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Research Application Summary

Agroforestry for soil fertility and sustainable agriculture in Sudan

Zeinab, M.H.[1*], Osman, E. A.[2] & Wihad, A.[3]

[1]Faculty of Forestry, University of Khartoum, Sudan
[2]Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan
[3]Forest National Corporation, South Kordofan State, Sudan
***Corresponding author:** bzeinab14@gmail.com

Abstract

This study was conducted in South Kordofan State where farming system stability and food security is threatened. The objective was to assess the effect of agroforestry in improving soil fertility, increasing crop productivity and supporting food security and sustainable farming. Accordingly, tree density forest compartments were divided into three strata. In each stratum random circular sample plots were laid out. A total of 21 sample plots were made. Tree performance, forage coverage and gum arabic production were measured for two seasons. Structured questionnaire was also administered to 50 households. Study results indicate that there was significant increase in crop productivity under Agroforestry, and also gum arabic production. Crop productivity was improved due to improvement in soil fertility and protection against wind erosion. The study concluded that agroforestry is suitable for improving degraded lands, improving soil fertility, and hence, food security and livelihoods.

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

Resume

Cette étude a été menée dans l'État du Sud Kordofan où la stabilité du système agricole et la sécurité alimentaire sont menacées. L'objectif était d'évaluer l'effet de l'agroforesterie sur l'amélioration de la fertilité des sols, l'augmentation de la productivité des cultures et le soutien de la sécurité alimentaire et de l'agriculture durable. En conséquence, les densités d'arbre dans les compartiments forestiers ont été divisées en trois strates. Dans chaque strate, des parcelles d'échantillonnage circulaires aléatoires ont été mises en place. Au total, 21 parcelles d'échantillonnage ont été établies. La performance des arbres, la couverture fourragère et la production de gomme arabique étaient mesurés pendant deux saisons. Un questionnaire structuré a également était administré à 50 ménages. Les résultats de l'étude indiquent qu'il y a eu une augmentation significative de la productivité des cultures grâce à l'agroforesterie, ainsi que de la production de gomme arabique. La productivité des cultures a été améliorée grâce à l'amélioration de la fertilité des sols et à la protection contre l'érosion éolienne. L'étude a conclu que l'agroforesterie est appropriée pour améliorer les terres dégradées, améliorer la fertilité des sols et, par conséquent, la sécurité alimentaire et les moyens de subsistance.

Mots clés : Agroforesterie, gomme arabique, réserve forestière de Nabag, Sud Kordofan

Introduction

Climate change coupled with increasing population number, have aggravated the problem of farming systems in Sudan. Soils have lost their fertility due to over-cultivation, overgrazing, and desertification. Agroforestry is an alternative to address these challenges. This study was conducted in Nabag Reserve Forest, South Kordofan State in the Western part of Sudan where low rainfall and woodland 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, 4000 ha, is situated in the eastern part of the State neighboring North Kordofan State where climate change and signs of desertification are increasing. There is lack of development institutions and job creating opportunities for people in the area. Therefore, they depend on the surrounding natural resources, namely forests, to provide for 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. The population reflects the influxes of transhumance and force migration due to civil wars in the area. The area also suffers from environmental changes, frequent drought episodes, high population growth and consequent recurring widespread food shortages, loss of soil fertility, reduction in crop yields, and labor out migration (Hammad *et al.,* 2013).

