



Potential of agroforestry as forest landscape restoration tool to solve forest cover loss cum food security in Sennar and Gedaref States, Sudan

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Abstract

Forest Cover Loss (FCL) is considered one of the most critical environmental problem that devastates biodiversity, natural resources, affect food production and instigates food insecurity. The continuous rate of Sudan FCL in the last decades is alarming. This study assesses the potential of agroforestry as Forest Landscape Restoration (FLR) remedy tool for Sudan's FCL in Tozi and Wad Al-Bashir forests in Sennar and Gedaref States respectively. Structured questionnaire, Key Informant Interview and on-the-spot assessment were used to collect primary data, where 179 respondents and 14 key informants were chosen purposively. Records from Sudan Forest National Corporation (FNC), Satellite-Images and literatures supplied Secondary data. The FCL was determined using Landsat-images of 1988-19⁹₈-2008-January-2018. The Primary data were analyzed using descriptive statistic, while Landsat-images were analyzed via supervised classification. Findings revealed that consistent but unpredictable magnitudes of FCL are taken place in the study areas with the communities encroaching the forests unabated. Encroached landed areas are mostly used for crops and animal farming, recreation, and nomadic activities with crops and animals accounts for more than 70%. Impacts of FCL had initiated farmlands, water and food contestations without evidence of robust plan to arrest FCL. An appropriate and robust Agroforestry framework has been developed for use in achieving FLR to check growing FCL. This study recommends collaborative effort between Sudan FNC and the local communities in Tozi and Wad Al-Bashir forests vicinities drive the adaptation of the Agroforestry System.

Keywords: Forest Cover Loss; Forest Landscape Restoration; Agroforestry; Tozi and Wad Al-Bashir Forests; Sudan

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1. Introduction

Climate change has been taken toll across African countries judging from recent experiences in rise in excessive heat, draught, land degradation, food insecurity, migration, flooding, mortality, insecurity among others. Perhaps the impacts are more stringently felt in North African countries like Sudan. This assertion may be justified by Alfred et al. (2010) report that climate change presents an additional stress for Sudanese people already struggling with poverty, post-conflict recovery and environmental degradation. Sudan, being the third largest country in landed area in Africa, has lost considerable forest cover (Gadallah, 2018). Forest Landscape Restoration (FLR) has been one of the major challenges for combating climate change and adapt forest landscapes to global change in the 21st century. Recent efforts by Bonn Challenge and New York Declaration at restoring 350 million hectares of forest landscapes has resulted in pledges of 150 million hectares (IUFRO, 2018), a far cry from attaining the needed forest cover restoration capable of mitigating impact of climate change.

Meanwhile, on global scale, world forest estates have lost significant cover and it is currently threatening the world ecological integrity thereby reducing the capacity of the global forests to support human livelihood and ecosystem services (Harrison and Miccolis, 2017). The Forest Cover Loss (FCL) seems to be contributing more to Sudan's food and water insecurity. Aerts & Honnay (2011); Agrawal *et. al.* (2013) and Müller (2011) confirmed the existence of proximate link between FCL and Food and Water Security (FWS). Indeed, an evidence-based report by HLPE (2017) established the diverse, direct and indirect contributions of forests and trees to food security and nutrition. The FCL had been reported as the main agent that devastates biodiversity, natural habitats, natural resources, food production and instigates food insecurity by Makki (2009). Thus, identifying appropriate tool capable of mitigating the challenges imposed by FCL require urgent attention in Sudan. But Deforestation and Forest Degradation (DFD) remain the most critical environmental problems engineering FCL (Bau, 2016) and more importantly in Sudan. Because Sudan lay in the arid lands regions where natural resources seem threatening by DFD activities.

