Global Scientific JOURNALS
GSJ: Volume 10, Issue 3, March 2022, Online: ISSN 2320-9186
www.globalscientificjournal.com

# Agroforestry for Soil Fertility and Sustainable Agriculture in Sudan

## Case of Nabag Reserve Forest, South Kordofan, Sudan

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**Abstract**

Climate change coupled by increasing population number, have aggravated the problem of different farming systems in Sudan. Soils have lost their fertility due to over-cultivation, overgrazing, and desertification. Added to that, civil war and continuous rural areas out migration in the study area, South Kordofan State, let to land over exploitation and conflicts over resources. Hence the sustainability of farming system is threatened and food security became an immediate issue for decision makers. Agroforestry is the available alternative in the study area as there is a reserve forest persists. Nabag reserve forest, 4000 ha was natural forest in which *Acacia senegal* trees dominate. There was an urgent need for forest rehabilitation. The introduction of agroforestry represented by Taungya practice would solve the problem of immigrants and landless war affected people at the same time forest rehabilitation would be achieved. The overall objective of this study was to assess the effect of adopting Taungya in improving soil fertility, increasing crop productivity and hence support food security and sustainable farming. According to tree density forest compartments were divided into three strata, low, medium and optimum. In each stratum random circular sample plots 0.001ha have been laid. A total of 21 sample plots were made. Tree performance, forage coverage and gum arabic production have been measured for two consecutive years. Structured questionnaire have been conducted for 50 households in villages surrounding the forest.. Study results revealed that there is significant increase in crop productivity under *Taungya*, tree performance was beyond the optimum and so the gum arabic. The comparison between crop productivity under the system and outside indicated, improvement in soil fertility and protection against wind erosion. The study concluded that

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agroforestry is a suitable method to improve degraded lands, improve soil fertility, increase crop productivity and hence food security as well as improving livelihood by diversifying and increasing income sources.

*Key words: Agroforestry, Taungya, Gum Arabic, South Kordofan, Nabag Reserve Forest*

**Introduction**

This study was conducted in Nabag Reserve forest, South Kordofan State in the Western part of Sudan where, low rainfall wood land Savanna dominates. South Kordofan State lies between latitudes $9^o$ 13'- $12^o$ 38' N and longitudes $27^o$ 05' - $32^o$ E, with total land area of about 158.355 $Km^2$; it borders South Darfur, North Kordofan, and White Nile.

Nabag reserve forest is in the eastern part of the State neighboring North Kordofan State where climate change and signs of desertification are obvious. There is Lack of development institutions and job creating opportunities for people. Therefore, they depend on the surrounding natural resources, namely forests to cover their daily needs from fuel wood and wild fruits, Hammad et al (2013).

Agriculture, namely subsistence farming is the main form of livelihood in the area. Population reflects the influxes of, transhumance and force migration due to civil wares. The area suffers from environmental changes, consecutive drought episodes, high population growth and consequent recurring food shortages, which resulted in loss of soil fertility, reduction in crop yields, and labor out migration, Hammad et al (2013).

**Agroforestry and food security**

Achieving food security and improving agricultural systems is a global priority that will continue to grow in magnitude over the coming years. Agroforestry is a conservation as well as rural development strategy that focuses on the enhancement of rural livelihoods, (FAO, 2017).

Communities are mobilizing to provide for local food security and to advance agroforestry practices that create jobs and protect the environment. The system is an important climate-smart agriculture approach. Fadl, (2010) reported, that agroforestry supports food and nutritional security, whereas, policy and market opportunities exist to promote multifunctional agricultural approach.

Agroforestry, as a new approach of production, is the means of integration of trees with annual field crop cultivation, livestock production and any other farm activities. Integration increases farm productivity when the various components occupy complementary niches and their associations are managed effectively, Steffan – Dewenter *et. al.,* (2007).

Appropriate combinations of crops, animals and trees in agroforestry systems can not only increase farm yields, they can promote ecological and social resilience to change because the various components of a system, and the interactions between them, will respond in differing ways to disturbances. A diversity of species and functions within integrated production systems is therefore a risk reduction strategy, and agroforestry is recognized as an important component in climate-smart agriculture for both its adaptation and mitigation roles. For example, soil fertility improvement technologies can stabilize crop yields in drought conditions. In Niger, farmers explain that increasing the number of tree species per function insures them against 'function failure' in their farming systems because at least some species will provide each required function, even in the driest years (Faye *et al*., 2011).

