A REVIEW OF THE ROLE OF WOODY VEGETATION IN THE SUSTAINABLE WATER MANAGEMENT IN AREAS WITH DRY CLIMATES, WITH A SPECIAL ATTENTION ON AGROFORESTRY

A thesis submitted in partial fulfilment of the requirements for the Bachelor of Agricultural Ecology in the faculty of Agriculture

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Abstract

Agriculture plays an important role in our everyday life. Agroforestry is the intended integration of plants and shrubs into farming systems of crops and animals to form an economic, environmental and social benefit. The study is focused on secondary information from different parts of the world. Reviewed papers include studies about agroforestry, water budgeting and dry climates. It has been discovered that there are several approaches introduced to promote agroforestry and water budgeting. Such approaches are encouraged in dry climates, especially in African countries such as Namibia. One of the best strategies to overcome challenges of dry climates in order to promote agroforestry is what is called water budgeting. Water budgeting can be used for a number of land use and water use developments. The study recommends that future studies should investigate tree species that will suit best in agroforestry projects to improve sustainable water management in agroforestry for dry climates.

Declaration of own work

I, LIKARIUS H MUTOTA declare that this thesis is my original piece of work and to my knowledge has not been submitted for a similar degree in any other university.

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Signature **Date**

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First and foremost I would like to appreciate the work of God for granting me an opportunity to further extend my career development and goals orientation through an amazing institution and team of professionals where by studying bachelor degree in Agricultural ecology awarded me not only extra competences but also an opportunity of learning new language and other cultural aspects in my time of staying abroad in the great country of Czech Republic. Secondly I would like to further appreciate the woman who believed in me, my girlfriend who extra supported me financially and morally during my time of applying for this study opportunity.

Dedications

I dedicate this study opportunity to everyone who encouraged me to not give up when I demonstrated lack of resources and needed help during the application process. I felt motivated instead and choose not to give up until I made it as they say “no matter what they, say never give up on your dreams”.

Acronyms

MAWLR	Ministry of Agriculture, Water and Land Reform
NAMSIP	Namibia Agricultural Mechanisation and Seed Improvement Project
USDA	Unites State Development of Agriculture
TAFS	Traditional Agroforestry Systems

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1 Introduction and background

1.1 Background of the study

Agriculture plays an important role in our everyday life. More especially, the developing world mostly depends on agriculture for rural livelihoods and development. However, agricultural systems in developing countries are adversely affected by land pressure and climate change, both of which threaten food production (Uthappa et al. 2017).

In order to combat the climatic related issues facing agricultural production, the concept of agroforestry was introduced. Agroforestry systems comprise a long list of land management practices, including crop diversification, long rotation systems for soil conservation, home gardens, boundary plantings, perennial crops, hedgerow intercropping, live fences, improved fallows or mixed strata agroforestry (Uthappa et al., 2017). When well-managed, agroforestry can play an important role in improving resilience to uncertain climates.

Alao and Shuaibu (2013) highlighted the importance of agroforestry practices and oriented concepts in sustainable land use systems. The benefit derivable from the interface between forest trees and agricultural crops are enormous. The paper concludes that indeed the advantage of agroforestry is all encompassing and germane to a sustainable production system and livelihood.

Agroforestry is the intended integration of plants, shrubs and trees into farming systems of crops and animals to form an economic, environmental and social benefits (Michael, 2015). It is a practical and low-cost method of applying many forms of combined and organization which search to minimise human influences on land and it subsidizes to a green economy by endorsing long-term, maintainable and renewable forest organization, particularly for small-scale people.

Agroforestry has many benefits such as improving livings through enhanced health, maximised economic growth, nutrition, strengthening environmental flexibility and ecosystem sustainability when applied correctly (USDA, 2019). In turn, the above advantage and improvement can pay back to the community to amplify social sustainability where human needs are fulfilled in a way that nurtures environmental health. Agroforestry systems also harvest confirmed strategies for long-term carbon appropriation, soil enrichment with the

additional nutrient some plant release like nitrogen, biodiversity maintenance and air quality enhancements.

According to Unites State Development of Agriculture (USDA), agroforestry systems are mostly managed to uphold their productive and shielding functions through cultivation, irrigation, fertilization and pruning. Preferably, components are physically and functionally joint and vigorously managed to enhance the positive biophysical networks between them.

The Namibian Government through the Ministry of Agriculture, Water and Land Reform (MAWLR) have implemented several projects such as Okashana irrigation project called, Namibia Agricultural Mechanisation and Seed Improvement Project (NAMSIP). This project aimed to expand everyday food security and nutrition, creating job to improve income from most household by supporting agricultural activities and forestry to maximize productivity. It was discovered that agriculture is a priority because it has potential to contribute to the development of economy, social transformation, good governance and environmental sustainability. The projected project's accent is on providing sustenance towards agricultural mechanization and certified seed systems enhancement as well as increasing volume of MAWLR and related institutions, farmers and farmer cooperatives (Ipeinge, 2017).

Rural development in West African countries has been focusing on a sector approach, that have to do with the production of crop, forestry, livestock, aquaculture and many more for a long time. Over the years however, they integrate additional factors to ensure sustained productivity by taking into account the climate change given than Africa is very hot. The reasons behind is because integrated production systems allow farmers to avoid such risks like dry and hot climate (Jules et al., 2015).

Most countries equipped themselves by using prevailing multi-stakeholder partnership platforms methods that promote the growth of climate-smart agriculture. It is done by defining indicators used for the soil degradation evaluation and its monitoring. They also identify main climate hazards and, restrictions, opportunities by recognizing technology as well as opportunities given for tests and farm demonstrations that will enable them to farm or do agroforestry practices (Rohit et al., 2006).

With dry climate at some area, agroforestry becomes a challenge and difficult to practice. With low rainfall at some places, it is affected well because of not enough water to keep the

plants and shrubs growing. Most of the African country have dry climate, which makes it hard to participate in agroforestry projects, due to low rainfall and higher temperature in some parts. However, most countries have projects such project to discourage deforestation, provide their food and earn income.

1.2 Problem statement

Dry climate is one of the problems especially in Africa, since most country receive low rain fall per year and water just evaporates quickly due to hot weather condition. These challenges are limit the use of agroforestry because water is scarce and the sun is hot and windy sometimes. Both researchers and farmers have established some ways to do farming from crops to animals in such dry climate, however, more equipment and training is needed to promote the respective knowledge and practice among people. Therefore, this research is to be conducted to determine the challenges that are affecting agroforestry in dry climate area in reference to Namibia and other parts of Africa.