It is therefore worrisome for a country where majority of population in rural areas depends on agriculture and forest products to support their livelihoods (Fahmi, 2017; SSGCM, 2012; World Bank, 2016). Also, the situation in which forest cover has sunk to 10.3% of country's landed area in 2015 as against 58% in 1958 where FAO (2015) calls for urgent attention. Especially with the potential that the rate may have grown worsen; adopting appropriate FLR tool to stem the growth of this phenomenon is nevertheless expedient to Sudan environment. Agroforestry system had been identified as provider of wide range of ecosystem services including increasing water availability and improving local people livelihoods, enhancement of goods, services and biodiversity conservation (FAO, 2017; Harrison and Miccolis, 2017). Arising from these backgrounds, this study was design to ascertain the status and rate of FCL at Sennar and Gedaref States cum investigating potential of Agroforestry practices serving as FLR tool in the selected forests of Tozi and Wad Al-Bashir respectively in the two States in Sudan.

2. Methodology

This study was conducted in two forest areas of Tozi and Wad Al-Bashir selected purposely from Sinner and Gedaref States respectively. Sennar is located in the central-east of Sudan and lays between latitude 12.5 – 14.7° N and longitude 32.9 – 35.4° E. The state covers an area of 3,924,228 hectares with estimated population of 1,270,500 and grows at 2.6% rate per annum according to the 2008 census (Mustafa, 2015). While Tozi forest is located in Southwestern of the State with an area of 6031.2 hectares and bounded by the Wad-Eneil and Tozi communities from east and west side respectively as shown in Figure 1. Gedaref State is located in the eastern part of Sudan and stretches between longitudes 33–36° E and latitudes 12–15 °N with an area of 7,800000 hectares between two major tributaries of the Blue Nile: the Atbara River and Rahad River (Glover, 2005). The Wad Al-Bashir forest, bounded by Al-Hawata and Al-Mafaza communities, is located in the Southwestern part of Gedaref State with an area of 3,468 hectares as shown Figure 1.

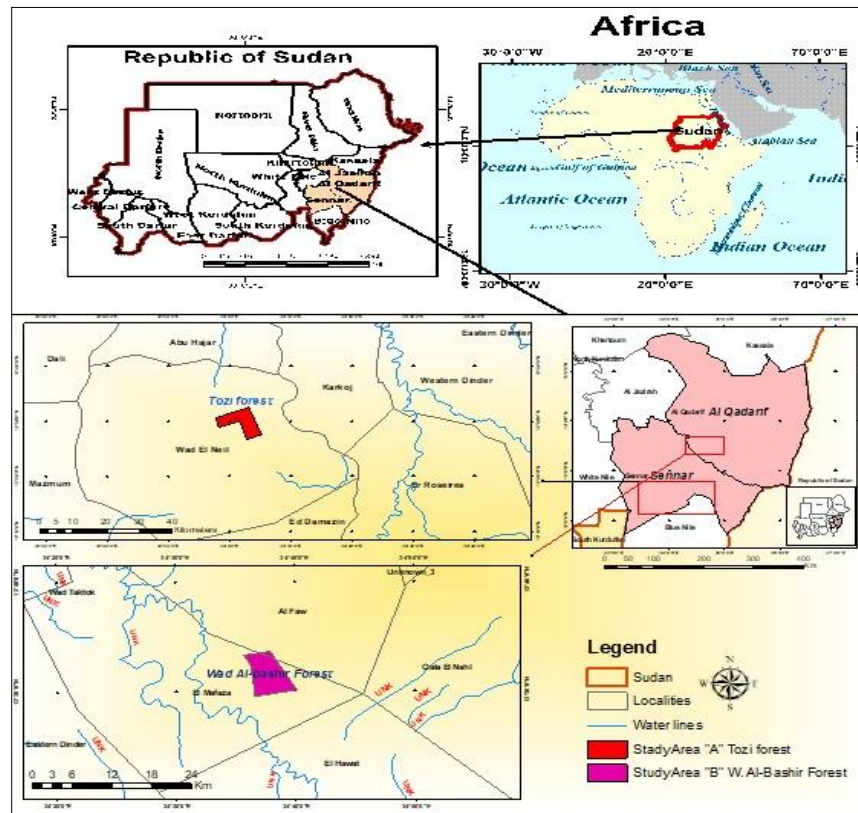


Figure 1. Study Areas: Tozi and Wad Al-Bashir Forests in Sudan

Structured questionnaire, Key Informant Interviews (KII) and On-the-Spot Assessment were used as survey tools to collect data from primary sources. Data collection begins in December 2017 and end in June 2018. Using Slovin’s formula reported by Ryan (2013):

$$n = \frac{N}{(1+N \cdot e^2)} \dots\dots\dots \text{Equation 1}$$

Where: *n* = No. of samples, *N* = total population, *e* = error margin (0.05)

