Agroforest Syst (2023) 97:1169–1184
https://doi.org/10.1007/s10457-023-00855-x

Socio-economic traits and constraints associated with smallholder farmers in Taungya agroforestry program in Sudan

Mohamed Hemida · Andrea Vityi · Zeinab. M. Hammad

Received: 12 April 2022 / Accepted: 12 May 2023 / Published online: 19 May 2023

Abstract Empirical evidence of Taungya agroforestry program in Sudan was generated. The objectives were to examine the association between socio-economic characteristics of farmers and Tuangya practice, assess the program's contribution to farmers' income, and highlight farmers' major incentives and constraints. The purposive sampling technique was applied targeting 200 Taungya farmers. Data were collected using questionnaires, focus group discussions, key informant interviews, direct field observations, and document reviews. Descriptive statistics, the chi-square test, and a paired sample t-test were used to analyze the data. Study results showed that 77% of farmers were male, with an average age of 41 years. About 77% of farmers cultivate an average land area of 3.5 hectares. The chi-square result showed that socio-economic characteristics such as marital status, age, family size, year of participation, and educational level had a significant association with Taungya practice, while gender, main occupation, and land size had no significant association. The study revealed that Taungya agroforestry program contributed significantly to farmers' income. Evidence of that was the sharp reduction in mean annual costs from SDG 32,851.75 to SDG 25,107.50, and a substantial increase in the mean annual net incomes of the farmers from SDG 35,298.52 to SDG 91,839.50 before and after participation, respectively. Farmers' participation was encouraged by the high productivity within the forest and access to free fertile land. Contrary, lack of extension services and supervision from Forest National Corporation, overgrazing and crop destruction, land size limitation, and crop species restrictions were identified as major challenges. The study suggests that prioritizing extension services, providing live fencing, and reconsidering farmers' interest in having intercropping sorghum on their farms to improve their sustenance will overcome the constraints and further boost farmers' productivity.

Keywords Taungya agroforestry · Income generation · Smallholder farmers · Sudan

M. Hemida (✉) · A. Vityi
Institute of Environmental Protection and Nature Conservation, Faculty of Forestry, University of Sopron, Sopron, Hungary
e-mail: Mohamed.Hemida@phd.uni-sopron.hu; singawy13@gmail.com

M. Hemida
Department of Forest Management, Faculty of Forestry, University of Khartoum, 13314 Khartoum North, Sudan

Z. M. Hammad
Department of Silviculture, Faculty of Forestry, University of Khartoum, 13314 Khartoum North, Sudan

Introduction

Sudan covers a land area of 1.9 million km^2, of which 29.8 million hectares are classified as forest

cover (FAO 2020). Sudan's forest resources play an essential role in providing livelihood needs. Particularly in the rural areas, the majority depend on wood and non-wood forest products as the main sources of income and daily food consumption (Suleman and Ibrahim 2018; Mohamed et al. 2021). Nonetheless, Sudan's forest cover has witnessed massive changes during the last decade (Gadallah 2020). It has substantially declined from 40% to 10.3% with annual deforestation rate of 1.6% due mainly to agricultural expansion and forest overexploitation (Sulieman 2018; Abdoun 2020). An important remedy to the problem of deforestation and forest degradation caused by anthropogenic activities is the establishment of more forest plantations and enhancement of management practices (Adekunle and Bakare 2004). In this regard, many models, initiatives, and schemes have been applied by the Forest National Corporation (FNC) of Sudan to rehabilitate forest cover and improve the livelihoods of the fringe communities. However, the cost of establishing forest plantations was the main constraint to farmers' participation. Moreover, the long rotation age of tree-crop plantations and a policy of the FNC that discourages logging are other limitations. This suggests projects with incentives during the establishment of trees could be a catalyst to spark farmers' interest. In this milieu, the implementation of the Taungya agroforestry program inside forest reserves is considered a best practice for the farmers in terms of costs, productivity, food security, and livelihood benefits (Acheampong et al. 2020; Appiah et al. 2020).

Taungya system is an agroforestry practice where annual agricultural crops grow temporarily with forestry trees at the early stage of forest plantation establishment. The co-habitation of agricultural crops and trees can take three to five years depending on factors such as tree species, growth rate, and planting spacing (Ndomba et al. 2015; Azeez et al. 2017). The system was originally developed in Myanmar in the early nineteenth century (Tani 2000) and has been widely used. In Sudan, however, the Taungya agroforestry system is a special contract between the FNC and smallholder farmers surrounding the reserves, where the FNC distributes the targeted area inside the forest reserve and provides the farmers with the seedlings and technical assistance. Farmers are allowed to grow their subsistence and commercial crops between tree spacing at the early stage of tree establishment (El Tahir and Vishwanath 2015). Taungya agroforestry has been seen as a promising practice to solve food shortages. It increases crop yields and thus achieve sustainable livelihood for farmers, particularly in African countries where food shortage is of great concern (Wiro and Ansa 2019).