1.3 Research objectives

To aim of the study was to review the information on the role of woody vegetation in the sustainable water management in areas with dry climates, with a special attention to agroforestry.

The review comprised the following aspects:

- To review the global problem of drought and its consequences for human populations;
- To review concepts of water stewardship and water budgeting;
- To review role of well-developed vegetation in water retention;
- To discuss potential of agroforestry for the sustainable development in dry areas.

1.4 Definitions of terms

The study concentrated mainly on the key terms as defined below:

Agroforestry: It is the cultivation and usage of trees and shrubs together with livestock and crops in agricultural systems. It pursues positive relations between its mechanisms, aiming to attain a more ecologically various and socially productive yield from the land than is probable through predictable agriculture (Michael, 2015).

Dry climate: It is associated with deserts and those places where the air is dry, hot and when it rains, the water evaporates quickly (Michael, 2015).

Challenges: A challenge is anything old or new that is difficult and it needs great energy and determination. In this research a challenge is something that is preventing or going into the way of doing something (Michael, 2015).

2 Literature review

2.1 The origin of agroforestry practices

The concept of agroforestry has a long tradition. Agroforestry, which can be defined as the purposeful growing of trees and crops in interacting combinations, began to attain prominence in the late 1970s, when the international scientific community embraced its potentials in the tropics and recognized it as a practice in search of science (Montagnini, 2017). The author further highlights that during the 1990s, the relevance of agroforestry for solving problems related to deterioration of family farms, increased soil erosion, surface and ground water pollution, and decreased biodiversity was recognized in the industrialized nations too (Montagnini, 2017).

The application of agroforestry can be determined by different conditions. Agroforestry is generally defined as a land used system or farming system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock and in which there is ecological and economic interaction between the trees and other components (Alao & Shuaibu, 2013).

Agroforestry is considered as one of the ways to avoid deforestation in order to reduce CO_2 emissions into the atmosphere and mitigate climate change (Kiyani et al., 2017). According to Mbow et al. (2014), several agroforestry practices can be determined by different agro-ecological zones, and many systems with a range of different compositions can fulfil essentially the same functions for livelihoods and landscapes. In other words, agroforestry has both protective and social-economic benefit (Alao & Shuaibu, 2013).

Agroforestry has a wide range of importance. For example, according to Mbow et al. (2014), agroforestry provides assets and income from carbon, wood energy, improved soil fertility and enhancement of local climate conditions. The same author further outlined that agroforestry provides ecosystem services and reduces human impacts on natural forests.

Agroforestry is also considered a cost-effective strategy for climate change mitigation (Mbow et al. 2014).

However, there is a wide range of challenges facing agroforestry that needs further investigations, especially in dry climates. Dry climates occur in many countries in Africa, but also in other part of the world.

2.2 Agroforestry in Africa

Thirty-five years ago widespread concerns over land degradation and the lack of effective solutions in Africa led to the hope that international agroforestry research could contribute new solutions (Mbow et al. 2014). Several agroforestry practices can be relevant for different agro-ecological zones (Mbow et al. 2014). Throughout Africa, agroforestry systems come in a wide variety of shapes and forms. Many of these systems have little more in common than the coincidence of woody perennials with agricultural crops and/or livestock (Mbow et al. 2014).

Agroforestry is practiced in many different forms in Africa. For example, table 1 gives an illustration of common types of agroforestry practices in Nigeria according to Alao and Shuaibu (2011).

Table 1: Agroforestry practices among farmers in Lafia Local Government Area, Nasarawa State, Nigeria

Types of agroforestry practices	Lafia North	Lafia South	Lafia West	Lafia East	Respondents	Percentage
Row/hedges	11	8	6	5	30	25
Trees on farm land	2	4	6	7	19	15.8
Scattered trees on farmland	13	10	16	14	53	44.2
Wind break	4	8	2	4	18	15
Total	30	30	30	30	120	100

Source: Alao and Shuaibu (2011)

From the table, it can be seen that there are various types of agroforestry practices including hedges, trees on farm land, and scattered trees on farmland and wind breaks with scattered trees on farmland being the most common practice (44.2%).

Nigeria is one of the countries in Africa that practice all types of agricultural activities. However, Nigeria is not classified as having dry climate. Unfortunately, there is little literature about agroforestry practices in dry countries of Africa.

2.3 Agroforestry in other parts of the world

Rohit et al. (2006), made a study about the status of carbon appropriation projects in Africa by focusing on the potential benefits and challenges to it.

Outside the mitigation of greenhouse gas emissions, the possible benefits of these schemes include locallly maintainable development, natural resource protection, fortification of treasured biodiversity and ecological renovation. In order to achieve this, investors should make better efforts to recognize good projects like agroforestry and the host countries require to deliver devices for more safe property rights, advance foundations for natural resource governance in order to teach people how to conserve their natural resources, and build institutional dimensions for project design and execution, (Rohit et al., 2006).

2.4 Benefits of agroforestry

Indu et al. (2017), mentioned that agroforestry systems are purposely designed and succeeded to maximize positive connections between tree and non-tree vegetation and incorporate a wide range of work practices. In order to introduce it, it is necessary to teach people that trees are a vital part of natural ecosystems, and their incidence in agricultural systems offers a variety of aids to the soil, to other plant kinds and all biodiversity. They add that, they are progressively recognize trees as an instrument for modifying climate change and also support adaptation to it of farming societies (Indu et al., 2017).

Syam et al. (2018) conducted a study and focused on Traditional agroforestry systems (TAFS), which are described as a set of age-old agroforestry schemes which are usually lacking intentional deepened cultivation of agricultural or fodder crops and which have been done across the world with variable structure, purpose, socio-economic characteristics and ecological services. Agroforestry system are mostly practised in dry and semiarid regions of India where people just need training on how to take care of their plants to avoid drying up or dying. Each of the agroforestry systems is exceptional to the region integrating their inherent trees into the TAFS (Syam et al., 2018).

According to Abhishek (2016), agroforestry is an environmentally sustainable land use scheme that upholds increase in total harvest by joining food crops, which are annuals, together with the tree crops, i.e., the perennials, and livestock at the same time on the same unit of land. He stated that trees collect carbon dioxide in their biomass. Agroforestry does not only assist in climate alteration mitigation but also assist with climate change adaptation.