Questionnaire was administered on 179 respondents purposively picked from the four communities bounding the two selected forests, while 14 people were participated as key informants purposely drawn from among the representatives of local communities, Universities staff, Forest National Corporation (FNC) staff, Farmers, Traders and animal Ranchers (Table 1). Language barriers were mitigated by using facilitator and translating questionnaire into Arabic language. Other data were collected from secondary sources through extraction of information

Table 1. Respondents Information

No. of Interviewed Key Informants	No. of Individuals subjected to questionnaire
2 University Staff	98 Farmer
3 FNC Staff	58 Animal Ranchers
5 Farmer	09 Civil-Service-Employee
4 Trader	14 Businessmen

from FNC records and reviewed literatures. Also the status of forest cover change was determined using Landsat Images of 1988, 1998, 2008, and 2018 that were downloaded from United State Geological Survey website (GloVis) at path 172 and row 51 as shown in Table 2.

Table 2. Utilized Landsat Images in Determining Forest Cover Change

Satellite/Sensor	Pass/Raw	Acquisition date	Spatial resolution
Landsat 5 TM	172/51	23/03/1988	80
Landsat 5 TM	172/51	19/02/1998	80
Landsat 5 TM	172/51	06/06/2008	80
Landsat 8 OLI/TIRS	172/51	19/01/ /2018	30

Source: (GloVis, 1988,1998,2008, 2018)

The images were clear of cloud cover. The data collected from primary sources were analyzed using descriptive statistic while satellite data and other information items were analysed with ERDAS Imagine 2015 and ArcMap 10.5, where images preprocessed through radiometric and geometric correction, image enhancement and supervised classification of Land Use Land Cover (LULC) with aid of GPS device. In addition to Microsoft Excel 2016, which was used in computing the LULC changes showing their percentages and changes rate in the two study areas.

3. Results and discussion

3.1. Status of forest cover, causes of the changes and reasons

There were three classes of LULC depicted by supervised image classification: the forest trees cover, barren land and farmland as shown in Figures 2 and 3. The images showed drastic LULC