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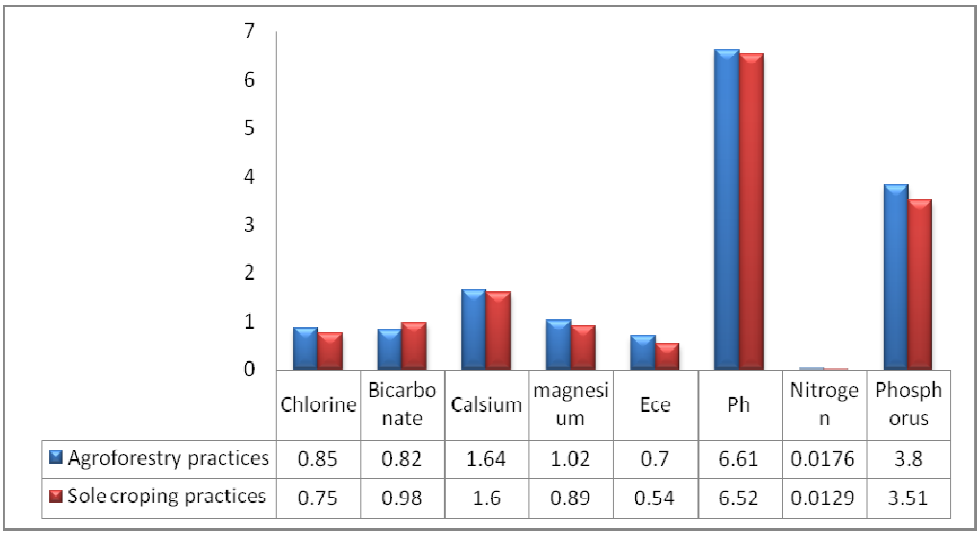
**Agroforestry and Foil Fertility:**

Several investigations have been carried out on soil fertility aspects of some tree-based systems (Kang et al., 1990; Amira and Ahmed, 2002). It has been suggested that the presence of trees will also lead to an improvement in soil-water supplies (Young, 1989). Hussein and El Tohami (1998) found that under agroforestry land use system using *Acacia senegal* in the central clay plain of the Sudan, soil properties have been greatly influenced by tree cover, total organic carbon and nitrogen are more under the trees than cultivated agricultural schemes in the vicinity. The same study revealed that, the cation exchange capacity is greatest under *Acacia senegal* indicating more available nutrients under the trees; and soils under *Acacia senegal* trees had less bulk density compared to cultivated fields, indicating favorable physical soil conditions under the trees.

The major differences between agroforestry and other land use systems lies in the transfer or turnover of nutrients within the system from one component to the other, and the possibility of managing the

system or its components to facilitate increased rates of turnover without affecting the overall productivity of the system (Nair, 1993).

Amira and Ahmed (2002) reported accumulation of carbon and nitrogen under an old *Acacia senegal* forest site than a young forest site, indicating positive effects of long fallow period, increased tree canopy and more accumulation of tree litter. Significantly, the old forest site contains more than twice as much carbon and nitrogen as the adjacent arable land. This difference is mostly confined to the top 20 cm. Similar findings were reported by Gerakis and Tsongarakis (1970). Hammad (2014) concluded that the integration of *Acacia senegal* in the farming practices in the gum belt of North Kordofan would maintain soil fertility, sustain production and enhance environmental stability, (Figure 1).




| | Chlorine | Bicarbonate | Calsium | magnesium | Ece | Ph | Nitrogen | Phosphorus |
|---|---|---|---|---|---|---|---|---|
| Agroforestry practices | 0.85 | 0.82 | 1.64 | 1.02 | 0.7 | 6.61 | 0.0176 | 3.8 |
| Solecroping practices | 0.75 | 0.98 | 1.6 | 0.89 | 0.54 | 6.52 | 0.0129 | 3.51 |

*Figure 1: Soil nutrients under Agroforestry and Monocropping*

*Source: Hammad et al (2014)*

**Methodology**

Nabag reserved Forest, is a natural reserved forest located in South Kordofan State, the main stock of trees in this forest is *Acacia senegal*. Forest national corporation (FNC), have started agroforestry namely, *Taungya* practice to rehabilitate the forest which was over-aged, making advantage of the available unemployed inhabitants and landless immigrants. Figure (2) shows the location of the study area.