The existence of trees on the ranches certifies income divergence through the establishment of additional resources like nuts, timber, fodder and vegetables just to mention some. Therefore, agroforestry structure is cautiously and ecologically sound performing with improvement of inclusive farm productivity, soil enrichment as well as maintaining environment (Abhishek, 2016).

Ekpo and Asuquo (2012) conducted a research about agroforestry Practice as Adaptation Tools to Climate Change Hazards in Itu Lga in their country Nigeria. They stated that agriculture is the human initiative that is most weak to climate variation. Tropical agriculture, mainly subsistence agriculture is mostly vulnerable, because smallholder agriculturalists do not have suitable resources to adjust to climate change. However, agroforestry may perform an important role in justifying the atmospheric accrual of greenhouse gases and it as well has a character to play in serving smallholder farmers to familiarize to climate change. A mixture of partaking methods including organized questionnaire, household survey, effort group debates and field study was for them to get more information about climate change effects to determine possible mitigation measures to maintain sustainability practices such as agroforestry, forestations, and land use. Climatic essentials of rainfall, virtual humidity and temperature were gathered from Uyo Meteorological Station. The study was intended at determining changes in climate outline and input of agroforestry to the edition in the study area for its contribution on carbon sequestering, reducing greenhouse emissions, enhancing resiliency, reducing threat while facilitating migration to more favourable conditions in the highly fragmented agricultural landscapes. Rainfall shows a declining trend of -1.32 mm/year. Relative humidity and temperature showed that they are increasing per year and 0.13 percent year correspondingly (Ekpo & Asuquo, 2012).

3 Agroforestry and drought

3.1 Drought in the world and its consequences for agriculture and people well-being

Drought is arguably the biggest single threat from climate change. Its impacts are global. An estimated 55 million people globally are affected by droughts every year, and they are the most serious hazard to livestock and crops in nearly every part of the world. Drought threatens people's livelihoods, increases the risk of disease and death, and fuels mass migration. Water scarcity impacts 40% of the world's population, and as many as 700 million

people are at-risk of being displaced as a result of drought by 2030, (WHO). Roughly 2.5 billion people 30% of the world's population live in the dry areas, which cover more than 40% of the world's land surface. Scarce natural resources, land degradation and frequent droughts severely challenge food production in these areas. Africa is the driest of the world continents with 45% of its landmass falling under dry lands. Furthermore 38% of this land is occupied by hyper-arid or desert land. About 50% of the African population lives in the arid, semi-arid, dry sub-humid and hyper-arid areas.

A hydrological drought is when the lack of rainfall goes on long enough to empty rivers and lower water tables. Agricultural drought begins when the lack of water starts killing crops and livestock. It is an event of prolonged shortages in the water supply, whether atmospheric (below-average precipitation), surface water or ground water. A drought can last for months or years It can have a substantial impact on the ecosystem and agriculture of the affected region and harm to the local economy. Annual dry seasons in the tropics significantly increase the chances of a drought developing and subsequent bush fires. Periods of heat can significantly worsen drought conditions by hastening evaporation of water vapour.

Droughts affect food production and human society. Effects vary according to vulnerability. For example, subsistence farmers are more likely to migrate during drought because they do not have alternative food-sources. Areas with populations that depend on water sources as a major food-source are more vulnerable to famine. Economic losses include lower agricultural, forests, game and fishing output, higher food-production costs, and lower energy production levels in hydro plants. It can also bring problems with water supply for the energy sector and for technological processes in metallurgy, mining, the chemical, paper, wood, foodstuff industries as well as disruption of water supplies for municipal economies.

In the case of environmental effects worldly, drought lower surface and subterranean water-levels, lower flow-levels (with a decrease below the minimum leading to direct danger for amphibian life), increased pollution of surface water, the drying out of wetlands, more and larger fires, higher deflation intensity, loss of biodiversity, worse health of trees and the appearance of pests and dendroid diseases that can significantly affect agricultural produces.

3.2 Agricultural practices in Namibia

Agriculture in Namibia contributes around 5% of the national Gross Domestic Product though 25% to 40% of Namibians depend on subsistence agriculture and herding. Primary products included livestock and meat products, crop farming and forestry. Only 2% of Namibia's land receives sufficient rainfall to grow crops. The Ministry of Agriculture, Water and Land Reform (MAWLR) has two initiatives, the Green Scheme and the National Horticulture Development Initiative (NHDI) aimed at increasing local agricultural production. The Green Scheme encourages the development of irrigated agronomic production with a target of reaching approximately 27,000 hectares along the perennial rivers bordering Namibia. The green scheme is designed to maximize irrigation opportunities along the maize triangle (Grootfontein, Tsumeb and Otavi) as well as in the North Central and North Eastern Regions using the Kunene, Kavango and Zambezi rivers as well as the promotion of agro projects in the South using orange river and dams such as Naute and Hardap. This policy aims at harnessing the resources of government and other stakeholders in order to increase agriculture productivity and social development as envisaged in NDP IV and Vision 2030 and the Harambee Prosperity Plan.

One of the green scheme project is Etunda irrigation project. The farm is about 600 hectares in size, which is split in half for both commercial and small scale farming. Maize is the main crop on the commercial plot (300ha), where various agricultural cereal crops such as wheat, potatoes, cabbage, onion, tomatoes, butter nuts, ground nuts, water melons and bananas are cultivated seasonally throughout the year by small-scale farmers.

Under the NHDI, the government aims to increase local production and facilitate the marketing of fruit, vegetables, livestock fodder, and other horticultural products. In further support of the NHDI, government set up the Fresh Produce Hub in the northern regions with the aim to increase food production while preserving the freshness of food. To protect local farmers, to encourage greater production of grain products, and to meet its food security goals the government (via the Agronomic Board) has established policies to control certain grains. White maize, wheat, mahangu (pearl millet), and products derived from these three grains are controlled. Controlled grain crops can only be imported or exported with permits issued by the Agronomic Board and the Ministry of Agriculture, Water and Land Reform (MWLR).

