneer, Boards, Furniture	WA
E. candolli	Kosipo Plywood	Veneer, Boards, Furniture	WA
E. utile	Sipo plywood	Veneer, Boards, Furniture Plywood	WA
Ceiba pentandra	Ceiba	Veneer Plywood, Boards	WA, CA
Hallea stipulosa	Subaha	Furniture Boards	WA
Milicia excelsa	Odum/Iroko	Furniture, Parquet	CA, WA, EA, WA
Terminalia ivorensis	Emire/Framire	Veneer, Plywood	CA, WA
Nauclea diderrichii	Kusia/Bilinga	Furniture, Parquets, panelling	WA

Tree germplasm for indigenous commercial species

A major concern for the planting of indigenous commercial species is the un-availability of planting stock. Rather than relying on seed alone, some species can be propagated vegetatively. For example, in Ghana, the Forestry Research Institute has developed techniques for production of *M. excelsa* (Iroko) clones that are tolerant and 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 up opportunities for large scale planting of this important timber species in Ghana and Cote d'Ivoire and also as a way of addressing plantation failure of African Mahoganies (*Khaya* and *Entandrophragma* spp, *K. ivorensis, E. utile), T. scleroxylon* and *M. excelsa.* (Acquah *et al.,* 2013).

ANAFOR nursery in Adamaoua region, Cameroon (left); Green house at CNSF Ouagadougou, Burkina Faso (Right). Photo by V. A. Kemeuze, 2014

For most of the indigenous commercial species, a key reforestation strategy will be to collect seed during harvesting operations and use the seed to regenerate the harvested areas. This strategy would require detailed knowledge of the ecology of the species and how they regenerate under natural conditions. For example, most of the tropical forest species regenerate by responding to gaps created after felling and there is need to use appropriate silvicultural interventions favouring the attainment of the canopy of selected species (e.g. Bongjoh and Mama, 1999). This process can be augmented by collecting and using seed from the harvested trees for regeneration, which ensures that the best possible seed sources are used and contributes to genetic conservation.

The challenge of planting ICS is to access a supply of genetically superior seeds since existing seed trees are continuously being depleted by indiscriminate felling as well as other deforestation and forest degradation drivers. In response to this depletion of natural forest resources, activities have been carried out in recent decades on tree germplasm production and improvement to meet growing demand from public and private plantation owners. African countries have conducted joint seed collection of key species such as *Khaya* spp., *Entandrophragma* spp., *Terminalia* spp. and *Milicia* to exploit the genetic variability throughout the geographical distribution of the species. As a default strategy, harvested areas should always be planted with seed collected from the same area as this could provide higher chances of successful regeneration than using seed from other locations that might have different climatic and ecological conditions.

2.4 Tree germplasm supply: constraints and opportunities

National tree seed centres (NTSC)

Given the importance of tree planting in Africa, many governments established national tree seed centres to support tree planting through the supply of tree seeds and seedlings. Seed centres are viewed as the bridge between forest research such as tree breeding and improvement and the deployment and use of tree germplasm in tree planting. Seed centres in Africa were developed over the last few decades and their roles concentrated on supplying the tree seeds to government-directed tree planting projects and in a few countries to supply seed to commercial forest companies and for export (e.g. South Africa, Tanzania and Zimbabwe). All seed centres were designed to manage all aspect of seed management from collection, processing, testing, storage documentation and certification, supportive research and development, and the provision of advice on use of appropriate planting material to tree growers. The main pathways for tree germplasm deployment include the government model (NTSC), the NGO model were seed, mainly MPTS, is distributed through NGOs, the informal decentralised model (farmer to farmer), private sector (e.g. SAPPI in South Africa) and nurseries especially for fruit trees and species difficult to raise from seed e.g. species with recalcitrant seed common in tropical forests of W/C Africa (Avana-Tientcheu, 2016).

Most seed centres in Africa were established with international support. For example, in Southern Africa, the SADC Tree Seed Centre Network was funded by the Canadian International Development Agency (CIDA) and seed centres were established in all of the 11 countries in the region. In East Africa, DANIDA and NORAD supported the establishment of the seed centres in Tanzania and Uganda, respectively. The Rwanda Tree Seed Centre was supported by the Australian Tree Seed Centre (ATSC) with ICRAF supporting and promoting agroforestry technologies in the country. The Kenya Tree Seed Centre was supported by the German Agency for Technical Co-operation (GTZ). In West Africa, the Burkina Faso and Senegal Tree Seed Centres ((Centre National de Semences Forestières (CNSF) and Programme National de Semences Forestières (PRONASEF)) were supported by the Royal Botanic Gardens, Kew (UK), Ministère de la Région Wallone, Direction Générale des Ressources Naturelles et de l'Environnement (Belgium), Plant Resources of Tropical Africa (PROTA) Network Office Europe (Netherlands) and DANIDA Forest Seed Centre (Denmark) (Henri Bouda, personal communication, 2016).

The sustainability of some of the national tree seed centres has been declining due to low levels of investments after the donor funds ended, institutional re-structuring of the national tree seed programme (e.g. in Mozambique where the seed centre is now under an agricultural department rather than forestry), involvement of the private sector (e.g. South Africa). The NTSC were designed to supply seed to large-scale government funded programmes and are failing to supply seed to small-scale tree growers who are often dispersed over large landscapes.

Technical capacity

Most seed centres reported a decline of funding for research, especially tree breeding, resulting in loss of capacity to advance the breeding programmes to yield superior planting stock. Tree seed centres in many countries are failing to meet the demand. For example in Tanzania, the demand is 40 tons of seed but the NTSC can only supply 12 tons, Kenya needs 30 tons but supply is 7 tons, Uganda demands 30 tons against a supply of 15 tons (Msanga, 2016). In Uganda, the Saw-Log Production Grant Scheme indicated that the supply of seed for species such as *P. caribaea var. hondurensis* is a challenge and the country has resorted to importing un-tested seed from other countries such as Australia (Jacovelli, 2009). In countries, such as Malawi, Zambia and Zimbabwe, most of the pine seed orchards are old and have lost vigour to produce large quantities of seed and there is need to re-graft clones for pines and establish new seed orchards. Almost all countries reported on the poor state of equipment and lack of funding for seed collection.

In other countries, seed centres are facing challenges from competition from the private sector and lack of support from the Government. In countries like South Africa and Mozambique, the private sector has taken the lead in the development and deployment of seed for commercial species and for own use with specified products (e.g. fibre gain in South Africa, saw-log and poles in Mozambique). This means that whilst seed is available for commercial planting, other

Figure 3. Seed storage facility at PRONASEF, Senegal. Photo: V. A. Kemeuze, 2014

planting programmes such as community woodlots and environmental restoration efforts face seed shortage (e.g. in South Africa). The privatisation of commercial seed production has also resulted in government agencies not being able to plan strategically to make sure that other tree-growers, such as small-scale farmers, have access to good quality planting stock.

Pests and diseases

Review by Gichora *et al.* (2017) found that many tree species in Africa are threatened by pests and diseases. For instance, *Eucalyptus* genetic resources are facing threats from pests such as Blue gum chalcid (*Leptocybe invasa*), Red gum Lerp (*Glycapsis brimblecombei*) and termites. Diseases have also been reported on *Pinus* spp., *Cupressus* spp. and *Acacia* spp. *P. patula* seedlings have shown susceptibility to Pitch canker caused by *Fusarium circinatum* (Couitinho *et al.,* 2007). As a control strategy, forestry research and development agencies would need to breed the current tree genetic resources against these pests and diseases or import new material that is resistant. Without resistant germplasm, tree planting outcomes would be sub-optimal.

Regulatory constraints

Most of the widely planted trees in Africa are exotic species that were introduced many years ago. The early trees were established by European settlers in botanical gardens and the seeds imported had no formal documentation. The transfer of tree germplasm has shaped the management, ecology and genetic diversity of forests and has brought prosperity to many countries especially those with large scale plantations (Koskela *et al.,* 2014). The need to increase productivity of the early tree species through the establishment of research trials promoted international collaboration and the sharing of tree germplasm and information. In this regard, Africa benefited from importation of tree germplasm from other parts of the world, for instance, *Pinus* spp. came from South, Central and North America, *Eucalyptus* spp. came from Australia and teak from South East Asia. This process of moving germplasm still continues and the scope has broadened to include many other species such as MPTS, fruit trees and others.

At a global level, many countries have benefited from the transfer of tree germplasm. There is global recognition for the need of a fair and equitable sharing of benefits arising out of the utilization of genetic resources and contributing to the conservation and sustainable use of biodiversity. To this end the tenth Conference of Parties to the Convention on Biological Diversity (CBD) adopted an international agreement called the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (Convention of Biological Diversity, 2014). There are concerns that this regulation may impact on the collection and access to genetic resources for research and development through increased costs especially for countries that would want to broaden existing exotic forest genetic resources (Koskela *et al.,* 2014).

Other agreements which may affect the transfer of forest genetic resources are country specific. For example, tree germplasm coming from the Australian Tree Seed Centre is subject to a Material

Transfer Agreement (MTA) that, *inter alia*, requires the recipient countries to share information with Australia. The MTA has been well received by recipient countries and the only concern is when disputes arise which might be costly and time consuming (Thompson *et al.,* 2001). The exchange of research seedlots was also promoted in the SADC Tree Seed Centre Network project funded by the Canadian International Development Agency and helped scientists exchange information on tree growth on different sites and helped inform better site-species matching in the region (SADC Tree Seed Centres Project Inception Report, 1992). The exchange of research seedlots was based on good will and scientific information sharing.

Opportunities

In the past few years, Africa has been experiencing a new wave of plantation development funded by private equity and venture capital funds (see Table 9) (Jacovelli, 2014). Most of these new plantation developments are 'green-field' investments (i.e. new planting). The high growth rates of trees possible in some African countries has often been cited as the main reason why there is growing interest, but the availability of land and coastal location of potential plantation lands are some of the reasons. For example, in Mozambique, potential plantation land is close to the coast for exporting products to Asia and China (Jacovelli, 2014). The massive tree planting projects require the timely supply of seed and offer a strong opportunity for tree seed production systems in Africa to supply good tree planting stock. As outlined in previous sections, a lot of information has been generated on tree performance and most countries have assembled tree germplasm resources that can be used for supporting this new wave of tree planting happening across the continent. There is need for these tree planting programmes to understand that good tree planting stock is one of the critical component of successful tree planting. High survival and growth rates can be achieved with good site-species matching, good silvicultural management and forest protection practices against pests, diseases and fires.

Table 9. Existing and new tree planting initiatives in Africa. Adapted and modified from Jacovelli, 2014).

Country	Afforestation Strategy/Investors
Pan-Africa	New Forest for Africa Initiative launched in Ghana targeting 100 M ha The Great Green Wall of the Sahara and the Sahel Initiative - Africa's flagship initiative to combat the effects of climate change and desertification Billion Tree Campaign – plant billion trees annually Bonn Challenge – to rehabilitate degraded forest by 2030
Ghana	Africa Plantations for Sustainable Development, Siricec (Holland) Miro Forestry Co.
Congo	The National programme for reforestation and afforestation in The Republic of Congo (Le Programme National d'Afforestation et de Reboisement (ProNAR).
Cameroon	The National Programme of Tree planting of Cameroon (Programme National de Reboisement)
Mozambique	New Forests Co. (UK) ,Green Resources AS (Norway), Portucel Florestas Do Planalto SA (UPM), Chikweti Forests, Nyassa Florestas de Niassa, ABP, Komatiland Ltd. (South African state),.
Rwanda	New Forests Company Ltd. (UK) Mature plantations
South Africa	International Finance Corporation (USA), Global Environment Fund, Hans Merensky Holdings Ltd, 700 000 ha potential land for afforestation
South Sudan	Maris Capital Includes mature Teak concessions
Swaziland	Global Environment Fund Peak Timbers Ltd. – existing plantations + sawmill
Tanzania	Green Resources AS, New Forests Co. Global Environment Fund Mature plantations, sawmill + new planting Green-field development KVTC – existing plantations + sawmill
Uganda	New Forests Co. Ltd., Green Resources AS, Global Woods AG (International Woodland Co.), Small-scale private investors under the Saw-log Production Grant Scheme funded by the European Union
Zambia	Green Forestry Development Ltd. (Ireland),
Zimbabwe	Timber Producers Federation – restoration of plantations in Zimbabwe after the land reform programme, Allied Timbers to replant 6000 ha per year from 2017

2.5 Conclusion

This chapter has reviewed the state of tree germplasm in Africa. Most countries have traditionally invested in tree breeding and tree improvement that has resulted in good growth rates of commercial tree species, mainly of the *Eucalyptus* and *Pinus* genera. The situational analyses on tree germplasm in African countries commissioned by the AFF has shown declining trends in forest research resulting in increasing shortages of tree germplasm especially in countries that have embarked on tree planting in green fields. The shortages have been directly attributed to absence of strategic tree breeding activities in most countries by government agencies, poor tree seed handling facilities and privatisation of commercial tree seed production that excludes the small-scale tree grower. The supply and distribution of multipurpose tree germplasm is still dominated by NGOs and there are bottlenecks in the supply chain. Most of the MPTS germplasm has been supplied by donors for tree planting projects and there has been no real investment by forestry departments in the production of seed of MPTS. The supply of IFT germplasm is still very limited and the production of grafted material is promising for most species. For indigenous commercial species, there are no clearly defined strategies to collect and test the seed sources for superior growth. The few plantations still depend on ordinary-run-of the mill seed collected from natural forests. The regeneration of harvested areas appears to be the preferred management practices for most tropical species. The management practices in natural forests and woodlands have a significant impact on the status of forest genetic resources, but there is need for genetic studies to understand the geographical distribution of important species, including indigenous fruit trees whose fruits are collected and sold in urban markets.

The new wave of tree planting puts in sharper focus the need to increase attention and investment in tree germplasm. If inferior seed is used, the productivity of the new forests will be sub-optimal and forests will not meet the expected high demand of wood and other forest products. The threats posed by pest, diseases and climate change on forest genetic resources, and the constraints imposed by international seed movement regulations may make it harder for the forestry sector in Africa to supply high quality tree planting stock. This calls for a need by governments and the forestry sector to pay more attention to investments in tree germplasm management.

Fall armyworm larvae. Photo credit: FAO

Chapter 3: The status and trends of forest pests and diseases and their management in Africa

Harrison Kojwang, Mercy Gichora and Paul Bosu

3.1 Introduction

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

This chapter on pests and diseases of trees in Africa is largely motivated by the economic losses that pests and diseases have caused in modern forestry practice in Africa and indeed in all continents, particularly those with a history of industrial plantations. The material presented and discussed is based on both literature reviews and expert interviews mainly covering the sub-regions of Sub-Saharan Africa (SSA) (Bosu, 2016; Gichora, 2016; Kojwang, 2015). A deliberate focus was made on the current status and trends of pests and diseases, the economic impacts they cause, and regional or cross-border collaboration to manage them.

The history of pest and disease problems is largely associated with modern forestry practice in the continent, which started with the early establishments of industrial plantations, which dates back to the colonial era in the early part of the 20th century. Industrial forest plantations were initiated to create sustainably managed forests, largely in response to the rapid depletion of natural forests (Kojwang, 2015). Mainly exotic conifer species were established in much of eastern, southern (Evans, 1992) and parts of West Africa. In southern Africa, plantations were established in countries such as Angola, Malawi, South Africa, Swaziland, Zambia and Zimbabwe. In East Africa, Kenya and Tanzania were and are still the leaders in industrial plantations. In many of these countries, planted forest estates were well over 100 000 ha, with South Africa having by far the largest planted forest area, currently standing at 1.35 million ha (Forestry South Africa, 2014). By their sheer sizes, the plantations represent significant investments of public resources, though in South Africa they are largely privately owned. As such, any pests and diseases that could impede growth increment and lower the quality and volumes of wood are of economic importance and thus need to be addressed. 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 (Kojwang, 2009; Roux *et al.*, 2005, Roux *et al.*, 2012). An important point worth remembering is that in natural forests, there are also disease and pest problems which are often overlooked, except for their cumulative effects on timber degradation. Some examples are heart rots and insect damage that reduce harvestable timber volumes and also lower quality (Nsolomo and Venn, 2000; Ryvarden, 1980). While conventional knowledge has suggested that heart rots and decay fungi of standing trees gain entry at later stages in living trees, recent evidence of the latency of some species in living sapwood is surprising (Parfitt *et al*., 2010). In eastern and southern Africa, the bulk of diseases are those that affect plantations of exotic species such as pines, cypress and eucalypts. Historical examples of plantation diseases that were recorded with the advent of plantation forestry using exotic tree species include *Dothistroma* needle blight and *Diplodia* die back on pines, cankers of cypress and *Armillaria* root rot (Ciesla, 1994; Gibson, 1964; Gibson, 1972; Heath and Wingfield, 2005; Roux *et al.,* 2005; Zwolinski *et al*., 1990).

The report therefore describes the pests of exotic species of pine, cypress and eucalyptus, and a few other species such as wattle (*Acaia mearnsii*) and *Cedrela odorata* which are widely grown in the tropics, having been introduced from their natural ranges in other parts of the world. Likewise, the study of pests and diseases also reveals the fact that many originate from the natural ranges of their tree species hosts. This is the case of pests such as woolly aphids, sirex wood wasp and a variety of defoliators, sap-sucking and gall-farming pests described herein. The scientifically interesting phenomenon of indigenous pests finding new hosts in introduced tree species is also described. For instance, *Gonometa podocarpi*, a native caterpillar of eastern Africa, is one such example that effectively curtailed the propagation of *Eucalyptus globulus* as a plantation species in Kenya. *Gonometa podocarpi* (*Lepidoptera*: *Lasiocampidae),* is a well-studied forest pest in eastern Africa (Okelo, 1972). During its larval stage, it causes serious defoliation of conifers, in addition to attacking leaves of many dicotyledons. *Acacia lahai, A. mearnsii, Cupressus benthamii, C. lusitanica, Eucalyptus regnans, Juniperus procera, Pinus halepensis, P. leiophylla, P. montezumae, P. patula, P. radiata,* and *Podocarpus gracilior* are among its various hosts. It was first reported as a pest in 1925 on *Podocarpus* sp. in the Mt. Kenya region and in later years caused other outbreaks in the Mt. Elgon area on *Pinus* sp. Fortunately, eggs of *G. podocarpi* are parasitized by a Hymenopteron of the family *Eupelmidae*, belonging to the genus *Anastus*, the only known parasite of *G. podocarpi* eggs.

More recently, and interesting from a scientific perspective, is the Cossid Moth (*Coryphodema tristis*) also known as the Quince borer**,** which is native to South Africa, but has selectively adapted to the high elevation *Eucalyptus nitens* as its only host among Eucalypts grown in South Africa. 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. For diseases, the most well-known and described cases are *Armillaria* root-rot which is a disease with a wide host range of exotic species established on recently converted natural forest land.

Species of pests native to Africa which attack indigenous trees and forests include pests of some of the most valuable timber species, e.g. the Iroko Gall Fly, which is a pest on *Milicia excelsa* (Cobbina and Wagner, 1995; Ugwu and Omoloye, 2014), and a shoot borer; *Heteronygmia dissimilis* (Lepidoptera: Pyralidae), a lymantrid pest of African mahogany. They are described in greater detail in section 2 of this paper and have hindered the development of plantations of the two species in West, Central, Eastern and Southern Africa (Schabel *et al.*, 1988). In Sudan, tree locusts, termites and several beetles are recognized pests. They cause damage to the bark, seeds, leaves and roots (El Tahir *et al.*, 2010; FAO, 2007b; El Atta, 2000). The most serious pest of trees and forests is *Sphenoptera chalcichroa arenosa*, a cambium and wood boring beetle that is wide-spread on Sunt (*Acacia nilotica*), the most valuable timber-producing species in northern Sudan (more on this below).

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

The paper therefore covers pests and diseases of exotic industrial plantation species, indigenous timber species in SSA, and widely planted MPTs such as neem and others.

Pests and diseases and their effects on SFM: a justification for cross-border collaboration among African countries

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; Wiley and Speight, 2012). 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, Ips in North America and Europe, and the spruce budworm (*Christoneura fumiferana*) in North America, are all noteworthy. As to economic damage, tree yields can be reduced through direct mortality and growth loss with potential economic returns 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 Africa, where most countries are dependent on natural resources for economic development, and investment funds are relatively scarce, the economic effects of pests and diseases can be devastating, particularly in industrial plantations which are expensive to establish. The relative scarcity of capital means that countries have to depend on scarce public investments, private investment funds which are sourced at high costs, or from bi- and multilateral donor agencies. Growth and yield losses caused by pests and diseases can increase the risks of investments and deter the inflow of funds. The management of pests and diseases, particularly in plantation forestry is therefore imperative.

In East Africa, growing of *Pinus radiata* was massively reduced and eventually abandoned as a result of Dothistroma needle blight in plantations (Odera and Sang, 1980; Gibson, 1964; Gibson, 1972). *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 reduces and degrades wood converted into lumber, while decay of wood in service can cause serious structural damage and be costly to replace. Because of this, wood preservation using chemicals is an expensive but useful process. Furthermore, damage caused by termites is serious 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 the 1980s and 1990s, sap-sucking aphids on exotic species of pine and cypress were detected in both eastern and southern Africa (Heath and Wingfield, 2005). In 1994, the *Sirex* Woodwasp (*Sirex noctilio*) invaded South Africa, which is worrying since it is associated with a fungus, *Amylostereum areolatum,* which causes direct tree mortality in pines (Hurley, 2007; Slippers *et al*., 2015). A biological control programme was successfully developed for managing it (Slippers *et al.*, 2015).These are examples of pests and diseases of trees, their detection and control, particularly winged pests and vectors and aerially dispersed diseases which often require cross-border cooperation. They also illustrate that pests and diseases can be transmitted or dispersed through movement of traded forest products.

More recently, eastern and southern Africa has increased plantings with recently developed hybrid cultivars of *Eucalyptus.* Along with these*,* a new range of pests and diseases have appeared on the scene and countries of east and southern Africa illustrate this relatively new phenomenon which appears to have started from southern Africa (Mausse-Sitoe, unpubl.; Chungu *et al.*, 2010a and 2010b; Roux *et al.*, 2005; Wingfield *et al.,* 2008). In a recent global review on the introduction and spread of eucalyptus pests, Hurley *et al.* (2016) listed a total of 42 pest introductions from Australia which is the home of the genus *Eucalyptus*.

In the Sahelian part of SSA, the most serious tree pest problem in recent memory has been the outbreak of the oriental yellow scale insect, *Aonidiella orientalis,* on the commonly planted multi-purpose tree neem (*Azadirachta indica*). The outbreak of this pest, believed to have originated from India, was particularly serious in countries within the so-called Lake Chad Basin, which includes Cameroon, Chad, Niger and Nigeria (Lale, 1988). Attack is followed by premature browning which frequently leads to death of leaves on some or all of the branches of the affected tree (Bosu, 2016). Given that neem is a multipurpose tree that can survive in the arid Sahelian Belt, such a pest is necessarily of concern since the tree is planted in virtually all countries in the belt. As such, it can therefore spread quite rapidly and, given the history of germplasm movement across borders without protective measures, its control and management can be quite problematic.

3.2 Forest pests: their occurrence, distribution and management in Sub-Saharan Africa

In the last three decades, the best examples of pest outbreaks in east and southern Africa are the cypress aphid and pine woolly aphids. Economic damage by the cypress aphid *Cinara cupressivora* which caused tree mortality was 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). The situation regarding occurrence, distribution and management of forest insect pests on the African continent was described in detail by FAO (2009). Defoliators were mentioned as the most common problem in the belt of natural forest running across northern and central Africa. The current situation in different regions of Africa has been reviewed based on recent studies by Gichora (2016), Bosu (2016) and Kojwang (2015) and literature available on North Africa. Lists of selected pests in SSA are in tables 1 and 2 in this section of the report.

Pests in the natural forests

Pests and diseases of indigenous tree species in SSA occur in natural and planted stands and also on scattered or row plantings common on farmed landscapes and in urban areas. In general, the pests and diseases are assumed to have co-evolved with their host plants and rarely are outbreaks of epidemic proportions observed except for a few episodic events in particular species. Such episodic pest infestations have been observed in the Montane Forests of Rwanda by an indigenous caterpillar defoliator. Outbreaks are known to occur at irregular intervals in Nyungwe Forest where they first attack the pine buffer forest along its periphery and then spread to *Newtonia buchananii*, an indigenous species that is dominant in the park as well as *Alchornea hirtella*, an undergrowth shrub. Sporadic outbreaks of a shoot borer in mangrove forests affecting *Sonneratia alba* were reported in Kwale and Mombasa in Kenya in the mid-1990s and re-occurred in Gazi Bay as recently as 2013. Damage is caused by the caterpillar stage of *Salagena discata*, a wood moth which tunnels into the bark and wood and causes defoliation (FAO, 2007a). In terms of diseases of trees, the natural forests in Africa and elsewhere are vulnerable to wood decay fungi, particularly the heart rots which damage and degrade timber and other tree species growing naturally, as well as planted species.

In West Africa's humid zone, other important endemic pests include *Lamprosema lateritialis* (Lepidoptera: Pyralidae) on *Pericopsis elata* (Afrormosia), *Orygmophora mediofoveata* (Lepidoptera: Noctuidae) on *Nauclea diderrichii* (Opepe/Kusia) and *Anafe venata* (Lepidoptera: Notodontidae) on *Triplochiton scleroxylon* (Obeche/Wawa). The insects described above usually occur on host trees in natural forest stands where their presence is hardly noticeable and impact on tree survival and growth is almost insignificant. As a result, insect pest outbreaks are rare in natural forest stands in the humid/closed forest zone. From related literature at least one major pest outbreak has been recorded in a natural forest stand in the humid forest zone (Sidibe, 2009). In late 2009 to 2010, *Achaea catacoloides* (Lepidoptera: Erebidae) occurred in Liberia, Sierra Leone and Guinea, with devastating environmental and socioeconomic effects on forests and agriculture (Bosu, 2016).

Pests of widely planted and/or highly valued indigenous tree species

With regard to highly valued tree species, particularly the timber producing ones, it is worth remembering that at the onset of modern forestry practice in much of SSA, attempts were made to establish species such as *Milicia excelsa* and mahogany species (*Khaya* and *Entandophragma*) in industrial plantations from West Africa all the way to eastern and southern Africa. One of the few well-studied pests of indigenous tree species is the Iroko Gall Fly which is a pest on *Milicia excelsa* known as Iroko in West Africa and Mvule in Eastern Africa (Cobbina and Wagner, 1995; Ugwu and Omoloye, 2014). It is considered one of the most valuable timber species in Africa and, despite a high demand for it, its cultivation has been historically constrained across the continent by a psyllid gall bug, *Phytolyma lata* (Homoptera: Psyllidae). 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* (Lepidoptera: Pyralidae), a lymantrid of African mahogany, *Khaya nyasica* (*K. anthotheca*). 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 many countries in Central, East and West Africa 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 is 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*, the ecology and biology of which has been described by Griffiths (2001). The genus, as currently understood, is a species complex and its taxonomy is being resolved.

Noting the relative success of South America's big leaf mahogany (*Swietenia spp*) as a plantation species in the tropics, including Australia, the fact that two of Africa's most valuable timber species have not been successfully grown in plantations because of pests is a fact that underscores the importance of pests and diseases to the practice of modern forestry in Africa.

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

Insect pest species	Order: Family	Countries of occurrence	Host species	Feeding habit
Anaphe venata	Lepidoptera: Notodontidae	Ghana, Nigeria	*Triplochiton scleroxylon*	Defoliator
Analeptes trifasciata	Coleoptera: Cerambycidae	Ghana, Nigeria, Sierra Leone, Benin, Côte d'Ivoire	*Ceiba pentandra, Tectona grandis, Bombax costatum, Eucalyptus alba, E. territicornis, Adansonia digitata, Anacardium occidentalis, etc.*	Stem borer, mainly in the savannah zone and dry forest
Apate monachus	Coleoptera: Bostrichidae	Ghana	*Azadirachta indica, Terminalia ivorensis, Antiaris africana,* various other species	Stem borer
Apate terebrans	Coleoptera: Bostrichidae	Ghana	*Tectona grandis, Terminalia ivorensis, Cedrela odorata, T. scleroxylon, Eucalyptus* spp.*, Khaya senegalensis,* various other species	Stem borer
Diclidophlebia eastopi	Homoptera: Psyllidae	Nigeria, Ghana, Côte d'Ivoire	*Triplochiton scleroxylon*	Sap feeder
Hypsipyla robusta	Lepidoptera: Psyllidae	Ghana, Nigeria, Togo, Côte d'Ivoire, Cameroon	*Khaya ivorensis, K. anthotheca, K. grandi-foliola, 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, Côte d'Ivoire, Liberia,	*Milicia regia*	Gall maker
Phytolyma fusca	Homoptera: Psyllidae	Ghana, Nigeria, Togo, Cameroon	*Milicia excelsa*	Gall maker

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

Pests of exotic trees

In East and Southern Africa, forest pests such as *Gonometa podocarpi,* a defoliator*,* which is native of 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 (Ciesla, 1991, 1994; Odera, 1974). More recently, the *Sirex* Woodwasp (*Sirex noctilio*), which invaded South Africa in 1914 (Slippers *et al.,* 2015), motivated South Africa's current biological control programme. As southern and eastern Africa have increased plantings with recently developed hybrid cultivars of *Eucalyptus,* a new range of pests and diseases have appeared on the scene, e.g. in Mozambique, South Africa, Zambia Zimbabwe, Tanzania, Kenya and Ethiopia (Mausse-Sitoe, unpubl.; Chungu *et al.*, 2010a and 2010b; Roux *et al.*, 2005; Wingfield *et al.,* 2008). In fact, Kenya, Uganda and Tanzania have imported tree germplasm from South Africa, particularly improved eucalypts which are clonally propagated, and, as a result, have reported incidences of both pests and diseases of eucalypts (Heath and Wingfield, 2005; Nakabonge *et al.*, 2006; FAO, 2007; Roux *et al.*, 2005; Wingfield *et al.*, 2008) which are also found in southern Africa.

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 represent a number of different taxonomic groups and feeding types and in total 16 different families have been introduced. *Hemiptera* (bugs, aphids, cicadas psyllids) being the dominant order with 17 species, 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, all of which were first detected in New Zealand (Hurley *et al.,* 2016).