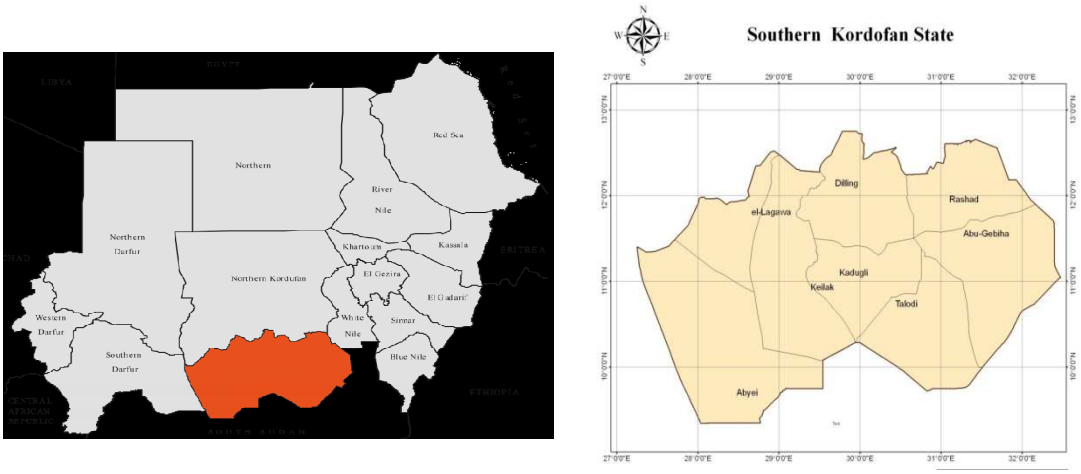



*Figure (2): The location of the study area*

*Source : Forest National Corporation Reports (2017)*

According to tree density forest compartments were divided into three strata, these were high, medium and low density stands. In each stratum random circular sample plots 0.001ha have been designed. A total of 21 sample plots were laid. In each sample plot crown diameter, number of branches, general tree performance, forage coverage and gum arabic production have been measured for two consecutive years. To calculate gum arabic production trees have been tapped using the recommended tool for tapping "*Sunki*". All recommended technical aspects for tapping and gum collection have been considered. The average gum arabic production was taken for the two consecutive seasons. A social survey was made to assess social attributes and economic benefit to people who adopted the system. Accordingly, structured questionnaires have been conducted for 50 beneficiaries who were rural people settled in 6 villages surrounding the forest, the sample size was 10%. Six focus group discussions were also held in addition to general observations and informal discussion with forest officials and nomads. Data were analyzed using SPSS.

**Results and discussions**

Study results revealed that there is significant difference between crop productivity under agroforestry and outside the system. Increase crop production under agroforestry might be due to increase in soil fertility as *Acacia senegal* is a leguminous tree species that enhance soil fertility through Nitrogen fixation, other reason might be due to crop protection from wind erosion and provision of microclimate that reduces soil temperature and water loss, and might be due to improvement in water use efficiency, Table (1) shows this result.

Table 1: crop productivity per ha under agroforestry and outside

| Crop | Productivity under agroforestry/ Kg | Productivity outside/Kg | average | p-value 0.05 | Test of significance |
|---|---|---|---|---|---|
| Hibiscus | 1.59 | 0.688 | 81.08 | 0.05 | * |
| Water melon | 3363.75 | 436,5 | 95267.25 | 0.000 | ** |
| Sesame | 6.3 | 2.19 | 42.15 | 0.003 | ** |
| Cow pea | 1.8 | 0.85 | 3884.4 | 0.05 | * |
| Ground nut | 15.41 | 5.55 | 140.78 | 0.025 | * |

This result synchronized with (Ong et al. 2002) findings who reported that there is also strong evidence that agroforestry can potentially improve the water use efficiency by minimizing the unproductive part of the available soil water. This finding goes with the same line with Sharrow and Ismail 2004 cited in A.G. Mohamed (2005) who concluded that more efficient sharing of site resources between trees and other intercropping components together with nitrogen fixation and micro-climate modification by trees may significantly increase the overall net production. The same authors added that agroforestry could lead to efficient carbon and nitrogen sequestration over time.

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The result of socio economic data revealed that adoption of agroforestry has a significant effect in improving livelihood through increasing household income. This took place either through product diversification, stated by 85% of respondents, or production of large quantities of farm products mentioned all respondents (100%) hence increasing income from cash crops and securing food throughout the year from food crops. This result coincides with previous studies which reported that farmers' income increased by 50% when adopting agroforestry. Apart from income the result of the social data indicated that there is evidence of absence of village out migration, involvement of women in all farming activities, involvement of school children during school off season in forest rehabilitation activities and obvious community participation in general forest namely, forest protection. Study results also revealed that the forest is completely covered by trees, Figure 3 and Figure 4. Forest rehabilitation plan was implemented exactly as scheduled, and landless farmers have secured lands for seasonal crop production.

*Figure 3: the site before adopting agroforestry*

*Source: Forestry Report, South Kordofan 2017*

*Figure 4: the site after adopting agroforestry*

*Source: Forestry Report, South Kordofan 2017*

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**Conclusions and recommendations**

The study concluded that agroforestry practice have proved to contribute significantly to forest rehabilitation and vegetation cover, hence the forest area is protected from wind erosion and desert encroachment, soil fertility is improved. As crop yield is increased, hence food security and sustainable farming could be obtained. Among the challenges that confront implementation of agroforestry in the study area are grazing, frequent locust attack and the increasing number of landless people which result in decreasing the land allocated for each farmer. The study recommended that agroforestry is to be adopted as one of the optimum solutions for soil maintenance, climate change mitigation and food security challenges in the study area and in dry land Africa in general.

**Acknowledgement**

Many thanks to Forest National Corporation South Kordofan State, Debaibat Forest Circle, for all kind of help and support they have provided during the study period, the authors are also indebted with gratitude and appreciation to the collaborating people in the study area. Their creativity in making the best out of such unstable environment has been the constant base of motivation to carry out the research.

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