Several studies have highlighted multiple benefits of Taungya system in terms of improving crop productivity (Kalu et al. 2011), income generation (Suang et al. 2020; Nigussie et al. 2020), the socio-economic wellbeing of rural populations (Wiro and Ansa 2019), as well as its considerable role in restoring degraded forests (Ebenzer et al. 2018; Appiah et al. 2020). In Sudan, however, most studies (e.g., El Tahir and Vishwanath 2015; Fadl et al. 2015) carried out have focused exclusively on a general vision of agroforestry practices and have overlooked the need to shed light on and measure the value of agroforestry on the above-mentioned traits, particularly in the drylands of Sudan where our case study was carried out. As evidenced by the reviewed literature, the study area has experienced a long history of drought-prone and rainfall shortages, as well as frequent civil wars that led to the loss of vegetation cover, failures in food crop production, a food deficit, and famine, which negatively affected many communities that rely heavily on this forest for their livelihoods (Deafalla et al. 2019). However, to improve the livelihood of poor farmers in the rural areas of Sudan suffering from crop failure, drought, and food insecurity, there is an urgent need to assess and quantify the prevailing agroforestry practice and its contribution to farmers income as well as its challenges; hence, the information generated by this research will fill the knowledge gap in understanding the inextricable linkage between agroforestry practice and add knowledge on the value of this practices in income generation. This will be useful in setting recommendations for decision-makers in Sudan to create/develop, or design active agroforestry projects and cooperatives that could be adopted as an appropriate mechanism for climate change adaptation and hence contribute to sustainable forest management, food security, and rural livelihood improvement. Considering the above introduction, this paper introduces empirical survey information on the Taungya agroforestry program implemented by FNC in Nabag Forest Reserve (NFR) in South Kordofan State, Sudan, to (i) examine the association between socio-economic characteristics of farmers

and Tuangya practice, (ii) assess the program's contribution to farmers' income, and (iii) explore farmers' major incentives and constraints related to the program.

Materials and methods

Study area

South Kordofan State is in the south-central part of Sudan between latitude 9°–12° N and longitude 27°–32° E (Fig. 1) with a total area of about 13.44 million ha (Ballal et al. 2014). Its climate lies within the savanna zone, with an annual rainfall between 350 and 850 mm. The average temperature ranges from 20 to 35 °C (Adam and Bello 2017). The total human population is about 2.3 million, with a variety of ethnic groups. Agriculture is the main livelihood option. The vegetation cover is characterized by savannah forest tree species (e.g. *Tamarindus indica, Acacia sieberana, and Faidherbia albida*), shrubs (e.g. *Acacia mellifera, Boscia senegalensis, and Pilostigma reteculata*), as well as herbs and grasses (e.g. *Asparaus sp., Triumpheta flavescens, Hibiscus canabinus*) (Eisawi et al. 2021).

Nabag forest reserve is in EL Dilling district, South Kordofan State between the latitude 12°30′0″ N and 12°36′0″ N and the longitude 29°36′0″ E to 29°58′0″ E (Fig. 1). It was reserved in 1961 as a state forest and is managed by FNC. It covers an area of 4174.2 hectares. The dominant tree species is *Acacia senegal*. Species including *Azadirachta indica*, *Balanites aegyptiaca*, *Sclerocarya birrea*, are also present.

Sampling procedure and data collection

A purposive sampling technique was applied in this study. The sampling frame was comprised of 400 Taungya farmers. The sample size was determined by applying the formula (Yamane 1967) as shown in Eq. (1). This approach has been widely used in agroforestry studies (Pello et al. 2021; Amare et al. 2019; Acheampong et al. 2016).

$$n = N/\left(1 + N(e)^2\right) \quad (1)$$

where n = sample size; N = the total number of Taungya farmers; and e = marginal error at a 5% precision level.