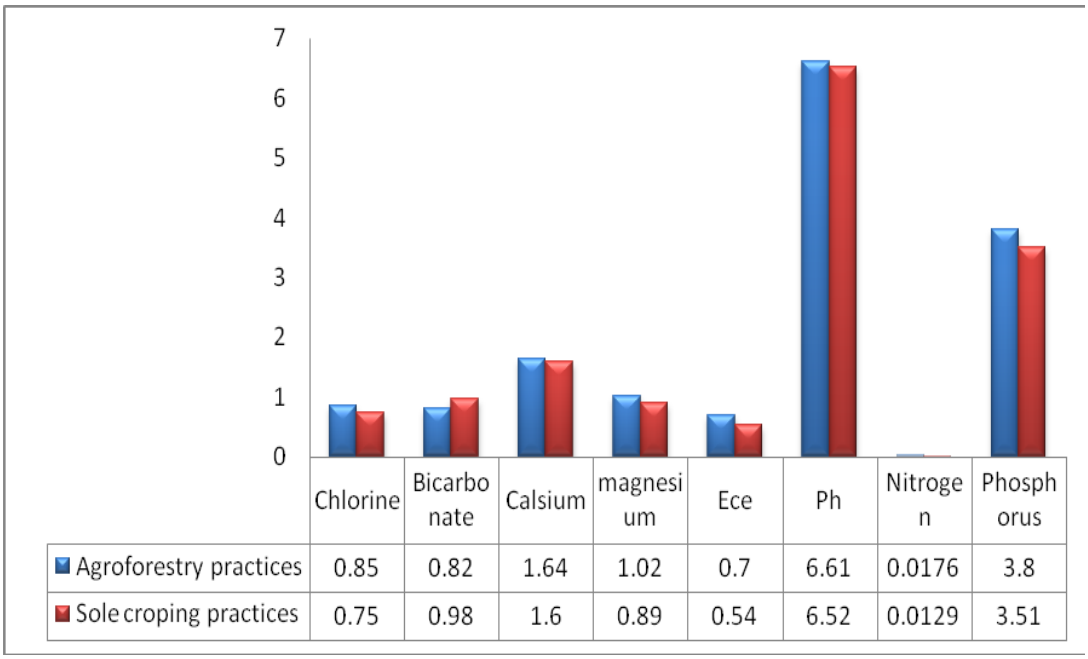
Agroforestry and food security. Achieving food security and improving agricultural systems is a global priority that will continue to grow in magnitude over the coming years. Agroforestry is a conservation as well as rural development strategy that focuses on the enhancement of rural livelihoods (FAO, 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. According to Fadl (2010), agroforestry supports food and nutritional security. However, policy and market opportunities need to be developed to promote multifunctional agricultural approach.

Agroforestry, as an 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.

Agroforestry and soil 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 were greatly improved by tree cover, and total organic carbon and nitrogen are more under the trees than in the cultivated agricultural schemes in the vicinity. The same study revealed that, the cation

exchange capacity was 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 senega*l 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). Therefore, this study investigated the effects of agroforestry in improving soil fertility and enhancing crop productivituy in a natural forest reserve.



	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
Sole croping 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

The study was conducted in the Nabag Reserve Forest, which is a natural reserved forest located in South Kordofan State in Sudan. The main stock of trees in this forest is *Acacia senegal*. Forest National Corporation (FNC) has started promoting agroforestry practices, such as Taungya practice to rehabilitate the forest which was over-aged, taking advantage of the available unemployed inhabitants and landless immigrants. Figure (2) shows the location of the study area.