In the humid zone of West and Central Africa, widely planted introduced or exotic species such as *Gmelina arborea*, *Cedrela odorata*, *Tectona grandis* and various *Eucalyptus* species often succumb to insect pest attacks. For instance, *G. arborea* suffers from severe attack by *Achaea* and *Apophylia* species. Records show that this resulted in significant damage in Nigeria in the past (Louppe, 2008).Teak (*Tectona grandis*) and Cedrela (*Cedrela odorata*) are perhaps the most commonly planted species in the humid zone of West Africa and occur in Ghana, Togo, Nigeria and Cote d'Ivoire. The two species do not have serious problems with insect pests, except for sporadic attacks by some generalist insects. In Ghana, outbreaks of the wood borer *Apate terebrans* during the dry season are of some concern to tree growers. In young plantations, defoliation by the grasshopper *Zonocerus variegatus* is visible in plantations in the forest zone but attacks appear to have very little impact on plant growth as the trees usually recover over time. Cedrela also suffers attacks from another species of *Apate* (*A. monachus*) and other bark borers, especially when the trees are under stress. Unlike teak, however, Cedrela often responds to borer attack by exuding sap which pushes out the invading insects, often killing them. This has been observed in various plantations in Ghana, including the Afram Headwaters, Anhwiaso South and Worobong South forest reserves.

In the open and semi-open savannas, of West and Central Africa, like in the humid forest zone, incidences of pests in the woodlands are uncommon, except perhaps the routine outbreak of the desert locust (*Shistocerca gregaria*) in the Sahel zone that is a major problem on agricultural crops (Bosu, 2016). It also affects tree species such as neem (*Azadirachta indica*), *Terminalia mentalis, T. catappa* and *Eucalyptus* spp. Nearly all of these are commonly planted in towns and cities in the humid zones of West and Central Africa. *Terminalia mentalis* grows very vigorously and is the tree of choice in most cities for shade and avenue planting. *Terminalia* species rarely suffer attacks from pests and diseases except for occasional infestation by generalist stem and bark borers. Damage inflicted by borers becomes conspicuous and makes the trees unattractive which may necessitate prompt pest control intervention or outright removal.

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

In southern Africa, a comprehensive list of all types of pests that occur in sub-region have been described by Roux *et al*. (2012) and in other scientific publications which concentrate on the biology and management of specific types (Kojwang, 2015). Table 2 above contains a list of eleven pests which are prioritized as the most economically important in the southern African region with a few of those that also occur in eastern Africa. The table also provides brief descriptions on the type of damage caused by each pest and the countries and regions in which occurrence has been recorded.

Table 2. Priority pests of commercial tree species in southern Africa, including those that also occur in Eastern Africa (modified from Kojwang, 2015).

Pest	Host Species	Nature of Damage	Distribution (Reported)
Deodar Weevil *Pissodes nemorensis*	*Pinus* spp.	Feeds on tips, kills shoots, causes forking and branching, tree mortality	South Africa
Sirex Woodwasp *Sirex noctilio*	*Pinus* spp.	Wilting and mortality	South Africa, Swaziland
Bronze Bug *Thaumastocoris peregrinus*	*Eucalyptus* spp. & hybrids	Canopy reddening, yellowing and browning; canopy thinning and branch dieback	Eastern and Southern Africa
Blue gum chalcid (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	Eastern and Southern Africa
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	Eastern and Southern Africa
Eucalyptus weevil / Snout beetle *Gonipterus spp.*	*Eucalyptus dunnii, E. smithii*, and hybrids	Feeds on foliage and young shoots – causing stunting and mortality in severe cases	Southern Africa Mauritius
Shell lerp psyllid *Spondyliaspsis c.f. pliocatuloides*	*Eucalyptus* spp.	Brown sea shell-like lerp and reddish brown foliage lesions	South Africa
Eucalyptus gall wasp *Ophelimus maskelelli*	*Eucalyptus* spp.	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 tunnelling (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*	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

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

In Eastern Africa, the most widely studied insect pests in the region are those attacking *Eucalyptus* species. A recent study by Mutitu *et al.* (2013) outlines the methods followed in studying the biology and rearing of *Cleruchoides noackae* (Hymenoptera: Mymaridae), a solitary egg parasitoid and biological control agent under consideration for management of the Bronze Bug (*Thaumastocoris peregrinus*), a relatively new pest of planted eucalypts (Mutitu *et al.*, 2008).

What is interesting and should be of concern is that, in West Africa, various species of *Eucalyptus* are widely planted in the sub-region, among which are *E. camaldulensis, E. territicornis* and *E. alba,* have also been attacked by the same pests that have been recorded in East and Southern Africa. They are grown for pulp, poles, amenity or wood fuel. Worldwide, eucalypts are highly susceptible to the same pests, such as the blue gum chalcid (BGC) *Leptocybe invasa,* that has caused significant losses in Eastern and Southern Africa. During the field survey in Niger and Senegal, leaf galls characteristic of BGC attacks were observed on saplings of *Eucalyptus* in plantations. In Senegal, the observation was made in a small plot of *Eucalyptus* located within the city of Dakar and in Niger 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.

3.3 Forest diseases: their occurrence, distribution and management in Sub-Saharan Africa

Depending on the tissues and organs of the host plant that diseases attack at any stage of growth, they can be described as foliar, stem, root and branch diseases. In addition, there are decay fungi in living trees which may be described as heart and butt rots. In the natural forests in Africa, abiotic diseases, also known as physiological diseases, are associated with harsh physical environments and are attributed to prolonged droughts, flooding, mineral deficiencies and toxicities (Kojwang, 2015). 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 host tree species. Such situations are described as pest-disease complexes. Some insects are vectors of plant diseases and help to disperse a disease to its hosts. For example, the Sirex Wood Wasp 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)

Diseases of naturally occurring indigenous tree species

Unlike pests, which can occur in easily observed episodic outbreaks, disease outbreaks on natural forests are usually not common in Africa. This is often attributed to the diversity of species and also genetic diversity within species in natural systems. Traditionally, and even in modern forestry practice, valuable timber species have been harvested through selective cutting systems and the most common incidences of diseases which are of economic concern, are the fungi that cause decay of living trees. These are mainly heart and butt rots which often invade heartwood (Nsolomo and Venn 2000) and have cumulative effects in timber degradation. Some examples are heart rots and insect damage that reduce harvestable timber volumes and also lower its quality (Nsolomo and Venn, 2000; Ryvarden, 1980). Contrary to what has been understood, heart rots and decay fungi of standing trees do not just gain entry at later stages in living trees. Recent evidence of the latency of some species in living sapwood is surprising (Parfitt *et al*., 2010). Another interesting point is that root rots in Africa's natural forests tend to be endemic and do not cause any dramatic damage to standing trees as such. Of this, *Armillaria* root-rot is the most famous, mainly because it is widespread and has been a menace in the early stages of plantation development using exotic species, of which the most susceptible have been pines in SSA. As such, it is appropriately discussed under diseases of exotic pine plantations and other exotic tree species.

Diseases of planted multipurpose trees

There are a number of MPTs that are widely planted as ornamentals in urban areas, shade, farm boundaries and woodlots. In East Africa, an example is *Grevillia robusta* which had historically been planted as shade trees in coffee plantations. In Ethiopia, species of *Boswellia,* a native species in Africa, are planted for making of frankincense. In central, eastern and West Africa, the neem tree (*Azadirachta indica)* is one of the most widely planted MPT in the humid, semi-arid and arid zones. On the East African Coast, *Casuarina equisetifolia* is both a plantation and ornamental species, whereas in West Africa, species of Bombax (*Ceiba pentandra*) are planted as ornamentals and shade trees.

Two species of *Terminalia* (*T. ivorensis* and *T. superba*), native to Central and West Africa, have been established in plantations. The occurrence of dieback on *T. ivorensis* in Ghana and Côte d'Ivoire during the early 1970s was a major setback to the progress of forest plantation development in the sub-region. Dieback was observed at the time when *T. ivorensis* was gaining popularity as a candidate for the establishment of indigenous species plantations.

Plantations aged 10-20 years were mostly affected with very high mortalities. Symptoms of attack included branch dieback beginning at the crown apex, chlorotic and wilting foliage, crown thinning and sapwood staining. In Ghana, the imperfect stage of *Endothia* sp. was associated with the high mortality recorded (Ofosu-Asiedu and Canon, 1976). However, no biotic agents were clearly linked to the disease and the infection was generally associated with environmental and nutritional stresses. Fortunately, *T. superba* was not affected and is currently planted widely in West Africa (Bosu, 2016).

On Bombax or Kapok Tree (*Ceiba pentandra*), a dieback disease has a major impact on the regeneration of the affected species (Apetorgbor *et al.,* 2003 and 2013; Apertorgbor and Roux, 2015). It was first observed in Ghana in experimental trials at the Bobiri Forest Reserve in 1996 but is not yet reported in other countries of the sub-region. Unlike the *T. ivorensis* dieback, *Ceiba* dieback affects hosts at the nursery stage, can cause significant damage to seedlings and can persist throughout the growing stage. Without proper care and maintenance the likelihood of recording a 100% mortality of the seedlings at the nursery stage is quite high. However, infected plants two years old and above often recover from the attack, which occurs during the wet season. *Fusarium* sp. and *Lasiodiplodia theobromae* have been associated with the disease (Apetorgbor *et al*., 2003).

A tree species grown in Ethiopia for the extraction of frankincense is *Boswellia,* which is related to other species in the genus *Commiphora,* which produce aromatic gums and resins. In this regard, a report on *Lasiodiplodia theobromae* infecting *Boswellia papyrifera* in Ethiopia, represents a new constraint to the sustainable management of this commercial tree species (Alemu *et al.,* 2014). Incense is extracted by frequent, intensive and repeated wounding made at different directions and positions on the bole of the tree. Depending on the size of the tree, there could be between 6 and 16 tapping spots that are refreshed and widened 8-12 times each year at an interval of 15 to 20 days. Sustained tapping for frankincense has a negative impact on the survival rate, growth and reproduction of the tree (Rijkers *et al*., 2006) and wounding predisposes trees to microbial infections. Disease symptoms and death of *Boswellia* trees have been commonly observed in all areas where tapping has been practiced. Specific symptoms include canker formation, exudation of gum, wilting, dieback, vascular browning and death of the tree.

On the neem tree (*A. indica*), widely grown from East to West Africa including the Sahel, symptoms of decline have also been reported, first in Niger and subsequently in other countries of the Lake Chad Basin. The symptoms of the decline were initially confused with a scale insect outbreak. According to Boa (1992, 1995), the most conspicuous symptom of neem decline is the loss of older foliage, which gives the normally dense crowns an open appearance with clumps of foliage occurring at the branch apices. In advanced cases, only a small tuft of foliage remains at the branch tip, a condition described as 'giraffe neck'. Similar to the *Terminalia* and *Gmelina* dieback described above, neem decline has not been clearly associated with any biotic agents. Although several fungi, such as *Nigrospora sphaerica* and *Curvularia eragrostidis,* have been recovered from affected trees, they have been shown to be secondary pathogens (Bosu, 2016). The diseases on the above MPTs have been generally described as decline and dieback, the causes of which have been seen as abiotic or physical environmental conditions (Bosu, 2016).

On *Grevillea robusta*, one of the most popular agroforestry trees planted in Eastern Africa, a comprehensive study of stem canker and dieback disease was undertaken by Njuguna (2011) in Kenya. Its distribution, causes and implications were examined in detail. She concluded that the canker and die back are associated with the *Botryosphaeriaceae* species complex with *Neofusicoccum parvum* as the most important pathogens.

Diseases of exotic plantation species

In both eastern and southern Africa, recorded disease problems appeared in the first half of the twentieth century when forest plantations were established (Roux *et al.*, 2005). Since then, research programmes of South Africa have given priority to tree provenance-site matching, growth and yield, and resistance to pests and diseases (Louw, 2012; Roux *et al.*, 2005). In Eastern Africa, the planting of *P. radiata* was banned and *P. elliottii* was introduced as an alternative species in response to *Dothistroma* and *Cercospora* needle blights. *Cupressus macrocarpa* and its hybrids were also found to be more susceptible to canker attack and were replaced by *C. lusitanica.*

Eucalypts. In addition to the growing of exotic softwoods in Eastern and Southern Africa, the increasing popularity of *Eucalyptus* species as an exotic hardwood has been accompanied by reports of a number of disease problems in its many species and hybrids (Alemu *et al.,* 2003 and 2005; Alemu, 2006; Chungu *et al*., 2010; Roux *et al*., 2005; Mausse-Sitoe *et al*., 2016).

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

Canker diseases: The fungus *Chrysoporthe austroafrica* (*Cryphonectria eucalypi*) occurs in all areas of East and Southern Africa where eucalypts are grown. It causes canker disease, and its key hosts are *E. grandis*, *E. camaldulensis*, *E. saligna* and hybrids, especially those of *E. grandis x camadulensis* (GC) and *E. grandis x urophylla* (GU). In addition, species related to *Eucalyptus* such as *Syzygium* and *Tibouchina* are also susceptible to the fungus. *Cryphonectria cubensis* is a related fungus that infects eucalyptus trees through wounds. Infection of the bases of young trees is the most common and infection sites are presumed to be natural growth cracks at the root collar. The spores are dispersed by rain splash. *Botryosphaeria* canker is especially common on trees that are planted off-site, resulting in the development of stem cankers. These first become visible as small cracks, with the exudation of kino, and may develop into larger, girdling cankers which seriously affect wood quality and growth, and may result in stem breakages. The fungus is an opportunistic pathogen that manifests itself under conditions of environmental stress, including drought, frosts, cold and hot winds, branch pruning, insect damage and off-site planting. Species of *Botryosphaeria* spread via airborne spores that can also be spread through rain splash. Another serious canker of eucalyptus species and their hybrid clones, particularly clones and hybrids of *E. grandis,* is caused by a fungus which was first named *Coniothyrium zuluense* (and later *Teratosphaeria zuluense*) and another species known as *T. gauchensi (*Cortinas *et al.,* 2006), Thought at first to be restricted to Southern Africa, particularly South Africa, *T. zuluense* had since been reported Ethiopia (Alemu *et al.,* 2005) and also in Central and South America and Asia.

Leaf diseases: Mycosphaerella leaf blotch is serious on eucalypts and is present in all countries in Southern Africa where they are grown. It is also present in all East Africa. In South Africa, for example, it is a disease of cold tolerant *Eucalyptus* spp., e.g. *E. nitens, E. globulus, E. grandis* and *E. smithii.* The rust *Puccinia psidii* causes leaf spots and death of young new shoots that are often covered by a bright yellow spore masse - uredinia/ uredospores - and it requires high humidity and periods of low light, such as cloudy overcast conditions, for its germination and infection. It is mostly a problem in sub-tropical areas of the world where eucalypts are grown. In eastern and southern Africa, the disease has been recorded in Ethiopia, Kenya, Mozambique, South Africa and Zimbabwe.

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

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

Wattle (*Acacia mearnsii*) has historically been grown in South Africa, Zimbabwe and Kenya. In South Africa, its major disease is currently a rust fungus, *Uromycladium acaciae*, which has multiple life stages typical of a macro-cyclic life cycle, hence produces spermagonia, telia and uredinia. The foliage rust affects *A. mearnsii* and *A. decurrens*, which occur throughout South Africa and, since 2013, seems to be spreading. It has also been documented that *A. mearnsii* is attacked by *Armillaria* root rot.

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

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

Teak (*Tectona grandis*), the valuable timber species native to India and South East Asia, is planted in both East and West Africa. In 2006, *Armillaria* root rot was observed on exotic teak and cedrela plantations located within the Kwamisa, Tano Nimiri and Mamiri reserves in the Moist Forest zone of Ghana, while in Côte d'Ivoire and Nigeria. *Armillaria mellea, Chaetophoma* sp., *Polyporus* sp. and *Thanatephorus cucumeris* have been reported as fungal pathogens (Gbadegesin, *et*. *al*., 1999). The effects of *Armillaria* root rot on exotic plantations established on converted indigenous forests is well known and recorded in the all regions of SSA below the Sahel.

Cedrela odorata. In addition to *Armillaria* root rot, a stem canker of *Cedrela odorata* was first reported in a 16 ha plantation in Anwhiaso Forest Reserve and thereafter in Worobong South and Afram Headwaters Forest Reserves (Bosu, 2017).

Gmelina arborea is a fast growing tree species introduced to some West African countries with the aim of producing wood for pulp and paper (Bosu, 2017). Over time, many of the plantations established in Ghana, Nigeria and Sierra Leone suffered from dieback. In Ghana, dieback was prevalent in the 15 000 ha Subri Industrial Plantation at Daboase in the Western Region. The cause was not determined but it was believed that regional droughts and changes in water tables were possible causes, with the disease condition complicated in some cases by the activity of weak pathogens. In Sierra Leone, dieback incidence was very high with infection rates up to 40% in plantations.

Major diseases of trees and forests in West and Central Africa are summarized in Table 3 and in Southern Africa in Table 4. They occur on introduced and indigenous hosts and comprise of diebacks, stem canker and root diseases.

Table 3. Major diseases of trees and forests in West and Central Africa (Bosu, 2016).

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

Table 4. Diseases of commercial plantation species in Southern and Eastern Africa (Source: Kojwang, 2015).

Host Species	**Nature of Damage**	**Disease**	**Distribution (Reported)**
Eucalyptus spp., Psidium guava and *Zyzigium spp.*	Death of new young shoots, normally covered by bright yellow spore masses	Myrtle Rust *Puccinia psidii*	South Africa
Eucalyptus, Tibouchina and *Zyzigium spp.*	Stem cankers on older trees (cracking and splitting of bark, sunken, target cankers), discolouration of bark, cambium and mortality in young trees	Chrysoporthe Canker *Chrysoporthe austroafricana*	Mozambique,South Africa, Zambia, Zimbabwe
Eucalyptus spp.	Small sunken necrotic lesions on young stems, measles-like spots that penetrate to the pith on older trees	Kirramyces stem canker *Teratosphaeria zuluensis*	Mozambique, South Africa, Zambia
Eucalyptus nitens, E. globulus, E. smithii, E. grandis	Leaf spots first appear on lower branches, causes defoliation and growth loss	Leaf Blotches *Mycosphaerela* and *Teratosphaeria* (*Kirramyces*) *destructans*	Mozambique, South Africa, Ethiopia, Kenya

Host Species	**Nature of Damage**	**Disease**	**Distribution (Reported)**
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	Pitch Canker *Fusarium circinatum*	South Africa
Acacia mearnsii, A. decurrens	Chlorotic spots on pinnules, galls on leaves and branches, defoliation and death of young shoots – growth loss	Wattle Rust *Uromycladium acacia*	South Africa
Acacia mearnsii, A. decurrens	Rapid wilt and death, stem cankers, gummosis	Ceratocystis Wattle Wilt *Ceratocystis albifundus*	South Africa, Kenya
Pinus spp., Eucalyptus spp., 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	Botryosphaeriaceae Cankers: *Diplodia pinea* (on pines), *Botryosphaeria & Neophoscoccum spp.*	Mozambique, Zimbabwe, Zambia, Malawi. Kenya
Pinus, Acacia, Eucalyptus, Podocarpus, Tectona, Cedrela	Crown thinning, foliage discoloration, tree death – signs mycelial fans in the bark and base of stems, mushrooms	Armillaria root rot *Armillaria fuscipes* (Southern Africa)*, A, heimii* (Eastern Africa)	Whole of Eastern and Southern Africa, and elsewhere in SSA
Acacia mearnsii, A decurrens, Eucalyptus spp.	Rapid wilt of trees, basal cankers, bark discoloration, cracking and gummosis	Phytophthora root rot *Phytophthora cinnamoni, P. nicotianeae* and others	Virtually all of Eastern and Southern Africa
Eucalyptus spp.	Spot lesions and kino exudation	Coniothyrium canker *Readerilla zuluensis*	Mozambique, Ethiopia, Kenya
Eucalyptus spp.	Seedling deaths in nurseries, leaf blight in planted tress – mortality and growth loss	*Calonectria* canker & blight – nursery and small trees	Mozambique, Kenya
Eucalyptus spp.	Stem cracking, stem lesions	Holocryphia canker *Holocryphia eucalypti*	Mozambique
Coffee varieties	Indigenous	Coffee berry disease *Colletotrichum kahawae*	Eastern and Central Africa
Boswellia papyrifera		Boswellia Canker *Lasiodiplodia theobromae*	Ethiopia
Anacardium occidentale	Shoot dieback, decline	Cashew Dieback *Phomopsis anarcadii*	Kenya

3.4 General observations on forest pests and diseases in Sub-Saharan Africa

The history of modern forestry in Africa suggests that formal research on pests and diseases started with the onset of industrial plantation forestry in much of SSA and particularly in East and Southern Africa where the British established the bulk of industrial plantations with exotic species. In line with that a number of pests and diseases were introduced with their exotic hosts. Examples of such are described in the paper.

Another important observation is that some diseases and pests of indigenous tree species have shown a potential to cross-over from their native tree hosts to introduced tree species of which *Armillaria* root-rot is a widespread example. Other examples include native insect wood borers that have adopted to new hosts of exotic species in Eastern Africa. Most recently, a native species known as the Quince Borer has found a new host on a single species of Eucalyptus in South Africa, namely *Eucalyptus nitens*, which is rather unique compared to *Armillaria* root rot which is a non-host specific root pathogen.

In the discussions it has also been shown that some native pests have effectively prohibited the development of industrial plantations of two of Africa's highly valuable timber species, viz. Iroko or Mvule (*Milicia excelsa*) and species of Mahogany (*Entandophragma* and *Khaya*).. The shoot borer, *Hypsipyla robusta*, is a major pest of several high quality timber species, including African mahogany (*Khaya* spp.), mahogany (*Swietenia macrophylla, S. mahagoni*) and teak (*Tectona grandis*). While *Swietenia* has been successfully grown in other counties as an exotic plantation tree, species of *Khaya* have not been grown successfully in the African countries in which they are indigenous.

It is also important to remember that, within the last 15 years or so, pest and disease problems in the forest sector are largely a result of the rapid spread of *Eucalyptus* as industrial plantation species in East and Southern Africa. Some pests have spread quite rapidly within and across political boundaries in the regions. Despite this, the evidence is that cross-border collaboration is weak despite regional policies that have called upon countries to monitor the movement of pests and diseases across borders. For instance, the blue gum chalcid, *Leptocybe invasa*, is a relatively new threat to planted eucalypt forests in Africa, reported first from Kenya in 2002 and from South Africa in 2007. This pest is also known to occur in Morocco although the date of introduction is unknown.

The above observations suggest that Africa must take cross-border collaboration in pest and disease management more seriously than has been the case, since a few commercially grown species. *Eucalyptus spp*. and their hybrids are the best examples.

3.5 Global and regional cooperation in the management of forest pests and diseases

Global Frameworks for Pest and Disease Management

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

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

Today the expected activities of the Council as outlined in the Maputo Declaration by AU in 2003 are as follows:

- Plant protection information management.
- Promotion of safe and sustainable plant protection techniques.
- Enlightenment of member states on the implications of the WTO-SPS Agreement on international agricultural trade.
- Capacity building among member states in phytosanitary and plant protection activities.
- Development of regional strategies against the introduction and spread of plant pests (insects, plant pathogens, weeds etc.).

- Training of various cadres of NPPOs in Pest Risk Analysis (PRA), phytosanitary inspections and treatment, field inspection and certification, laboratory diagnoses, pest surveillance and monitoring, etc.

Continental Frameworks

At the scale of the entire continent, plant protection and phytosanitary issues are supposed to be addressed by IAPSC which is the RPPO of IPPC. It is structured to bring together expertise from different regional economic communities in the continent to work on pests of economic importance but it does not pay sufficient attention to forest insect management. What is not clear, from the literature and the expert interviews that preceded this paper, is whether the continental structures have been used to address the most recent pest and disease outbreaks in the forest sector. So far, there is no evidence to suggest that.

An example of regional collaboration was when the eastern and southern regions of the continent were battling with rapid invasions of exotic aphids in the mid-1990s. FAO then organized a workshop in Kenya in 1991 and participants recommended that the countries concerned should establish a network to address issues of training, information exchange, exchange of expertise, collaborative research, detection and monitoring, screening of insecticides, and ecological and socio-economic impact studies. These would be further supported by quarantine services, public awareness and education. Tied to that, collaboration in pest management programmes was proposed between national institutions and relevant regional and international organizations, such as FAO, IIBC, ICIPE and the PTA. The network was expected to stimulate synergy, an essential ingredient for overcoming constraints to integrated management of the exotic aphids and related pernicious forest pests in the region. It was proposed that a regional biological control programme would be funded by CIDA and implemented by IIBC and national institutions. Unfortunately, the concept failed to materialize.

Later, a similar proposal by FAO (2009) elaborated how a Forest Invasive Species Network for Africa (FISNA), created by a group of African scientists with the support of FAO and the United States Forest Service, could coordinate the collation and dissemination of information relating to forest invasive species in SSA. FAO has also described guidelines on setting phytosanitary standards (FAO, 2011). The network was expected to raise regional awareness on forest invasive species, encourage the publication and sharing of research results, management and monitoring strategies, and act as a link among experts, institutions, networks and other stakeholders concerned with forest invasive species in the region. The network exists today but is virtually dormant, mostly because African countries have not backed it with the required funding despite disease and pest problems.

Coming down to the sub-regions of SSA, a number of regional economic commissions, such as the East African Community (ECA), the Economic Commission of West African States (ECOWAS) an the Southern Africa Development Commission (SADC), exist and promote SFM. As such, what ought to happen and what is happening within those sub-regions are legitimate areas of inquiry.

Status of Regional Sanitary and Phytosanitary protocols

EAC has already developed and adopted a common phytosanitary protocol which is based on the requirements of IPPC and whose benefits are many-fold (EAC, undated). The EAC protocol on Sanitary and Phytosanitary measures is based on the provisions of Chapter XVIII of the treaty for the establishment of EAC. However, it has not been fully activated to address current shared disease and pest problems in the forest sector. Nonetheless, it is expected that it will, among other things, harmonize inspections and certification procedures of plant and plant products, regulate the importation, research on, development and use of living modified organisms and products of modern biotechnology and biological control agents.

SADC has a phytosanitary protocol which member countries adopted in 2008 (Kojwang, 2015). While it has stated the rationale for cross-border collaboration, appropriate objectives and basic procedures for initiating such collaboration to manage plant pests and diseases, it has not been used to drive any practical efforts within SADC States and certainly not in response to the recent outbreaks and spread of pests of *Eucalyptus* which have been described in this paper. The need to activate this protocol is considered all the more urgent given the current pests and diseases of commonly planted species.

For the regulation of trade, there is a tri-partite agreement that is under negotiation between EAC, SADC and COMESA, which covers seed exchange. It addresses seed trade policy harmonization and was launched in 2014. It recognizes that differences in seed policies and standards across countries (and between different regions), as well as that differing levels of technical capacity, can create challenges that ultimately impact the availability and access of seeds (Kuhlmann and Zhou, 2015).

ECOWAS does not have a regional phytosanitary protocol. However, a draft ECOWAS Regulation has been developed (Magalhães, 2010). Through specific projects, ECOWAS, in collaboration with AU, organizes training workshops for "SPS focal persons" in its Member States (Magalhães, 2010).

3.6 General observations and concluding remarks

The report presents SFM as the approach that will ensure trees and forests to remain healthy and that they enrich ecosystems with goods and services to support meaningful livelihoods for people and nature-based sectors of the economy that depend on them. The current situation is marked by a shortage of technical skills in undertaking surveillance for tree pests and diseases as well as inadequate infrastructure to match the field and subsequent laboratory investigations that are often necessary. It is proposed that management of pests and diseases can be made more cost effective by recognizing 'centres of excellence' that offer support services and assist in building capacity of experts at regional and continental level. In that regard, significant strides have been made in understanding pests and diseases of introduced trees and the Forestry and Agricultural Biotechnology Institute (FABI), based at the University of Pretoria, continues to play a crucial role for Southern Africa in training and equipping scientists to tackle related challenges. It is important that Member States and Regional Economic Commission's give official recognition and support to such an institutions and also help develop similar ones in various parts of SSA. Research institutions, such as FABI, which have played crucial roles in research, should be facilitated to interact more widely with other institutions in SSA that are responsible for forest pest and disease management. These will be supported by systematic surveillance systems to generate pest alerts. As countries continue to trade with each other through their regional economic communities, there is ample justification to adopt regional protocols which cover all member countries and to do that a few points are worth noting. Historically, the eastern and southern Africa regions have shared similar disease and pest problems of exotic tree species grown in industrial plantations. Findings of this study also confirmed that the sub-regions of central, western, southern and eastern Africa share some disease and pest problems, particularly those that affect species of *Eucalyptus*.

An important point that is routinely understated is that some of the Continent's premier indigenous commercial timbers have not been grown in industrial plantations because of pest problems. Furthermore, the Iroko gall fly (*Phytolyma* sp) and Mahogany shoot borer are widespread in west, central, eastern and some parts of southern Africa. This suggests that much cooperation on research to manage these pests should have been initiated and substantive efforts made. Despite the fact that these pest problems have effectively inhibited the commercial growing of the two species, it is not clear why sufficient efforts have not been put into their control and management, and there has been no concerted research effort in the continent.

The rates at which pests and diseases of *Eucalyptus* have spread in Africa over the decade starting from 2010 is a cause for alarm and the situation calls for research and management action to develop or reactivate dormant protocols for regional and bilateral surveillance. In practical terms, tree disease and pest problems in Africa have implications on selection, breeding and silvicultural practices to be adopted for plantations, such as mixed species planting, provenance-site matching and sanitation programmes, to name but a few. Any research will have to contend with the fact that, based on what we know about interactions between hosts, pests and the environment, the phenomenon of climate change could favour their faster spread and, as a result, may exacerbate economic damage. This is clearly an issue for the attention of policy makers who will be required to allocate resources for both research and integrated disease and pest management.

At the regional level, countries ought to adopt harmonized surveillance approaches for monitoring the health of trees and forests and in that regard, RECs should support the adoption and effective use of common SPS protocols. Such regional efforts will require scientists to generate data to demonstrate urgency with which countries need to reactivate dormant protocols for regional implementation and provide strong economic basis for collaborative arrangements.