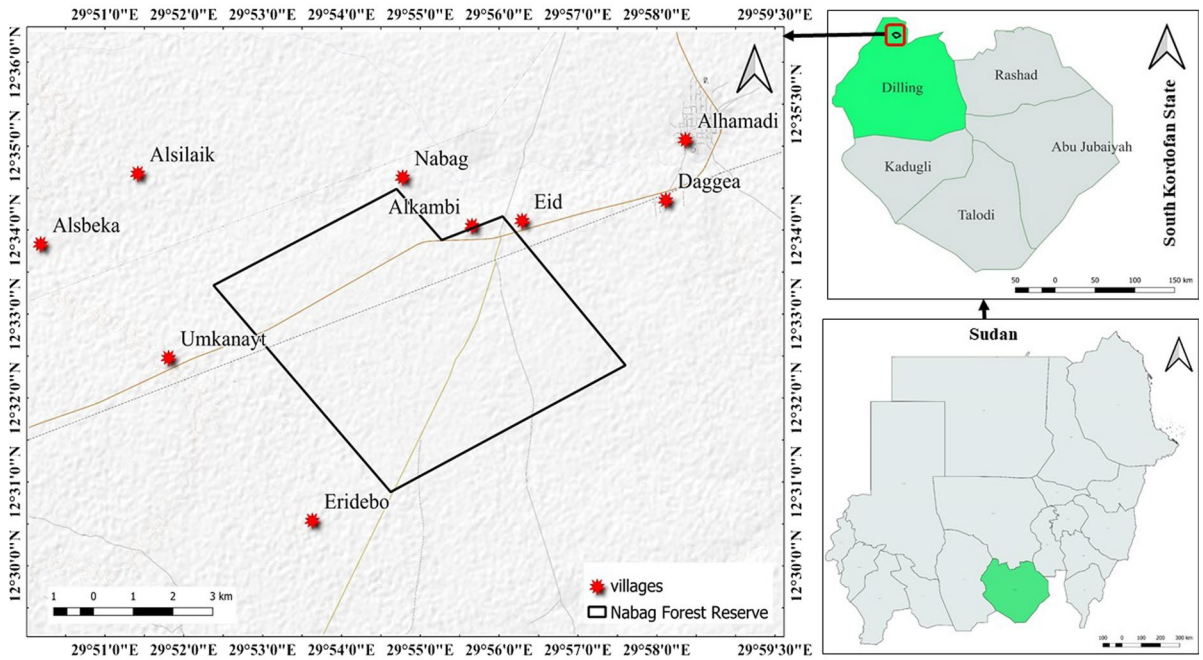

Fig. 1 Map of the study area

Accordingly, a total of 200 farmers were randomly selected from nine villages surrounding the NFR. The distributions are namely Eid (n = 37), Daggea (n = 35), Alsbeka (n = 30), Alkambi (n = 29), Nabag (n = 21), Alhamadi (n = 16), Eridebo (n = 15), Alsilaik (n = 9), and Umkanayt (n = 8). The inclusion of farmers was based on their availability and willingness to participate.

The data collection was by both primary and secondary means (Fig. 2). Primary data was collected based on face-to-face interview using a semi-structured questionnaire (SSQ). This was complemented and validated through focus group discussions (FGDs), key informant interviews (KIIs), and direct field observations (DFOs). Prior to the formal interview, the questionnaire was rigorously pre-tested with a cohort of 10 farmers to observe its reliability and validity. The interviews were conducted by the first author of this paper, field assistants, and enumerators. The selection of the enumerators and field assistants was based on their familiarity with the community of the study area. Before starting the interviews, verbal consent was obtained from the farmers to take part in the interview and each respondent was informed about the purpose of the research, questionnaire protocol, and timelines. Respondents were given the full right to respond to the interview or to refuse it. This ethical issue was important to build confidence between enumerators and respondents and to connote voluntary participation. The interview period lasted between 20 and 45 min and was carried out mainly in Sheikh (village leader) houses, village markets, and farming. The semi-structured questionnaire encompassed information pertaining to the socio-economic status of Taungya farmers (i.e., age structure, family size, education, and source of income), the kind of crops planted, productivity, costs and revenues, incentives, and constraints associated with the Taungya program.

The FGDs were carried out with a group ranging from 8 to 10 respondents. It included farmers, village leaders, and forestry officials, having more detailed discussions on the specific issues raised during the survey. The discussion was organized and guided by the first author in the presence of forestry officials. The presence of forestry officials facilitated the discussions and communication between the researcher and the respondents. The information generated from these FGDs was used to check the key responses from the survey.

The KIIs were done with elders who had experience and traditional knowledge of the Taungya agroforestry program and the history of the study area (n = 5), forestry officials including the director (n = 1), forest inspectors (n = 3), and forest guards (n = 5). This was meant to gather information on the Taungya agroforestry program from their own knowledge, experience, and understanding. It was also to cross-check the information given by the other interviewees for validating the data and revealing any ambiguities. In addition to the abovementioned methods, DFOs through site visits were conducted to get a better insight into the general characteristics of the farming and to validate the information gathered from the farmers.

The secondary data was collected from a wide range of documents, archival records, reports by FNC, available literature (articles, books, policy briefs),

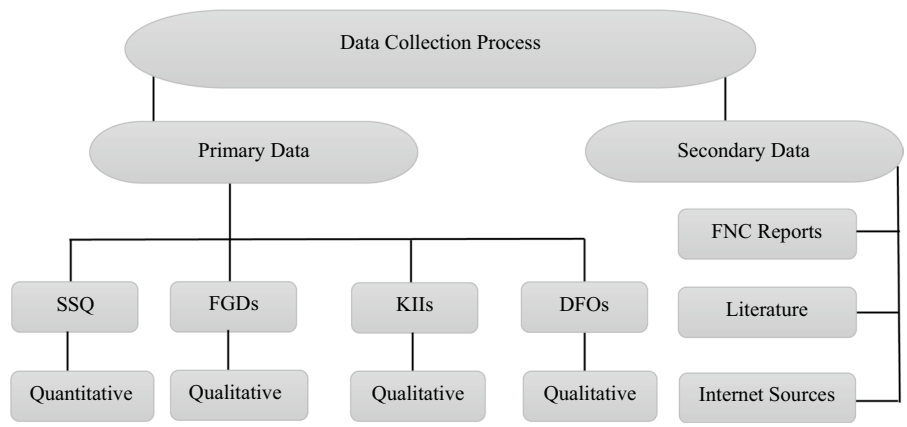

Fig. 2 Methodological framework of the study

and internet sources. The secondary data played an important part during primary data collection. It facilitated the identification of the villages around the forest and the sampling process. It was also used to determine the indicators and factors that were used in the study, and the design of the questionnaire for data collection.