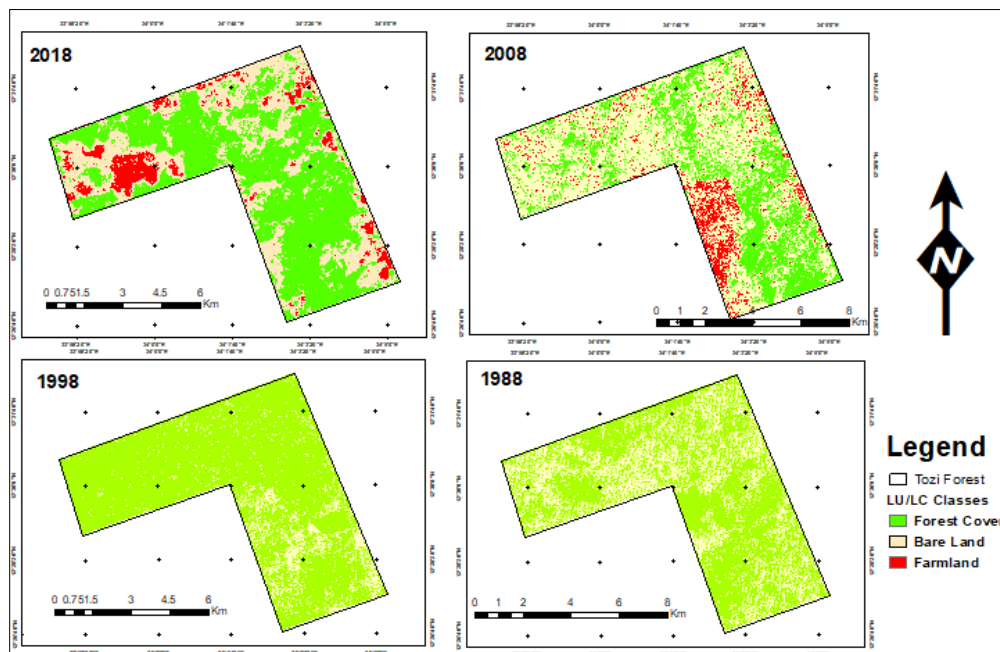


Figure 2: Land Use and Land Cover Changes in Tozi Forest (from 1988-2018)

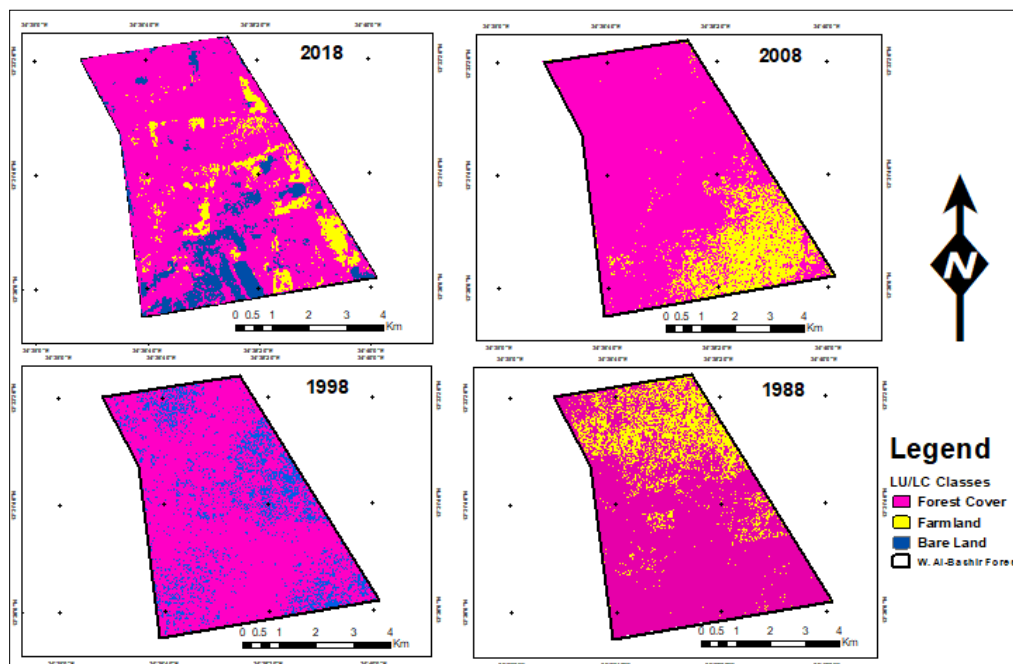


Figure 3. Land Use and Land Cover Changes in Wad Al-Bashir Forest (from 1988-2018)

modifications that have occurred in the study areas from 1988 to January, 2018. The status of forest covers at Tozi forest have witness non-uniform changes: 63%, 87%, 32%, and 56% of the total forest area in 1988, 1998, 2008, and 2018 respectively as depicted in Figure 2.

The same trend but varying magnitude was observed at Wad Al-Bashir forest in 1988, 1998, 2008, and 2018: 83%, 85%, 82, and 79%, respectively as shown in Figure 3. While forest cover is fluctuating in Tozi forest the farmland and barren land area continued to expand steadily from 2008 – 2018 as a result of continuous conversion of forestland to farmlands by farmers in forest precinct. A key reason for farmers’ quest to expand their farmland areas into forest zone is attributable to forestland fertility that gives good crop yield.