For the forest sector, it should be borne in mind that in virtually all African countries, plant quarantine services fall under the departments of Agriculture whose technical personnel have little or no experience in handling forest pests and diseases. Therefore, Forest Departments in all countries will often need to proactively engage with national plant quarantine authorities to ensure that materials infested with forest pests and diseases of concern are recognized and intercepted.

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


Scott Olson/Getty Images

Chapter 4: Climate change challenges and opportunities in African Forestry

Vincent O.Oeba, Larwanou Mahamane, Henri-Noel Bouda

4.1 Introduction

Climate change has presented both challenges and opportunities in different sectors of social and economic development at different levels. The UN Framework Convention on Climate Change (UNFCCC) in its Article 1 defines climate change as *"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"* (UNFCCC, 1992). This definition focused mainly on human activities that will alter the atmosphere without taking into considerations other components of climate systems such as biosphere, cryosphere and, especially, human activities on the lithosphere (land surface). It also provides a distinction on the role of human activities attributable to climate change and those attributable to natural causes. The IPCC advanced this definition and referred climate change to *"a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer"*. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2018). Both definitions on climate change have laid a strong foundation under which various discourses are being carried out by different actors, whose livelihood sources are climate dependent, at national, regional and international levels.

Studying climate change in different sectors of economy, social and environmental well-being, such as forestry, agriculture and health, among others, therefore becomes paramount in order to provide a knowledgeable response to the changing climate and how it affects the mentioned sectors. For example, the challenges associated with rise of temperature and decreasing precipitation on different biomes include, but are not limited to: increased frequencies of bush and forest fires; changes and emergence of new pests and diseases affecting plants and people; variation in agricultural production and depleting biodiversity; water scarcity resulting from shifts of rainfall patterns; and, prolonged droughts resulting to loss of livelihood due to changes in vital supporting ecosystems (IPCC, 2014).

The African forestry sector is currently impacted by climate change in different ways. For example, the changes in hydrological cycles that are linked with various processes characterized by physical, chemical and biological interactions, have resulted in reduced rainfall availability to support plant growth, good functioning of forests and other livelihood sources on the land surface.

The temperature rise has also resulted in increase of forest fires and pests and disease incidences affecting forest and tree resources that has recorded reduced supply of seeds, nuts, resins as well as products used in pharmaceutical and botanical medicine, including for the cosmetic industry in Africa (IPCC, 2014). The continued increase of green house gases (GHG) in the atmosphere is expected to pose significant challenges to the forestry sector, e.g. due to temperature rise. The recent special report under Assessment Reporting (AR) series of IPCC indicated that consistent with the fifth assessment report (AR5) of IPCC, there is high confidence that by 2006-2015 the Global Mean Surface Temperature (GMST) had reached 0.87^0C (+/-0.10^0C) above the pre-industrial period due to anthropogenic activities. The Special Report further indicated, with a high degree of confidence, that global warming of 1.5^0C, as well as the difference with 2^0C, are detectable almost in all locations globally (Hoegh-Guldberg et al., 2018; IPCC, 2014; IPCC, 2001). These negative impacts are being addressed through mitigation and adaptation responses as outlined in various national plans and programmes aimed at combating climate change and strengthening resilience of biophysical and social systems. In addition, countries that are member states to the UN are aligning their climate change strategies to the UN Sustainable Development Goals (SDGs), with major focus on Goal 13 that requires countries and the international community to take urgent action to combat climate change and its impacts.

However, climate change is not only causing negative impacts, but also positive ones on different biomes. Research (Field et al., 2014; IPCC, 2007, 2014) has, for example, shown that climate change may have positive impact on forest net primary production (NPP) where simulation of the yield models has indicated an increase of global timber production through location changes of forests and higher growth rates, especially when positive effects of elevated CO_2 concentration are taken into consideration. Specifically, in Australia and New Zealand, climate change is likely to increase productivity of exotic softwood and native hardwood plantations due to increased CO_2 fertilization effects, although the amount of increase will be limited by projected increases in temperature-induced respiratory losses, reductions in rainfall and through feedbacks e.g. from drought-induced impeded nutrient cycling. Several simulation studies in North America indicate that, over the 21st century, warming will lengthen growing seasons, sustaining forest carbon sinks as well as shifting demand of timber and non-timber forest products globally. This is expected to alter some commercial forestry activities to the North, leading to increased international trade of forest products that is likely to tilt the demand and supply imbalances in Africa and other continents (Kirilenko and Sedjo, 2007).

In addressing some of the challenges and opportunities arising from climate change in Africa, the African Forest Forum (AFF), in partnership with other stakeholders, has undertaken studies on African forests, people and climate change; and on strengthening SFM in Africa. Some of these studies have focused on improving understanding of the impacts and responses to climate change as related to forests, trees and people who depend on them, and on forest-based mitigation options and their implementation in Africa. AFF has also, through its projects, identified innovative approaches for restoration of degraded lands and forests in order to improve resilience to the impacts of climate change as well as responding the Bonn Challenge and the African Forest Landscape Restoration Initiative of restoring 100 million (AFR100) ha of deforested and degraded lands by 2030.

AFF has also generated knowledge and shared information on: building capacities of African stakeholders in managing forests and landscapes in the context of climate change; shaping of policies and initiatives relevant to forests and climate change; profiling of the forest sector relative to other sectors of the economy in response to the challenges of climate change; and, on improving forest governance and equitable trade practices related to climate change. The other specific areas that have been studied include understanding of vulnerability to climate change and application of promising adaptation and mitigation measures pertinent to Agriculture, Forestry and Other Land Uses (AFOLU); the role of the African private forestry sector in addressing climate change challenges; and on best practices that integrate both mitigation and adaptation options to strengthen resilience of biophysical and social systems in Africa. This book chapter, therefore, addresses climate change challenges and opportunities in African forestry, considering the gains made through AFF's work and other studies carried out globally, especially those focusing on Africa. It specifically provides an overview of the climate determinants of biomes, climate change projections in Africa, climate change risks and challenges in different forest types, key technical responses on various challenges, key forest based climate change opportunities and technical and policy responses addressing forest-based climate change adaptation and mitigation options.

4.2 Climate determinants of African biomes

The climate of any given geographical region on earth plays an important role in determining the distribution of plants and other living organisms in an interrelated manner. The World Meteorological Organisation (WMO) defines climate as the average weather/statistical description in terms of the mean and variability of relevant quantities such as surface temperature, precipitation and wind over a period ranging from months to thousands or millions of years (WMO, 2018). The classical period for the averaging of the stated quantities according to WMO is 30 years. This is the period climatologists found statistically significant in describing the changes in different components of the climate system, viz. the atmosphere, hydrosphere, lithosphere, cryosphere and biosphere.

The climate has been studied and documented (Ciesla, 1995; Lindner et al., 2001; Settele et al., 2014) to determine the distribution of global biomes in different regions. The factors that influence biome characteristics and distribution include temperature, precipitation, latitude, elevation and ocean currents among others (Settle et al., 2014). These factors are also known to determine the composition and productivity of forests, species populations and migration, and of forest regeneration. Similarly, the vegetative transition from deserts to grasslands, and to forests, are commonly determined by moisture conditions and altitudinal gradient. In extreme conditions, the vegetative transition is reversed, and forests are displaced by grassland, implying that forests flourish best in warm, wet environments and do progressively less well as temperature and moisture decrease. Overall, the mean annual temperature and mean annual precipitation have been documented to significantly influence the biome distributions.

The African biomes are broadly classified as moist, dry and Sahelian parklands. The dryland forests, commonly referred to as woodlands and savannas, grow in areas characterized by frequent droughts and occasional floods, making these ecosystems highly vulnerable to the impacts of climate change. Woody plants, mainly trees, with canopy cover of over 10 % of the land area, are the major vegetation type in dryland forests. This formation covers about 17.3 million km^2, spread over 31 African countries that stretch from Southern Africa, through Eastern Africa to West Africa (FAO, 2015). The formation provides diverse sources of livelihood to an estimated population of over 500 million (Chidumayo and Gumbo, 2010; Muoghalu, 2014) that is now significantly threatened by climate change and climate variability. The fragility of African dryland forests is compounded by unstainable anthropogenic activities such as illegal charcoal production, unsustainable harvesting of non-timber forest products, rampant deforestation due to illegal logging, encroachment for agricultural farming, human settlement, uncontrolled bushfires and legal gazettement for agricultural expansion to meet food security and nutrition needs of the burgeoning population in Africa that is projected to reach 2.3 billion people by 2050 (UN, 2015). These human activities continue to remain major sources of GHG emissions that is known to increase global warming, making woodlands and savannas very vulnerable to climate change and variability.

The moist forests in Africa present a unique ecological system ranging from tropical highlands to lowland humid and swamp forest areas that are estimated to cover about 2 million km^2, of which 89.3% is in Central Africa, 6.0% in West Africa, 2.2% in Southern Africa (mainly Madagascar) and 2.4 % in Eastern Africa. The Democratic Republic of Congo (DRC) accounts for 53.6% of Africa's lowland rainforest, followed by Gabon at 11.2%, Republic of Congo at 10.4% and Cameroon at 10.0%, with the remaining 11.4 % in other countries (FAO, 2015, Mayaux et al., 2003). Moist forests are also a major source of livelihood and provision of environmental services for sustainable development among people in Africa. However, these forests are experiencing teething problems that are both human-induced such as high rate of deforestation, natural, such as climate shifts, and interactions of anthropogenic and natural forces. For example, Mayaux et al. (2003) estimated net deforestation rates at 0.59 million ha/y between 1990 and 2000. This decreased to 0.29 million ha/y between 2000 and 2010, implying that African moist forests have experienced significant disturbance challenges that must have affected succession due to unsustainable exploitation of both timber and NTFPs compounded with impacts of climate change and variability. This has resulted in loss of biodiversity of both fauna and flora, decline in productivity due to accelerated forest degradation and erosion, thus reducing the resilience of moist forests to the impacts of changing climate.

Mangrove forests form an important ecosystem in coastal and marine areas globally. Africa has about 3.2 million ha, representing 19% of the total of 15.2 million ha of mangrove forest worldwide, of which 1 million ha are in Nigeria. Studies have shown that mangrove forests offer a wide range of goods and services to ocean bodies and the people who live adjacent to the forests. Key products from mangrove forests include firewood and building poles, while the services offered by this ecosystem include protection of coral reefs and shorelines among others (FAO, 2015; Spalding et al., 2010). The immense direct and indirect benefits associated with mangrove forests have driven many African countries that have the forest type, like other nations with mangroves, to engage in extensive research and education, development of management plans for tourism and rehabilitation of degraded mangroves, all aimed at sustainable utilization and conservation of the ecosystem. These management plans have sought to overcome anthropogenic challenges such as deforestation, limited technical capacity to address mangrove forests, limited or lack of alternative sources of livelihood among communities adjacent to mangroves, poor governance of marine resources and population increase that put pressure on mangrove forest resources.

Forest plantations and trees on farms remain major sources of timber, fuelwood, pulp and other uses that support livelihoods at all levels. Africa has an estimated 3.8 million ha of forest plantations that supply timber products for different uses (FAO, 2015). The establishment of woodlots and commercial plantations by the private sector and governments, and the development of management plans for sustainable harvesting of community forests, are intended to reduce pressure on natural forests and protected areas. These different types of forest biomes are affected differently by change on temperature and precipitations.

4.3 Climate change projections

Climate change projections play an important role in predicting the various scenarios based on different assumptions and drivers of climate change and climate variability. In a strict sense, there is a clear difference between climate change and climate variability, where the latter refers to a phenomenon that describes the short-term fluctuations on seasonal or multi-seasonal time scales ranging from months to as many years as 30 years (IPCC, 2013). The frequency and intensity of climate variability results in some weak or strong extreme events such as flooding, prolonged droughts, and cyclones, among others. In this regard, extreme events are defined as the occurrence of a value of a weather or climate variable above or below a threshold value near the upper or lower ends of the tail of the range of observed value of the variable such as rainfall or temperature (IPCC, 2014). For example, large amount of precipitation in the atmosphere results in the occurrence of floods that have devastating effects on biophysical and social systems. Also, high temperatures result in heat waves with negative consequences on vegetation and people.

In terms of physiological impact, extreme events have more impact on vegetation than changes in average conditions. Increase in the frequency, duration, and/or severity of drought stress associated with climate change could severely impact physiological functions of trees and fundamentally affect the composition and structure, and possibly lead to widespread tree mortality, altering the biogeography, of forests in many regions (Allen et al., 2010; Bouda et al., 2013). Among other indices, climate change is associated with a high concentration in the atmosphere of CO2, which is a raw material for photosynthesis, the basis of plant growth. Based on laboratory studies on growth rates and yield of plants grown in elevated CO_2 environments, Ciesla (1995) reported increased rates of photosynthesis, lowered plant water use, increased carbon sequestration and increased soil microbial activity. The production of plant biomass in general is related to photosynthetic dynamics. If the increase in the availability of CO_2 can be a factor favorable to photosynthesis, this phenomenon is not enough by itself to boost the production of biomass. In fact, although light and heat are enough in most parts of Africa, the issue will be water and its spatial and temporal distribution. On one hand, the increase in rainfall forecast in some regions is not necessarily an asset because floods followed by drought are not favorable to plants. Too much water in one season and prolonged drought in another can destabilize the equilibrium between vegetative and reproductive production in fruit trees, resulting in intense vegetative production to the detriment of fructification.

Climate change and variability are projected to affect the relationship and biological balance between forest pests, their environment and other species like their natural enemies, competitors and mutualists. It can directly impact the development, survival, reproduction and spread of pests, altering host defenses. Moore and Allard (2008) reported that a deeper understanding of the complex relationships between a changing climate, forests and forest pests is vital to enable those in forest health protection and management to prepare for changes in pest behavior, outbreaks and invasions. New climatic conditions will also alter the disturbance dynamics of native forest insects, pests and pathogens, and facilitate the establishment and spread of non-indigenous species, sometimes out of control (Davis, 1989).

Since the last two decades of the 20th century, climate change and its impact have dominated the international policy agenda and public attention. Climate change is a leading environmental concern, as changes in the world's climate have the potential to significantly affect forests. The issue is complex and filled with uncertainties, because the information available on the subject is often confusing and conflicting. While many researchers (Saeed et al., 2013, IPPC, 2014, Sylla et al., 2016, Abiodun et al., 2017), sound the alarm about climate change and its impacts on the environment, animal and human systems, some political and social leaders prefer to speak about the natural cycle of climate variability.

The forecasts are, however, worrying. Climate change scenario simulations with the Community Climate System Model version 3 (CCSM3), show that even with stabilizing the GHG concentrations at the year 2000 levels, the climate system is already heading for 0.4°C more warming by the end of the twenty-first century (Meehl et al., 2005). At both global and African levels, predictions suggest that climate change will mainly manifest itself in the following ways (Houghton, 1991; Ciesla, 1995):

- Increase of earth's average temperature;
- Disruption of global rainfall: floods will be pronounced in some regions, while droughts will be persistent in others;
- Reduction of ice and snow cover, as well as permafrost;
- Rise of sea level;
- Increase of acidity of the oceans;
- Increase of the frequency, intensity, and/or duration of extreme events;
- Storms, especially tropical storms could have more impact on forests in Africa. As observed by Houghton (1991), there is a great deal of uncertainty associated with the effects of climate change on storm events;
- Shift of ecosystem characteristics; and,
- Increase of threats to human health.

Regarding Africa, the region has been identified as one of the parts of the world most vulnerable to the impacts of climate change (IPCC, 2014; Niang et al., 2014).

Analyzing three scenarios of global warming (1.5, 2 and 3°C), Weber et al. (2018) reported that for Africa in general (West Africa-WA, Equatorial Africa-EQA, Great Horn of Africa-GHA, and the Western Cape Region of South Africa-WCR), the Mean Annual Hot Nights (HN), the Mean Annual Heat Wave Days (HWD), the Heat Waves (HW) and the Extreme Daily Rainfall Intensity during the Rainy Season (ERIRS) will continually increase with global warming, while the Mean Length of Rainy Season (LRS), the Mean Sum of Rainfall during Rainy Season (SRRS) will be decreasing.

However, climate projections for Africa remain a challenge for two main reasons (Heinrigs, 2010): first, the climate instability over the 20th century makes it difficult to identify a sign that can be attributed to climate change. Second, climate model projections are in significant disagreement over some regions (e.g. the Sahel).

Among the subjects of debate, there is precipitation where models disagree even on the direction of change (e.g. Serdeczny et al., 2016; Mueller, 2011). The distribution of rainfall and the spatial and temporal partitioning of the rain in African areas display contradictory cases according to the scenario of prediction at the global level (low or high emission). The models disagree on the direction of change over larger areas of the dipole pattern with wetting in tropical East Africa and drying in southern Africa emerging in both seasons and in both emissions scenarios described by Serdeczny et al. (2016). Under the high-emission scenario, the increase in the total amount of annual precipitation in the Horn of Africa (Sillmann et al., 2016) represents a strong relative change over a very dry area (Sillmann et al., 2013). There is also contrast of models between the global and the regional for some areas. While the global climate models project wetter East Africa, the regional climate models project no change, or even a drying for East Africa, especially during the long rains (Laprise et al., 2013). This is consistent with the projection of the regional climate model study of Vizy and Cook (2012), which predicts an increase in the number of dry days over East Africa.

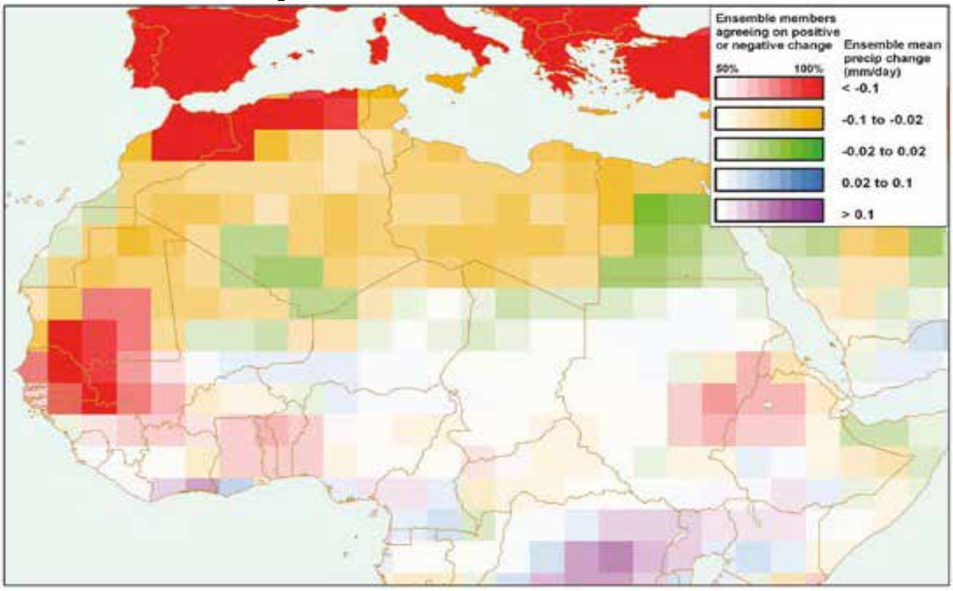
For Southern Africa, the projections in precipitation mostly predict a general and consistent decrease (Pinto et al., 2016; Weber et al., 2018) connected to an increase in consecutive dry days. For West and Central Africa, projected changes in precipitation are also different from one regional climate model to another (Haensler et al., 2013; Sylla et al., 2016) increasing the uncertainty regarding future hydrological changes in West and Central Africa (Klutse et al., 2016; Yira et al., 2017; Weber et al., 2018). Figure 1 shows the example of West Africa and the Sahel.

In terms of temperature projections, the different climate models agree in the same direction and suggest a noticeable increase, especially for summer (Russo et al., 2016; Dosio, 2017). This warming is likely to be higher than the global average in some parts of the continent such as the Sahel, with temperature increasing between 3 and 4 degrees by the end of the century compared with the last twenty years of the 20th century (Heinrigs, 2010). In addition, extremely hot seasons are likely to become more frequent in the future. The situation is likely going to be more complicated for some African regions in 50 years and further. During the 2071–2099 period, Sub-Saharan African summer months are projected to be hotter, with especially strong increases in tropical West Africa. Robinson (2013) predicted that for a global warming of 2°C, African summer temperatures will increase until 2050 at about 1.5°C above the 1951–1980 baseline and remain at this level until the end of the century. In the global higher warming (about 4°C of global temperature increase), warming continues until the end of the century, with monthly summer temperatures reaching 5°C above the 1951–1980 baseline by 2100 in Sub-Saharan Africa.

This projection (temperature) leaves us a little pensive about the natural regreening of the Sahel reported by some authors, including Mueller (2011). Indeed, this strong warming implies a strong increase in evapotranspiration that a slight increase in rainfall (especially if it is not spatially and temporally well distributed) cannot compensate for avoiding the water deficit.

There exist many approaches of analyzing climate change and related impacts over Africa, linked to specific levels of global warming as projected by General Circulation Model - GCM, Regional Climate Models (RCMs) and CORDEX-Africa, which show African flood and drought risk areas (Schewe et al., 2014; Alfieri et al., 2017; Engelbrecht and Engelbrecht, 2016; Déqué et al., 2017; Abiodun et al., 2017). Weber et al. (2018) insist on drastic increases in the number of high fire-danger days, very hot days and heat-wave days across the African continent under low mitigation. The southern African region will likely become drier with more frequent droughts, increases in temperature and extreme events that will surely impact forests.

IPCC AR 4 ensemble models agreement



Met Office Hadley Centre ensemble models agreement

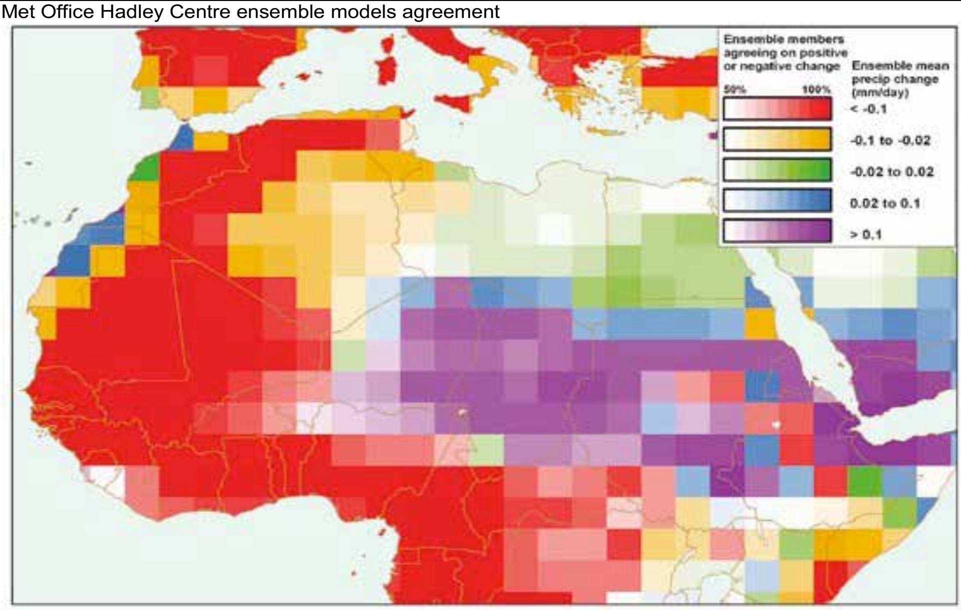


Figure 1: Climate model projections 2041 – 2070 for West Africa and Sahel: agreement vs. disagreement (Source: UK Met Hardley Office Center, in Sahel and West Africa Club / OECD 2010)

These maps illustrate agreement of model projections (more than 50% of models in ensemble) for difference (mm/day) in summer (June-July-August) precipitation between 2041–2070 and 1960–1990 across IPCC Assessment Report 4 and Met Office Hadley Centre ensembles. The colour indicates the strength of the signal (variation in precipitation), while the colour intensity indicates the consistency across the ensemble (agreement). For example, deep red colours indicated where close to 100% of models agree on a precipitation reduction of more than 0.1 mm/day, dark green indicates where nearly 100% of models agree on no change. White colours indicate areas where models disagree on the direction of change (50% of models indicate increase in precipitation and 50% decrease).

Figure 1. Projected changes in precipitation in West and Central Africa.

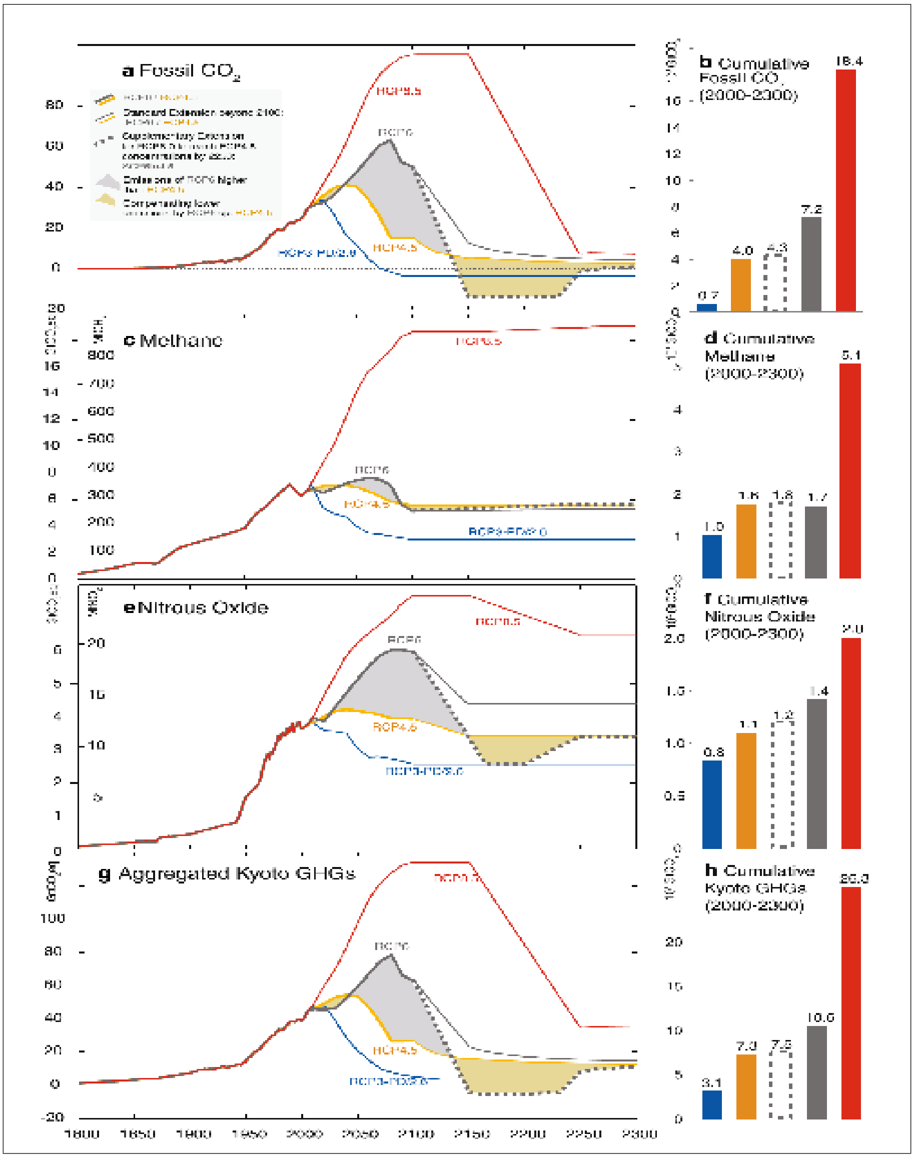


Figure 2. Emissions for the four RCPs and the supplementary extension SCP 6 to 4.5, which starts from the RCP6 scenario and merges with the ECP4.5 concentrations by 2250. The shaded areas denote times of higher emissions (grey shading) and compensating lower emissions (beige shading). Source: Meinshausen et al., 2011; in Climatic Change 109:213–241.

Equally, major anthropogenic GHGs such as CO_2, nitrous oxide, methane, etc., have been determined and found to significantly influence temperature rise above 1^0C from the pre-industrial levels. This has been demonstrated by various simulation experiments under different conditions representing GHG concentrations for Representative Concentration Pathways (RCPs) and their extensions beyond 2100 referred to as Extended Concentration Pathways (Meinshausen et al., 2011; Figure 2 above).

Such temperature increase is expected to have devastating effects on forest and tree resources among other elements of various ecosystems, and on the social well-being of people. The recent special report under Assessment Reporting (AR) series of IPCC indicated that consistent with the fifth assessment report (AR5) of IPCC, there is high confidence that by 2006-2015 the Global Mean Surface Temperature (GMST) had reached 0.87^{0}C (+/-0.10^{0}C) above pre-industrial period due to anthropogenic activities (Hoegh-Guldberg et al., 2018). The Special Report further indicated, with a high degree of confidence, that global warming of 1.5^{0}C, as well as the difference with 2^{0}C, are detectable almost in all locations globally (Figure 3).