Data analysis

Both qualitative and quantitative analysis using descriptive and inferential statistics were applied to analyze the collected data. The data were first filtered, coded into numerical values, and organized in an excel sheet using Microsoft Excel 2013. The data was then imported into the Statistical Package for Social Science (SPSS, version 22). The qualitative data gathered through SSQ, FGDs, KIIs, and DFOs were summarized and organized to describe and analyze the socio-economic characteristics of the farmers and major constraints associated with the Taungya program. The chi-square test was applied to determine the existence of a statistically significant association among categorical explanatory variables of Taungya farmers (e.g., gender, marital status, education level, and main occupation) and Taungya agroforestry practice. A paired sample t-test at a 5% level of significance was used to test and compare the distribution of farmers' costs and revenues before and after the implementation of the Taungya agroforestry program. Before running the analysis, the data requirements and statistical assumptions were checked by testing two key assumptions: the normality test and the absence of outliers required for selected statistical tests (Rietveld and van Hout 2017).

The estimated total costs refer to all costs incurred over one agricultural season (e.g., land clearing and preparation for sowing, planting materials (agricultural equipment, crop seeds), weeding, maintenance, and harvesting costs). While the estimated total income refers to income from harvesting and selling crop yields. Farmers were asked to estimate the total costs (SDG/Mukhamas) and total income (SDG/sack/crop) from cultivated crops during the specific agricultural season. The total costs were calculated by summing up all incurred costs, while the total income was computed by multiplying the crop yields with their farm gate price. Information on farming activities and costs incurred was gathered from the farmers through the questionnaire survey, while the prices of crops were obtained from the local markets. The obtained results were presented in the form of charts, tables, frequencies, and percentages.

Results and discussion

Socioeconomic characteristics of Taungya farmers and their association with Taunga practice

Gender and marital status

The study findings on the socioeconomic characteristics of the farmers and their associations with Taungya practice, as summarized in Table 1 revealed that Taungya practice was dominated by male farmers, they represent 77% of respondents. The high proportion of males could be explained by the fact that in most African countries in general and in the Sudan's rural communities in particular, men are

Table 1 Sociodemographic characteristics of Taungya's farmers and their association with Taungya practice in the study area (N = 200)

Variable	Frequency	(%)	χ^2	*P* value
Gender				
Male	154	77	3.136	0.371
Female	46	23		
Marital status				
Single	11	5.5	34.449**	0.000
Married	188	94		
Widowed	1	0.5		
Educational level				
Illiterate	42	21	24.403**	0.018
Khalwa*	46	23		
Primary	69	34.5		
Secondary	33	16.5		
University	10	5		
Main occupation				
Farmer	158	97	3.412	0.946
Farmer and trader	16	8		
Farmer and laborer	24	12		
Farmer and teacher	2	1		

*A religious school in which Muslims learn the Holy Quran and Quran studies

**Is 5% level of significance; χ^2 is chi-square value; *P* is significance value

the primary landowners and are in charge of providing their families with food and other necessities of life due to sociocultural milieu of the area. (Muaura et al. 2021). This result agrees with (Abuzwaid 2015) who reported that male farmers were dominant in the study area. Similarly, in Nigeria, Azeez et al. (2017) found that only male farmers were practicing Taungya agroforestry. The chi-square test showed that there was no significant association between gender and Taungya practice ($\chi^2 = 3.136$, $P > 0.05$).

Results also indicated that the majority of farmers (94%) were married, and the chi-square test revealed a highly statistically significant association between marital status and Taungya practice ($\chi^2 = 34.449$, $P = 0.000$). This is important because having a spouse could increase a household's access to labor, which is necessary for such a program. The results are in line with the work of Bandi et al. (2022), who demonstrated a positive relationship between marital status and farmers practicing agroforestry in the Luki Biosphere Reserve in the Democratic Republic of the Congo.

Education and occupation

Regarding the presentation in Table 1, most of the farmers have attained different levels of formal and informal education, ranging from Khalwa 23%, primary 34.5%, secondary 16.5%, and university 5%, while 21% were illiterate. It is obvious that most of the farmers in the study area have attained at least formal or informal education, meaning that they are more likely to easily understand the extension programs and have access to up-to-date agricultural technologies compared to illiterate farmers (Adolwa et al. 2012; Ibrahim et al. 2021). The chi-square test showed a significant relationship between farmer's educational level and Taungya practice ($\chi^2 = 24.403$, $P < 0.05$). This indicates that farmers with a higher level of education are more likely to practice Taungya than those with a lower level of education. This alludes to the fact that farmers with some formal or informal education are more likely to understand the consequent benefits of agroforestry practice as they are easily able to digest new knowledge and are more able to change their perception in comparison to illiterate farmers. This result is supported by different scholars (Bandi et al. 2022; Mbwiga 2016; Rahim et al. 2013) who reported a significant association between farmer's educational level and agroforestry practices.