Another secondary reason is hinged on scarcity of farmland to meet growing population need for agricultural purposes. The activities of animal ranchers with their herds during the rainy season play significant role at retarding or obstructing natural regeneration of the forest trees. The experience at Wad Al-Bashir forest is similar but with varying reasons for changes in forest cover and farmland expansion. The conversion of forestland into farmlands is rather caused by population expansion and since the population in the area depends largely on Agricultural activities to earn a living, the shortfall in the available area for farming will have to be mitigated by encroachment into reserved forest area.

3.2. Implications of forest cover change

It was established that the landscape of the study areas had changed due to the FCL caused by the factors earlier adduced for both Tozi and Wad Al-Bashir forests. This has obviously affected the areas ecosystem and biodiversity thereby threatened both water and food security while there are increase potential for conflict on land for farming and grazing. These were observed during on-the-spot assessment of the two forest areas and deducible from the responses from the key informants and other respondents. These observations agreed with findings by Zhang et al. (2017) that FCL alters landscape patterns and affects regional ecosystems. The FCL had also been reported to impact on, natural hydrological system, global carbon cycle, biodiversity at local, regional and global scale (Deb and Mishra, 2016;). The interconnectivity of FCL and its various impacts are illustrated by Makki (2009) in Figure 4.

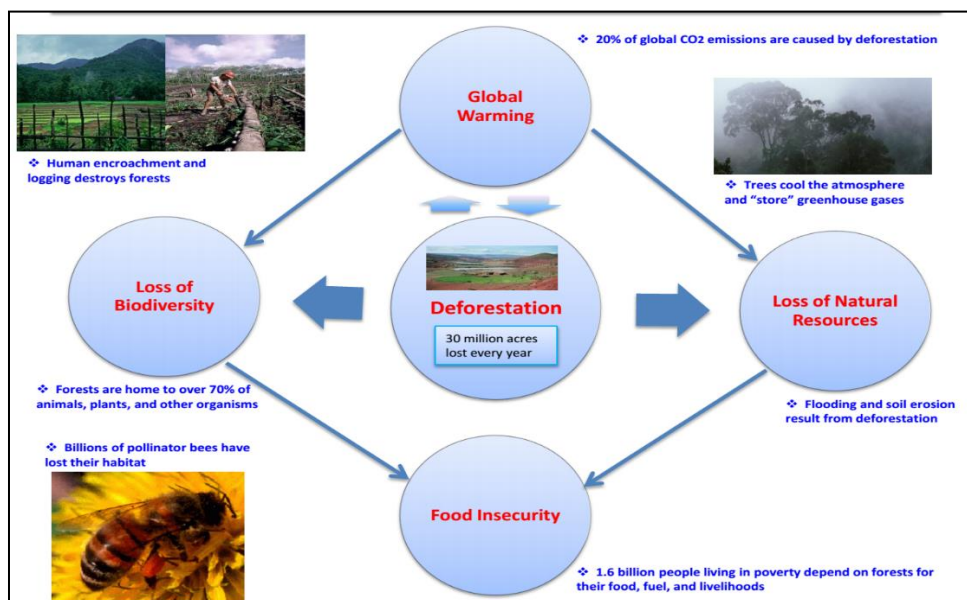


Figure 4. Implication of Forest Cover Loss (Source: Makki, 2009)

At the study locations, forest cover declination exposes soil to wind and water erosions that aggravated land degradation and desertification. This must have been responsible for the reduction in the potential of biological land productivity and crops yield indicated by the respondents.

3.3. Income sources and forestland utilization by respondents

The four studied Communities in the two states appears to have comparable demographic characteristics in that majority of them engaged in either crop or animal farming as indicated in Figure 5. The figure shows that about 54% of the total respondents were farmers while the rest of the respondents from the Tozi communities were either civil servants or engaged in businesses. That is 54% depends on Agricultural and Forest Products exclusively for their income, livelihoods and food. This suggest the need to institute a program to restructure the contributions of more than half of the populations in the Tozi area to land cover restoration. One other possible inference is an insinuation that educational level cum awareness of the people living around Tozi forest is low judging from the percentages of respondents that are engaged in civil service work.