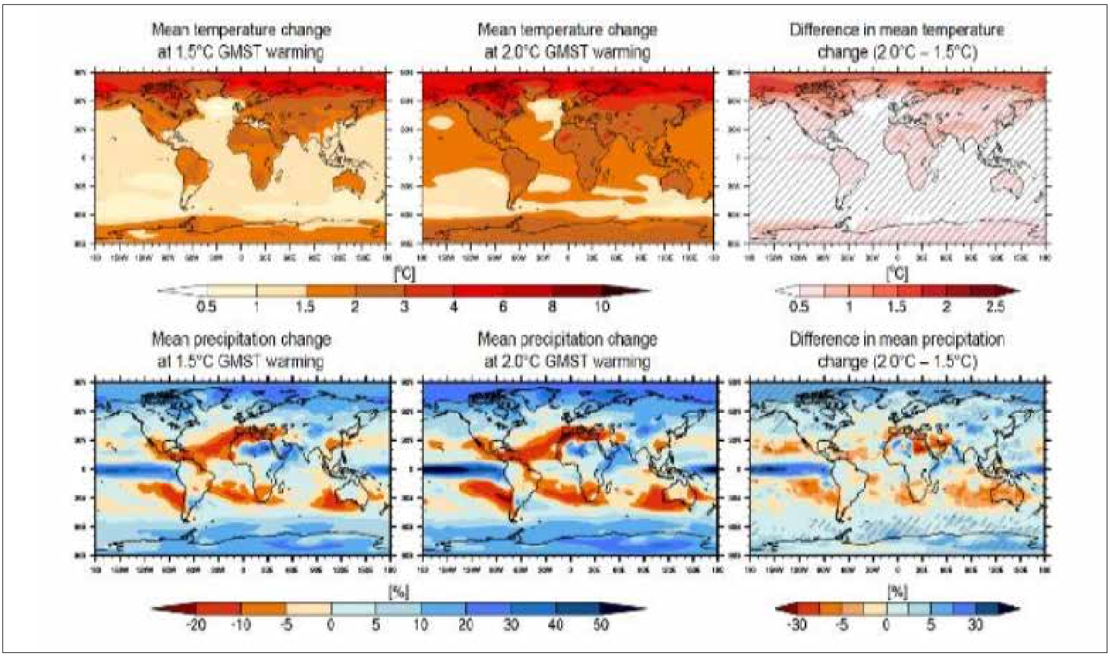


Figure 3. Projected mean temperature (top) and mean precipitation changes (bottom) at 1.5°C global warming (left) and 2°C global warming (middle) compared to pre-industrial time period (1861-1880), and difference (right; hatching highlights areas in which 2/3 of the models agree on the sign of change). Assessed by transient response over 20-year time period at given warming, based on Representative Concentration Pathway (RCP) 8.5 Coupled Model Intercomparison Project Phase 5 (CMIP5) model simulations (adapted from Seneviratne et al., 2016, and Wartenburger et al., 2017). Note that the responses at 1.5°C Global Mean Surface Temperature (GMST) warming are similar for RCP2.6 simulations.

In view of this, temperature is projected to rise further if no appropriate interventions are in place as highlighted in the Paris Agreement (PA), where both Annex I and non-Annex I countries are required to mitigate ever increasing GHG emissions due to their economic activities and changes in land use. It is in this context that Sub-Saharan African countries that are experiencing significant effects of climate change signed the PA. They did this through their Nationally Determined Contributions (NDCs), by which they committed to contribute to the global effort of mitigating GHG emissions, with the aim of holding global temperature below 2^0C and to pursue efforts to limit warming to 1.5^0C above pre-industrial levels.

The rise of CO_2 emission due to change in land use is mainly attributed to significant cutting of forest to create land for agriculture, urbanization, settlement and roads among other economic activities. Statistics show that Africa is the third in CO_2 emission after South America and Asia due to land use change. This essentially increases the level of vulnerability to climate change and climate variability, especially in Africa that has weak adaptive capacity.

4.4 Climate change risks and challenges in African biomes

Global warming is causing serious risks and challenges to the forestry sector like other natural resources sectors. This section attempts to provide key highlights on the climate change risks and challenges in different African biomes stratified into the following:

- Woodlands and savannas;
- Lowland and montane moist forests;
- Mangroves;
- Plantations and trees outside forests; and,
- Other vegetation types (parklands, rangelands, community forests, protected areas).

Climate change risks and challenges in African woodlands and savannas

Studies undertaken by Hoegh-Guldberg et al. (2018) have shown that at regional levels, Sub-Saharan Africa is projected to have higher temperatures than the global mean temperature increase at global warming of 1.5^0C and 2^0C. West Africa is predicted to have more hot days than the global mean temperature due to relatively small interannual present-day variability, indicating that climate change signals can be detected much earlier than in other areas. Equally, changes in precipitation in WA are predicted to show high level of confidence on uncertainties, especially in the Sahel. Overall, the western Sahel region is projected by most climate models (80%) to experience strongest drying with a significant increase in the maximum length of dry spells, making WA a 'hot spot' with the likelihood of negative impacts of climate change. Also, in the Southern Africa region, most areas are projected to experience increased temperatures, especially in South Africa, Namibia, Zimbabwe, Malawi and Botswana, as well as significant reduction of precipitation in the Limpopo basin, smaller areas of the Zambezi basin in Zambia and parts of Western Cape, in South Africa. Equally, at 2^0C, the SA region will face robust decline of precipitation of about 10-20%, especially in Namibia, Botswana, northern Zimbabwe and southern Zambia. In Eastern Africa, there are mixed signals of reduced dry spell periods, like in Somalia, and in other areas increased dry spells, especially in central and northern Ethiopia. These studies, among others, show that woodlands and savannas remain highly vulnerable to climate variability and climate change.

Increase of dry spells will impact biodiversity through increase of bush fires and wild fires that may cause complete extinction of important species. This also implies that sources of livelihood will be significantly affected due to impacts of climate change. Specifically, changing weather patterns in this type of ecosystem has a profound effect on crop production and livestock yields, leading to food insecurity and nutrition deficits that put the populations that depend on woodlands and savannas at a significant risk. These climate related challenges could ultimately push people living around woodlands and savannas to continuously exploit, unsustainably, the limited forest and tree resources accessible to them. This will happen at the expense of environmental health resulting in increased forest degradation and increased poverty due to reduced development and loss of biodiversity. This is well evidenced by studies carried out in northern Burkina Faso where it was reported that rising temperatures and changing rainfall , together with human activities, like deforestation, over-harvesting of woodlands and savannas, annual fires and overgrazing, have caused significant decline of some nutritive species of NTFPs putting health and livelihood sources of people at high risk (Muoghalu, 2014).

The other notable change as a result of depopulation and shifts on fire regimes attributed to climate change and variability is that forests in central Africa are moving towards adjacent savannas and grassland of this region. This corroborates studies in the Amazon basin that reported that drying and greater seasonality, in conjunction with increased fire incidences, have caused former forested areas to be changing to savanna. It is also evident that in woodlands and savannas, the proportion of grass and trees is increasingly becoming unstable due to different effects of climate change, rising CO_2, fire and herbivory altering the tree cover in a significant way. The rainfall variability in woodlands and savannas is documented to cause changes on the biological processes of this ecosystem, specially its effect on seed germination, seedling establishment, plant growth, flowering time, root mass development, community composition, population and community dynamics, microbial processes, carbon stocks and soil nutrients among others (Settele et al., 2014).

These attributes of changing climate have also increased aridity and droughts in the woodlands and savannas affecting effective functioning of the ecosystem. While there is lack of data and information on some woodlands and savannas in Africa, there is evidence that species composition has changed over time in this forest type due to shifts in temperature and moisture regimes. Water limitations to tree growth and tree-grass competition for water remain key factors in determining savanna presence in arid and semi-arid areas (Baudena et al., 2015). Equally, a study carried out by Pienaar et al. (2015) in the miombo woodlands of southern Africa showed that woodland, especially those dominated by the genus *Brachystegia* has experienced rapid range retraction, between 31% and 47% in the continuous *Brachystegia spiciformis* woodland in Zimbabwe and southern Mozambique. This suggests a shift in the ecological niche of this species, due to climate change and variability. A study carried out by Jin et al. (2013) also showed that there is shift in the phenology and gross primary production of mopane and savanna woodlands in southern Africa that is attributable to climate change and variability.

Overall, there is clear indication that woodlands and savannas, among other types of dryland forests, are experiencing the impacts of climate change. However, there is need to have more data and information to link the observations on this forest type explicitly to climate change and variability. This can be achieved by investing in establishment of permanent sample plots (PSPs), and use of technologies, such as GIS and remote sensing, together with modelling in order to monitor and report the structural changes in African woodlands and savannas. This will enable Africa to track the changes that may be as a result of human induced activities, natural catastrophes and those linked to climate change for effective decision making and sustainable management of these useful natural resources.

Climate change risks and challenges in African moist forests

According to IPCC (2007), moist tropical forests are being affected by climate change, especially in Africa. Limited water supply arising from climate change-induced reduction of precipitation depresses primary production of trees and forests resulting in reduced yields and forest cover. Rising temperature has also caused shifts of species to areas that are more suited for their growth and production. The impacts associated with increased temperatures include but are not limited to, increased evapotranspiration, reduced runoff and frequent wild fires. Some areas in Africa that are projected to have increased precipitation are likely to experience extreme events such as floods, landslides and storms that result in loss of fauna and flora that are critical in enhancing resilience of tropical moist forests.

Muoghalu (2014) also reported that parts of West and Central African tropical moist forests are experiencing changes in precipitation within seasons as well as inter-annual variation that affects species composition, phenology and regeneration. This has happened with decline of rainfall in the Congo Basin and WA in the last two decades. This implies that such areas in Africa will be affected by reduction of goods and services provided by moist topical forests in support of livelihoods and reduction in overall biodiversity, leading to increased levels of vulnerability to climate change.

Climate change risks and challenges in African mangroves

The climate change risks and challenges in mangroves are imminent. Studies (Ward et al., 2016) show that vulnerability of mangroves is linked to sea level rise between glacial and interglacial periods especially in West, Central (Cameroon) and East Africa. For example, mangrove natural stands in Gazi Bay, Kenya, is reported to have experienced increased surface sea level elevation by an average of 4.2 mm/y due to climate change and climate variability. Also the aridity of the Sahara Desert has limited the distribution of mangrove forests, especially on the west coast of Africa, to the tropics (Trzaska et al., 2018). Increasing temperature has been observed to push mangrove forests southwards in Africa. This may, on the other hand, be indicating that as temperature rises, new places are becoming suitable for mangrove forests. Overall, Africa as compared with other subregions, has not invested much in generating data about the response of mangrove forests to climate change and variability, an area that requires much attention.

Climate change risks and challenges in African forest plantations and other vegetation types

Forest plantations, woodlots, protected areas, rangelands, community forests and trees outside forests are also affected by climate change and variability. The global rise of temperature and changes in precipitation and other climatic factors also affect these forests and trees as they do woodlands, savannas and tropical moist forests. Some of the documented (Settele et al., 2014) effects of climate change on these forests associated with temperature rise and decline in precipitation include emergence of new forest/tree pests and diseases causing significant loss of forest/tree productivity. Similarly, changes in rainfall distribution affect afforestation and reforestation programmes in most areas in Africa where rainfall shifts have been reported. The new pests and diseases that have been reported to occur in unexpected areas include blue gum chalcid (*Leptocybe invasa)* that affects young seedlings and saplings of eucalypts, deforming leaves and shoots and resulting in reduction of growth. This has been associated with shifts in temperature and delays in rainfall associated with climate change and variability.

Climate modelling studies (Settele et al., 2014; IPCC, 2018) have shown that areas such as eastern Africa that have been projected to have high precipitation, may experience increased floods that erode top soil nutrients essential for plant growth. Increased rainfall beyond required threshold and temperature has also been reported to accelerate rate of mortality in forest plantations and in trees outside forests. Emergence of forest fires has also affected forest plantations resulting in high levels of mortality and reduced production from that projected to meet the increasing demand for timber and NTFPs. Some plantation tree species have failed to adapt to new climatic zones because of unexpected changes in climate. There are also cases of late maturity of some species due to climate change and variability. It is also expected that changes in water availability and increase in the incidence of forest pests and fires may reduce yields in plantation forests.

4.5 Climate change opportunities and technical responses in African forestry

Climate change and climate variability does not only present challenges, there are also opportunities associated with mechanisms of adaptation or coping strategies to the climatic challenge or deriving from natural responses to shifts of climate in given forest types. This sub-section therefore highlights key opportunities and technical responses associated with climate change that Africa has already taken up and areas to focus on in order to build resilience against the impacts of climate change. Some of the opportunities in focus include, but are not limited to the following:

- Improved forest productivity and yields;
- Carbon incentives in voluntary and compliance markets;
    - o Investment in climate change mitigation and adaptation;

- Capacity building and technology transfer and networking to cope with climate change and variability;
    - Improved globalization and networking;
    - Globalization;
    - Building of strategic partnerships;
- Strengthening role of private sector engagement in African forestry in response to climate change; and,
- Role of forest and tree resources as source of food in response to climate change;
    - Diversification of livelihood sources.

This sub section provides key highlights on how each of these key opportunities and technical responses in addressing challenges associated with changing climate and variability.

Improved forest productivity and yields

The increased levels of CO_2 concentration in the atmosphere, as well as precipitation, associated with climate change, have been reported to serve as increased fertilization for improved primary forest production (Field et al., 2014; IPCC, 2007, 2014). This is because plants require water, sunlight and CO_2 to manufacture food for survival and growth, primarily through the process of photosynthesis. In this regard, changing climate associated with increased CO_2 concentration, presents an opportunity for trees and forests, especially primary forests without intervention from man, to flourish. Studies have shown, for example, in some parts of Africa, that woodlands and savannas have increased woody cover due to modified rainfall patterns and variability that has reduced fire regimes (Bauden et al., 2015). The areas that have reported less frequency in fire mortality have increased woody vegetation. Also, increase in water use efficiency, due to the increase of CO_2 in the atmosphere shifting tree-grass competition for water in favour of C3 trees over C4 grasses, has led to encroachment of woodlands on grasslands, and hence savanna expansion. This is also supported by paleo-ecological evidence and other observations of the last 50-100 years in African savannas that suggest that rise of CO_2 in the atmosphere has been accompanied by increase in savanna woody plant growth.

Overall, models have shown that African forests are also likely to benefit from positive feedback where trees are expected to accumulate enough biomass under elevated atmospheric CO_2 to recover from fires, while shading of C4 plants will reduce fire incidences and increase productivity. Also, with high rainfall, savannas will be replaced by forests implying increased productivity in such places (Serdecyny et al., 2016).

Carbon incentives in voluntary and compliance markets

The introduction of forest carbon (C) markets aimed at rewarding efforts made by countries in mitigation of GHG emissions has raised some level of awareness among African countries in tapping such global opportunities for the forestry sector. In this regard, some projects have been initiated in African moist tropical forests, forest plantations, mangroves, woodlands and other dry land forests to address emission reduction, drivers of deforestation, forest degradation, forest conservation, enhancement of C stock and sustainable use of forest and tree resources. This is being carried out through various climate change strategies and Reducing Emissions from Deforestation and Forest Degradation (REDD+) processes and programmes. Afforestation and reforestation programmes in African forests are also occurring through the Clean Development Mechanism (CDM) for countries that have ratified the Kyoto Protocol (KP). Both REDD+ and CDM interventions have collateral advantages; they contribute to landscape restoration, climate change mitigation and adaptation, sustainable forest management, improved forest governance and improved forestry and environmental policies, as well as other institutional frameworks that support management of forest and tree resources. In this sense, REDD+ and CDM have become policy instruments for Africa and the rest of the developing world in reducing poverty and increasing resilience of poor communities to the impacts of climate change and variability (Oeba and Larwanou, 2017; Oeba and Larwanou, 2015).

The C credits realized from REDD+ and forest-based CDM projects are sold in voluntary and compliance markets, respectively, in the form of voluntary emission reductions (VERs) and certified emission reductions (CERs), in that order. There are also some instances where CERs have been sold in voluntary markets, depending on the mode of agreement and negotiations undertaken by the investors to capitalize on the best prices of C. African countries have also committed to REDD+ and CDM interventions where they are being piloted or are scheduled for implementation as part of their initiatives on Nationally Determined Contributions (NDCs) for voluntary periodical reporting as per the Paris Agreement. For example, through the UN-REDD programme, countries such as Democratic Republic of Congo, Senegal, Tanzania, Kenya, Uganda, Madagascar, Mozambique, Ethiopia, Zimbabwe and Zambia have secured funds, piloted and developed REDD+ projects.

Specifically, through REDD+ offset projects, DRC converted 4220 ha of degraded savanna land into forest plantations for sustainable supply of fuelwood and agricultural crops. Overall the piloted REDD+ projects in these countries and others have focused on promoting sustainable land use practices in forest adjacent communities; development of alternative livelihoods in such communities; mopane and savanna woodlands in southern Africa that is attributable to climate change and variability; building local and national capacity and understanding of REDD+ mechanisms; contributing to national REDD+ strategies and policies and building village-level, local government and civil society organizational capacity towards understanding REDD+ in view of participating in the future, global forest C trading. The C co-benefits have also resulted in construction of schools and health facilities, providing education and health services to local children (Oeba and Larwanou, 2017; Nyambura et al., 2013). In general, the key economic and social benefits identified through implementation of REDD+ and forest-based CDM project included the following: employment creation among the community members and experts on project formulation and implementation; improved income as a result of enhanced infrastructure on project sites; and, increased investment.

There exist also good examples in Africa where REDD+ is piloted, demonstrating direct and indirect social-economic benefits from sale of C. For instance, the Kasigau phase II REDD+ project employed about 100 staff undertaking different duties such as forest patrols, tree nursery attendants, cloth sewing in the eco-factory, greenhouse attendants for production of horticultural crops (Figure 4) and eco-friendly charcoal producers. The same project also supports construc-tion and equipping of health centres, while activities promoted by Cameroon estuary mangroves promoted improved smoke stoves that have positive health implications. The social development from C offset projects in Africa correlates well with those in Asian, Latin American and Caribbean countries where some projects are providing medical insurance, building hospitals or health centres, and providing access to ambulance and other related services. In some projects, like the case of Nhambita community project in Mozambique, farmers received direct payments that promoted their rural livelihood, an important characteristic of enhancing resilience to climate change. Similar economic returns from most of the C sequestration projects have been reported where local communities receive cash incomes as well as access to NTFPs through forestry activities and adoption of cleaner energy practices (Oeba and Larwanou, 2015; Nyambura and Nhamo, 2014; Romero et al., 2013; TNRF, 2011; Jindal et al., 2008;). Energy-based CDM offset projects are also viewed to enhance green economy and clean energy through improved investment in technology such as efficient cook stoves to reduce pressure on forests, hence enhanced resilience of forestry and people.

Figure 4. (Clockwise): tree nursery, greenhouse for horticultural crops and eco-factory at Kasigau REDD+ Phase II in coastal Kenya. Source: Corresponding author.

Overall, the forestry sector and land use globally, represent the second largest contributor of C offsets after energy efficiency and fuel switching since 2005 to date (Table 1). The distribution of the C offsets shows that Africa has contributed 11% since 2005 of the total 2,008 projects that have issued offsets, leading from Asia (51%), North America (18%), Latin America and Caribbean (11%), Europe (11%). In addition, the projects from Asia and North America have generated the largest share of 435.4 $MtCO_2e$ of offsets issue followed by Africa (Mellisa and Kelly 2018).

Table 1. Categories of voluntary carbon projects 2018.

Project Categories	Projects with Issued Offsets	Volume of offsets Issued in $MtCO_2e$ (2005 – present)	New projects
Agriculture – Modi fying agricultural practices to reduce emissions by switching to no-till farming, reducing chemical fertilizer use, etc	87	6.7	1
Chemical process and Industrial Manufacturing- modifying industrial process to emit fewer greenhouse gases	72	63.5	0
Energy Efficiency and fuel Switching – improving energy efficiency or switching to cleaner fuel sources	633	127.9	8
Forestry and Land Use – managing forests, soil, grasslands, and other land types to avoid releasing carbon and/or increasing the amount of carbon the land absorbs	170	95.3	3
Household Devices – Distributing cleaner-burning stoves or water purification devices to reduce or eliminate the need to burn wood (or other inefficient types of energy)	161	23.4	0
Renewable Energy – Installing solar, wind, and other forms of renewable energy production	611	61.9	2
Transportation- increasing access to public and/or alternative transportation like cars and trucks	43	1.1	0
Water Disposal – reducing methane emissions from landfills or wastewater, often by collecting converting it to usable fuel.	238	57.5	0

Source: Kelley and Melissa, 2018. Voluntary carbon markets outlooks and trends January to March 2018.

Improved technology transfer, capacity building and networking to cope with climate change

The clamor by different stakeholders and environmental players to address the challenges associated with impacts of climate change and variability has led to formation of global platforms such as the Conference of Parties (COP) under the UN Framework Convention on Climate Change (UNFCCC), for countries and organizations to dialogue on how to mitigate and adapt to climate change. During COPs, key decisions are passed for implementation by parties. They have also provided opportunities for Annex I countries and banking institutions to make financial commitments to address climate change mitigation and adaptation, especially for developing countries (non-Annex I countries) that are vulnerable to the impacts of climate change and variability. In this regard, special funds such as Global Environment Facility (GEF), Climate Change

Partnership Facility (CCPF) of the World Bank, Green Climate Fund, Adaptation Fund, Bio Carbon Fund, among other modes of funding at bi-lateral and multi-lateral agreements, have been set aside to address climate change mitigation and adaptation. These funds have provided excellent opportunities for the developing world to design appropriate institutional frameworks on how to combat climate change and take advantage of opportunities of climate financing.

It is in this context that the forestry sector has made significant gains on climate change mitigation and adaptation options as evidenced in REDD+ and forest-based CDM projects in Africa and the rest of the world. Indeed, land use change in the forestry sector is known to be one of the great sources of GHG emission in Africa and the developing world, but it is also the best C sink through C sequestration in different pools, making it one of the options that most countries have profiled in climate change mitigation. For example, according to IPCC (2014) and recent studies (Bisong, 2017), agriculture, forestry and other land uses (AFOLU) contributes 30% of the total anthropogenic GHG emission but at the same time, the interventions through agriculture and forestry have the potential of sequestering 5.5-6 $GtCO_2e$ and 5.4 $GtCO_2e$ per year, respectively. These findings show enhancement of research in forestry sector towards climate change mitigation and adaptation. Specifically, agroforestry technologies and practices, rehabilitation of degraded forest lands, planting of mixed species, intensification of afforestation and reforestation, forest conservation, capacity building programmes among others, have reported significant progress on best adaptation and mitigation options in reducing vulnerability of social and biophysical systems, thus improving resilience of such ecosystems.

Equally, the data from REDD+ projects in Africa show significant amount of anthropogenic GHG emission reduction expected over the REDD+ implementation period. For instance, the Sofala community C project in Mozambique is anticipated, within the project crediting period, 2006 to 2048, to result in 796,005 tCO_2e GHG emission reduction, translating to 7 960.05 tCO_2e per year and 0.83 tCO_2e per ha of the study area. Since the project started, 346,923 tCO_2e have been issued as of January 2015 and 261,294 were sold between 2004 and 2010. Similarly, in Kenya, the Kasigau Phase II project covering an area of 169,741 ha is anticipated, within 30 years of crediting period. to result in emission reduction of 38,759,010 tCO_2e (Table 5.2).

Table 2. Estimates of emission reduction expected from REDD+ offset projects from selected African countries.

Country	Ex-ante estimate GHG emission reduction (1000 tCO_2e)	Total land area under project activity (ha)	Crediting period (years)
Kenya	38,759	169,741	30
Mozambique	796	9,599	42
Uganda	1,480	27,000	20
DRC	195,987	4,473,842	30
Zimbabwe	196,514	784,987	30
Ethiopia	37,984	261,053	20

Source: Oeba and Larwanou, 2015.

Overall, the variances of climate change impacts in different African countries have also led to the promotion of forest-based technology transfers and capacity building, to address the different vulnerabilities of people, forests and tree resources. Some of the technologies that have been gained for addressing data on climate change in forestry include, but are not limited to, the following:

- GIS and remote sensing;
- early warning systems;
- modern forest inventory tools;
- modern tools in biomass assessment using destructive and non-destructive methods;
- modern tools for forest soil biomass assessment; and,
- high computer capacities for climate modelling and scenario development with applications to forest sector.

There are also areas that communities and countries require technical capacity building in, in order to improve their adaptive capacity and approach to mitigation of climate change. Institutions, firms and organizations have, therefore, taken the opportunity to train and build capacities of vulnerable communities and countries.

In this regard, some of the key areas in climate change that the African Forest Forum (AFF), for example, has identified to address in a modular approach in the forestry sector, include:

1. *Basic science of climate change in African forestry;*
2. *Forests and climate change adaptation;*
3. *Forests and climate change mitigation; and,*
4. *Carbon markets and trade*.

Additional materials have been developed in expanding knowledge in these areas, such that the forestry sector remains critical for addressing climate change challenges in Africa. For instance, on rapid forest stock C appraisal (RaCSA), AFF has trained over 500 trainers of trainers drawn from research and academia, civil society organizations, forest administration, extension staff in government and other stakeholders in African forestry, covering over 15 countries. The participants trained on RaCSA have gained knowledge and understanding in the following areas:

1. *Payment of environmental services*
2. *Principles and concepts of carbon markets and trading*
3. *Climate financing processes*
4. *Development of project idea note (PIN) and project design document (PDD)*
5. *Methods of carbon assessment at plot-level carbon measurement and spatial analysis of land-use cover), monitoring/measurement, reporting and verification -MRV of carbon projects; and*
6. *Policy and other regulatory frameworks in carbon markets and trading*

This implies that new capacities and skills are slowly being introduced into countries and communities, enabling them to develop forest-based C projects and tap into existing and future financing mechanisms. These training programmes have also enhanced networking amongst various professionals and created platforms for information sharing on climate change issues among other forestry matters. In this regard, countries have been encouraged to promote and cooperate in the development and diffusion, including transfer, of technologies that control, reduce or prevent GHG emissions, required to achieve the most effective rate and approach for transfer of technology in relation to national and international needs and objectives. This is important because statistics have shown that Africa's contribution to forest based CDM projects is wanting, due to: low level of awareness in Africa of taking the initiative to develop such projects, jointly with development partners; lack of updated forestry inventory data in most African countries, which is important for developing PIN and PDD for either REDD+ or CDM offset projects; inadequate technical and institutional capacity in Africa associated with complicated methodologies on MRV, resulting in higher transactional costs because of over-dependence on international experts to undertake the work; unfavourable forest policies, inadequate political commitment and political instability resulting in high prevalence of conflicts and civil wars, which have continued to scare investors on long term C project development; and stringent application of afforestation concept as per KP, which does not favour Africa as many parts, especially sub-Saharan parts, were forested. Specifically, afforestation projects are considered where there were no forests in the 50 years before ratification of KP and reforestation where there was no forest since December 31, 1989 (Oeba and Larwanou, 2015).

For resource assessment, there is the critical need for a robust measurement, reporting and verification approach to be in place for effective implementation of C projects. Intervention from development partners has enabled some countries, such as Ethiopia, Kenya and Tanzania, to develop MRV road map and systems, to effectively account for C and establish available resources and future projections, based on business as usual and REDD+ interventions. In Ethiopia, the MRV system is at the planning stage where an MRV road map has been developed by experts from the University of Wageningen, Netherlands, with financial support from the Government of Norway. In Tanzania, the task force coordinated by the National Forest Resource Monitoring and Assessment programme (NAFORMA) is currently finalizing development of an MRV system within the framework of the National REDD+ Strategy and R-PP initiatives. Kenya is currently developing an MRV system in the context of the system for land-based emission estimation in Kenya (SLEEK), funded by the government of Australia through Australian Aid. The completion of robust MRV systems will enhance monitoring of resources available for sustainable development and enhancement of C stock. The private sector has, overall, played a significant role in promotion of various technologies, and its partnership with the public sector is expected to bring the required change in addressing forest-based climate change mitigation and adaption options to communities and countries at different levels of governance.

Strengthening the role of the private sector in African forestry in response to climate change

The private sector in African forestry, in response to climate change, is consciously getting involved in mitigation and adaptation programmes and projects at different scales. Some of the key activities they are engaged in include conservation in water catchment areas, promotion of forest-based adaptation and mitigation options such as energy saving cookstoves to reduce pressure on forests and reduce emissions from land use change and cover, tree pest and disease management, management of invasive species, implementing community outreach programmes, investment on REDD+ based projects, seedling production, promotion of mixed species in forest plantations as well as in rehabilitation of degraded forests, reforestation and afforestation programmes. This demonstrates that the private sector is increasingly aware of climate change risks and is striving to alleviate the negative impacts of climate change by maximizing the potential opportunities through low C economic growth.

Other NGOs that work closely with government and the private sector in promoting forestry activities to address the challenges of climate change and variability include WWF, World Vision, Nature International, Conservational International, African Forest Forum, Wildlife Works, Vi Agroforestry, The International Small Tree Program, Mikoko Pamoja, and airlines, among others. These organizations and institutions are engaged in tree planting, development and implementation of REDD+ projects, watershed management, flood management, diversification of livelihood, disaster management mitigation activities, capacity building and skills development, natural resources management, sustainable management of NTFPs, conservation of high valued germplasm, supporting development of climate change mitigation and adaptation action plans, strengthening forest governance in face of climate change, among many other roles they are undertaking in a number of African countries.

For example, in Zimbabwe, Friends of the Environment (FOTE) are non-forestry private enterprises contributing to climate change mitigation through tree planting activities. They have re-established 14 tree nurseries around the country. The FOTE players promote seedling production by resuscitating rural forestry nurseries since 2011 including OK Zimbabwe (5), Nyaradzo funeral services (3), Zimplasts (2), Old Mutual (1), Mimosa (1), Kingdom Bank (1) and Standard Chartered Bank (1). The FOTE had also supported the walkathon event - walking for the trees - which is held annually at the beginning of the tree planting season. A total of 42,624 seedlings were planted during the walk from 2012 to 2014. Other organisations such as Towards Sustainable Use of Resources Organisation (TSURO) Trust established in 2000, located in Chimanimani district, support small holder farmers in natural resources management and strengthen their capacity in the production, value addition and marketing of healthy agricultural produce. They also implemented projects that promoted sustainable land and livestock management practices as Holistic Land and Livestock Management (HLLM) and sustainable watershed management (Mujuru, 2018).

For instance, the Kenya Association of Manufacturers (KAM) is playing a crucial role in mitigation and adaptation of climate change risks in the manufacturing sector in Kenya leading to reduction in C emissions. KAM was the vice-chair of the Government of Kenya appointed taskforce that came up with the climate change policy and bill. It has also organized sensitization and capacity building forums on climate change and mitigation for the membership of the manufacturing sector. This has enabled KAM to forge strong working alliances with the National Treasury which is spearheading climate finance and budget codes in Kenya, as well as with the Ministry of Environment and Natural Resources. KAM, in collaboration with other like-minded organizations, successfully lobbied the government of Kenya to develop and launch the Climate Change Mitigation Program (supported by DFID) in April 2014. It seeks to:

- Catalyze private-sector investment in renewable energy by facilitating implementation of the renewable energy projects;
- Support improved policy and regulatory framework conditions in the County Governments, aiming at enabling and attracting investments in low C and climate resilient infrastructure;
- Promote renewable energy technologies and solutions by facilitating industrial and technology cooperation through project demonstration; and,
- Strengthen business society engagement in climate change mitigation advocacy at all levels of policy authority (National and County).