Results in Table 1 show that practicing agriculture as a full-time farmer was the main occupation of the majority (79%) of farmers in the study area, while the rest of the respondents had additional (secondary) occupations such as trading 8%, laboring 12%, and teaching 1%. This suggests that agriculture was the main source of livelihood for most of the population in the study area. These results are in line with the findings of Fadl et al. (2015) and Ali et al. (2020), who reported that agriculture constitutes the main source of livelihoods and income generation for most of the population of Sudan. On the other hand, the participation of some farmers in other secondary jobs may be due to a need to maximize income. Ibrahim et al. (2015) have reported that farmers in South Kordofan State engage in a variety of activities for income generation. However, full-time farmers are more likely to use a different strategy to boost farm productivity compared to farmers with alternative activities and income sources (Martey et al. 2014; Mugi-Ngenga et al. 2016). According to the chi-square test, there was no significant statistical relationship between the main occupation of the farmers and Taungya agroforestry practice ($\chi^2 = 3.412$, $P > 0.05$).

Age and family size

This study found that 57.7% of the farmers fell within the age range of 36–55 years, with an average age of 40.96 years as shown in Table 2. These findings suggest that most of the farmers were above youthful age but still considered within an economically active age range. This means that they could participate effectively in Taungya agroforestry program. Conversely, the small proportion of youthful farmers aged between 18 and 35 may be attributed to the rural–urban migration. This result is consistent with the previous studies (Bello et al. 2015; Abdel-Rahim and Kodeal 2020). With a chi-square value of 191.586, $P < 0.05$ (Table 2), the study indicated a significant statistical association between farmer's age and Taungya practice. This suggests that older farmers are generally less interested in or reluctant to adopt new technologies and approaches, and they resist innovations compared to younger farmers. This finding concurs with Mahmood and

Table 2 Sociodemographic characteristics of Taungya's farmers in the study area for continuous variables and their association with Taungya practice in the study area (N = 200)

Continuous variable	Frequency	(%)	Mean (SD)	χ^2	*P* value
Age			40.96 (12.36)	191.586**	0.002
18–25	20	10			
26–35	45	22.5			
36–55	115	57.5			
> 55	20	10			
Family size			5.97 (3.43)	103.645**	0.000
1–5	97	48.5			
6–10	84	42			
11–15	16	8			
> 15	3	1.5			
*Land size (Mukhamas)**			4.66 (3.77)	71.531	0.093
1–5	154	77			
6–10	29	14.5			
11–15	14	17			
> 15	3	1.5			
Year of participation			6.70 (3.50)	10.800**	0.013
1–5 years	115	57.5			
6–10 years	46	23			
11–15 years	31	15.5			
> 15 years	8	4			

*Land unit in the study area (1 Mukhamas = 0.75 hectare)

**Is 5% level of significance; χ^2 is chi-square value; *P* is significance value

Zubair (2020); Sharmin and Rabbi (2016); and contradicts studies carried out by (Saha et al. 2018; Mwase et al. 2015) who stated no significant association between age and agroforestry practice.

Regarding family size, the findings in Table 2 show that 48.5% of the farmers had a family size of 1–5 persons, 42% had between 6 and 10, 8% had between 11 and 15, while only 1.5% had more than 15 persons. The mean family size was 6 people. This implies that about half the population of farmers in the study area had small family sizes, which may affect the availability of household labor for farm activities (Ibrahim 2018). Again, the chi-square test as depicted in Table 2 showed a highly statistically significant association ($\chi^2 = 103.645$, $P = 0.000$) between family size and Taungya practice. This could be a reasonable outcome because, in most cases, having a larger family means having more labor available to diversify household income. The positive association between family size and the likelihood of practicing agroforestry can be found in other studies (Nyamweya and Moronge 2019; Basamba et al. 2016; Irshad et al. 2011).

Cultivated land size and Taungya experience

Traditionally, the farmers in these rural communities have a local unit of land measurement called Mukhamas. This unit is equivalent to 0.75 hectare. This study found that 77% of farmers cultivated between 1 and 5 Mukhamas, while the other farmers cultivated a total land ranging between 6 and 10 Mukhamas, 11–15 Mukhamas, and more than 15 Mukhamas, respectively (Table 2). The mean total of cultivated land was 4.66 Mukhamas. The chi-square test showed no significant relationship ($\chi^2 = 71.531$, $P > 0.05$) between land size and Taungya practice. However, the small land area cultivated by farmers could be attributed to two factors; First is the nature of the contract between FNC and farmers. Second is the limitation of the specific area targeted inside the reserved forest. This study's findings corroborated with other literature (Obiri et al. 2021; Aung 2018) where the average land size of Taungya farmers ranged between 1 and 5 Acres.