The population of farmers in Wad Al-Bashir forest area is alarming in that they completely overshadow other possible form of engagement. More than 80% of the total respondents engaged in either crop or animal farming. There is no gainsaying the fact that their activities will dictate the environmental status of the area. Indeed, there is possibility of free access to forest land for farming which might have been encourage by perception of farming productivities as driven by culture and

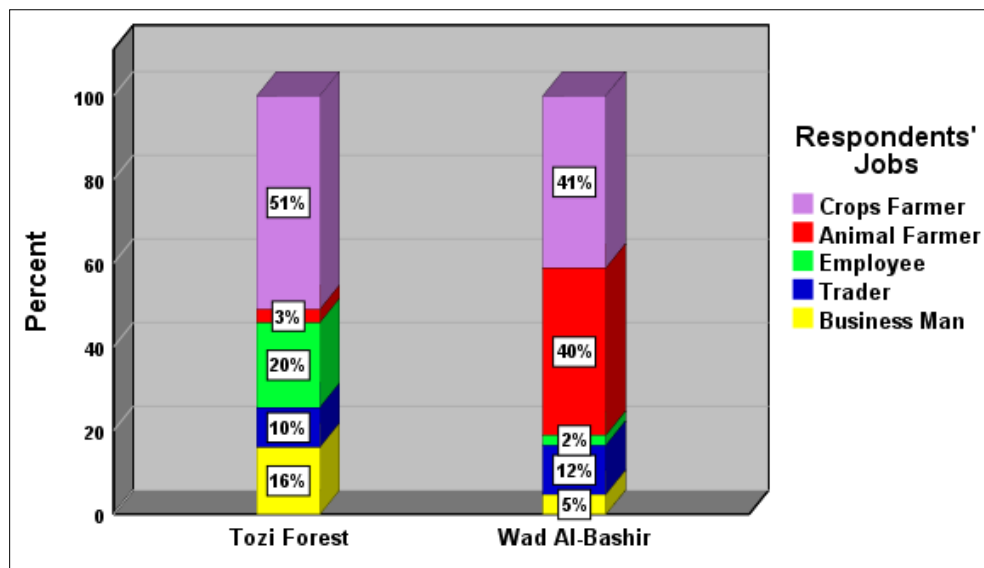


Figure 5. Respondents' Jobs in Tozi and Wad Al-Bashir Forests

there are six form of uses at Wad Al-Bashir. Although, utilizations for animal grazing, farming, recreation and settlement were common at both, the proportion of the encroached land utilizes for various use were differs as attested to by the respondents. The critical inference from the responses is that not less than 70% of

the encroached land in the two forests are channeled into animal and crop farming. Hence, majorities of the populations around Tozi and Wad Al-Bashir forests were

traditions in the area. The apathy to Civil Servant work is clearly manifested in the percentage of respondents that engaged in white-collar job.

The information retrieved from the records of Sudan FNC shows that forests land at Tozi and Wad Al-Bashir are being encroached steadily. Findings on what encroachers uses the encroached forestland for at Tozi and Wad Al-Bashir forests point to the fact that that pattern of use varied for