With the support of DFID, KAM is encouraging private-sector investments in climate change mitigation by conducting pre-feasibility studies. So far, KAM has completed 16 studies for renewable energy projects in Small-Hydro, Solar, Biogas and Biomass. The total project pipeline from this initiative will enable the development of project sizes amounting to 24MW, and $57 Million in total investment. Overall, the private sector in forestry is expected to play an important role in climate change mitigation and adaptation, building capacities at different levels essential for strengthening resilience to climate change and variability. They also remain an important entity in mobilizing resources to synergize with government efforts in addressing the impacts of climate change at various levels.

Role of forest and tree resources as source of food in response to climate change

Forest and tree resources play a significant role in providing livelihood sources, especially during prolonged drought periods, in the face of climate change and variability. In this regard, they remain useful in meeting food security and nutritional needs to vulnerable people and communities in Africa. There is a wide literature that has demonstrated how forest and tree resources contribute to dietary diversity and quality, and acting as safety nets during periods of less food supply (Oeba and Larwanou, 2017). Fuel, fodder and green fertilizers, for example, are essential to food production and nutrition for the poorest and most vulnerable groups such as children, women and marginalized communities in Africa. NTFPs and agroforestry systems are also important sources of revenue which contribute to food supply. In addition, forest and tree-based systems provide valuable ecosystem services that are essential for staple crop production and a wide range of edible plants. Some of the notable services provided by forests and diverse tree-based cropping systems within a landscape mosaic are pollination of important crops that support livelihoods among rural and urban dwellers, and enhancement of adaptability to a broad range of environmental conditions produced by climate change.

The impacts of climate change are more pronounced to rural communities who have limited alternatives/adaptive capacity to climate variability as compared to those who live in urban areas. Such rural dwellers in most cases depend on forest products and services for income and nutrition. For instance, in Africa, many rural communities use NTFPs for direct consumption or for trading when agriculture or livestock is affected by climate events. Some of the common NTFPs that are major sources of income and nutrition to rural people in Africa include food, fodder, medicines, gums and resins. Agricultural production in most African countries is rain fed, and thus highly vulnerable to climate change and variability. Support for livelihoods thus depends significantly on the state of forests. Therefore, forest restoration programmes are key in strengthening and securing ecosystem services for enhanced resilience to climate change among the rural poor. Forests supply much-needed wild fruits, vegetables, seeds, nuts, oils, roots, fungi, herbs and animal protein, which complement conventional staple diets derived from agricultural production systems, thus providing alternative mechanisms for coping with climate change.

4.6 Policy responses to challenges and opportunities of climate change and outlook

The highlights on challenges provided in this chapter show that Africa's forest and tree resources are increasingly becoming vulnerable to effects of climate change and global warming. However, the arguments advanced on the opportunities demonstrate that African forest and trees resources rekindle the needed hope in Africa to address climate change mitigation and adaptation. This can be realized if the appropriate policies and institutional frameworks are put in place that recognize the role of the private sector, public-private partnership engagement in the forestry sector, mainstreaming of multilateral environment agreements into national plans and programmes, strengthening of nationally determined contributions (NDCs) in plans of work and budget, enhancement of global decisions on forestry and climate, among others. It is evident from this chapter that trees, forests, people and environment are intricately related through food chains, life support systems, maintenance of the hydrological cycle and provision of other environmental services. For example, forests are conserved as gene-pools that are sources of genetic materials for plant breeding programmes to improve food crops and produce herbal remedies and generic drugs. Forest biomes support flora and fauna that serve agronomic purposes, e.g. pollination.

It is in this context that Africa needs to invest more on the discussed opportunities, to take advantage of global decisions that address the causes of vulnerability to climate change for better environment and provision of livelihood sources. In this regard, Africa is required to undertake more activities on afforestation/reforestation, REDD+, Agriculture, Forestry and Other Land Uses (AFOLU) activities (forest management, agriculture management, bio-energy, wetland resource conservation, avoided deforestation and degradation, afforestation and reforestation) and forest-based NDCs, implement AFR100 in the framework of the Bonn Challenge. This will help to gain multiple benefits like sustainable land management, increased food production, GHG emission reduction and ecosystem resilience, for better environment and enhanced livelihood support. This will be catalyzed by investing in technology transfer, capacity building, better financing mechanisms, creating awareness and sensitization of different stakeholders. The countries that are member states to the U are currently aligning their climate change strategies to the UN Sustainable Development Goals (SDGs), with focus on Goal 13 that requires countries and the international community to take urgent action to combat climate change and its impacts.

In this goal, global targets include, but are not limited to: strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; integrating climate change measures into national policies, strategies and planning; improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning; implementing the commitment undertaken by developed-country parties to UNFCCC to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible; and promoting mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities (UNDP, 2018).

Overall, any change in the forest implies a change in the ecosystem and life-support services provided by forests and trees. It is obviously difficult to predict with accuracy what the climate will be at a specific location and time in the future. For that reason, it is advised that forest managers give greater weight to risk management measures and allow greater flexibility in adjusting forest management plans and practices. Likewise, in assessing adaptation options, forest managers may consider their relative contributions to climate change mitigation and choose management options that have synergistic adaptation and mitigation benefits. The challenge to understanding climate change effects is beyond getting updated information on the impacts of climatic factors on forests. It extends also to acquiring knowledge on the interaction between the different climate change factors. It is evident, for example, in most Africa, that there is no updated information on forest and tree resources because of lack of permanent sampling plots (PSPs) that are important not only in monitoring long term changes but also in dealing with uncertainties over projections about regional rainfall patterns and soil moisture among different forest types. This has resulted in Africa lacking adequate data for informed decision making. There exist clear gaps on data for plant phenology, forest structure and composition, growth and regeneration dynamics as well as productivity. In this, regard, Africa needs more information on the impacts on African forests and the complex relationships relating to climate change. The African forest sector needs effective monitoring and detection activities for action to face the changing or increasing climate change impacts. It is also necessary to determine some alternative practices to reduce vulnerability of forests by planting pest tolerant trees, drought and heat stress tolerant trees, identified through breeding programmes.

Biofuels feedstocks.
Photo: Idaho National Laboratory

Chapter 5: Production and use of biofuels in Sub-Saharan Africa

Labode Popoola, Bariki Kaale and Godwin Kowero

5.1 Introduction

The rising wave of interest to produce biofuels in Africa has been driven by a number of potential opportunities in their production, consumption and trade as reported in many studies including those by Akande and Olorunfemi (2009), Sielhorst *et al.* (2009), IIED, (2009), von Maltitz *et al.* (2009), Amigun *et al.* (2010), Deenanath *et al.* (2011), Mitchell (2011), Sekoai and Yoro (2016), IRENA (2017) and Fundira and Henley (2017). These include the following:

(a) Domestic production is believed to enable African countries to reduce their dependence on imported fossil fuels that have been characterized by periods of fluctuating prices, mainly due to global politics. Domestic production will then contain fuel shortages that occur in many countries due to high global oil prices and fluctuations in their supply, in addition to enabling national governments to maintain stable budgets during such periods and avoiding the need to shield its citizens from high prices of imported oil through subsidies on the same.

(b) Local production of biofuels holds considerable potential for rural development in many Sub-Saharan countries. Production is expected to create employment opportunities in growing feedstock crops, both agricultural and trees, and also in their harvesting, transport, processing and distribution of biofuels. The whole process will have to be supported by infrastructure like roads and transport facilities that will not be of use in biofuel production only but could also support the rural economy at large. Accompanying all the related activities will be incomes to rural people and tax incomes to national governments; the latter could further spur national economic development.

(c) Biofuel production could facilitate the diversification of African agriculture in terms of growing food crops with biofuel feedstock crops. It could also facilitate diversification of energy supplies on the continent (i.e. oil, gas, electricity, biothermal, solar, etc.). Both measures could then improve local livelihood opportunities and national economies, and possibly improve food and energy security.

(d) With rapid urbanization of the continent, high population growth, growing industrialization in some countries and good economic growth in many African countries, the demand for energy on the continent is expected to increase fairly rapidly. Energy is a key ingredient to economic development and growth. In this regard the continent will then have to import large quantities of oil and largely for its transport sector, given that about 42 African countries are net importers of fossil fuels. In an environment of declining global supplies of these traditional fuels at affordable prices and considerable environmental concerns on their production and consumption, reliance on biofuels that could be produced sustainably from renewable sources like agricultural crops and trees has since attracted attention of policy makers on the continent as reflected in various national strategies and the 2007 Addis Ababa Declaration on Sustainable Biofuels Development in Africa.

(e) Many landlocked African countries incur very high costs in transporting imported fuel to their countries, thereby raising the prices of diesel and petrol considerably higher than in coastal countries. This makes local production of biofuels attractive, especially if it can shoulder the bulk of the transport fuel demands.

(f) The belief that Africa has large tracts of unutilized land, some estimates putting it at over one billion hectares, which could be put under biofuel crops. Some key biofuel crops, like jatropha and cassava, could thrive on the marginal lands that constitute the bulk of this unutilsed land. This could then make Africa a big and strategic producer of biofuels.

(g) The growing concern about global warming induced by climate change and the need to contain it through approaches that reduce the emission of greenhouse gases is gaining momentum on the continent, given that most countries are now signatories to the Paris Agreement and have already formulated and are working on activities that will help them achieve their Nationally Determined Contributions (NDCs). Such measures include the promotion of production and use of renewable energy like biofuels. Given that this is a global agenda, African countries also expect to tap into global climate and renewable energy financing facilities to complement their own resources in developing their energy industry.

(h) There are already established methods for cultivating the crops that will be used as feedstocks in biofuel production, techniques for raising the potential trees for this industry, as well as transport facilities and networks for distributing the biofuels. These could facilitate production and distribution of biofuels in the initial stages pending improvements as scale and scope of production and trade expands.

(i) The global demand for biofuels is expected to rise rapidly up to 2020, largely led by the European Union (EU) and USA, whose requirements will continue to be met through imports. The EU policies require its countries to have 10% of their transport fuels obtained from renewable sources by 2020. Unlike USA, the EU grants Africa duty free access to its market with biofuels. This has provided Africa with a good incentive for large scale production of biofuels to export to this market.

These and other considerations contributed to putting renewable energy, including biofuels, high on the development agenda in Africa; though some of them have since changed, like the availability of a ready EU market.

The term biofuel has been used variously to mean any liquid fuel made from plant material that can be used as a substitute for petroleum-derived fuel (UNCTAD, 2008; FARA, 2010). The most commonly produced biofuel in Africa is bioethanol from sugar and starch crops like sugarcane, maize and cassava. Biodiesel is produced from various feedstocks, including those of edible and non-edible oils like palm oil, jatropha, soya beans, coconut, sunflower and castor beans. The bioethanol and biodiesel fuels already have well established technologies for raising the crops within the agricultural sector as well as the technology for the extraction of the fuels from the crops. However, because the sugar and starch crops and edible oil crops are also food crops, their diversion to biofuel production or the increased use of available cropland for production of biofuel feedstocks can adversely compete with food security.

Biofuels of food crop origin like sugars (sugarcane and sweet sorghum) and starch (like cassava and maize), i.e. bioethanol, or from vegetable oils and animal fats, are 'first generation' biofuels. The biofuels from non-food biomass (like wastes from wood harvesting and processing, and tree crops grown for such a purpose) are 'second generation' biofuels, and employ technologies like lignocellulose digestion, Fischer-Tropsch (gasification) and fast pyrolysis (von Maltitz *et al.*, 2009). Already many African countries have technologies for producing first generation biofuels and are blending these fuels with gasoline/petrol for use in transport.

When compared to other sources of energy, biofuels potentially offer some developmental advantages as already mentioned above. Nevertheless, there are concerns with respect to the viability of first generation of biofuels, including their environmental and socio-economic desirability as well as their sustained supply, in addition to their potential competition for cropland thereby impacting negatively on food security. Further, the production of biofuels requires land use activities that release greenhouse gases thereby casting doubt on the effectiveness of first generation biofuels in reducing carbon emissions.

The production of high quality second generation biofuels is more advanced in developed countries, and more specifically the USA, China, Canada, European Union countries and Brazil, in that order, in terms of installed capacity for cellulosic ethanol production (UNCTAD, 2016). However, for developing countries, and especially those in Africa, such production has not been a priority because access to basic energy supply, like electricity and clean cooking fuels, is more urgent than the supply of clean second generation transport fuels. However, the use of lignocellulosic biomass as feedstock for second generation biofuels could minimize competition for agricultural cropland and at the same time increase income opportunities for producers.

The interest in the biofuel industry in Africa could wane because in January 2018 the European Parliament voted to ban the use of palm oil for production of biofuel in EU by 2020, though the date has been extended to 2030 due to protests by major palm oil producers (Malaysia and Indonesia) (https://news.mongabay.com/2018/06/activists-blast-eu-for-extending-deadline-to-ban-palm-oil-in-biofuels/). The concern has been the potential impact biofuel production could have in terms of deforestation and forest degradation on tropical rain forests. Africa has also been eying this market whose window is shrinking, and there are considerable investments in African rain forest countries for palm oil production. Further, Brazil and USA, two other big global biofuel producers, have a price advantage over African biofuels further narrowing chances for African biofuel exports. This might also incentivise African countries to import from them.

This chapter does not seek to exhaustively examine the current state of and potential for production of liquid biofuels on the African continent. It seeks to increase awareness on this opportunity for increasing the use of some biofuels in developing green national economies, as well as to cultivate interest in critically examining the economic, employment and environmental opportunities that biofuels can bring to Africa. As such, it should serve as an introductory text that is mainly based on some preliminary results of on-going work by AFF and literature on the subject, and that more efforts should be made to understand how the sector could be better developed on the continent.

5.2 Scale of production and use of different biofuels in Sub-Sahara Africa

The production of biofuels in Sub-Saharan Africa (SSA) is still at its infancy in many countries, with a few having considerable investments and experience in the industry. The investors are of two types, namely small-scale growers and large-scale growers with big commercial plantations; and they are both in the private sector. The small-scale growers could, in some cases, link with the large-scale growers as out-growers. Other interested parties in biofuel at national level include the academia and research, NGOs, development partners, and national governments.

Examples of initiatives for producing biofuel feedstocks on a large scale

Millions of hectares (ha) of land have been allocated for biofuel production in many SSA countries, mainly through concessions for establishing large scale plantations and also through allocations made by small scale farmers. Some of these farms and plantations are still in production while in others production has either been scaled down or collapsed. This section gives some highlights on developments with respect to production of biofuel feedstocks.

Developments in Central Africa. About 80% of arable land is still uncultivated in the countries constituting the Economic Commission for Central African States (ECCAS), with more than 90% of this land in the Democratic Republic of Congo (DRC). ECCAS countries have a favourable climate, affordable labour and abundant land resources for production of biofuel crops. It is also important to note that all ECCAS countries are net food importers and promoting growing of biofuel crops should be conceived in this context.

In the DRC, there are Chinese companies with concessions close to 3 million ha of land allocated for biofuels, principally oil palm. They have yet to use all this vast land. There are other smaller investors as well. South African companies have access to large tracts of land for growing food crops that could also be suitable as biofuel feedstocks. In Cameroon, 200,000 ha of land have been allocated to BioPalm Energy of India for palm oil production. In the Republic of Congo, Atama Plantations SARL has a concession agreement for 470,000 ha of mostly forested land in the northern area of the country to develop at least 180,000 ha for oil palm, and this would be the largest oil palm plantation in the country (GRAIN, 2012).

Developments in East Africa. Uganda is one of the first African countries to pick up interest in biofuel (Xavier, 2007). A plan for large-scale production of agro-fuels was first unveiled in 2006 with the hope of overcoming energy deficiencies in the country. Since then, there has been a steady move towards increased biodiesel production, with the Government using incentives like tax holidays to woo foreign investors into the sector (MEMD, 2011; WWF, 2012). Farmers in several parts of Uganda started growing jatropha with enthusiasm. Records indicate that by 2010, Nexus Biodiesel Ltd., a private company, had planted over 400 ha of jatropha in the Isimba and Masindi areas in collaboration with over 2,000 registered out-growers. Also, the African Power Initiatives (API) had planted about 800 ha of castor oil and jatropha in Namalu and Karamoja areas by the end of 2010 (WWF, 2012).

In Tanzania, biofuel production has been carried out hoping that liquid biofuels could have a significant advantage for the Tanzania economy in terms of increased energy security, employment creation, environmental protection and opportunities for carbon trade (MEM, 2013). Increasing demand for biofuels in Europe encouraged some foreign investors to acquire large areas of land for production of biofuels. Action Aid Tanzania (2009) reported that by the end of 2008, around 435,000 ha of land had been acquired for biofuel production in the country, mainly by foreign investors (Table 1). Existing field experiences on biofuels development have shown that achievements attained so far do not meet, on a sustainable basis, the expected objectives of promoting biofuels in the country (EU, 2013; MEM, 2013). Major challenges have been lack of effective biofuel policy, legal instruments and low community awareness on biofuels production and utilization (MEM, 2015).

Developments in West Africa. In the Republic of Benin, the area of land used for biofuel production, as reported in Popoola *et al.* (2015), was 11,420 ha for bioethanol and 55 ha for biodiesel in 2013 (Table 2). The crops used for biofuel production in the country are: sugarcane, cassava and jatropha, though the country's biofuel policy supported production from four others: maize, soybean, oil palm and sorghum. Both biodiesel and bioethanol are used for electricity generation in Benin without any combination with fossil fuels. Details on the land area used for the cultivation of the crops and the previous uses of those lands that currently support biofuel production are presented in Table 2.

Table 1: Acquired land for liquid biofuel production in Tanzania.

Region	District	Investor	Land (ha)	Target crop
Coastal	Rufiji	SEKAB Tanzania Ltd	100,000	Sugar cane
	Rufiji	SYNERGY Tanzania Ltd	20,000	Sugar cane
	Rufiji	African Green Oil	30,000	Oil palm
		Subtotal	**150,000**	
		SEKAB Tanzania Ltd 22,000+(RAZARA & Bagamoyo Prison 500)	22,500	Sugar cane
	Bagamoyo	Bio-energy Tanzania Ltd	16,000	Jatropha
	Bagamoyo	Tanzania Biodiesel Plant Ltd	16,000	Oil palm
	Bagamoyo	Shanta Estates Ltd	14,500	Jatropha
	Bagamoyo	Clean Power Tanzania Ltd	3,500	Oil palm
	Bagamoyo	CMC Agric Bioenergy Tanzania	25,000	White sorghum
	Bagamoyo	KITOMONDO Ltd Tanzania	2,000	Jatropha
		Subtotal	**99,500**	
	Kisarawe	SunBiofuels Tanzania Ltd	9,000	Jatropha
	Kisarawe	CHAWAGWA	200	Jatropha
	Mkuranga	Mkuranga District Council	6	Jatropha
		Total	**258,706**	
Arusha	Arusha	Diligent Tanzania	10,000	Jatropha and Cotton
	Arusha	KAKUTE	3	
		Total	**10,003**	
	Kilwa	Biosphere Tanzania Ltd	80,000	Jatropha
Lindi	Lindi	BioMassive Tanzania Ltd (Sweden)	50,000	Jatropha
	Lindi	NESSTER	50	Jatropha
		Total	**130,050**	
Dodoma	Bahi	Biodiesel East Africa Ltd (Kenya)	10,000	Jatropha
	Kongwa	DONESTER	2,000	Jatropha
	Kongwa & Dodoma	SAVANNA Biofuels	5,000	Sunflower and Jatropha
		Total	**17,000**	
	Kigoma	FELISTER (Belgium)	10,000	Oil palm
Rukwa	Mpanda	PROKON Renewable Energy Ltd (Germany)	1,750	Jatropha
	Mpanda	Mpanda District Council	50	Jatropha
	Sumbawanga	Sumbawanga DED	50	Jatropha
		Total	**1,850**	
Morogoro	Mvomero	Info Energy Ltd (UK)	5,818	Jatropha
	Morogoro (Mikese)	ECO Green Fuels TZ Ltd	500	Jatropha
		Total	**6,318**	
Kilimanjaro	Moshi-Arushachini	KIKULETWA Farm Ltd (UK)	400	Jatropha
	Same	Same DED	50	Jatropha
		Total	**450**	
Mtwara	Mtwara	Fuel Stock (UK)	120	Jatropha
		Grand Total	**434,500**	

Source: Action Aid Tanzania (2009).

Table 2: Land area used for cultivation of biofuel crops and their previous uses.

Agro-ecological zone	Crop	Land area (ha)	Previous land uses
Sudano-Guinean	Cassava	5,420	Fields and fallows
Sudano-Guinean	Sugar cane	6,000	Forest and fallows
Sudano-Guinean	Jatropha	25	Fields and fallows
Guinean zone	Jatropha	30	Fields and fallows

Source: Field survey in 2013

In Ghana, a portion of uncultivated arable agricultural land has been dedicated to cultivating four potential energy crops (maize, cassava, oil palm and sweet sorghum) as reported in Popoola *et al.* (2015). Besides being the most cultivated bioenergy crops in terms of land area, Ghanaian farmers are familiar with their cultivation and the crops are also well suited to the climatic and soil conditions in the country. In 2010, c. 2,480 ha of land was dedicated to these four crops, with maize and cassava occupying about 75%. Table 3 presents information on the cultivation of jatropha in Ghana and its biofuel end-products.

Table 3: Cultivation of Jatropha in Ghana.

Institution	Crop	Area under cultivation (ha)	Product
Biodiesel 1 Ghana Ltd.	Jatropha	700	Biodiesel
ADRA/UNDP	Jatropha	800	Biodiesel
New Energy	Jatropha	6	Biodiesel
Gbimsi Women Group	Jatropha	4	Biodiesel
Anglo-Gold Ashanti Ltd.	Jatropha	20	Biodiesel
Valley View University	Jatropha	4	Biodiesel
BioFuel Africa Ltd.	Jatropha	23,672	Biodiesel
Scan Fuel AS	Jatropha	400,000	Biodiesel
Europian Union	Jatropha	500	Biodiesel
Sub-total		**425,706**	
Banket Ltd.	Cassava	1,180	Ethanol

Source: Field survey in 2013.

In Mali, there are two types of biofuels produced, namely the seed oil-based biofuel (i.e. biodiesel) primarily produced from jatropha in the region of Koulikoro, and the alcohol-based biofuel (i.e. ethanol), primarily produced from sugar cane by the sugar company SUKALA (Popoola *et al,* 2015). Vegetable oils from crops such as cotton and peanuts, have a high demand (and profit margins) in an unsatisfied local alimentary oil market, which makes them unsuitable feedstocks for biofuel. The country has been at the centre of development of jatropha oil as biofuel in West Africa. The jatropha plant was introduced in Mali for use as live fence, territory demarcation and for protection of land against erosion (Manalili *et al.,* 2006). Mali has more than 20,000 km of jatropha hedges that are geographically dispersed and with little or no maintenance (UNIDO, 2008). There are c. 2 to 15 km per village of such fences, which represent a production potential of 1.7 million litres of oil per annum. The yields are estimated at between 1 and 2 kg per lineal meter of fence. The hedge plantings increased significantly by 76% during the 2000-2007 period, from 17,000 km to 30,000 km. Based on a maximum estimate of 2 kg seeds per linear meter of hedges, the production potential increased by 34,000 tonnes to 60,000 tonnes during this period. The main zones with jatropha concentration are the regions of Kayes, Koulikoro and Sikasso (Boccanfuso *et al*., 2012).

In Nigeria, the major feedstock for production of liquid biofuels is jatropha (Popoola *et al.,* 2015). Land areas earmarked for this purpose are mostly marginal land, fallow and abandoned farmland. In fertile lands jatropha has been intercropped with other crops such as cassava (Plate 1). Considerable land is still available for biofuel production in the country.

Jatropha is used in the production of biodiesel which is currently being used to power some GSM provider's (particularly MTN) base stations across the country. In addition, and in very few instances, biofuels have been used in combination with fossil fuels (20% biofuel: 80% fossil fuel; 50% biofuel: 50% fossil fuel). There are also confirmed cases of biofuel usage for domestic cooking in the country (Plate 2). Solid wastes are used in the production of solid biofuels in the form of briquettes. Wastes are collected from farms, grazing locations, sawmills and abattoirs/kraals.

Plate 1: Jatropha intercropped with cassava and plantain, Eku, Delta State, Nigeria

Plate 2: Biofuel cooking stove in Ibadan and the extracted bio-fuel in Makurdi, Nigeria

FAO *et al*. (2011) reports several bioethanol projects in Nigeria based on sugarcane and cassava plantations. The sugarcane projects are being implemented in Kupto (Gombe State), Buruku and Agasha (both in Benue State). Cultivation is on a scale of land greater than 15,000-20,000 ha to produce 1.8 million tonnes of cane that can yield 75 million litres/y of ethanol. Out-grower schemes are of less than 1,000 ha (Osu, 2009). Two cassava projects are also located in Okeluse (Ondo State) and Ebenebe (Anambra State) with cultivation on a scale greater than 15,000 ha. The cassava production target is put at 3-4 million tonnes/y and can yield 40-60 million litres of ethanol. The Energy Commission of Nigeria (ECN), National Centre for Energy Research and Development (NCERD), Nsukka and the Sokoto Energy Research Centre (SERC) are among local institutions reported to have constructed bio-digesters in Nigeria.

Developments in Southern Africa. There is varied experience in biofuels among southern African countries, with some having blended fuel ethanol with gasoline since the early 1980s (Table 4).

Table 4. The state of biofuel mandates in selected Southern African countries.

Country	Existing target and status
Malawi	Mandate for E10 exists and met since 1982.
Mozambique	Mandate for E10 exists since 2012 but not enforced.
South Africa	Mandate for between E2 and E10 into force from October 2015 but not enforced.
Zambia	Target for E10 planned but not entered into force.
Zimbabwe	Mandate for E10 exists (enforced since October 2013), planned targets for E15/E20.

Source: Fundira and Henley (2017). *(This table is published here with acknowledgement of UNU-WIDER, Helsinki, which commissioned the original research and holds copyright thereon).*

South Africa has a small biofuel industry whose development is guided by the 2007 National Biofuels Industrial Strategy that requires that 2% of total road transport pool uses biofuel. Mukonza and Nhamo (2016) report that the consumption of biodiesel in South Africa could be around 100 million litres by 2020 which will be less than the targeted 2% capacity for domestic biodiesel production. A few policies and regulatory frameworks related to energy continue to shape the evolution of the biofuel industry in the country, in the absence of a concrete policy on biofuel. However, given the need to safeguard food security in the country a Biofuels Feedstock Protocol has been established to guide production of biofuel crops versus food crops, as well as how idle land can be used for commercial and small-scale biofuel feedstock production. Use of maize and potatoes as biofuel feedstocks is prohibited (Fundira and Henley, 2017).

Zambia has had some long experience with biofuels (Table 5), with a mixture of small scale farmers and big companies involved in their production which has seen bioethanol production as the main liquid biofuel as compared to biodiesel. Fundira and Henley (2017) report that the production of large scale commercial biofuels in Zambia started in the early 2000s involving six major firms and the main crop being jatropha, that was also planted by small scale farmers on out-grower schemes. In some cases, the small-scale farmers are in out-growers to the larger industrial plantation companies (von Maltitz, et al, 2009). The production and consumption of bioethanol has grown steadily from 2000 to 2016. In 2008, a National Energy Policy was established setting national standards for biofuels; e.g., in 2011 blending ratios were established as 5% for biodiesel and 10% for bioethanol.

Compared to Zambia, Mozambique has more recent experiences with biofuel production. In 2009, Mozambique put in place a National Policy and Strategy for Biofuels. The policy sets out conditions that will limit damage to biodiversity. The government has also put in place measures to safeguard food security in production of biofuels. However, before this policy and strategy was enacted plantations of jatropha were established following political and investor interests in biofuel, and without regard to key things like seed quality, agronomic practices, production systems and markets; and in addition, also guided by the belief that jatropha could thrive on marginal lands and without inputs like fertilisers (Schut *et al.*, 2010). Sugarcane and sweet sorghum were also seen as suitable biofuel feedstocks. In 2017, the government declared that "it is not viable to use biodiesel now, because the cost of production is more than the price of conventional fuels," according to Admiral Dima, national deputy director of hydrocarbons and energy at the Ministry of Mineral Resources and Energy (http://clubofmozambique.com/news/govt-says-production-of-biodiesel-from-jatropha-has-become-impracticable-mozambique/.

Table 5. Biofuel production and consumption in Zambia ('000 barrels/day).

Year	Biodiesel Consumption	Fuel Ethanol Consumption	Fuel Ethanol Production	Total Biofuels Consumption	Biodiesel Production
2000		108	106	108	
2001	0.7	114	115	115	0.6
2002	1.1	135	140	136	0.7
2003	0.9	184	183	185	0.9
2004	1.7	231	221	233	1.8
2005	5.9	265	255	271	5.9
2006	17	358	319	375	16
2007	23	449	425	472	32
2008	21	630	606	651	44
2009	22	713	711	735	35
2010	20	817	851	837	25
2011	57	824	894	881	62
2012	68	880	898	948	71
2013	121	898	909	1,019	97
2014	120	913	973	1,033	92
2015	105	936	993	1,041	92
2016	84	920	977	1,003	104

Source: International Energy Data, Monthly Update. Last updated: Tuesday, 05 June 2018
http://zambia.opendataforafrica.org/nhbrxod/biofuels-production-and-consumption

For SADC, Stiles and Murove (2015) report that Malawi, South Africa and Zimbabwe have more experiences in producing ethanol from molasses and sugar cane and are on an upward trend in such production. Angola, Mozambique, Zambia and Tanzania have smaller sugar companies but are also on an upward trend in producing ethanol. The production of biodiesel developed more slowly in SADC countries because it took some time for big investors to acquire land and grow jatropha for its production. Since many of these plantations were not based on sound scientific information to guide their field production (e.g. soil, pests/diseases and weather) as well as lack of feedstock processing and distribution infrastructure, many of these investments have failed, with some investors withdrawing from biofuel production. There are efforts to reinvigorate the biodiesel industry in the region. For example, in 2014, the Copperbelt Energy Corporation of Zambia indicated that it had built a plant in Kitwe that could produce one million litres per day. Additionally, Madagascar, Malawi and Mozambique have considerable jatropha plantations for biodiesel production (ibid).