The average number of years of participation in Taungya program was 6.70 years. Most of the farmers

(57.5%), had Taungya experience ranging between 1 and 5 years, while the others, 23%, 15.5%, and 4% had an experience of between 6 and 10 years, 11 and 15 years, and more than 15 years, respectively (Table 2). This implies that Taungya practice is well accepted by the farmers and the number of adopters is increasing, at the same time, farmers in the study area have enough experience in practicing Taungya agroforestry. It suggests that they are aware of different silvicultural operations and technologies. Thus, they are likely to continue to participate in the Taungya program. The chi-square test in Table 2 revealed a significant relationship between years of participation in the program and Taungya practice ($\chi^2 = 10.800$, $P < 0.05$). A reasonable explanation for this result could be that farmers who have enough Taungya experience are more likely to get and use the information relevant to silvicultural operations and production, which may increase their perception of the Taungya pracice. The finding is in agreement with Adeoye et al. (2015), who noted a positive correlation between years of experience and household participation in Taungya system in Oluwa Forest Reserve in Nigeria.

Crops cultivated and crop combination

The study findings as presented in Fig. 1 illustrated that five major crops were cultivated by Taungya farmers in the study area. These are groundnut, sesame, cowpea, watermelon, and hibiscus. Groundnut and sesame were found to be the main crops cultivated by 79.5% and 75.5% of farmers respectively (Fig. 3). This could be explained by the fact that groundnut and sesame are considered major cash crops in the study area (Abdalla et al. 2015). According to the focus group discussions, farmers revealed that roughly 80% of them obtained their household incomes from cultivating groundnut and sesame. On the other hand, cowpea was cultivated by 40.5% farmers mainly for subsistence and food security, whereas watermelon and hibiscus were cultivated by 38% and 17.5% of Taungya farmers, respectively, to provide additional income.

Further, the study results revealed that approximately ten kinds of cropping patterns were identified in the study area (Fig. 4). Among these, the major cropping patterns were groundnut and sesame, which were practiced by 23.5% of the farmers, while the

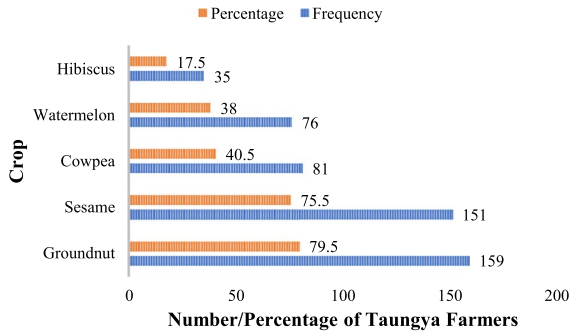

Fig. 3 Taungya farmers with respect to different crops

cropping patterns that included groundnut and watermelon were found to be less practiced and is reported only by 1%.

Distribution of costs and revenues of farmers before and after Taungya program

The annual total costs of farmers before and after participation in the Taungay program are shown in Table 3, while annual net incomes from crops are summarized in Table 4. The annual mean cost before participation was SDG 32,851.75 but was reduced to SDG 25,107.50 after participation. The specific annual costs before and after participation in the Taungya program ranged between SDG 0–437,000 and SDG 0–217,000, respectively (Table 3). It was well observed that after participation in the Taungya program, the annual total costs have been reduced drastically for most of the farmers. This was further detected using a paired-sample t-test as the statistics showed a significant difference among the farmers before and after participation in the Taungya program with ($T = 2.154$) at a level of significance ($P = 0.032$) (Table 5). The dramatic cost reduction can be ascribed to two reasons. First, land possession outside the forest is more expensive, which may lead to an increase in the cost of renting. This was also explored during the focus group discussion with the farmers. They mentioned that lack of land was one of the main reasons for participating in Taungya program. Second, the silvicultural operation costs could be lower inside the forest since there is no cost associated with purchasing fertilizer to improve soil nutrient content for maximum production (Kalu et al. 2011). These findings are corroborated with a study by Salih (2013),

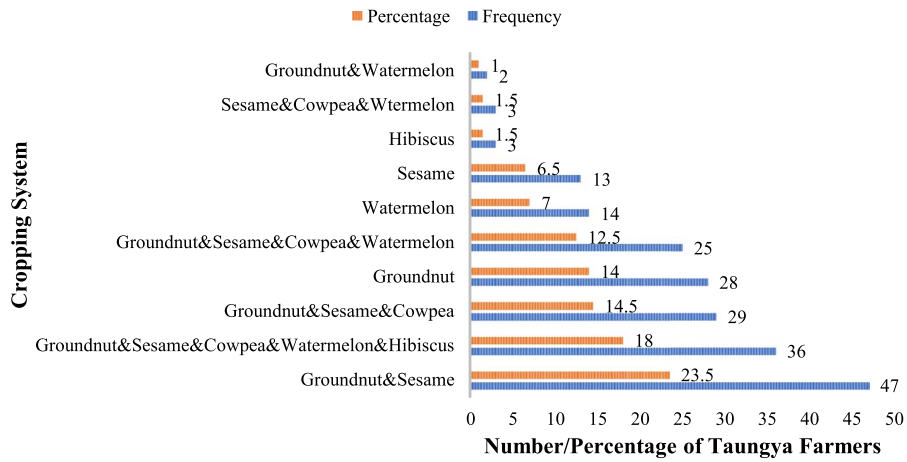

Fig. 4 Cropping combination of Taungya farmers in the study area

Table 3 An annual estimated cost (N = 200)