3. 3 Desertification and agriculture

Given a rate of vegetation degradation of 17,937 hectares per year, the annual desertification rate is 1.3%. Human activities that contribute to desertification include the expansion and intensive use of agricultural lands, poor irrigation practices, deforestation, and overgrazing. These unsustainable land uses place enormous pressure on the land by altering its soil chemistry and hydrology. Desertification is a land degradation process that occurs in drylands. It affects the land's capacity to supply ecosystem services, such as producing food or hosting biodiversity. Its drivers are related to both human activity and the climate, and depend on the specific context. More than 1 billion people in some 100 countries face some level of risk related to the effects of desertification. Climate change can further increase the risk of desertification for those regions of the world that may change into drylands for climatic reasons. Desertification involves many environmental and socio-economic aspects. It has many causes and triggers many consequences. Many countries around the world suffer from the problems caused by desertification but it is the Sahel region of Africa where the effects are greatest. A major cause is unsustainable agriculture; a major consequence is the threat to food production. Cropland expansion and intensification of agriculture are among the drivers of land degradation processes that can lead to desertification.

As a result, most arable possible agricultural lands are open and prone to erosion that decline soil fertility and reduce soil production capacity as the land become infertile. The more biodiversity is diminishing due to desertification, the more loss of productivity of agricultural land because where no biodiversity is especially the vegetation then there won't be life as the nutrient cycling system is affected.

4 Forestry in Namibia

4.1 Trees in Namibia

Namibia is located on the south-western coast of Africa between latitudes 17.5° and 29° south and longitudes 11.5° and 25.5° east. Namibia borders Angola to the north, Zambia and Zimbabwe to the north-east, Botswana to the east, South Africa to the south and the Atlantic Ocean to the west. The Kunene, Okavango, Zambesi, Kwando-Chobe and Orange Rivers form part of the borders and are the only perennial rivers in Namibia (Kolberg, 1995).

Most of Namibia's climate is characterized by semi-arid to hyper-arid conditions and highly variable rainfall; though small stretches of the country (about 8%) are classified as semi-humid or sub-tropical (Newsham and Thomas, 2009 and Odendaal, 2011). Despite being a dry country, due to its large size, Namibia has different vegetation areas that also include woodlands and forests. However, Namibia does not have true forest, therefore forest resources are mainly defined as woody plants that are found in woodlands and shrublands (savannas) (Barnes et al, 2005). Sola (2011), describes Namibia's vegetation types as mopane savanna, semi-desert and savanna transition, and dwarf shrub savanna. Namibia's natural broad-leafed forests and woodlands are located in the northern and north-eastern parts of the country, and almost no planted forests exist (Parviainen, 2012). Namibia is situated between two deserts; Namib Desert stretching along its west coast and Kalahari Desert borders which borders its eastern and southern neighbours, Botswana and South Africa.

4.2 Community forest projects in Namibia

Namibia's rural communities have much potential for forest oriented entrepreneurship and development opportunities. However, economic value for most rural industries, most especially community forestry oriented; in poverty alleviation at community level is still not well considered in Namibia (Parviainen, 2012). Consequently, the Namibia's national forestry policy tends to focus more on sustainability and resources conservation, while socio-economic development is neglected. It is of paramount importance for the policy makers to understand that the little that is available needs sound management, yet sustaining rural livelihoods. However, this is only possible when rural communities that are in closeness with the nature are satisfied with both management policies and community forest resources benefits.

If community people get satisfactory benefits from community forest resources, they will be more encouraged to manage the forests in sustainable manners rather than over-utilizing and degrading them. This can be achieved through both financial and technical supports from the government, Non-Governmental Organizations (NGOs) and other existing and potential forestry stakeholders. Community residents can improve their livelihoods through initiations of both individual and group forest based enterprises. However, problems like lack of funds, inadequate technical supports and communities training and awareness campaigns are some of the major setbacks. Once these are achieved, it will certainly enhance rural communities' benefits such as jobs creation and consequently, contribute to rural poverty alleviation.

A number of local people and several forest experts claim to be satisfied with the Namibia's national forestry policy performance, but the whole truth is that much still needs to be done to improve rural livelihoods. The programme of Community Forestry (CF) has been unable to directly reach the community households, individuals and group enterprises sufficiently or when reached, it is with lesser impacts. That is why challenges like poverty and the high rate of unemployment in rural areas are still prevailing (Mwinga, 2012).

This, on the other hand, can only be solved if the satisfaction of the community households is known and actively taken into account. It is for this reason this study aims to critically investigate the impacts of the Namibia's national forestry policy upon rural livelihoods of the forest resources dependent people and rural development with regards to community forests benefits and production outputs.

4. 3 Namibia's Community Forests and rural poverty alleviation

In both the industrialized and developing parts of the world, a number of evidences still demonstrate that the poor and marginalized lack access to justice, especially environmental justice (Ruppel, 2010). This, in a way, impedes development in rural areas, in particular. The reduction of poverty and inequality remains an overarching priority for the government of Namibia (A review of poverty and inequality in Namibia, 2008). Being ranked as an upper middle income country, Namibia's economic growth is estimated to have slowed to 4.2% in 2011 from high growth of 6.6% in the preceding year (Namibia's economy outlook, 2012). However, Namibia's real Gross Domestic Product (GDP) growth was expected to remain moderate at around 4.7% in 2012.

Namibia faces numerous socio-economic challenges such poverty, an ever-increasing and higher rate of unemployment, inadequate capacity building, low levels of industrialization, poor economic growth and the "Human Immunodefiency Virus and Acquired Immune Deficiency Syndrome" (HIV/ and AIDS) pandemic and other communicable diseases such as Tuberculosis (TB) and Malaria all contribute to the significant increase of mortality rates and the decline in life expectancy (NDP4, 2012). Parviainen (2012) stressed that in Namibia HIV/AIDS must be taken into account within the context of poverty. HIV/AIDS pandemic has seriously aggravated the situation and constitutes a unique threat to the country's economy and development (Bertelsmann, 2012). It affects mostly young adults who belong to the production segment of the nation. Poverty prevails especially in the rural households, of

which 60% live in poverty and are subjected to food and livelihood insecurity (Kuhnhenn, 2003).

4. 4 Uses of forest resources

These forest products are some of the pillar contributors to economic development in rural communities. As it was discussed earlier, community members have both management and benefits sharing rights over forestry resources. Therefore, revenue generated from these forest products are mostly through harvest permits as well as from the fines charged from illegal logging and poaching and the sales of confiscated items. Local people obtain harvesting permits from the tradition authority to harvest resources from the forest. They have to pay for the permits, and this gives income to the community forest as a whole. If a resident is caught extracting resources from the forest without a permit, a fine is charged from that individual as a penalty. The prices of permits vary depending on the type, number or amount the products to be harvested.