Small scale production of biofuels

There are many opportunities for small scale actors in biofuel production, processing, storage and distribution; activities that characterize the supply chain (IIED, 2009). At the production level, small-scale growers are of two types. First, there are those that produce at village or farm level to meet local demands. von Maltitz *et al.* (2009) gives examples of such producers in different countries, including Mali (e.g. Mali Folkecenter project), Ghana (e.g. Dumpong Biofuels), Mozambique, Tanzania, and Zambia; and that they have had the support of NGOs, national governments and international development partners in production.

The second type is comprised of small-scale out-growers that sell their feedstock directly to large commercial plantation companies or sell feedstock directly to commercial biofuel processing plants (ibid). These then supply national and international biofuel markets. In this case farmers derive incomes from sales of biofuel feedstocks. As practiced in other out-grower schemes, those for biofuel production could be supported with technical advice, inputs, financing, market access and other supportive infrastructure. All these incentivise farmers to put more effort on biofuel crops. Also, the sharing of costs and benefits with the commercial farmers has to be worked out amicably. Further, the extent to which the small-scale farmers shift resources (land, capital and labour) away from production of food crops to growing biofuel crops needs monitoring, in addition to timely provision of agricultural extension expert advice that will guide the production of both crops in ways that could lead to food security. By involving many small-scale farmers in biofuel production within this context, the biofuel industry will broaden their income sources and increase their food security as well as contribute to lifting them out of poverty.

5.3 Potential for increased biofuel production

Many countries in SSA have favourable climate, affordable labour and abundant land resources for growing biofuel crops. However, there is no comprehensive information on the actual state of the biofuel industry on the continent and on its future; there exists some limited country specific information on this. Efforts to examine the industry on a sub-regional or at continental levels are largely based on studies made in a few countries. This notwithstanding, some of this work raises hopes that the continent has good potential for production of biofuels and to also significantly increase its energy security. IRINA (2017) in a study that covered Ghana, Mozambique, Nigeria, South Africa and Uganda, notes that the biomass biofuel feedstock identified for these countries, if developed properly, could fully meet the needs of the transport sector in these countries by 2050.

This section will give a few country specific highlights on existing potentials for biofuel production, with the expectation that this will somehow resonate with the enthusiasm that has emerged on the continent about this industry. Also, it will identify some aspects to consider in developing this industry.

Improvements on what is already available

According to Amigun *et al.* (2010), ethanol appears to be the most promising biofuel that can be produced by many SSA countries because it can be produced from a wider range of feedstocks compared with biodiesel, given that many countries grow sugar and starch rich crops. Many countries already produce ethanol from molasses, sugarcane, cassava, cashew nuts, sorghum, maize and wheat. Biodiesel feedstocks include oil rich seeds like those from jatropha, oil palm and soya. All these crops are present in Africa, and the crop husbandry knowledge and practices are already with African farmers. In addition, there are institutions, policy and regulatory frameworks that support them. Further, these crops thrive well in the African tropics.

In the ECCAS countries, about 80% of arable land is still uncultivated. Much as the region is seen as potential for large scale oil palm plantations, it is also a region that can produce, with good plans, considerable biofuel feedstock from sugarcane. Table 6 illustrates this potential.

Table 6. Sugar production in some ECCAS countries ('000 mt) and potential bioethanol production ('000 litres) from low grade molasses.

Countries	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cameroon	115	120	125	115	100	110	125	130	120	120
Bioethanol	45,326	47,160	49,125	45,326	39,300	43,230	49,125	51,090	47,160	47,160
Rep. Congo	55	58	64	62	65	60	72	72	75	70
Bioethanol	21,615	22,794	25,152	24,366	26,331	23,580	28,296	28,296	29,475	27,510
DRC	70	75	75	75	75	75	70	85	75	80
Bioethanol	27,510	29,475	29,475	29,475	29,475	29,475	27,510	33,405	29,475	31,440

Source: Field survey in 2013

Also, agricultural and forestry residues form a readily available source of biomass and can provide feedstock from current harvesting activities without need for additional land. In the ECCAS countries, the transportation sector accounts for substantial energy-related CO_2 emissions and oil consumption (IEA, 2008). In this context increased consumption of biofuels in the transport sector could appreciably contribute to reducing CO_2 emissions.

The sugar industries in eastern Africa have shown a strong desire to produce ethanol from molasses. This could also create a market for excess molasses produced as the industry grows, hence providing financial incentive for sugar companies to increase sugar production and possibly improve food security, if planned properly. WWF (2012) reports that the estimated cost to produce ethanol from molasses is one of the lowest for current ethanol feedstocks cultivated in the eastern Africa region. Therefore, choice of this feedstock could lead to an ethanol industry that has a better chance of being less dependent on incentives to survive.

The most commonly used feedstocks in eastern Africa for ethanol production are molasses from sugarcane production and sweet sorghum stalks. For biodiesel, the commonly used feed stocks are castor, croton and jatropha. Field evaluations indicate that arable land suitable for agricultural food crops and forests have been allocated for production of biofuel feedstock crops and not marginal land as initially emphasized by most national energy policies and promoters of biofuel. Like agricultural crops, each biofuel feedstock has its own unique preference to agro-ecological zones. Research to find suitable biofuel crops for different agro-ecological zones has taken place in Kenya and Ethiopia, and is also on-going in other countries, aiming to initiate agro-ecological zoning for crops to be grown as liquid biofuel feedstocks.

In the West African sub-region, there are a few policies that guide biofuel production. For example, in Benin, there is a national policy supporting the production of biofuels. The crops earmarked for biofuel production in the national policy are maize, sugar cane, soybean, oil palm, cassava, sorghum and jatropha. The country's decision-makers are also aware of the production of biofuels from biomass (crops and ligno-cellulosic sources). There are no policies that constrain the production of biofuels in the country or in specific locations. Plans for the development of a biofuel industry in Benin have strong backing of the national government, and biofuel plans make up a key part of the government's Agricultural Revival Programme for economic development. Sugarcane is already used by industries to produce alcohol, and small-scale farmers already contribute to the production of some biofuels from their various household crops like cassava, cotton seed and peanut. These are integrated with current food production systems. The Benin government plans to scale up from household and small-scale production, to a large-scale biofuel production based on these and other crops, in order to facilitate entry into the international biofuels market.

In Ghana, there is optimism about increased demand of biofuels in the future and increased investments from New Energy, new companies and the national government. The national bioenergy policy aims to substitute national petroleum fuels consumption with 10% biofuel by 2020 and with 20% by 2030. The policy intends to make use of the country's vast biomass potential and resources for the production of transport fuels and electricity (Kemausuor *et al*., 2013). Biomass already dominates the energy consumption pattern in Ghana, accounting for over 63% of total energy consumed (Kemausuor *et al*., 2016) but used principally in traditional cook stoves as fuel-wood and charcoal. Liquid biofuel use is not commercialized in the country but there are plans for it as soon as the infrastructure is in place (ibid). Plans for biodiesel production are at a more advanced stage as opposed to those for ethanol production.

In Nigeria, the land available is presently not fully utilized. Potential agricultural land is about 72 million ha, of which a large portion has not been put to use. The implication is that the country has a high potential for agricultural production, and with considerable land which can be put under biofuel feedstock production. Although the biofuel industry is still at its infancy in the country, policy guidelines are available at the Nigeria National Petroleum Company (NNPC) for the development of the industry; with only a few ground-breaking achievements recorded. In 2007, the Kaduna State Government set up a pilot plant for bioethanol production with the aim of demonstrating the technology and viability of the biofuel production using local design and materials. In Ahmadu Bello University, a pilot plant for biodiesel production has also been set up. Efforts elsewhere in the country are also commendable as there are several initiatives towards some bench scale productions of bioethanol and biodiesel from a few feedstocks.

In Senegal, a wide range of biofuel feedstocks already exists in the country (UNEP, 2013). However, it appears that jatropha and molasses from sugarcane have been singled out as the prime feedstock candidates to fuel the biodiesel and bioethanol industries. Jatropha is an attractive biodiesel feedstock for the same reasons it is in other countries that are seeking to develop biodiesel production. Jatropha is expected to provide Senegal with more energy security, especially for individuals in rural areas that are off the centralized energy grid (ENDA, 2007). In 2007, the Senegalese ministry responsible for agriculture initiated a special biofuels programme 'New orientation for the Agriculture Sector Policy, REVA Plan', with the main objective being to ensure self-sufficiency in biodiesel (ibid).

Policy and regulatory frameworks

In many countries guidance on biofuel production is provided in broader national energy policies. At present, several African countries are putting in place policies and regulatory frameworks to guide the production, processing and trade in biofuels. These are still at their infancy in conception and development. This notwithstanding, given the opportunities that were initially seen in this industry, and especially available and accessible export markets for biofuels to EU, many investors have gone ahead to acquire considerable land for growing feedstock crops and this has resulted in various levels of success and failure in growing the industry. In fact, Thornbill *et al.* (2016) notes that there has been a high rate of failure of biofuel projects on the continent. Poor performance of the biofuel industry in some countries could be attributed to at least the following:

- Some biofuel crops have performed poorly in the field compared to expectations, killing their economic viability, especially when there was no advance research done with regard to their suitability to the ecological zones and weather patterns they were targeted to, in addition to other good crop husbandry considerations.
- In some countries, these crops were established without adequate policies and regulatory frameworks and incentives for the private sector to establish industrial processing facilities, the distribution and marketing of biofuels. Hence, when the crops matured there were no markets for them, a considerable loss and disincentive to some farmers for further production.
- Prevailing subsidies, in some countries, on imported fuel undermined the competitiveness of locally produced biofuels.
- In many countries, issues related to production of feedstock crops, their processing, marketing and trade in biofuels pertain to different central government departments and ministries, and mechanisms to effectively coordinate these issues across ministries in order to develop a viable and holistic biofuel industry are largely lacking,
- When it comes to energy, many African countries prioritise electricity more than any other fuel, including fuelwood that is consumed by the majority of the people in SSA. Hence, biofuel only appears at the tail end of energy priorities and consequently without much consideration to policies, regulatory frameworks, technical expertise, access to finance for investment and incentives for their production.

Since some of the biofuel feedstock crops were relatively new, some national governments initially took various measures to encourage or facilitate the acquiring of land for investors in their cultivation, and incentives for their marketing and local consumption. These included policy and regulatory frameworks on provision of subsidies on biofuels, making it mandatory for some sectors to use biofuel, and guidance or standards on blended fuels (Sekoai and Yoyo, 2016; Fundira and Henley, 2017).

The development of biofuels touch on sensitive sectors of national economies like land, food and water, all with potential social, economic and environmental impacts. As such, the development of policies and regulatory frameworks to guide the development of the biofuel industry in such a complex and dynamic environment, and addressing the needs and roles of various stakeholders, is very challenging (Amigun *et al.,* 2010). This notwithstanding, some countries continue to refine their energy policies to better address biofuels, among other things, while some are developing policies and strategies specific to biofuels. The choice of the path to follow had better be left to the discretion of individual countries given the potential and role biofuels could play in their economies and other country specific attributes.

At the sub-regional level, the situation is the same as at national level, in that biofuel production is part of broader energy policies, but then some clear guidance is given in some of these policies. For example, the ECOWAS Renewable Energy Policy (ECOWAS, 2015), while noting that the attitude towards biofuels in the region has been a cautious one in the sense that production is driven by national demands, it however provides some guidance on how the region could proceed, including the following:

- By 2020, ethanol shall constitute 5% of ECOWAS petrol consumption and this level should rise to 15% by 2030. The estimated corresponding reduction in CO_2 emissions should be 5% (2020) and 10% (2030) for light traffic.
- By 2020, biodiesel shall constitute 5% of ECOWAS diesel oil consumption and this should rise to 10% in 2030.
- Introduce blending ratios for ethanol and biodiesel in transport fuels of 5% 2020 and 10% 2030.
- Reduce importation of gasoline by 5% in 2020 and by10% in 2030.

The SADC region has developed a “SADC Framework for Sustainable Biofuels” that provides the region with guidelines for development of biofuels. The specific guiding principles seek to ensure that in the production of biofuels at least the following should be taken into account: national food security, formal and customary land and land use rights, national energy security, natural resources and ecosystem services, deforestation and forest degradation, climate change adaptation/mitigation including reduction of greenhouse gases, availability of quality water and air, and the specific attributes of agro-ecological zones for production (SADC, 2009).

At the pan-African level, the African Union, as reflected in the 2007 Addis Ababa Declaration on Sustainable Biofuels Development in Africa, has endorsed the production of biofuels on the continent as part of a sustainable energy strategy for Africa. It has emphasized the development of policy and regulatory frameworks to guide the development of the biofuel industry which it feels could contribute to poverty eradication on the continent, strengthening national economies and diversifying farmers' production options thereby minimizing their risks. It empahsises that individual countries should develop their national policies and strategies based on their natural resources, land tenure conditions and socio-economic requirements.

The foregoing paints a picture of available political will and national governments action as reflected in some guidelines that encourage biofuel production and consumption on the continent at all levels. However, clear policy guidance and strategies to grow and develop the biofuel industry are lacking at national, sub-regional and regional (continent) levels. This situation needs to be addressed urgently given the dynamism that characterizes various parameters in this industry, such as global fuel prices, global political environment, weather and technology, to mention a few.

Further, the agricultural sector is performing very poorly in many countries on the continent, largely due to inadequate investments to improve crop production and productivity, limited interest in farming by the youth who comprise almost two thirds of the African population, weak value added to primary production, vagaries of weather as most production is rain-fed, weak political action though there is strong expressed political will, among other factors. This is the sector which is the domain of most first-generation biofuel feedstock crops. Unless this situation changes, there will be limited scope for small farmers to produce food more than subsistence requirements, and therefore benefit much in participating in the biofuel industry. The growth of the biofuel industry will most likely depend more on medium to large scale farmers and individual companies that can grow these feedstock crops on a commercial basis. Some small-scale farmers could participate more effectively in out-grower schemes with individual companies and/or with bigger farmers.

5.4 Biofuels production and greenhouse gases

The production of biofuels may lead to adverse effects on the environment, including the destruction of forest and grass cover, biodiversity and ecosystem services potential, altering structure and fertility of soils, in addition to diverting land from food crop production. Also, some biofuel crops might require large quantities of water and also fertilisers and pesticides (Sekoai and Yoyo, 2016).

Until recently, it was believed that replacement of fossil fuels with biofuels would have significant and positive effects on climate change through less emission of the greenhouse gases that contribute to global warming. For example, FAO (2008) reports that sustainably sourced biofuels are believed to be carbon neutral and can contribute to climate change mitigation by replacing fossil fuels. However, this will depend on a number of things including:

- the type of crops grown as biofuel feedstocks,
- the emissions realized in clearing land for cultivation of biofuel crops,
- emissions realized when harvesting, transporting and processing feedstocks into biofuel, and,
- the efficiency with which the biofuels are used.

Bioenergy crops can reduce or offset greenhouse gas emissions by directly removing CO2 from the air and storing it in the crop and soil. However, greenhouse gases will be emitted by direct or indirect land-use changes triggered by increased biofuels production. Carbon stored in forests or grasslands is released from the soil during land conversion to feedstock crop production. For example, maize produced for ethanol can generate greenhouse gas savings of about 1.8 tonnes of carbon dioxide per ha and year, and switchgrass can generate savings of 8.6 tonnes per ha and year. However, the conversion of grassland to produce those crops can release 300 tonnes/ha, and conversion of forest land can release 600-1,000 tonnes/ha (Fargione *et al.*, 2008; The Royal Society, 2008; Searchinger, 2009). Amigun *et al.* (2010) notes that biofuels might emit more GHGs than they save. These are issues to be considered carefully in planning and implementing biofuel production and consumption.

Sekoai and Yoyo (2016) report that there are several studies that have made use of Life Cycle Analysis (LCA) as a tool that could assess the environmental impact of biofuels by evaluating the consumption and impacts of a product throughout its life cycle. It is very desirable to harmonize the different approaches employed in this regard, i.e. life-cycle analysis, greenhouse gas balances and sustainability criteria.

The ratio of the energy released by burning biofuel to the energy used in the various activities from the cultivation of the feedstock crops to their processing, and distribution to the point of consumption is known as the biofuel energy balance. These balances are not positive for all feedstocks (Bullis, 2011; Ravindranath *et al*., 2009), meaning that feedstock crops for biofuel production should be the ones with the highest positive balances, while also being associated with the lowest possible environmental and social impacts. Conventional petrol and diesel have energy balances around 0.8–0.9. The implication is that the production and consumption of a biofuel whose energy balance exceeds these numbers, would contribute to reducing dependence on fossil fuels. Estimated energy balances for biodiesel range from around 1 to 4 for rapeseed and soybean feedstocks. Estimated energy balances for oil palm are higher, at about 9; and for crop-based ethanol the energy balances using maize are from less than 2 and for sugar cane in the range 2 to 8. The range of estimated energy balances for cellulosic feedstocks is even wider, reflecting the uncertainty regarding this technology and the diversity of potential feedstocks and production systems (EU, 2013; IEA, 2013).

Optimizing the biomass fuels value chain could also provide opportunities for synergies with on-going and/or emerging climate change programmes like REDD+ that could provide rural communities with financial incentives for rehabilitation and sustainable management of degraded forests and wetlands. Positive contribution of biofuel production in terms of reduction of greenhouse gasses is possible through modern production and efficient utilization of biomass, by changing from traditional biomass utilization technologies to modern bioenergy technology. The modern bioenergy is normally distinguished from traditional biomass on the basis of higher efficiency in conversion and a higher quality of delivered energy services (FAO, 2010; ENR-CSOs, 2013). Growing trees, shrubs or grasses on degraded land can reverse damage to soils and provide a valuable bioenergy resource.

As a proportion of the total energy demand on the continent, biofuels are not significant. However, they can command significant attention when their production competes with food crops on the same land and therefore jeopardise food security. The extent of such impacts depends on how biofuel feedstocks are produced and processed, the scale of production and, in particular, how they influence land-use change and intensification in production and trade (IEA, 2013; UNCTAD, 2016).

In general, most recent biofuel developments also target reduction of greenhouse gas emissions through reducing energy use and switching to cleaner energy sources. There are opportunities to less carbon-intensive fuels on both the demand and the supply sides. Demand side fuel-switching strategies to reduce carbon emissions include the use of biofuels to supply residential, industrial and transport sectors. Many African countries have demonstrated interest in renewable energy, green economy and are signatories to the Paris Agreement. They are already implementing their first NDCs. All these are clear demonstrations of political will and action to reduce green house emissions as part of national sustainable development.

5.5 Biofuels production, deforestation, food security and gender considerations

The production of biofuels, food and forest products often competes for land, in many cases with resulting negative impacts like deforestation and food insecurity (MARGE and African Solar Design, 2013). It is very important for the continent, and specifically individual countries, to understand and provide guidance on how land shifts among these three products, so that the production of either does not jeopardise the sustainable production of the others, since the three are critical to socio-economic development and environmental stability at all levels.

Biofuels and food security

There have been considerable discussions on the impacts production of biofuels crops could have on food security, creating mixed opinions on the direction of impacts. For example, Amigun *et al.* (2010) reports that there is evidence that increased biofuel demand between 2000 and 2007 lead to an increase in weighed grain price by about 30% during this period. Further, the 20% increase in price of vegetable oil in 2014 is attributed to biofuel blending in USA, EU and Canada (ibid). However, Thornhill *et al.* (2016) observes that the bulk of biofuel production is from feedstock crops grown in mainly food secure countries and regions like USA, EC and Brazil and relatively food secure ones like Malaysia, Thailand and Argentina. Further, there is no conclusive evidence of impacts on food insecure households like those in Africa where there has not been much biofuel production and consumption. Hence, macro-level studies on impacts of biofuel production on food security have mainly been undertaken in these food secure developed countries and less so in developing countries that are currently food insecure. The expectation has been that the findings would also be applicable to the food insecure developing countries. Also, Thornhill *et al.*

(2016) notes that over the last decade only a few new biofuel operations were started in Africa compared with the many start-ups that were witnessed from about 2005, and further few have planted crops as biofuel feedstock. They note that the displacement of efforts from growing food crops in preference to biofuel feedstock crops has been relatively small in Africa.

There appears therefore a need to conduct comprehensive micro-level studies in developing countries, not only to establish the impact of biofuels on food security, but also their impact on greenhouse gas emissions, the shifting of land allocated between production of biofuel crops and food crops, in addition to identification of appropriate agro-ecological and other conditions for growing some of the feedstock crops.

However, there are few micro-level studies in most countries on these aspects of biofuels. For example, in Mali, a review of four small jatropha producers' projects and ventures showed that the impacts of these programmes on land tenure and food security are nonexistent, albeit in the medium term (Palliere and Fauveaud, 2009). In all the initiatives, land ownership remains with small jatropha farmers, who normally cultivate less than a hectare (many times in an intercropped fashion). However, jatropha adoption has been fairly slow due to the land delimiting character of jatropha, i.e. internal land claims that need to be solved before planting and this limits the number of adopters.

In Niger, the cultivation of food crops with potential for ethanol production is noted to be far below the nation's demand for food at present. Hence, there appears to be considerable competition between utilization of agricultural crops for biofuel and food, with the food production option gaining an upper hand.

In Nigeria, land area currently under full biodiesel production is small. Over 33 million ha are currently used for food crop production. It appears that no appreciable land is shifting between biofuel and food crop production. However, it has been observed that cassava expansion for biofuel production would likely occur on natural vegetation areas, mainly forests recovering from agricultural overuse (Abila, 2011). If this is done, there would be further threat to biodiversity in such areas since it is unlikely that pasture land would be used for cassava, based on low soil fertility and compatibility issues. Ohimain (2010) observed that an increased interest in crop production for ethanol purposes is likely to shift cultivation away from maize, rice and yams and therefore increase food insecurity in the long-run.

In eastern Africa, the general opinion of policy makers is that agricultural crops that are used for food should not be used for production of liquid biofuels. Policy statements in most of the countries of the region identify areas that have to be completely excluded from any large-scale biofuel expansion, including areas of high conservation values, global and national endemic species habitats, biodiversity hotspots, remaining woodland and forest stands, wetlands and key water catchment areas. Expansion in such areas needs to be banned, otherwise eastern African functioning but fragile ecosystems will not support future development (Republic of Kenya, 2012; MARGE and African Solar Design, 2013; MEM, 2013). While growing crops for biofuel feedstock, if well planned, could generate income opportunities for smallholder farmers, the potential risks and rewards must be carefully assessed, and technical feasibility assured before smallholders are encouraged to engage in the biofuel sector (Mgonja *et al*., 2011).

In South Africa, a Biofuels Feedstock Protocol addresses food security concerns by ensuring that the production of biofuel feedstock is not at the expense of food production. Further, it is prohibited to produce biofuel from maize and potatoes (Fundira and Henley, 2017).

Several countries in Africa have already put in place measures to safeguard food security when growing biofuel feedstock crops. For example, the framework developed by SADC countries on sustainable biofuel production and consumption (SADC, 2009) emphasises that the production of biofuels should contribute positively to food security.

Farmers who integrate production of biofuel feedstock with food crops could realise income from sale of the feedstock and increase household food security through purchase of food that is not adequately supplied on their farms. Also, potential good markets for biofuel feedstocks can be an incentive for rural people not currently engaged in farming, like youth, to cultivate these crops and therefore increase household food security. If the prices of feedstocks increase, farmers might be tempted to allocate more land and other inputs to growing biofuel feedstock crops and less to food crops, thus jeopardising food security. This has happened in the past in Africa when agricultural policies put more emphasis on cash crops for exports and less on those for subsistence, and food shortages surfaced.

As habitat loss and degradation are major threats to biodiversity in large-scale biofuels production, direct conversion of natural ecosystems and indirect land-use change to accommodate biofuel production are likely to be detrimental to food production and the environment. However, biofuel plantations on marginal or degraded lands could have positive effects on food production and in restoring such lands. Attention should also be directed at the off-farm impacts of biofuel feedstock plantations that can include, depending on the management regime, reduced water availability, soil erosion, and the spread of invasive species.

The foregoing notwithstanding, the impacts of growing biofuel feedstock crops on food security will largely depend on the existing agricultural and energy policies, the type of crops that are planted, biofuel infrastructure in individual countries, how individual countries plan to meet their liquid energy requirements (especially for the transport sector), availability of good ecological and weather conditions for growing the crops, availability of facilities for value addition on biofuel feedstock crops, and markets for biofuels, among others.

Deforestation, land tenure and gender aspects

Large scale/commercial production of biofuels on the continent has witnessed a wave of land either excised from forests and woodlands or acquired from local communities. This has led to "land grabbing" accusations by many parties, including environmental NGOs. Section 2 of this chapter has some examples on the magnitudes of land that has been made available to investors for biofuel production. However, what is lacking on the continent, and in many countries, is a comprehensive evaluation of the extent of forest clearing that has accompanied the growing of biofuel crops both at commercial (large scale) and small-scale farm levels.

For example, much of the discussion on the biodiversity impacts of biofuel production in the ECCAS countries revolves around the direct impacts of land conversion in rain forest, where natural ecosystems are replaced by biofuel feedstock plantations. The ECCAS countries contain the second largest expanse of tropical rain forest in the world, covering close to 200 million ha spanning six countries. These forests support the livelihoods of about 60 million people, generate income from timber exploitation, store huge amounts of carbon, comprise a unique biodiversity and regulate the flow of the major rivers across Central Africa. From the world's largest swamps, to the mountainous regions in Cameroon and eastern DRC, these diverse ecosystems support the people and wildlife found in the very heart of Africa. The ecological, biological, and climatic importance of this area is well known, and land grabbing for the development of first-generation biofuels could be harmful to the sustainability of these rich and unique biodiversity, if not planned and carried out properly. This notwithstanding, the availability of large agricultural space for food crops and for biofuels in ECCAS countries, second-generation biofuels that do not generate conflicts for land and food could also be explored for their production in this region.

Further, Africa should avoid expansion of biofuel production into wetlands. African wetlands store more that 50% of the world's fresh water supplies (Sielhorst *et al.*, 2009). Crops such as sugar cane and oil palms thrive well in wetlands and their cultivation will not only result in clearing the wetlands but will also increase sedimentation in the remaining wetlands.

Similarly, there are a lot of concerns around the trade-offs between biofuels production, food production and primary forest production in the West African sub-region. For example, in Ghana, food production currently does not meet the high demand for it, especially in the populous urban areas, and this makes food imports inevitable. The food supply emergencies and the accompanying high food prices in the country are predicted to worsen if there are big biofuel investments and consequent outsourcing of large land areas (Action Aid-Ghana, 2009). The land tenure system in Ghana does not encourage the production of jatropha or other crops for biofuel production on a large scale. Although farmers generally perceive the initiative as a potential means to reduce poverty and improve their livelihoods, they also express fears and see challenges which go beyond land tenure/right issues. Given that jatropha is a perennial crop, the traditional means of land acquisition would appear not favourable for its cultivation. As a result, farmers who are willing to cultivate the crop but who also do not have enough land are hesitant to do so. Nevertheless, New Energy, a Ghanian company founded in 1994 that, among other things, deals with renewable energy and local community issues, has initiated a legal agreement system of subletting land, which allows the jatropha farmers to maintain the plot for several years in order to ensure that they receive maximum benefit from the crop.

Generally, adoption of new technologies to increase land productivity per unit area and improve utilization efficiency of agricultural and forest products could provide win-win opportunities for decreasing land shifts between production of biofuel, food and fibre. This requires that all land stakeholders are well informed of existing land-use technologies and the efficient use of products from such land (ECA, 2012; GIZ, 2011; MWE, 2012; World Bank, 2009&2011).

To meet the increasing demand for extensive land areas for investing in biofuels, there is need to improve the land administration systems on the continent to deal with conflicting claims between different vested interests and the traditional land uses and ownership rights that are emerging under biofuels expansion (Campbell and Doswald, 2009; EU, 2013). There is need to ensure that changes and production practices associated with biofuel production are sustainable (Oxfam, 2008; UNEP, 2009). Responsible land allocation, land-use change, and proper policy guidance could minimize competition over land, and therefore increase food security and contain encroachment on protected and communal areas (Laura *et al*., 2012; Schoneveid, 2013; Sunderland *et al*., 2013).

Further, women produce the bulk of household food in SSA countries. With the exception of large scale commercial plantation crops like jatropha, oil palm and sugarcane, some biofuel feedstocks like maize, cassava, several other oil seed crops are mainly cultivated by women. Adding the biofuel feedstock their agenda might increase the incomes they receive, in addition to diversifying their income sources. The question is then how women can benefit from this nascent biofuel industry, and especially when they operate individually and on a small scale. They face a number of problems, including lack of capital to invest in biofuel feedstock farming, limited access to land, support from agricultural extension experts, and access to markets, to mention a few.

5.6 Looking at the future: factors that will shape the biofuel industry

The preceding sections touch on many factors that could shape the future of the biofuel industry in SSA, and at sub-regional or regional levels. Apart from formulating and implementing appropriate policies and regulatory frameworks, also resolutions of land tenure issues that constrain availability of land, availability of investment for large scale farmers and small-scale entrepreneurs and investors in value addition and marketing, and availability of knowledge on crop husbandry are required. Fluctuations in global prices of fossil fuels are also very important. For example, in the case of sugar cane as a feed stock for biofuel, such price fluctuations could shift its use in biofuels production to its processing into sugar and vice versa, depending on what product is more profitable. Global fossil fuel prices have been fluctuating over the years (Fig.1) and are likely to do the same in future.

Fig. 1. Prices of crude oil (US$/barrel): 2008-2018. http://www.infomine.com/investment/metal-prices/crude-oil/10-year/ (Accessed on August 22, 2018)

Table 7 summarises factors that could also influence the development of the biofuel industry. They include long, medium and short term factors arising from the global environment, and those obtaining in the domestic environment in individual African countries.

An inspection of these factors, together with information from the preceding sections, would imply that local conditions favour production of biofuels for domestic consumption in individual African countries (and possibly sub-regional and regional consumption on the continent), and less so for export to outside the continent. Also such biofuel expansion will not directly address energy security but adverse effects of climate change, rural employment and incomes.