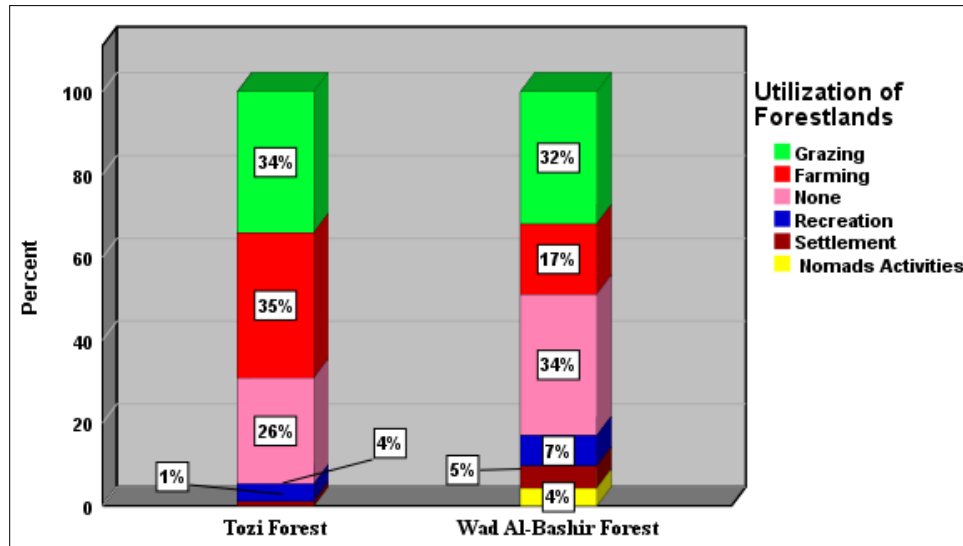


Figure 6. Utilization of Forestland by the Respondents

Tozi and Wad Al-Bashir forests as shown in Figure 6. While there are five form of uses at Tozi, farmers and their activities are actively influencing the environment around Tozi and Al-Bashir, especially in relation to FCL.

3.4. Agroforestry as Tool for FLR in the Study Areas

Mansourian (2016) reported the global trend in promoting FLR as a means of solving world’s FCL problem and climate change. The FLR helps in mitigations and adaptations processes that create support for poor rural communities against water draught and soil degradation occasioned by climate change. It had also been reported that FLR also contributes to the achievement of the Sustainable Development Goals (SDGs), as advanced by SDG15 (Protect, forest, land and services recovery), SDG1 (no poverty), SDG2 (zero hunger), SDG6 (clean water and sanitation) and SDG13 (climate action) (United Nations, 2015). As evidenced from the reviewed literatures, Agroforestry practices can increase forest cover. For instance, findings by IUCN and WRI (2014) identified Agroforestry as one of the approaches used in restoring degraded forests and agricultural lands thereby contributing to landscape restoration. This implies that Agroforestry has potential to restore

land productivity, conserve biodiversity, increase the resilience of agro-ecosystems, alleviate poverty and contribute to food security (FAO, 2017).

Arising from the current use of the encroached forestland at both Tozi and Wad Al-Bashir forests, factoring Agroforestry practices is capable of sustaining the soil fertility and increase biological productivity to take care of farmers' concern. That is adoption of Agroforestry practices at the study areas will guarantee good crop yield and availability of fodder for the livestock. Because Agroforestry involved a collective systems cum technologies in which woody perennials-trees, shrubs, palms and bamboos etc. are grown on the same land with agricultural crops and/or animals rearing in form of spatial arrangement or temporal sequence (Muneer, 2008). it facilitate both ecological and economic interactions between the different components (FAO, 2017). Accordingly, Agroforestry system would sort land conflicts, make land-use integration, provide food from the crops and forest, contribute to food security, increase forest cover, wood for building and energy, and generates income. This would lead to an active process that brings people together to identify, negotiate and implement practices that restore an agreed optical balance of the ecological, social and economic benefits of forests and trees within a broader pattern of land uses (GPFLR, 2018)