The Namibian forests are rich in resources that are very useful to the rural people. The study concentrated only on some of the most economic important forest products. The evaluations focused on the production costs and revenues of these selected five main forest products. Figure 12 presents the production costs of these products per year.

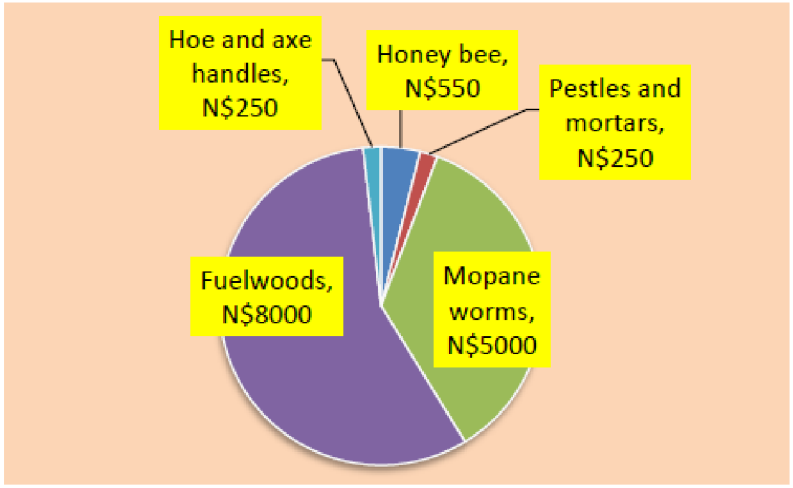

Figure 1: Forest products in Namibia's local communities

Mopane worms (*Imbrasia belina*) come second with the production cost of N$5000. Mopane worms are collected annually from mopane tree (*Colophospermum mopane*) and are dependent on the amount rainfall. In the years with low rainfall there are few or no mopane worms at all. Honey bee is another substantial forest product. Hoe and axe handles have the same lowest cost amount as pestles and mortars of N$250.

4.1.1 Firewood

The results demonstrate that fire wood is the most demanded forest product in UCF as most of the local people do not have access to electricity. As a result, firewood wood becomes the main source of energy for heating and cooking.

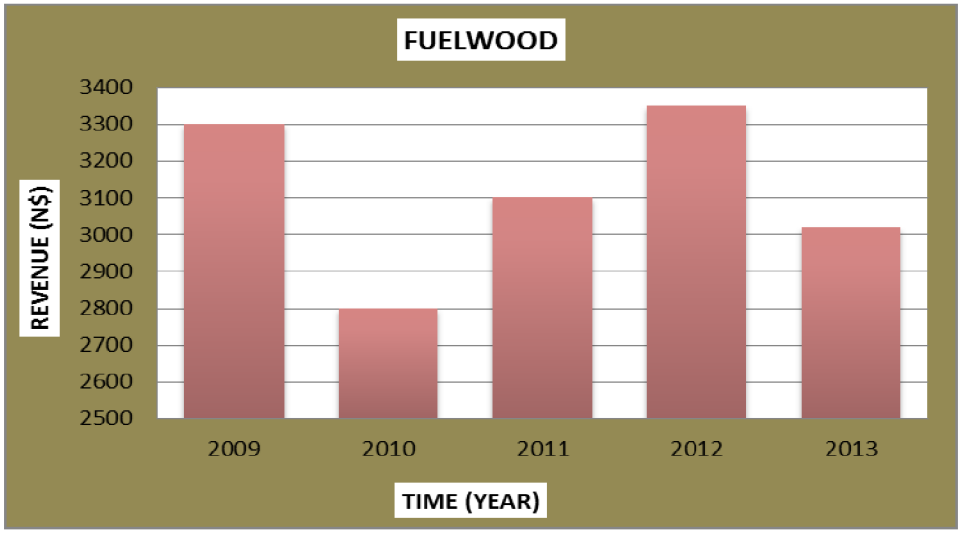

Figure 2: Firewood consumption in Namibia

Despite firewood being the most demanded forest product, its demand has been fluctuating in the past five years. The highest firewood revenue of N$3350 was made in 2012, followed by N$3300 in 2009. The least revenue was obtained in 2010 with N$2800. The respondents expressed that these fluctuations in the revenue are mainly caused by factors like local activities such as wedding ceremonies. In years with many wedding ceremonies people demand more firewood, thus higher revenues in those particular years.

5 Agriculture in Namibia with respect to drought

5.1 Effects of drought on cattle posts

Namibia is semi-arid desert country and rainfall season doesn't stay long and its normally rain in spatially due to desert environment and open spaces chiefly at Northern part of Namibia. However in regions with proper vegetation stand most common in Okavango and Zambezi region and part of Kunene region normally they receive very heavy good rain enough to sustain agricultural activities both subsistence and commercial, although not every rainy season but most often. |Systematically, through the Ministry of Agriculture Water and Land Reform, there are national dams that the government provide in order to catch enough water during rainy season, however this harvested and stored water is less for human

consumptions and industrial purposes. After the rainy season when the water gets dried out in pans and wells, livestock suffer the consequences especially at Northern part of Namibia because there might be water for drinking (tap water) but there is no grass for pasture. It is for that reason that the Government have allocated land to farmers in regions that contain good pastures, and this land is called cattle posts. It's a designed vegetation area where livestock are kept during dry season for grazing. However, when drought get to an extreme, theses grazing areas also get dried out. When pasture declines, farmers are forced to sell some of their livestock to keep a small herd to avoid animal dying on their own whereby the quality of meat won't be palatable. Farmers however are subsidized by the government to buy feed supplements as fodders, but this is not really a solution but a driving effort to adjust to the drought effects.

5.2 Effects of drought on nurseries and orchard development

In semiarid and arid regions particularly during spring and summer months, the evaporative demand for the atmosphere results in significant drought stress in many crop plants, which is one of the most severe environmental stresses and affects almost all plant functions. In these conditions, water stress causes serious reduction in growth, quantity, and quality in many plants. It frequently occurs in both intensive fruit orchards and nurseries in many parts of the world. This situation directed researchers to make further investigations to reduce severe effects of water stress on different plant species. Therefore, new approaches including effective use of water, selection of drought resistant species, cultivars, and rootstocks have been considered to reduce the effects of water stress.

In dry regions, seedlings production faces challenges due to shortages of water for irrigation and land preparations. Foresters need to choose the best varieties and cultivars that are drought resistance species for productions. In Namibia, nursery and orchard development is part of agroforestry system and because of its contribution for staple food for people and animal its need proper management and maintenance especially in seasons with water shortages.