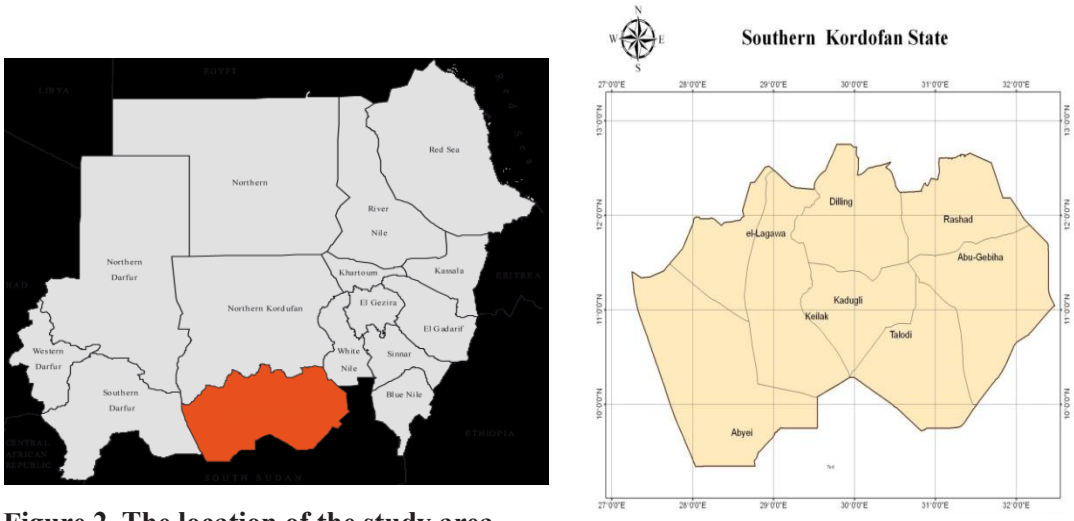


Figure 2. The location of the study area

Source :forest National Corporation Reports (2017)

Accordingly, tree density forest compartments were divided into three strata, and these were high, medium and low density stands. In each stratum random circular sample plots 0.001 ha were demarcated. A total of 21 sample plots were laid out. In each sample plot crown diameter, number of branches, general tree performance, forage coverage and gum arabic production were measured for two consecutive years. To calculate gum arabic production, trees were tapped using the recommended tool for tapping "Sunki". All recommended technical aspects were observed. The average gum arabic production was taken for the two consecutive seasons. A social survey was also made to assess social attributes and economic benefit to people who adopted the system. Accordingly, structured questionnaires were administered to 50 respondents who were rural people settled in six villages surrounding the forest. Six focus group discussions were 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 was significant difference between crop productivity under agroforestry and outside the system (Table 1). Increase crop productivity under agroforestry might be due to increase in soil fertility as *Acacia senegal* is a leguminous tree species that enhances soil fertility through nitrogen fixation. Additionally, agroforestry provides crop protection from wind erosion and provides a microclimate that reduces soil temperature and water loss.

Table 1. Crop productivity under agroforestry and outside the system

Crop	Productivity under agroforestry	Productivity outside agroforestry	Average	p-value 0.05	Test of significance
Hibiscus	6.43	2.78	327.6	0.05	*
Water melon	1495.2	194	42341	0.000	**
Sesame	4.20	1.46	28.1	0.003	**
Cowpea	2.00	0.94	4316	0.05	*
Groundnut	20.54	7.40	187.7	0.025	*

These results are similar to those reported by Ong *et al.* (2002) who indicated that there was strong evidence that agroforestry improves the water use efficiency by minimizing the unproductive part of the available soil water. Likewise, Sharrow and Ismail (2004) cited in Mohamed (2005) also 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.

The results of socio economic study revealed that adoption of agroforestry had a significant effect in improving livelihood through increasing household income. This took place either through product diversification or production of large quantities of farm products hence increasing income from cash crops and securing food throughout the year from the food crops grown. This results are consistent with what have been reported that farmers' income increased by 50% where agroforestry was adopted. Apart from income, the result of the social survey indicated that there was evidence of absence of village out-migration, and there was involvement of women in all farming activities, involvement of school children during school off season in forest rehabilitation activities and community participation in forest protection. Figure 3 and Figure 4 show the forest situation before and after agroforestry.

Figure 3. The site before incorporating agroforestry
Source: Forestry Report, South Kordofan 2017

Figure 4. The site after adopting agroforestry
Source: Forestry Report, South Kordofan 2017

Conclusions and recommendations

The study concluded that agroforestry practice contributes significantly to forest rehabilitation and improved vegetation cover, hence the forest area is protected from wind erosion and desert encroachment, and soil fertility is improved. There is also increased crop yield, hence food security and sustainable farming are enhanced. Therefore, it is recommended that agroforestry be adopted as one of the solutions for soil maintenance, climate change mitigation and food security challenges in Africa.

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