Table 7. Factors with positive and negative influences on biofuel expansion.

Factors or actors	Description of influence	For (+)/ against (-)
Long-term factors (international)		
EU renewable energy policy and programmes	Domestic policy changes have curtailed the prospects for importing biofuels into the EU by requiring compliance with standards.	-
	Development assistance. EU funding for renewable energy project development in Africa has pivoted away from biofuels. Biofuels projects are no longer considered eligible for funding under the EU Africa Energy Partnership.	-
EU sugar market reform	Shrinking opportunities to export sugar to the EU. While African countries have offered more protection to support prices, in the long term, for sugar producers, diversification into ethanol is more attractive.	+
Medium/short-term factors (international)		
High domestic production of biofuels in consuming countries, limited global trade	Oversupply of US ethanol leads to low global ethanol prices, which discourages investment in Africa for export.	-
Low oil prices	While low oil prices reduce the cost of production, they also reduce the incentives for oil importers to establish biofuel production.	-
Advocacy around biofuels and land grabbing	Companies are reluctant to invest in biofuels due to potential reputational risks, given the associations between biofuels, land grabbing, and negative social outcomes.	-
Domestic factors		
Land governance concerns	Pressure from domestic and international constituencies has limited enthusiasm and scope to allocate large land concessions.	-
Approaches to mitigating climate change	Biofuels are considered as part of countries' (Zambia and Mozambique) climate change mitigation strategies but not others (as reflected in Intended Nationally Determined Contributions (INDCs)).	+/-
Creating investment and jobs in rural areas	Whether or not investments in feedstock expansion represent the best use of resources, there is scope to gain political capital for domestic constituencies from visible investment and new jobs in rural areas.	+

Source: Fundira and Henley (2017). *(This table is published here with acknowledgement of UNU-WIDER, Helsinki, which commissioned the original research and holds copyright thereon).*

5.7 Some observations and recommendations

(a) The production of biofuels is gaining considerable attention in Africa. Although it is still at an embryonic stage in some countries, there is very good potential for production of biofuels given favourable climatic conditions and availability of land on the continent. Several African countries already have in place regulatory frameworks to guide some biofuel activities, like blending. The main biofuel crops being promoted so far in most African countries are jatropha, cassava, sugarcane and sweet sorghum. An effective mechanism should be put in place in individual countries and at regional and sub-regional levels, in terms of guiding policies and regulatory frameworks that could guide developing this industry. This should be in addition to efforts to monitor and share best field experiences on land uses in relation to biofuel production, agriculture, forestry and environmental conservation, and with the objective of taking timely and appropriate actions to ensure food security, affordable energy supply for all citizens and sustainable conservation of ecosystems. In other words, the development of the biofuel industry should be conceived in a much wider context so that it becomes an integral part of sustainable economic development and environmental stability.

(b) The impacts of increased biofuels production on greenhouse gas emissions, land, water and biodiversity vary widely across countries, depending on types of biofuel feedstocks and production practices. The fact that biofuel is basically CO2 neutral does not mean that the production and consumption will necessarily result in greenhouse gas savings. When natural habitats (forests, savannas, grasslands) are converted into feedstock crop plantations the stored carbon and nitrogen in the soil is released, in addition to loss of ecosystem goods and services. The release of greenhouse gases in the various operations constituting the growing of biofuel crops, their harvesting, transport, processing and transport to ultimate consumption points and at eventual consumption, should be weighed against the consumption of fossil fuels for similar ends in order to enable evaluating the merits of biofuel production.

(c) Currently, many African countries face serious problems with food security. In several cases, the production of first-generation biofuels would require considerable land, and this might depend on the degree of political will and action in their promotion. This could then compete strongly with other uses of land such as production of food, sustaining of forests and animal grazing lands. Under current food insecurity conditions, as well as insufficient and insecure access to land by many people, promoting the large-scale cultivation of biofuel crops would probably increase the risk of expropriation of land from existing forests, woodlands, rangelands, and even from existing farm land, as well as removal of land-use rights from farmers. While the commercial production of liquid biofuels requires minimizing business risks and maximizing corresponding benefits, a coherent political framework, appropriate sustainability standards and a clear concept on how the industry should develop are necessary for the sustainable development of this industry in Africa.

(d) The adoption of more efficient techniques for harvesting food crops, introducing better storage facilities, provision of good transport infrastructure, developing better cooking ways and less wasteful eating habits could appreciably reduce losses in the food chain and make more food crops available as biofuel feedstocks without jeopardising food security.

(e) There are potentially good possibilities for achieving sustainable biofuel production with proper feedstock selection. Based on agro-ecological suitability and zooning, biofuels can be grown in all Africa sub-regions. Some countries have already achieved different levels of success in production as well as in consumption of biofuels, including their blending with fossil fuels, mainly for electricity power generation and automobiles.

(g) Long term studies on how the biofuel sector is developing on the continent are necessary, especially in the context of fluctuating global fossil fuel prices and those of agricultural crops suitable for their production, the growing emphasis on clean energy and green economy, and the shrinking EU market. Given the small markets in individual countries, a need to explore the creation of larger sub-regional markets appears attractive, especially with respect to developing economies of scale on biofuel production and enhancing sub-regional energy security.

References

Abila, N., 2011. Promoting Biofuels Adoption in Nigeria: A Review of Socio- economic Drivers and Incentives. World Renewable Energy Congress. Linkoping, Sweden May 2011. Pp. 359-364.

Abiodun, B.J., J. Adegoke, A.A. Abatan, C.A. Ibe, T.S. Egbebiyi, F. Engelbrecht and I. Pinto, 2017. Potential impacts of climate change on extreme precipitation over four African coastal cities. *Climatic Change* 143(3–4):399–413.

Acquah, S.B., S. Pentsil, N. Appiah, W.K. Dumenu and B. Darimani, 2013. Technologies for forest management, utilization and development (1965-2012). In: E.G. Foli and M. Sraku-Lartey (eds). CSIR-Forestry Research Institute of Ghana, University KNUST, Kumasi, Ghana.. 50 p.

Action Aid-Ghana, 2009. Re: The biofuel Debate: Action Aid-Ghana responds to Rural Consult's.

Action Aid-Tanzania, 2009. Implication of Biofuels Production on Food Security in Tanzania.

African Eco-Labelling Mechanism (AEM), 2014. Newsletter - February 2014. AEM, Nairobi, Kenya.

African Forest Research Network (AFORNET), 2005. Lesson learnt on Sustainable Forest Management. Policy Brief No. 4.

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

Akachuku, A.E., 1984. The possibility of tree selection and breeding for genetic improvement of wood properties of *Gmelina arborea* Roxb. *Forest Science* 30(2): 275-283.

Akande, S.O. and F.B. Olorunfemi, 2009. Research and Development Potentials in Biofuel Production in Nigeria. *African Research Review* 3(3):34-45.

Akinnifesi, F.K., F.K. Kwesiga, J. Mhango, T. Chilanga, A. Mkonda, C.A.C. Kadu, I. Kadzere, D. Mithofer, J.D.K. Saka, G. Sileshi, T. Ramadhani and P. Dhliwayo, 2006. Towards the development of miombo fruit trees as commercial tree crops in Southern Africa. *For Trees Live* 16:103–121.

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

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

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

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

Alemu, G., J. Roux and M.J. Wingfield, 2003b. First report of pink disease on *Eucalyptus camaldulensis* in Ethiopia. *Plant Pathology* 52, 402.

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

Alfaro, R., F. Fady, G.G. Vendramin, I. Dawson, R.A. Fleming and C. Saenz-Romero, 2014. Role of forest genetic resources in responding to biotic and abiotic factors in the context of anthropogenic climate change. *Forest Ecology and Management* 333:76–87.

Alfieri, L. et al., 2017. Global projections of river flood risk in a warmer world. *Earths Future* 5(2):171–182.

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

Allen, C.D. et al., 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259:660–684.

Amigun, B., J.K. Musango and W. Stafford, 2010. Biofuels and sustainability in Africa. Renewable Sustainable Energy Review.

Anonymous, 2015. FSC Africa News 2015. (http://www.forestry.co.za/fsc-africa-news-for-2015/;).

Apetorgbor, M.M. and J. Roux, 2015. Diseases of plantation forestry trees in Southern Ghana. *International Journal of Phytopathology* 4(1):5-13.

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

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

Atkinson, P.R., 1989. Controlled-release insecticide granules compared with other soil insecticides for use against the termite, M*acrotermes natalensis* Haviland, in the establishment of *Eucalyptus* plantations. *Crop Protection* 6:387-396.

Atkinson, P.R., K.M. Nixon and M.J.P. Shaw, 1992. On the susceptibility of *Eucalyptus* species and clones to attack by *Macrotermes natalensis* Haviland (Isoptera: Termitidae). *Forest Ecology and Management* 48(1-2):15-30.

Avana-Tientcheu, M.L., 2016. Situational analysis of commercial and community tree planting in West and Central Africa: Trends in tree improvement and tree germplasm supply. A regional study commissioned by the AFF.

Awodoyin, R.O., O.S. Olubode, J.U. Ogbu, R.B. Balogun, J.U. Nwawuisi and K.O. Orji, 2016. Indigenous Fruit Trees of Tropical Africa: Status, Opportunity for Development and Biodiversity *Management. Agricultural Sciences* 6:31-41.

Barklund, A. and D. Teketay, 2004. Forest certification: a potential tool to promote sustainable forest management in Africa. A report prepared for the project "Lessons Learnt on SFM in Africa". KSLA/AFORNET/FAO. See: www.ksla.se/sv/retrieve_file.asp?n=752).

Bass, S., K. Thornber, M. Markopoulos, S. Roberts and M. Grieg-Gran, 2001. Certification's Impacts on Forests, Stakeholders and Supply Chains. IIED, London, UK.

Baudena M. et al., 2015. Forests, savanna and grasslands: bridging the knowledge gap between ecology and Dynamic Global Vegetation Models. *Biogeosciences* 12:1883-1848.

Beverly A.M. and G.B. Allard, 2008. Climate change impacts on forest health. Forest Health & Biosecurity Working Papers. FBS/9E. FAO, Rome, Italy

Bishnu, C.P., R. Sathre, L. Gustavsson, J. Bergh, A. Lundström and R. Hyvönen, 2011. Effects of climate change on biomass production and substitution in north-central Sweden. *Biomass and Bioenergy* 35(10): 4340-4355.

Bisong, F., 2017. Strengthening adaptation policies and AFOLU based climate change mitigation interventions relevant to African forestry and people in Anglophone Africa. AFF Working Paper 3(9). Nairobi.

Blaser, J., A. Sarre, D. Poore and S. Johnson, 2011. Status of Tropical Forest Management 2011. ITTO Technical Series No 38. ITTO, Yokohama, Japan.

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

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

Boccanfuso, D., M. Coulibaly, R. Govinda, G. Timilsina and L. Savard, 2012. The prospects of developing Biofuels in Mali. CREDI – Sherbrooke, Quenbec, Canada.

Boetekees, G., 2002. Capacity Building for Sustainable Forest Management and Forest Certification, Project Proposal. FSC International Center, Bonn, Germany.

Bongjoh, C.A. and N. Mama, 1999. Early regeneration of commercial timber species in a logged-over forest of southern Cameroon. Seminar FORAFRI Libreville. Session 2: Knowledge Ecosystem, 1–9.

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

Bouda, Z.H-N., J. Bayala, B. Markussen, J.S. Jensen and A. Ræbild, 2013. Provenance variation in survival, growth and dry matter partitioning of *Parkia biglobosa* (Jacq.) R.Br. ex G.Don seedlings in response to water stress. *Agroforestry Systems* 87:59–71.

Bouvet, J.M., 2011. Amélioration génétique d'espèces forestières: Créer des variétés adaptées aux demandes des partenaires. Unité de Recherche "Diversité génétique et amélioration des espèces spèces forestières ». Programme de recherche CIRAD Campus international de Baillarguet. 2p.

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

Bullis, K., 2011. Sustainable Energy: Do Biofuels Reduce Greenhouse Gases? A new study fuels the debate over the impact of growing crops for fuel. MIT Technology Review.

Buyinza. M. and N. Wambede, 2008. Extension for agroforestry technology adoption: mixed intercropping of crotolaria (*Crotolaria grahamiana*) and maize (*Zea mays* L.) in Kabale district, *Uganda. Environ. Res. J.* 2(30):131–137.

Campbell, A. and N. Doswald, 2009. The impacts of biofuel production on biodiversity: A review of the current literature. UNEP-WCMC, Cambridge, UK.

Caradang, W.M., E.L. Tolentino Jr. and J. Roshetko, 2006. Smallholder tree nursery operations in southern Philippines - supporting mechanisms for timber tree domestication. *Forests, Trees and Livelihoods* 16:71-84.

Chamshama, S.A.O and F.O.C. Nwonwu, 2004. Lessons Learnt on Sustainable Forest Management in Africa: Case study on forest plantations in Sub-Saharan Africa. FAO, AFORNET, KSLA. 89 p.

Chamshama, S.A.O., 2011. Forest plantations and woodlots in Eastern and North Eastern African countries. A regional overview. AFF working paper series. Volume 1(18).

Chidumayo, E., D. Okali, G. Kowero and M. Larwanou (eds.), 2011. Climate Change and African Forest and Wildlife Resources. AFF, Nairobi, Kenya.

Chidumayo, E.N. and D.J. Gumbo, 2010. The Dry Forests and Woodlands of Africa: Managing Products and Services. London: Earthscan.

Chidumayo, E.N., 1997. Miombo Ecology and Management: An Introduction. IT Publications in association with the Stockholm Environment Institute, London.

Chilima, C.Z., 1991. Termite control in young eucalyptus plantations in Malawi using controlled release insecticides *The Commonwealth Forestry Review* 70(4):237-247.

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

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

Ciesla, W.M., 1995. Climate change, forests and forest management. FAO, Rome, Italy.

Cobbinah, J.R. and M.R. Wagner, 1995. Phenotypic variation in *Milicia excelsa* to attack by *Phytolyma lata* (Psyllidae). *Forest Ecology and Management* 75:147-153.

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

Cossalter, C., 1987. Introducing Australian acacias in dry tropical Africa. In J.W. Turnbull (ed), Australian Acacias in developing countries. ACIAR Proceedings No. 16. pp 118-122. ACIAR: Canberra.

Coumou, D. and A. Robinson, 2013. Historic and future increase in the global land area affected by monthly heat extremes. *Environment Research Letters* 8(3).

Coutinho, T.A., E.T. Steenkamp, K.M. Mongwaketsi, M. Wilmot and M.J. Wingfield, 2007. First outbreak of pitch canker in a South African pine plantation. *Australasian* 36(3):256–261.

Das, H.P., 2004. Adaptation strategies required to reduce vulnerability in agriculture and forestry to climate change, climate variability and climate extremes. In WMO: Management Strategies in Agriculture and Forestry for Mitigation of Greenhouse Gas Emissions and Adaptation to Climate Variability and Climate Change, pp. 41-92. Report of CAgM Working Group. Technical Note No. 202, WMO No. 969, Geneva.

Davis, M.B., 1989. Lags in vegetation response to global warming. *Climate Change* 15:75-82.

Deenanath, E.D., S. Iyuke and K. Rumbold, 2012. The bioethanol industry in Sub-Saharan Africa: history, challenges and prospects. *Journal of Biomedicine and Biotechnology.*

Déqué, M. et al., 2017. A multi-model climate response over tropical Africa at +2°C. *Climate Services* 7:87–95.

Dosio, A., 2017. Projection of temperature and heat waves for Africa with an ensemble of CORDEX Regional Climate Models. *Climate Dynamics* 49:493–519.

Doughty, R.W., 2000. The Eucalyptus. A natural and commercial history of the gum tree. The Johns Hopkins University Press: Baltimore and London.

Dvorak, W.S. and E.A. Shaw, 1992: Five year results for growth and stem form of *Pinus tecunumanii* in Brazil, Colombia and South Africa. CAMCORE Bulletin on Tropical Forestry. College of Forest Resources, North Carolina State University, Raleigh, USA, 22 pp.

Dvorak, W.S., J.K. Donahue and G.R. Hodge, 1996. Fifteen years of *ex situ* gene conservation of Mexican and Central American forest species by the CAMCORE Cooperative. Forest Genetic Resources. No. 24. FAO, Rome.

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

ECA, 2012. Status of Food Security in Africa. UN Economic and Social Council, Economic Commission for Africa. Addis Ababa, Ethiopia.

ECOWAS, 2015. ECOWAS Renewable Energy Policy. ECOWAS, Abuja.

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

Eldridge, K., J. Davidson, C. Harwood and G. van Wyk, 1993. Eucalypt domestication and breeding. Oxford University Press, New York. 288 pp.

ENDA, 2007. Biofuels in Senegal, Jatropha program 2007-2012.

Engelbrecht, C.J. and F.A. Engelbrecht, 2016. Shifts in Köppen-Geiger climate zones over southern Africa in relation to key global temperature goals. *Theoretical and Applied Climatology* 123:247–261.

ENR-CSOs, 2013. Enhanced performance of the environment sector through promotion of sustainable production, trade and investments in natural resources. Environmental Alert, Uganda.

EU, 2013. Assessing the impact of biofuels production on developing countries from the point of view of Policy Coherence for Development. The European Union, Brussels.

Evans, J., 1992. Plantation forestry in the tropics. Second Edition. Clarendon Press, Oxford, UK. 403 p

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

FAO, 2003. Forest Outlook Studies for Africa. FAO, Rome, Italy.

FAO, 2008. Forests and Energy: Key Issues. FAO Forestry Paper 154. Rome, Italy.

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

FAO, 2010. What woodfuel can do to mitigate climate change. FAO Forestry Paper 162. Rome, Italy.

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

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

FAO, 2014. State of the World's Forests. FAO, Rome, Italy.

FAO, 2014. The State of the World's Forest Genetic Resources. Commission on Genetic Resources for Food and Agriculture. FAO, Rome.

FAO, 2014a. State of the World's Forests (SOFO). Enhancing the socio-economic benefits from forests: Putting people at the centre. ISSN 1020-5705. 133pp.

FAO, 2015. Global Forest Resource Assessment 2015. FAO, Rome. 244 pp.

FAO, 2016. Global forest resources assessment 2015. How are the world's forests changing? Second edition. Rome.

FAO, 2017. Analysis of forests and climate change in Eastern Africa. Forests and Climate Change Working Paper 16. FAO, Rome, Italy.

FAO/WB/AU-IBAR/ILRI, 2011. Livestock Assets, Livestock Income and Rural Households.

FARA, 2010. Mapping food and bioenergy in Africa. A report Prepared for FARA. 126pp.

Fargione, J., J. Hill, D. Tilman, S. Polasky and P. Hawthorne, 2008. Land clearing and the *biofuel* carbon debt. doi : 10.1126/ science.1152747.

Field, C.B. et al., 2014: Technical summary. In Field, C.B. et al. (eds.): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 35-94.

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

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

FSC (Forest Stewardship Council), 1994. FSC Principles and Criteria for Forest Stewardship. FSC A.C., Oaxaca, Mexico.

FSC, 2005a. SLIMF Eligibility Criteria (FSS-STD-01-003, Version 1-0 EN). FSC, Bonn, Germany.

FSC, 2005b. FSC Policy – Modular Approach to Forest Certification (FSC-POL-10-003, 2005 EN). FSC, Bonn, Germany.

FSC, 2009. Guidance on the interpretation of FSC principles and criteria to take account of small scale and low intensity (FSC-GUI-60-001 V1-0 EN). FSC, Bonn, Germany.

FSC, 2013. FSC Modular Approach Programme (MAP). FSC, Bonn, Germany.

FSC, 2014a. National Standards in Africa: Africa Harbours the Second Largest Bloc of Rainforest after Amazonia (https://ic.fsc.org/africa.248.htm).

FSC, 2014b. National Standards – Congo Basin (https://ic.fsc.org/congo-basin.372.htm).

FSC, 2014c. National Standards in Africa (https://ic.fsc.org/national-standards.247.htm).

FSC, 2014d. Our History (https://ic.fsc.org/our-history.17.htm).

FSC, 2017. FSC Facts & Figures. Forest Stewardship Council, Bonn, Germany.

Fundira, T. and G. Henley, 2017. Biofuels in Southern Africa. Political economy, trade and policy environment. WIDER Working Paper 2017/48.United Nations University.

Funke, T., P. Klein and F. Meyer, 2011. Biofuel production in South Africa. *Biofuels* 2(2):209-220.

Gabou, M.H. and A. Maisharou, 2014. Management Practices/Techniques Commonly Used in Niger Republic, West Africa. In Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa. pp 305-314.

Gapare, W.J., G.R. Hodge and W.S. Dvorak, 2001. Genetic parameters and provenance variation of Pinus maximinoi in Brazil, Colombia, and South Africa. *Forest Genetics* 8:159–170.

Garnas, J.R., M. Auger-Rozenberg, A. Roques, C. Bertelsmeier, M.J. Wingfield and D.L. Saccaggi, 2015. Complex patterns of global spread in invasive insects: eco-evolutionary and management consequences. Biological Invasions.

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

Gerald, A. *et al*., 2005. Climate Change Projections for the Twenty-First Century and Climate Change Commitment in the CCSM3. *Journal of Climate* 19:2597-2616.

German, L., J. Mowo, T. Amende and K. Masuki (Eds.), 2012. Integrated Natural Resource Manage-ment in the Highlands of Eastern Africa. From concepts to practice. IDRC, Ottawa.

Ghazi, P., E. Barrow, G. Monela and W. Mlenge, 2005. Regenerating Woodlands: Tanzania's HASHI Project. World Resources 2005: The Wealth of the Poor - Managing Ecosystems to Fight Poverty. WRI in collaboration with UNDP: 131-138.

Ghazoul, J., 2011. Landscape labeling: combining certification with ecosystem service conservation at landscape scales. In: Koellner, T. (ed.), Ecosystem Services and Global Trade of Natural Resources: Ecology, Economics and Policies. Oxon, UK and New York, USA.

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

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

Gichora, M., 2016. The status of tree and forest pests and diseases in Eastern Africa Sub-region. Technical Report, African Forest Forum, Nairobi.

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

GIZ, 2011. The potential of sustainable liquid biofuel production in Rwanda. A study on the agri-cultural, technical and economic conditions and food security. Min. of Infrastructure, Rwanda.

Goncalves, M.P., M. Panjer, T.S. Greenberg and W.B. Magrath, 2012. Justice for Forests: Improving Criminal Justice Efforts to Combat Illegal Logging. The World Bank, Washington, DC, USA.

Gouma, R., J.M. Bouvet, P. Vigneron and N. Kimbouma, 1995. Ex-situ conservation of genetic resources in the Congo: Case studies of two introduced species: Eucalyptus grandis and E. urophylla. Forest Genetic Resource No. 28. FAO, Rome.

GRAIN, 2012. Land grabbing and food sovereignty in West and Central Africa. Website at: http://www.grain.org/articles.

Griffin, A.R., 2014. Clones or Improved Seedlings of Eucalyptus? Not a Simple Choice. *International Forestry Review* 16(2):216- 224.

Gullison, R.E., 2003. Does Forest Certification Conserve Biodiversity. *Oryx* 37(2):153-165.

Haensler, A., F. Saeed and D. Jacob, 2013. Assessing the robustness of projected precipitation changes over central Africa on the basis of a multitude of global and regional climate projections. *Climatic Change* 121:349–363.

Hakizumwami, E., 2011. Progress of FSC certification in the Congo Basin. International Seminar on Forest certification, Madrid.

Harris, M.S., 1993. Working towards the wider distribution of tree seed in Africa: The activities of the Henry Doubleday Research Association.12p.

Harwood, C.E., 2011. Introductions: doing it right. In: Developing a eucalypt resource: learning from Australia and elsewhere. Wood Technology Research Centre. Workshop Proceedings. 43-54.

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

Heinrigs, 2010. Security Implications of Climate Change in the Sahel Region: Policy considerations. SWAC, 2010.

Henson, M., 2011. Fast tracking genetic improvement. In: Developing a eucalypt resource: learning from Australia and elsewhere. Wood Technology Research Centre. Workshop Proceedings. 27-34.

Hoegh-Guldberg, O. *et al.*, 2018. Impacts of 1.5ºC global warming on natural and human systems. IPCC SR1.5

Hosonuma, N., M. Herold, V.D. Sy, R.S.D. Fries, M. Brockhaus, L. Verchot, A. Angelsen and E. Romijn, 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters* 7**,** 044009.

Houghton, J.T., 1991. Scientific assessment of climate change: Summary of the IPCC Working Group 1 report. Proceedings 2nd World Climate Conference, Geneva, Switzerland, Cambridge University Press, pp 23-46.

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

Hurley, B.P., J. Garnas. M.J. Wingfield, M. Branco, D.M. Richardson and B. Slippers, 2016. Increasing numbers and intercontinental spread of invasive insects on eucalypts. Biological Invasions. Springer International Publishing, Switzerland.

IEA, 2008. From 1st to 2nd generation biofuel technologies: An overview of current industry and RD&D activities. IEA Bioenergy.

IEA, 2013. Tracking Clean Energy Progress 2013. IEA input to the clean energy. International Energy Agency.

Institute of Commercial Forestry Research, 2014. Annual Report. South Africa.

IPCC, 2001. Climate Change 2001: Working Group I: The Scientific Basis (eds.: B. Bolin and S. Pollonais). Cambridge, UK and New York, NY, USA: Cambridge University Press. 85-99 pp.

IPCC, 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK. 976 pp

IPCC, 2014. Summary for policymakers. In Field, C.B. et al. (eds.): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IRENA, 2017. Biofuel potential in Sub-Saharan Africa: raising food yields, reducing food waste and utilizing residues. International Renewable Energy Agency, Abu Dhabi.

Jacovelli, P.A., 2009. Uganda's Sawlog Production Grant Scheme: A success story from Africa. *Inter-national Forestry Review* 11(3):119-125.

Jacovelli, P.A., 2014. The future of plantations in Africa. *International Forestry Review* 16(2):144–159.

Janisch, C., 2007. Background to Assessment and Survey of of Existng Initiatives in Ecolabelling in the Africa Region. UNEP, Nairobi.

Jin, C., X. Xiao, L. Merbold, A. Arneth, E. Veenendaal and L.W. Kutsch, 2013. Phenology and gross primary production of two dominant savanna woodland ecosystems in Southern Africa. *Remote Sensing of Environment* 135:189-201.

Jindal, R., B. Swallow and J. Kerr, 2008. Forestry-based carbon sequestration projects in Africa: potential benefits and challenges. *Natural resources Forum* 32:116-130.

Jusu, A. and A. Cuni-Sanchez, 2016. Indigenous fruit trees in the African rainforest zone - insights from Sierra Leone. Genetic Resources and Crop Evaluation, 1-16.

Kalinganire A. and B. Koné, 2010. *Ziziphus mauritiana*, ber. SAFORGEN. Priority Food Tree Species. Guidelines for conservation and sustainable use. Bioversity International, Rome, Italy.

Kalonga, S., 2014. Forest Certification in Eastern and Southern Africa. AFF, Nairobi, Kenya.

Kamwenda, G.J., 1999. Analysis of ngitili as a traditional silvo-pasture system among agro-pastoralists of Meatu, Shinyanga, Tanzania. Unpublished M.Sc. dissertation, Sokoine University of Agriculture, Morogoro, Tanzania.

Kawanga V., Undated. Mukula Tree at the edge of extinction in Zambia (www.gefcso.org).

Kelley, H. and M. Gallant, 2018. Voluntary carbon markets outlook and trends January-March 2018.

Kemausuor, F., J.O. Akowuah and E. Ofori, 2013. Assessment of Feedstock Options for Biofuels Production in Ghana. Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Kemausuor, F., S. Bolwig and S. Miller, 2016. Modelling the socio-economic impacts of modern bioenergy in rural communities in Ghana. *Sustainable Energy Technologies and Assessments* 14:9–20.

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

Kilimo Trust, 2011. Eucalyptus Hybrid Clones in East Africa; Meeting the Demand for Wood through Clonal Forestry Technology. Occasional Paper No.1.

Kindt R., J.P.B. Lillesø, A. Mbora, J. Muriuki, C. Wambugu, W. Frost, J. Beniest, A. Aithal, J. Awimbo, S. Rao and C. Holding-Anyongo, 2006. Tree Seeds for Farmers: a Toolkit and Reference Source. World Agroforestry Centre, Nairobi.

Klutse, N.A.B. *et al*., 2016. Daily characteristics of West African summer monsoon precipitation in CORDEX simulations. *Theoretical and Applied Climatology* 123(1–2):369–386.

Kojwang, H., 2015. Forest Pests and Diseases in Southern Africa. Main Report. African Forest Forum, Nairobi.

Koskela, J., B. Vinceti, W. Dvorak, D. Bush, I.K. Dawson, J. Loo, E.D. Kjaer, C. Navarro, C. Pado-lina, S. Bordács, R. Jamnadass, L. Graudal and L. Ramamonjisoa, 2014. Utilization and transfer of forest genetic resources: a global review. *Forest Ecology and Management* 333:22-24.

Kowero, G., J. Njuki and C.T.S. Nair, 2009. Some Drivers of Change in Forest Conditions in Africa. *Discovery and Innovation (SFM Special Edition No. 1)* 21:4-11.

Kuhlmann K. and Y. Zhou, 2015. Seed Policy Harmonization in the EAC and COMESA: The Case of Kenya. Working paper. Syngenta Foundation for Sustainable Agriculture. 29 pp.

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

Lamprecht, H., 1990. Silviculture in the Tropics: tropical forest ecosystems and their tree species-possibilities and methods for their long-term utilization. GTZ, Eschborn. Germany. 296 p.

Laprise, R., L. Hernández-Díaz, K. Tete, L. Sushama, L. Šeparovic, A. Martynov, K. Winger and M. Valin, 2013. Climate projections over CORDEX Africa domain using the fifth-generation Canadian Regional Climate Model (CRCM5). *Climate Dynamics* 41:3219–3246.

Lauridsen E.B. and E.D. Kjaer, 2002. Provenance research in *Gmelina arborea* Linn., Roxb. A summary of results from three decades of research and a discussion of how to use them. *Inter-national Forestry Review* 4(1):1-15.