One of the drought resistance species produced in Namibian nurseries include *Acacia erioloba* and *Acacia galpinii*. Theses *Acacia* can survive the drought season as it is a naturally a rained species. A seedling required one can of water, two times a week. *Acacia erioloba* is one of the trees that provide fodders for animal as it produces pods and seeds. Nursery owners also tend to collect sand for pot filling under *Acacia erioloba* because is

fertile due to its small soft leaves that fall and, in the process, it enhances soil fertility. *Azadirachta indica* is a neem evergreen shade tree that can also survived well in dry season. Baobab *Adonsonia digitata* is one of the trees that provide staple for people in distant area. It has a succulent characteristic with deep roots and big trunk enough to store water for years. Other trees species that are resistant to drought and provide food for people in remote areas include jackal berries or African ebony (*Diospyros mespiliformis*), *Berchemia discolor, marura* tree and (*Sclerocarya birrea*). They are naturally rained trees they don't require regular watering. People in distant areas brew traditional beer in these plants species and they also cater for fodders of livestock, firewood as well as building materials for traditional structures.

Drought resistance fruit tree that can be found in Namibian orchards include guava (*Psidium guajava*). It requires regular watering but it is not susceptible to drought. *Hyphaene petersiana* is a palm tree species most commonly in African countries. It provides staple food for people in distant areas and its leaves make traditional buckets and thatch roof for traditional houses. *Trichilia emetica* and Eucalyptus species is tree that can survive dry season not only in Namibia but in most arid regions. All these trees are found in most part of the country except in the desert.

As a result, drought can limit the production capacity as nursery owners can only stick to limited plant species that are drought resistance, rain fed tree and plants that require minimum irrigation.

5.3 Drought resistance crops

About 62 % of Namibian live in rural areas and practice subsistence farming, meaning, producing food for the family. The practice of growing crops and raising livestock is sufficient only for one's own use, without any surplus for trade. Namibian climates provide a conducive environment to some agricultural crops. Millets is one of the stable foods for most people in rural dwelling however due to spatial rain sequence, farmers have specific varieties of millets to grow in less water season. There is Okashana N0.1 and Okashana N0.2. These are drought resistance dwarf millet species that are grown locally. The differences are that Okashana No.1 produce fast during the first rain and it can be ready for harvesting in 3 months. Okashana No.2 grows fast during the first rain however harvesting take longer than 3 months and due to its instability to withstand the second heavy rain, it is easily destroyed down on the grown even before it starts producing. Regardless of their morphological

differences, both varieties produce well in short rain seasons. Maize produce corn and maize mill and is also a major source of stable food produced locally in Namibia and much of its production take place in commercial farming. In subsistence farming is not the main crop but rather part of mixed cropping as rural farmers practice mixed cropping because they can grow millet, maize and sorghum on the same piece of land at the same time however 85% is dominated by millet.

6 Climate change

6.1 Climate change on Subsistence farming

Climate change considered one of the utmost serious threats to crop production and rapidly emerging as a global critical development concern. According to Global Humanitarian Forum (GHF) (2009), emphasized that local overpopulation and poor land and water management, climate is responsible for ceaseless hunger and malnutrition for 45 million people worldwide as a result of reduced yields of cereals, fruits, vegetable, livestock and dairy and other cash crops. An increasing occurrences and intensity of extreme weather events such as droughts and floods are some of the consequences caused by climate change (Field, 2014). Furthermore, literature (Arshad et al., 2017; Reed et al., 2017; Arshad et al., 2018) indicated that in low income countries climate change has been established to significantly and destructively crop production and yield of crop production. Similarly, IPCC (2014) and Arshad et al. (2018) affirm that climate change will ominously affect crop productivity and lead to vital change in agricultural outcomes.

Moreover, Africa is more susceptible to climate change impacts than other continents, hence this is the big challenge the current generation is facing (UNISDR, 2011). The reduction in crop production by 17 % globally without accounting for good fertilized land had been estimate as an outcome of climate change (Nelson et al., 2017). In addition about 62% of Namibians are living in rural areas and depend heavily on rain-fed agriculture, which is highly vulnerable to changes in climate, seasonal shifts and precipitation patterns (WFP, 2017; FAO, 2016).

According to Kaundjua, Angula and Angombe (2012), reoccurring droughts, heavy rainfall events, incidences of higher temperature and unpredictable and inconstant rainfall have been experienced in the past 30 to 40 years in Namibia. The changes in temperature,

rainfall variability, length of winter seasons and humidity could lead to crop failures and the reduced viability of rain-fed agriculture in many areas (Makondo et al., 2014, Newsham & Thomas, 2011; Barnes et al., 2012). Furthermore, the impacts of climate changes lead to vulnerability of rural subsistence farmers particularly in crop production in Namibia as in the rest of Africa. Only a few studies have been conducted in recent years to assess the impact of climate change on Agriculture (Sarker et al., 2012; Amin et al., 2015; Chowdhury & Khan, 2015). Lastly, Amin et al. (2015) reported the significant impact of different climate variables namely, temperature, rainfall, humidity, and sunshine on the yield of major food crops (rice and wheat). As a result, the effects of climate change on crop production within subsistence farming sector is still a major problem that needs to be addressed appropriately with the support of scientific work. Numerous studies have shown how climatic changes have already impacted and will continue to impact, crop production and hence food security in northern Namibia (Newsham and Thomas,2009; Government of Namibia, 2002; Barnes et al., 2012; Reid et al., 2008; UNDP, 2015).

6.2 Challenges of drought and its consequences for human populations

Climate change is one of the greatest challenges that the world is currently facing (Shikangalah, 2020). The challenges of drought can be severe in the dry climates. Countries like Namibia experience long seasons of drought and shorter periods of rainfall.