Range of cost (SDG)	Cost before taungya frequency	Cost after taungya frequency
0–20,000	124 (62.0)	138 (69)
21,000–40,000	32 (16.0)	15 (7.5)
41,000–60,000	10 (5.0)	16 (8.0)
61,000–80,000	11 (5.5)	11 (5.5)
81,000–100,000	9 (4.5)	7 (3.5)
> 100,000	14 (7.0)	13 (6.5)
Minimum	0	0
Maximum	437,000	217,000
Std.Dev	57,592.255	41,771.329

Mean cost before Taungya = SDG 32,851.75 (Sudanese pound)

Mean cost after Taungya = SDG 25,107.50 (Sudanese pound)

Figures in parenthesis are percentages

Table 4 An annual estimated net income (N = 200)

Range of net income (SDG)	Net income before taungya frequency	Net income after taungya frequency
0–20,000	123 (61.5)	43 (21.5)
21,000–40,000	23 (11.5)	34 (17.0)
41,000–60,000	20 (10.0)	22 (11.0)
61,000–80,000	11 (5.5)	22 (11.0)
81,000–100,000	1 (0.5)	19 (9.5)
> 100,000	22 (11.0)	60 (30.0)
Minimum	0	0
Maximum	560,500	655,000
Std.Dev	86,294.926	124,410.000

Mean net income before Taungya = SDG 35,298.25 (Sudanese pound)

Mean net income after Taungya = SDG 91,839.50 (Sudanese pound)

Figures in parenthesis are percentages

who reported that Taungya agroforestry contributed to reducing and saving the initial establishment cost of the plantation. Also, Kalame et al. (2011), concluded that the system was cost-effective, with the benefits exceeding the costs.

The annual mean net income of the farmers before participation in the Taungya program was SDG 35,298.52. This increased substantially to SDG 91,839.50 after participation. The specific annual net incomes before and after participation in the Taungya program ranged between SDG 0–560,500 and SDG 0–655,000 respectively (Table 4). Most farmers (61.5%) earned net income between (SDG 0 and 20,000) before joining the Tuangya program. This percentage was reduced sharply to (21.5%) after joining the program. This means that more farmers (40%) earned net income above (SDG 20,000). In contrast, the number of farmers (11%) who earned net income (SDG > 100,000) significantly increased to (30%) (Table 4). These results were further affirmed through a paired-sample t-test as statistically significant differences ($P = 0.000$; $T = 8.034$) were found between farmers' net income before and after participation in the Taungya program (Table 5). The observed increment of income could be attributed to the increasing productivity of crops under Taungya agroforestry. This assertion was supported by several studies (Kalu

Table 5 Paired sample T-test of cost and net income before and after Taungya program (N = 200)

Paired variables	T value	DF	*P* values
Cost before Taungya/SDG—Cost after taungya/SDG	2.154	199	0.032*
Net income before Taungya/SDG—Net income after Taungya/SDG	8.034	199	0.000*

*Is 5% level of significance

et al. 2011; Wiro and Ansa 2019; Appiah et al. 2020). This study's findings agree with the study by Suang et al. (2020), who found that farmers inside the forest had a much higher cash income (80%) compared to farmers outside the forest (32%). Also, this study is in line with Nigussie et al. (2020), who in a financial analysis study concluded that the Taungya system significantly contributes to income generation.

Major incentives and constraints associated with Taungya farmers in the study area

The study findings expressed in Fig. 5 and Fig. 6 explored several incentives and constraints associated with Taungya farmers in the study area. According to the interview and FGDs, farmers highlighted having three main incentives or motivations to participate in Taungya program. These included the high productivity inside a forest in comparison to an open area, which was mentioned by 69% of the farmers. Other motivations were the access to free land and the fertile soil inside a forest, as mentioned by 27% and 4% respectively (Fig. 5). An old farmer stated that:

> All the farmers in these villages are aware of the increased agricultural production and income generation found within NFR. As a result, they were more motivated to acquire land within the NFR.

Another farmer added:

> I am currently employed in the capital city, Khartoum, but when the agricultural season started, I left my job and returned to my village to take part in the Taungya program as the land is free, and crop productivity is higher.