Lindner et al., 2008. Impacts of Climate Change on European Forests and Options for Adaptation. Report to the European Commission Directorate-General for Agriculture and Rural Development. AGRI-2007-G4- 06.

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

Luoga, E.J., E.T.F. Witkowski and K. Balkwill, 2004. Regeneration by coppicing (resprouting) of the miombo (African savanna) trees in relation to land-use. *Forest Ecology and Management* 186(1-3):23-25.

Madhibha, T., R. Murepa, C. Musokonyi and W. Gapare, 2013. Genetic parameter estimates for interspecific Eucalyptus hybrids and implications for hybrid breeding strategy. *New Forests* 44:63-84.

Magalhães, J, 2010. Regional sanitary and phytosanitary frameworks and strategies in Africa. http://www.standardsfacility.org/sites/default/files/STDF_Regional_SPS_Stategies_in_Africa_EN_0.pdf

Maisharou, A., P.W. Chirwa, M. Larwanou, M.F. Babalola and C. Ofoegbu, 2015. Sustainable land management practices in the Sahel: review of practices, techniques and technologies for land restoration and strategy for up-scaling. *International Forestry Review* 17(S3):1-19.

Manalili N.M. and M.A. Dorado, 2006. Regional Evidence Generation and Policy & Institutional Mapping on Food & Bioenergy: An Integration. Southern Advisory Group.

MARGE and African Solar Designs, 2013. Value Chain Study on the Renewable Energy and Biofuels Industry in the EAC region. Eastern African Community, Industrial Development Dept.

Marien, J.N. and R. Peltier, 2010. La gestion durable des plantations forestières en Afrique centrale: Des réponses adaptées aux nouveaux besoins de la société. Présentation du CIRAD à la réunion de reflexion sur le Partenariat pour les Forêts du Bassin du Congo tenue à Kinshasa du 17-19 Septembre 2010.

Marunda, C.T., 2016. Situational analysis of commercial and community tree planting in Southern Africa: trends in tree improvement and tree germplasm supply – a study commissioned by AFF.

Marunda, C.T., M.L. Avana-Tientcheu and H.P. Msanga, 2016. Situational analysis of tree breeding and tree germplasm supply in Africa: under-pining sustainable forest management. African Forest Forum Working Paper series. Nairobi, Kenya.

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

Mayaux, P. *et al.*, 2003. A Land Cover Map of Africa. Joint Research Centre, European Commission

Mbolo, M., 2014a. Forest Certification in Central Africa. AFF, Nairobi, Kenya.

Mbolo, M., 2014b. Forest Certification in Northern Africa. AFF, Nairobi, Kenya.

McComb, A.L. and J.K. Jackson, 1969. The role of tree plantations in savanna development -technical and economic aspects, with special reference to Nigeria. *Unasylva* 23(5):8-18.

Meer, P., K. Kramek and M. Wjik, 2001. Climate change and forest ecosystem dynamics. Amsterdam, RVIM Report No 410200069. 130 pp

Meidinger, E., E. Elliott and G. Oesten (eds.), 2002. Social and Political Dimensions of Forest Certifi-cation. Verlag, Remagen-Oberwinter.

Meinshausen, M. et al., 2011. The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change* 109:213–241.

MEM, 2013. National Liquid Bioenergy Policy. Ministry of Energy and Minerals, Tanzania.

MEM, 2015. The Draft National Energy Policy 2015. Ministry of Energy and Minerals, Tanzania.

MEMD, 2011. Balancing Biofuels and Food Security. Ministry of Energy and Mineral Development, Uganda.

Mgonja, M.A., R.B. Belum, E. Manyasa and H. Ojulong, 2011. Sweet sorghum for bioethanol: Advances in Research and Development: Challenges & opportunities. ICRISAT, Nairobi, Kenya and Patancheru, India.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Current State and Trends, Vol. 1. Washington, DC. Island Press.

Mitchell, D., 2011. Biofuels in Africa. Opportunities, prospects and challenges. World Bank, Washington, D.C.

Msanga, H.P., 2016. The status of tree germplasm improvement, production, supply and demand in Eastern Africa - a study commissioned by AFF.

Mueller, 2011. The Sahel is greening. GWPF Briefing Paper No 2

Mugunga, C.P. and G. van Wyk, 2003. Potential for genetic improvement of yield of exotic softwood tree species in Rwandan plantation forestry. *Southern African Forestry Journal* 199(1):65-75.

Mujuru, L., 2018. Role of private forestry sector in response to climate change in Zimbabwe. African Forest Forum Working Paper, Nairobi.

Mukonza, C. and G. Nhamo, 2016. Institutional and regulatory framework for biodiesel production: international perspectivies and lessons for South Africa. *African Journal of Science, Techno-logy, Innovation and Development* 8(1):1-11.

Muoghalu, I.J., 2014. Vulnerability of biosphysical and socioeconomic systems in savannahs and woodlands of West and Central Africa to climate change. African Forest Forum, Working Paper Series 2(14). 31 pp.

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

Muthoo, M.K., 2012. Forest Certification and Green Economy. *Unasylva* 239:17-23.

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

Mutitu, E.K., J.R. Garnas, B.P. Hurley, M.J. Wingfield, M. Harney, S.J. Bush and B. Slippers, 2013. Biology and Rearing of *Cleruchoides noackae* (Hymenoptera: Mymaridae), an Egg Parasitoid for the Biological Control of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae). *J. Econ. Entomol.* 106(5):1979-1985.

MWE, 2012. Ethiopian National Energy Policy. Ministry of Water and Energy, Addis Ababa.

Nair, C.T.S. and J. Tieguhong, 2004. African forests, an overview. A report prepared for the project “Lessons Learnt on Sustainable Forest Management in Africa”. AFORNET, Nairobi, Kenya.

Naka, K., A.L. Hammet and W.B. Stuart, 2000. Forest Certification: Stakeholders, Constraints and Effects. *Local Environment* 5(4):475–481.

Nakabonge, G., J. Roux, M. Gryzenhout and M.J. Wingfield, 2006. Distribution of Chrysoporthe canker pathogens on *Eucalyptus* and *Syzygium* spp. in eastern and southern Africa. *Plant Disease* 90:734-740.

Ngamau, C., B. Kanyi, J. Epila-Otara, P. Mwangingo and S. Wakhusama, 2004. Towards Optimizing the Benefits of Clonal Forestry to Small-scale Farmers in East Africa. ISAAA Briefs No. 33. Ithaca, New York, USA.

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham and P. Urquhart, 2014. Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fifth Assess-ment Report of IPCC. Cambridge University Press, Cambridge.

Njuguna, J.W., 2011. Stem canker and die back disease of *Grevillea robusta* in Kenya.

Njuki, J., G. Kowero and C.T.S. Nair, 2004. What Shapes Forestry in Africa? A report prepared for the project “Lessons Learnt on Sustainable Forest Management in Africa”. AFORNET, Nairobi, Kenya.

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

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

Nussbaum, R. and M. Simula, 2005. The Forest Certification Handbook (Second Edition). Earthscan, London, UK.

Nussbaum, R., 2002. Group Certifiction for Forests: A Practical Guide. ProForest, Oxford, UK.

Nyambura, B. and G. Nhamo, 2014. CDM projects and their impacts on sustainable development: a case study from Kenya. *Environmental economics* 5(1).

Nyoka, B.I., J. Roshetko, R. Jamnadass, J. Muriuki, A. Kalinganire, J.P.B. Lillesø, T. Beedy and J. Cornelius, 2014. Tree seed and seedling supply systems: a review of the Asia, Africa and Latin America Models. Small Scale Forestry 1–21.

Nyoka, B.I., P. Tongoona and C.M. Gumbie, 2010. Provenance productivity of high and low elevation *Pinus tecunumanii* in Zimbabwe. *Silvae Genetica* 59:189-199.

Odera, J.A. and F.K. arap Sang, 1980. Quarantine as a tool of control of pest and disease control with reference to Kenya situation. In Proc. Commonwealth Forestry Conference, Tirindad and Tobago. 12pp.

Oeba, V.O. and M. Larwanou, 2015. Opportunities and prospects of forest based CDM and REDD+ projects for sustainable development in Sub-Saharan Africa. Oral paper presented during fifth conference on climate change and development in Africa (CCDA-V); Africa sustainable development and climate change; prospects of Paris and beyond, Oct. 28-30, 2015, Victoria Falls, Zimbabwe.

Oeba, V.O. and M. Larwanou, 2017. Forestry and resilience to climate change: a synthesis on application of forest based adaptation strategies to reduce vulnerability among communities in Sub-Saharan Africa. In W. Leal Filho *et al*. (eds): Climate Change Adaptation in Africa - Fostering Resilience and Capacity to Adapt. Springer, Berlin.

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

Ohimain, E.I., 2010. Emerging bio-ethanol projects in Nigeria: Their opportunities and challenges. *Energy Policy* 38:7161-7168.

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

Olivier, A., 2004. Forest Certification in Western Africa. AFF, Nairobi, Kenya.

Osu, E.T., 2009. Biofuels, Impact on food security: A case study of Nigeria. Master Thesis in the programme Globalization, Environment and Social Change, Stockholm University, Sweden. 72pp.

Otegbeye, G.O., 1991. Variation among *Pinus oocarpa* provenances tested in the Savanna region of Nigeria. ***Forest Ecology and Management*** **43(1–2)**:61-68.

Oxfam, 2008. Inconvenient Truth: How biofuel policies are deepening poverty and accelerating climate change. Oxfam Briefing Paper, Oxfam International energy policy in Sub-Saharan Africa without biomass. The Journal of the International Energy initiative.

Palliere, G. and S. Fauveaud, 2009. Biofuels: issues for the farming community in Mali.

Parfitt, D., J. Hunt, D. Dockrell, H.J. Rogers and L. Boddy, 2010. Do all trees carry the seeds of their own destruction? PCR reveals numerous wood decay fungi latently present in sapwood of a wide range of angiosperm trees. *Fungal Ecology* 3(4):338-346.

PEFC (Programme for the Endorsement of Forest Certification Schemes), 2014. Stakeholder Engagement (http://www.pefc.org/standards/stakeholder-engagement).

PEFC, 2015a. National Members (http://pefc.org/about-pefc/membership/national-members/34-Gabon).

PEFC, 2015b. National Forest Certification System of Gabon Achieves Re-endorsement (http://www.developingstandards.org/resources/news/389-national-forest-certification-system-of-gabon-achieves-re-endorsement).

PEFC, 2017. PEFC Global Statistics: SFM & CoC Certification. PEFC, Geneva, Switzerland.

Peña-Claros, M., S. Blommerde and F. Bongers, 2009. Assessing the Progress Made: An Evaluation of Forest Management Certification in the Tropics. Tropical Resource Management Papers 95. Wageningen University and Research Centre, Wageningen.

Perera, P. and R.P. Vlosky, 2006. A History of Forest Certification. Louisiana Forest Products Development Center Working Paper No. 71. Louisiana State University, Baton Rouge, LA.

Pienaar, B., D.I. Thompson, B.F.N. Erasmus, T.R. Hill and E.T.F.Witkowski, 2015. Evidence for climate-induced range shift in *Brachystegia* (miombo) woodland. *South African Journal of Science* 111(7/8), 9 p.

Pinto, I. *et al*., 2016. Evaluation and projections of extreme precipitation over southern Africa from two CORDEX models. *Climatic Change* 135(3–4):655–668.

Popoola. L., M. Larwanou and S.O. Jimoh, 2015. Biofuel initiatives in West Africa and the Sahel: potential for success. *International Forestry Review* 17(S3).

Raebild A., J.S. Jensen, M. Ouedraogo, S. de Groote, P. van Damme, B.O. Diallo, J. Bayala, H. Sanou, A. Kalinganire and E.D. Kjaer, 2011. Advances in domestication of indigenous fruit trees in the West African Sahel. *New Forests* 41(3):297-315.

Rainforest Alliance, 2007. SmartStep - A Stepwise Approach toward FSC Forest Management Certification, Program Description. Rainforest Alliance, New York.

Ratnam, W., O.P. Rajora, R. Finkeldey, F. Aravanopoulos, J.M. Bouvet, R.E. Vaillancourt, M. Kanashiro, B. Fady, M. Tomita and C. Vinson, 2014. Genetic effects of forest management practices: Global synthesis and perspectives. *Forest Ecology and Management* 333:52-65.

Ravindranath, N.H., R. Manuvie, J. Fargione, J.G. Canadell, G. Berndes, J. Woods, H. Watson and J. Sathaye, 2009. Greenhouse Gas Implications of Land Use and Land Conversion to Biofuel Crops. In Howarth, R.W. and S. Bringezu (eds): Biofuels: Environmental Consequences and Interactions with Changing Land Use., Scientific Committee on Problems of the Environment (SCOPE), Island Press, New York.

Republic of Kenya, 2012. National Energy Policy. Ministry of Energy, Kenya.

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

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

Roux, J., G. Meke, B. Kanyi, L. Mwangi, A. Mbaga, G.C. Hunter and G. Nakabonge, 2005. Diseases of plantation forestry trees in eastern and southern Africa. *South African Journal of Science* 101:409-413.

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

Russo, S., A.F. Marchese, J. Sillmann and G. Immé, 2016. When will unusual heat waves become normal in a warming Africa? *Environmental Research Letters* 11.

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

SADC Tree Seed Centres Project Inception Report, 1992. CIDA, Ottawa, Canada.

SADC, 2009. SADC framework for sustainable biofuels.

Saeed, F., A. Haensler, T. Weber, S. Hagemann and D. Jacob, 2013. Representation of extreme precipitation events leading to opposite climate change signals over the Congo basin. *Atmosphere* 4(3):254–271..

SAIF, 2000. South African forestry handbook vol 1. South African Institute of Forestry, V&R Printers, Pretoria, South Africa. 416pp.

Sanchez, P.A., 1995. Science in agroforestry. *Agroforestry Systems* 30:1–5.

Sawadogo, H., F. Hien, A. Sohor and F. Kambou, 2001. Pits for Trees. How farmers in semi-arid Burkina-Faso increase and diversify plant biomass. In Reij, C. and A. Waters-Bayer (eds): Farmer Innovation in Africa: a source of inspiration for agricultural development. Earthscan, London, UK.

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

Schewe, J. *et al.*, 2014. Multimodel assessment of water scarcity under climate change. *Proceedings of the National Academy of Sciences* 111(9):3245–3250.

Schoneveid, G.S., 2013. The Governance on Large Scale Farmland Investments in Sub-Saharan Africa. CIFOR. Nairobi, Kenya.

Schut, M., M. Slingerland and A. Locke, 2010. Biofuel developments in Mozambique. Update and analysis of policy, potential and reality. *Energy Policy* 38 (2010).

Searchinger, T., 2009. Government policies and drivers of world biofuels, sustainability criteria, certification proposals and their limitations. In R.W. Howarth and S. Bringezu (Eds.): Biofuels: Environmental Consequences and Interactions with Changing Land Use. Proc. SCOPE International Biofuels Project Rapid Assessment. 22-25 September 2008, Gummersbach Germany. Cornell University, Ithaca NY, USA. Pp. 37-52.

Sebukera, C., E. Muramira, C. Momokama, A. Elkholei, I. Elbagouri, B. Masumbuko and V. Rabesa-hala, 2006. Forests and Woodlands. Africa Environmental Outlook 2. Our Environment, Our Wealth. UNEP, Nairobi, Kenya.

Sekoai, P. and K.O. Yoro, 2016. Biofuel development initiatives in Sub-Saharan Africa: Opportunities and challenges. *Climate* 4(33).

Sendzimir, J., C.P. Reij and P. Magnuszewski, 2011. Rebuilding resilience in the Sahel: Re-greening in the Maradi and Zinder regions of Niger. *Ecology and Society* 16(3):1.

Serdeczny, O., S. Adams, F. Baarsch, D. Coumou, A. Robinson, W. Hare, M. Schaeffer, M. Perrette and J. Reinhardt. 2016. Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Reg. Environ Change* 15(8).

Settele, J., R. Scholes, R. Betts, S. Bunn, P. Leadley, D. Nepstad, J.T. Overpeck and M.A. Taboada, 2014. Terrestrial and inland water systems. In C.B. Field *et al*. (eds.): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of IPCC. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 271-359.

Sidibe, B., 2009. Mission Report to Liberia (Monrovia) from January 30th to February 8th, 2009.

Sielshorst, S., J.W. Molenaar and D. Offermans, 2008. Biofuels in Africa. An assessment of risks and benefits for African wetlands. Wetlands International, Wageningen, Netherlands.

Sillmann, J., V.V. Kharin, F.W. Zweiers, X. Zhang and D. Bronaugh, 2013. Climate extreme indices in the CMIP5 multi-model ensemble. Part 2: future climate projections. *J Geophys Res Atmos* 118(6):1–55.

Slippers, B., B.P. Hurley and M.J. Wingfield, 2015. Sirex Woodwasp: A Model for Evolving Manage-ment Paradigms of Invasive Forest Pests. *Ann. Rev. Entomol.* 60:601–619.

Souverijns, N., W. Thiery, M. Demuzere and N.P.M. van Lipzig, 2016. Drivers of future changes in East African precipitation. *Environmental Research Letters* 11. .

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

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

Stiles, G. and C. Murove, 2015. SADC renewable energy and energy efficiency. Status report. REN21, Paris, France.

Sunderland, T., B. Powell, A. Ickowitz and C. Padoch, 2013. Food security and nutrition. The role of forests. Discussion paper. CIFOR, Bogor, Indonesia.

Swain, T.L. and R.A.W. Gardner, 2003. A summary of current knowledge of cold tolerant eucalypt species (CTE's) grown in South Africa. ICFR Bulletin Series 03/2003. Institute for Commercial Forestry Research, Pietermaritzburg.

Sylla, M.B., N. Elguindi, F. Giorgi and D. Wisser, 2016. Projected robust shift of climate zones over West Africa in response to anthropogenic climate change for the late 21st century. *Climatic Change* 134:241–253.

Tchoundjeu, Z., E.K. Asaah, P. Anegbeh, A. Degrande, P. Mbile, C. Facheux, A. Tsobeng, A.R. Atangana, M.L. Ngo Mpeck and A.J. Simons, 2006. Putting participatory domestication into practice in West and Central Africa. For. *Trees Livelihoods* 16:53–69.

Teketay, D., 2004/05/06. Capacity Building for Sustainable Forest Management and Certification in Africa: Narrative Reports for the Periods 01 January - 31 December 2003, 2004, 2005, respectively. FSC-Africa Regional Office, Kumasi, Ghana.

Teketay, D., 2004-2005. Causes and consequences of dryland forest degradation in Sub-Saharan Africa. *Walia* 24:3-20.

Teketay, D., 2007/08. Capacity Building for Sustainable Forest Management and Certification in Africa: Integrated Narrative and Financial Reports for the Periods 01 January - 31 December 2006 and 2007. FSC-Africa Regional Office, Accra, Ghana.

Teketay, D., 2012a. The African Ecolabelling Mechanism (AEM) and its Eco Mark Africa (EMA): Current Status. Presentation during the "ECOWAS Workshop on Ecolabelling", 24 May 2012, Mensvic Grand Hotel, Accra, Ghana.

Teketay, D., 2012b. African Eco-Labelling Mechanism: Options to Promote Sustainable Consump-tion. Keynote presentation during the "Think Tank Event on Eco-labelling of African Fisheries: Policy Dialogue on Eco-Labelling of African Fisheries", 20-21 November 2012, Windsor Hotel, Nairobi, Kenya.

Teketay, D., 2015. Forest Certification in Africa. AFF, Nairobi, Kenya.

Teketay, D., M. Mbolo, S. Kalonga and A. Olivier, 2016. Forest Certification in Africa: Achieve-ments, Challenges and Opportunities. AFF, Nairobi, Kenya.

Teklehaimanot, Z., 2005. Indigenous fruit trees for Eastern Africa. The Leverhulme Trust: A Study Abroad Fellowship Report. University of Wales, Bangor, UK.

Tembani, M., T. Madhibha, C.T. Marunda and W.J. Gapare, 2014. Sustaining and improving forest genetic resources for Zimbabwe: Lessons from 100 years. *International Forestry Review* 16(6):615-632.

TEREA (Terre Environnement Aménagement), 2008. Gabonese Forest Certification Scheme. Gabonese Association of the Pan African Forest Certification System PAFC Gabon, Libreville.

Tesfaye M. and Y. Gebru, 2011. Assessment of Biofuel Development Activities in Ethiopia. Forum for Environment.

Teulières C, G. Bossinger, G. Moran and C. Marque, 2007. Stress studies in Eucalyptus. *Plant Stress* 1:197-215.

The Royal Society, 2008. Sustainable biofuels: prospects and challenges. Royalsociety.org.

Thompson, L. S. Midgley and D. Boland, 2001. Access issues in forest genetic resources - experiences in sharing and exchange of germplasm in Australia and the South Pacific. In J. Koskela, S.S. Appanah, A.P. Pederson and M.D. Markpoulos (eds.): Proceedings of the Southeast Asia moving workshop on conservation, management and utilisation of forest genetic resources. 25 February -10 March 2001, Thailand.

Thornhill, S., E. Vargyas, T. Fitzgerald and N. Chilsom, 2016. Household food security and biofuel feedstock production in rural Mozambique and Tanzania. *Food Security* 8:953-971.

TNRF (Tanzania Natural Resource Forum), 2011. REDD realities: learning from REDD pilot projects to make REDD work.

Trzaska, S., A. de Sherbinin, P. Kim-Blanco, V. Mara, E. Schnarr, M. Jaiteh and P. Mondal, 2018. Climate Change Vulnerability Assessment in Mangrove regions of Sierra Leone: Long Version. Report published under the USAID West Africa Biodiversity and Climate Change (WA BiCC) project. Palisades, NY: Center for International Earth Science Information Network, Columbia University.

Ugwu J.A., and A.A. Omoloye, 2014. Biology of Iroko Gall Bug, *Phytolyma lata* Scott. (Homoptera; Psylidae) on *Milicia excelsa* (Welw) C.C. Berg. *Jour. of Entomology* 11:34-41.

UN Department of Economic and Social Affairs, Population Division, 2015. World Population Pro-spects: The 2015 Revision. New York: United Nations.

UNCTAD, 2016. Second generation biofuel market - State of play, trade and developing country perspectives. UN Conference on Trade and Development, New York and Geneva.

UNCTAD, 2008. Biofuel production technologies: status, prospects and implications for trade and development. UN Conference on Trade and Development, New York and Geneva. 49pp.

UNDP, 2018. Sustainable Development Goals.

UNEP, 2008. Strategy Document of the African Eco-Labelling Mechanism (AEM). UNEP, Nairobi, Kenya.

UNEP, 2009. Towards sustainable production and use of resources: assessing biofuels UNEP, Nairobi, Kenya.

UNEP, 2013. Emission Reduction Profile – Senegal. 21pp.

UNIDO, 2008. International Conference on Renewable Energy in Africa. Making Renewable Energy Markets Work for Africa. Policies, Industries and Finance for Scaling up. 16-18 April 2008. UNIDO. Dakar, Senegal.

Upton, C. and S. Bass, 1995. The Forest Certification Handbook. Earthscan Publication Limited, London, UK.

Van Dam, J. and H. Savenije, 2011. Enhancing the Trade of Legally Produced Timber: A Guide to Initiatives. Tropenbos International, Wageningen, Netherlands.

Verma, M., S. Sharma and R. Prasad, 2009. Biological alternatives for termite control: A review. *International Biodeterioration and Biodegradation* 63(8):959–972.

Vermeulen, S., E. Sulle and S. Fauvead, 2009. Biofuels in Africa: growing small-scale opportunities. IIED, London, UK.

Vizy, E.K. and K.H. Cook, 2012. Mid-twenty-first-century changes in extreme events over northern and tropical Africa. *Journal of Climatology* 25:5748–5767.

Vogt, K.A., B.C. Larsen, J.C. Gordon, D.J. Vogt and A. Franzeres, 2000. Forest Certification, Roots, Causes, Challenges and Benefits. CRS Press, Boca Raton, Florida.

von Maltitz, G., L. Haywood, M. Mapako and A. Brent, 2009 Analysis of opportunities for biofuel production in sub-Sharan Africa. Environment brief. CIFOR, Bogor.

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

Ward, R.D., D.A. Friess, R.H. Day and R.A. MacKenzie, 2016. Impacts of climate change on mangrove ecosystems: a region by region overview. *Ecosystem Health and Sustainability* 2(4).

Weber, T., A. Haensler, D. Rechid, S. Pfeifer, B. Eggert and D. Jacob, 2018. Analyzing regional climate change in Africa in a 1.5, 2, and 3°C global warming world. *Earth's Future* 6:643–655.

WHO, 2006. Fuel for Life: Household Energy and Health. Geneva.

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

WMO. 2018. World Meteorological Organization, weather and climate change. Available at: http://www.wmo.int/pages/prog/wcp/ccl/faq/faq_doc_en.html.

World Bank, 1991. Zimbabwe - Rural Afforestation Project. Washington DC: World Bank.

World Bank, 2009. Environmental crisis or sustainable development opportunity: Transforming the charcoal sector in Tanzania. Washington DC, Africa Environment Unit.

World Bank, 2011. Wood Based Biomass Energy Development for Sub-Saharan Africa: Issues and approaches. Washington D.C.

WWF, 2012. Opportunities and barriers to the use of renewable energy technologies in Uganda. World Wide Fund for Nature.

Wylie F.R. and M.R. Speight, 2012. Insect pests in tropical forestry. CABI. 365pp.

Xavier, M.R., 2007. The Brazilian sugarcane ethanol experience. Advancing liberty from the economy to ecology, issue. *Analysis* No. 3.

Yadav, M., P.C. Kotwal and B.L. Menaria, 2007. Forest Certification: A Tool for Sustainable Forest Management. Monograph on Forest Certification and Sustainable Forest Management. Indian Institute of Forest Management, Bhopal, India.

Yira, Y., B. Diekkrüger, G. Steup and A. Yaovi Bossa, 2017. Impact of climate change on hydrolo-gical conditions in a tropical West African catchment using an ensemble of climate simulations. *Hydrology and Earth System Sciences* 21:2143–2161.

Zaballa, R.M., S. Traerup, E. Wieben, L.R. Moller and A. Koch, 2013. Economics of forest and forest carbon projects-translating lessons learned into national REDD+ implementation. Technical report.

Zomer, R.J., A. Trabucco, R. Coe and F. Place, 2009. Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agroforestry. ICRAF Working Paper 89. Nairobi, Kenya.

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

Contributors

Chapter 1: The role of certification in accelerating sustainable forest management on the continent

Demel Teketay
Botswana University of Agriculture and Natural Resources,
Depratment of Crop Science and Production,
Private Bag 0027, Gaborone, Botswana.
demelteketay@gmail.com
dteketay@buan.ac.bw

Marie Mbolo
The University of Yaoundé I, Faculty of Sciences,
Department of Plant Biology,
P. O. Box 812, Yaoundé, Cameroon.
mbolo821@gmail.com

Severin Kalonga
Environment and Forest Certification (EFC) Limited,
3rd Floor Infotech Place,
565 Old Bagamoyo Road,
P. O. Box 33125, Dar es Salaam, Tanzania.
mbolo821@gmail.com

Ahmin A.Olivier
The International Tropical Timber Organization (ITTO),
BP 329 Libreville, Gabon.
ahiminolivier@yahoo.fr

Doris Mutta
African Forest Forum (AFF),
United Nations Avenue,
P. O. Box 30677-00100, Nairobi, Kenya.
d.mutta@cgiar.org

Godwin Kowero
African Forest Forum (AFF),
United Nations Avenue,
P. O. Box 30677-00100, Nairobi, Kenya.
g.kowero@cgiar.org

Chapter 2: Tree germplasm in Africa: status, opportunities and challenges

Crispen T. Marunda
Forestry Tasmania Division of Forestry Research and Development
79 Melville Street GPO Box 207,
Hobart, Tasmania Australia.
Crispen.marunda@sttas.com.au; ctmarunda@gmail.com

Marie Louie Avana-Tienctheu
African Forest Forum,
P.O. Box 30677-00100, Nairobi, Kenya.
M.Avana@cgiar.org

Heriel P. Msanga
Sebastian Kolowa Memorial University (SEKOMU)
P.O Box 2244,
11 Lumumba Street,
Morogoro, Tanzania.
hpmsanga@hptmail.com

Chapter 3: The status and trends of forest pests and diseases and their management in Africa

Harrison Kojwang
No. 4 Reiher Street,
Hochland Park Windhoek;
Private Bag 98617,
Pelican Square, Namibia.
hokojwang@gmail.com
hkojwang@yahoo.com

Mercy Gichora
Kenya Forestry Research Institute,
P.O. Box 201412-00200,
Nairobi, Kenya.
mgichora@kefri.org
Mewagi05@yahoo.com

Paul Bosu
Forestry Research Institute of Ghana,
P.O. Box 63,
Kumasi, Ghana.
paul_bosu@yahoo.com

Chapter 4: Climate change challenges and opportunities in African forestry

Vincent O.Oeba
African Forest Forum,
P.O. Box 30677-00100,
Nairobi, Kenya.
v.oeba@cgiar.org
vongusoeba@gmail.com

Larwanou Mahamane
International Crops Research Institute for Semi-Arid Tropics (ICRISAT),
Niamey, BP12404, Niger.
m.larwanou@cgiar.org

Henri-Noel Bouda
African Forest Forum,
P.O. Box 30677-00100,
Nairobi, Kenya.
H.Bouda@cgiar.org

Chapter 5: Production and use of biofuels in Sub-Saharan Africa

Labode Popoola
Osun State University,
Private Bag,
Osogbo, Nigeria.
labo.popoola@uniosun.edu.ng
labopopoola@yahoo.com

Bariki Kaale
Community Natural Resources and Biodiversity Conservation (TASONABI),
Private Bag,
Dar es Salaam, Tanzania.
barikaale@gmail.com

Godwin Kowero
African Forest Forum (AFF),
United Nations Avenue,
P. O. Box 30677 - 00100, Nairobi, Kenya.
g.kowero@cgiar.org

African Forest Forum

A platform for stakeholders in African forestry

African Forest Forum
United Nations Avenue, Gigiri
P.O. Box 30677-00100
Nairobi, Kenya
Tel: +254 20 722 4203
Fax: +254 20 722 4001
Email: exec.sec@afforum.org

ISBN 978-9966-7465-9-7