Namibia is one of most vulnerable countries to the effects of climate change due the aridity to most parts of the country (Shikangalah, 2020). Most of Namibia's climate is characterized by semi-arid to hyper-arid conditions and highly variable rainfall; though small stretches of the country (about 8%) are classified as semi-humid or sub-tropical (Newsham & Thomas, 2009; Odendaal, 2011). Namibia's climate is distinctly arid in most of the country except in the north and north-eastern areas (Rothauge, 2001). Despite being a dry country, due to its large size, Namibia has different vegetation areas that also include woodlands and forests. However, Namibia does not have true forest, therefore forest resources are mainly defined as woody plants that are found in woodlands and shrub lands (savannahs) (Barnes *et al*, 2005). Sola (2011), describes Namibia's vegetation types as mopane savannah, semi-desert and savannah transition, and dwarf shrub savannah. Namibia's natural broad-leafed forests and woodlands are located in the northern and north-eastern parts of the country, and almost no planted forests exist (Parviainen, 2012). Namibia is situated between two deserts; Namib

Desert stretching along its west coast and Kalahari Desert borders which borders its eastern and southern neighbours, Botswana and South Africa. As a result, Namibia experiences recurring droughts.

Namibia, the driest country in sub-Saharan Africa, experiences more years of below-average than above-average rainfall (Rothauge, 2001). The rainfall season of Namibia is relatively short and recorded to run from October/November of one year to March/April of the succeeding year. Annual rainfall varies from 650 mm in the northeast to less than 50mm along the coastal areas (Rothauge, 2001).

As a result of its dry climates, Namibia has a small population of 2.3 million in comparison to its total surface area. The total surface area was last reported to be 825,418 km^2 (World Bank, 2012). It can be said that the population of Namibia is attributed to its dry climates. The same applies to other sub-Saharan countries such as Burkina Faso, Cape Verde, Chad, Gambia, Guinea Bissau, Mali, Mauritania etc.

Droughts can inflict major adverse effects on agriculture, and through that on the producers and the local and regional economy (Kulshreshtha et al., 2015). The same can be said about agroforestry practices in dry climates. Due to severe droughts in dry climates, agroforestry can be ineffective in some areas. As a result, the concept of water budgeting has been introduced.

7 Water regime

7.1 Influence of woody vegetation on water regime

The water regime of a freshwater ecosystem is the prevailing pattern of water flow over a given time. More specifically, it refers to the duration and timing of flooding resulting from surface water (overland flow), precipitation, and ground water inflow. Increases in biomass, stem densities or cover of woody plants in arid and semi-arid environments have been documented over the past decades in various regions around the planet, with a number of proposed abiotic and biotic mechanisms. Among the possible factors behind woody encroachment are changes in rainfall regime, elevation of atmospheric CO_2 concentration, invasion by exotic trees, changes in disturbance regimes such as suppression of fire, and decline in browsers or overgrazing. Increases in woody cover or density can result in altered

habitat for specialized fauna, changes in plant species composition and also biogeochemical cycles and ecosystem services, such as carbon storage and water provisioning.

Vegetation structure is closely linked to hydrological processes, and several studies have shown that reduction in forest cover causes increases in water yield and increasing tree cover on low biomass vegetation causes a decrease in water yield. Therefore, woody encroachment can have direct consequences on the water cycle. Increases in tree biomass leads to higher evaporative losses but the vapour returned to the atmosphere does not become rain in the same location where it evaporates. Consequently, at the scale of a watershed, the biomass increase has been demonstrated to result in lower production of water in spite of models predicting that this vapour may have the effect of increasing rainfall at the global scale. The increase in carbon storage due to woody encroachment or through forest plantations (in regions where the historical vegetation was not forest) may come at the cost of water aggravating the water crisis already experienced by countries in savannah regions, (nih.gov).

Besides land-use changes, woody encroachment has the potential to modify the ecohydrology of watersheds covered by world vegetation. The proportion of rainfall lost as evapotranspiration or recharging groundwater reserves and providing stream flow vary across the structural gradient worldwide. If biomass increases due to woody encroachment, changes are also expected in the partitioning of rainfall in interception, stem flow and through fall. They are not equipped with the theme of saying “the more trees the better”.

7.2 Water scarcity in remote area

Rural water supplies have traditionally been overshadowed by urban ones especially in Namibia and other part of African continent. Drinking water is domestic water used for both drinking and hygiene purposes. Centralized water provision is distributed through taps and standpipes, with water supplied from either surface or groundwater and this water is usually treated. Standpipes are provided along the pipelines at specified intervals. However, tap water inside a house is available only at the expense of a house owner. Decentralized water supplies from boreholes and wells do not have any delivery services to houses and can be used public or individually. However, despite the supply of drinking water to the villages, the population in Northern Namibia and those that lives in desert prone areas still facing challenges especially if the country didn’t receive enough rainfall.

During drought season people travelled long distances to fetch water for domestic purposes as well as to cutter for home gardening. Consequently, the situation can be detrimental to people that lives alone in the traditional houses especially elderly. Households that contain large family members can collect enough water that can stays long as far as 3 weeks that if they limit their daily consumption. Collections of water at remote areas during dry season people use buckets and drums and they use donkey carts as a form of transport but because there can be only one sources of water in the village or constituency, water point always overcrowded, people stay there for long hours, it is a time-consuming exercise. As a result of water scarcity, young people have drop out of school and some with many absenteeism for them to stays home just to fetch water because of the long distances to water points, (Namibian senses 2001).

As far as Agroforestry is concern, farmers in rural areas and must adjust to system that use less water for plants and animal sustainability. Changing to drip irrigation for home garden is one of the major priorities. They must prioritize which species of plants require water regularly and at what time of the day to water. Livestock are subjected to undergoing breaks for one day between without drinking especially big animals and only provide minimum to the young ones as much as possible every day.

If drought prolong for months, people in remote areas begin the digging of wells and fence them off to keep animal away to avoid contamination of water. Villages that are geographically located in areas that contain underground water (aquifer) tend to dig boreholes subsidized by the government and NGOs responsible for rural development. Boreholes water can last up to the entire dry season if it is prepared well.

7.3 Concepts of water stewardship and water budgeting

Water is a physical basis for life. This means that without sufficient water on the planet earth, the existence of biodiversity is highly impossible (Niveditha, 2019). The same can be said for agroforestry. Agroforestry can be vulnerable to changing conditions, especially climatic variability. In other words, where there is insufficient water supply or moisture content, agroforestry cannot be effective. This phenomenon calls for a better understanding of the impacts of agroforestry implementation on water resources, both quality and quantity, at the watershed scale.

A water budget is a basic tool that can be used to evaluate the occurrence and movement of water through the natural environment (Conservation Ontario, 2011). Water budgets provide a foundation for evaluating its use in relationship to other important influencing conditions such as other ecological systems and features, as well as social and economic components – how much water is being used by industry, residents, etc.