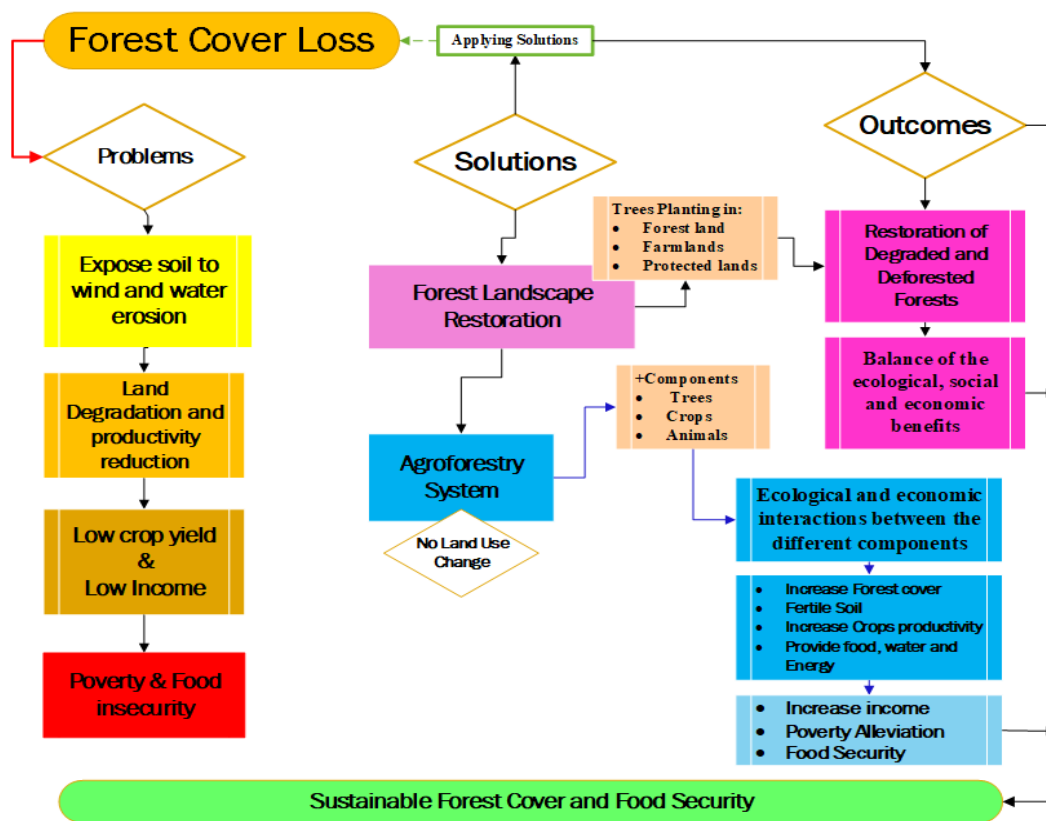


Figure 7. Agroforestry System Framework for Sudan Forest Landscape Restoration

In practicing Agroforestry, there is need to note the tree species that grows naturally, have faster growth and environmental and social relevance to the study areas. This study noted the salient tree species growing at Tozi Wad Al-Bashir forest areas. The *Acacia seyal*, *Acacia Senegal* and *Balanites aegyptiaca* were

predominant while *Acacia seyal*, *Acacia Senegal* were the chief tree species that grows in Wad Al-Bashir forest. These tree species can be adopted for use in Agroforestry framework developed for the study locations and which is graphically presented in Figure 7. From this background, adoption of Agroforestry system in the forest management plans and strategies will contribute significantly to recovering Sudan's forest cover, because of their renowned environmental and economic role; especially *A. senegal*.

A step to achieving this goal will be by mounting campaign to boost effective extension channels at local level. This campaign is to educate various stakeholders in the communities around Tozi and Wad Al-Bashir specifically, and Sudan's communities in general, on the economic and environmental importance of retaining and restoring forest cover as it relates to their livelihood sustenance.

4. Conclusion and recommendations

This study established that consistent but unpredictable magnitudes of FCL are taken place at Tozi and Wad Al-Bashir Forests in Sennar and Gedaref States respectively in Sudan. Communities around the two forest areas continue to encroach into the forestlands, using the encroached lands for activities ranging from crop and animal farming, recreation, settlement and nomadic activities. Although, the stable work at the communities surrounding the two forests varied, farming of crops and animals accounts for more than 50% of other job activities. The FCL in the areas are aggravated by growing population living on limited farm land, trees cutting for domestic energy uses, utilization of forestland for animal grazing and crops farming and limited funding for reforestation activities. A robust Agroforestry framework is developed for the two forest areas to restore degraded lands, support livelihoods, improve food and nutrition security, alleviate poverty and contribute to forest landscape restoration. The study recommended that advocacy for the adoption of Agroforestry, as a vital tool for FLR will be better achieved if Sudan Forest National Corporation and local communities in Tozi and Wad Al-Bashir forests vicinities can collaborate.

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