Water budgets commonly go well beyond how much water is available and where it is. Water availability can be increased. For example, Niveditha (2019) that the supply side can be supported by constructing farm ponds, percolation tanks, check-dams, etc. A water budget is a hydrological tool used to quantify the flow of water in and out of a system. In other words, it is an accounting of all water stored and exchanged on the land surface (rivers, lakes), subsurface (aquifer, groundwater), and atmosphere (precipitation, evaporation).

It is worth noting that, water availability is crucially important for the success of agroforestry. Therefore, achieving water security through various above mentioned measures leads to 100% food security (Niveditha, 2019).

According to Conservation Ontario (2011), water budgets can be used for a number of land use and water use developments. More specifically, they can be used:

- To set water allocation targets and recharge rates within local watersheds;
- As a decision-making tool to evaluate land and water uses such as restoration and rehabilitation projects identified in management plans;
- Evaluate the cumulative effects of land and water uses within watersheds;
- To provide a watershed scale framework for site scale studies (e.g. evaluation of a sewage & water system plan);
- To help make informed decisions about the design of environmental monitoring programs; and
- To assist in setting targets for water conservation.

7.4 The potential of agroforestry for the sustainable development in dry areas

Improved placement and design of agroforestry practices that enhance the control over water pollution and soil erosion (Schoeneberger et al., 2012). Figure 1 below shows the roles of trees in water retention.

Agroforestry has been encouraged as a means of managing excess water that has accumulated in the agricultural landscape (Lefroy & Stirzaker, 1999). Water breaks offer a novel agroforestry system for reducing impacts from flood events by providing a series of strategically placed buffers in the floodplain (Schoeneberger et al., 2012).

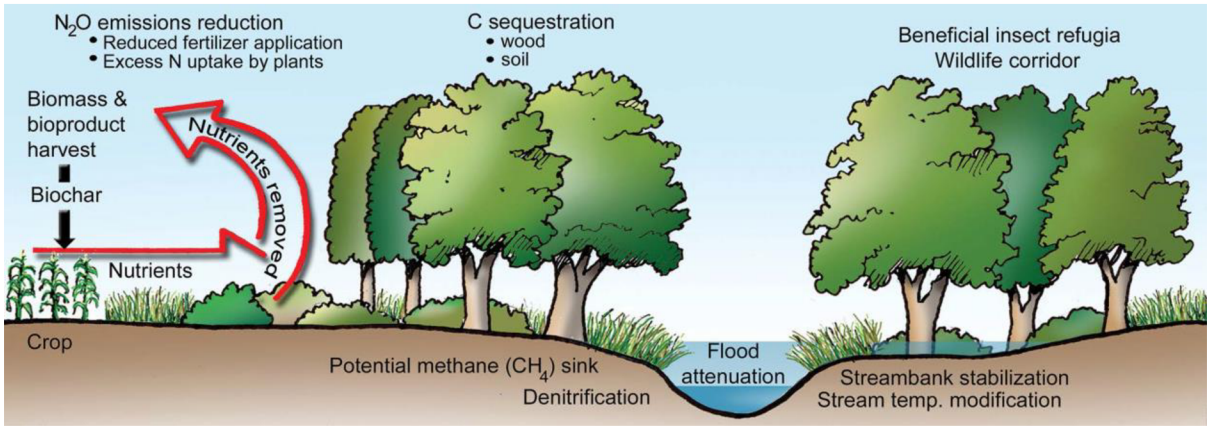

Figure 3: A conceptual illustration of a riparian forest buffer producing biofeedstock for bioenergy while offering services, including water-quality protection, greenhouse gas mitigation, climate change adaptation, and other ecosystem services.

Source: Schoeneberger et al. (2012)

Agroforestry systems can potentially augment biofeedstock production for bioenergy use, offering several advantages, especially when services for adapting to shifting weather and climate are considered (Schoeneberger et al., 2012). From the illustration, it can be seen that trees (forests) play an important role in water retention.

8 Conclusion and recommendations

8.1 Limitations of the study

Sekaran (2010) defines the concept as follow: "limitations" as conditions beyond the control of the research that may place limit on the conclusion of the study and their application to the situation (Sakora, 2010). This study is restricted to the boundary of agroforestry practices. One limitation is that there are few studies done and not all of them list the challenge they have encountered. All such limitations affect the findings of the study to some extent.

8.2 Conclusions

This study aimed to identify the challenges, the importance and the challenges facing the agroforestry practices in dry climates. Agroforestry is the intended integration of plants and shrubs into farming systems of crop and animal to form an economic, environmental and social benefit. It is a practical and low-cost method of applying many forms of combined approaches which search to minimise human influences on land and it subsidizes to a green economy by endorsing long-term, maintainable and renewable forest organization, particularly for small-scale people. Dry climate is one of the problems especially in Africa, since many countries receive low rain fall per year and water just evaporates quickly due to hot weather condition. Drought represents a major challenge for the introduction of agroforestry in dry climate areas.

The advantages of agroforestry are quite significant. The advantages of agroforestry range from food security to water retention. These approaches are encouraged in dry climates, especially in African countries such as Namibia. One of the best strategies to overcome challenges of dry climates in order to promote agroforestry is what is called water budgeting. Water budgeting can be used for a number of land use and water use developments.

Furthermore, it is perceived that agroforestry, among other benefits strives to optimize the use of land for agricultural production on a sustainable basis and, at the same time, meets other needs from forestry (Alao & Shuaibu, 2013).

8.3 Recommendations

This study addresses challenges to the agroforestry practices in dry climates, particularly by looking at the challenges faced by farmers in Namibia in relation to other agricultural and farming practices in Africa. The findings of the study shed light on some types of related challenges. Finally, the findings of the study offer a stepping stone for further studies concerning the same subject.

For agroforestry to reach its full potential, barriers need to be addressed at all levels. Policy- and decision-makers can contribute by making visible and promoting agroforestry projects and policies, for instance by 1) finding ways to adequately identify, classify and report on agroforestry projects, 2) by increasing finance to agroforestry projects and 3) by increasing knowledge and cooperation among key stakeholders, including supporting more demand-driven, participatory research and knowledge exchange (Alao & Shuaibu, 2013).

Effective adaptation to climatic variability and change requires timely information and actionable science to assist in decision-making. This includes information about tree species that work best under dry climatic conditions, especially in Africa. Therefore, this study recommends that future studies should investigate tree species that will suit best in agroforestry projects to improve sustainable water management in agroforestry for dry climates.

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