However, it is worth mentioning that land tenure is considered the main obstacle confronting farmers in the study area. Kansanga and Luginaah (2019); Meaza et al. (2016) have noted that farmers surrounding the reserves prioritize secure land tenure and crop cultivation as the main motivation, while their willingness to join such rehabilitation programs is determined by the benefits attained (Acheampong et al. 2020). Study findings are in line with other studies carried out in Nepal (Adhikari et al. 2014), Burkina

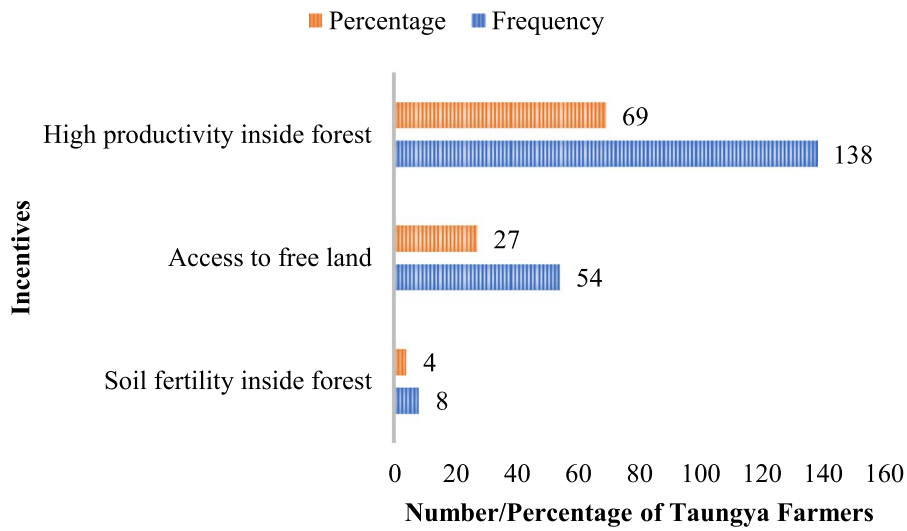

Fig. 5 Incentives associated with farmers in Taungya agroforestry program

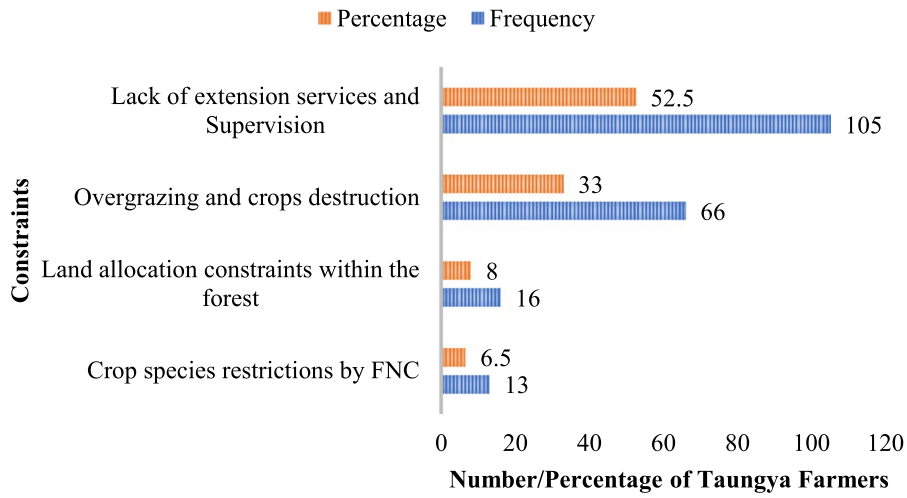

Fig. 6 Constraints associated with farmers in Taungya agroforestry program

Faso (Coulibaly-Lingani et al. 2011), and Ghana (Acheampong et al. 2018). This literature reported similar incentives for farmers to participate in forest rehabilitation projects.

The study results (Fig. 6) further uncovered four main constraints confronting Taungya farmers in the study area. More than half (52.5%) of farmers indicated that a lack of extension services and supervision from FNC are the main challenges. This is followed by overgrazing and crop destruction, as claimed by 33%, while land allocation constraints within the forest and crop species restrictions by FNC were asserted by 8% and 6.5% respectively (Fig. 6). However, access to forestry extension services and technical assistance is crucial for the success and sustainability of agroforestry schemes (Nketiah et al. 2016). Farmers expressed their concerns about the extension services and training provided by FNC through FGDs and KIIs. They indicated that the main services provided by FNC officers were allocation of land inside the forest and providing them with seedlings of *Acacia senegal* trees for planting. There was no additional subsequent technical support. To overcome this challenge, study suggests that the priority budget allocation should be given to the extension services that could empower farmers and guarantee the transfer and delivery of the extension services adequately. This could have a substantial positive impact on boosting agricultural knowledge, enhancing farmers skills for implementing innovative farming technologies, and enhancing farm productivity (Ojijo et al. 2022). Moreover, it could enable building friendly relationships with forestry advisers and farmers, which can facilitate and enhance farmers' participation in forest restoration practices (Amare et al. 2016; Ullah and Khan 2019). These findings agree with Fahmi et al. (2015) and Azeez et al. (2017) and contradict the findings of Akinwalere and Okunlola (2019), who reported no significant relation between extension services and sustainable adoption of agroforestry practices among farmers in the southwest of Nigeria.

Overgrazing and crop destruction were the second challenges claimed by Taungya farmers in the study area. Although nomadic grazing brings several benefits to communities surrounding the forest, it imposes ecological damage on ecosystem services, especially in drylands where ecosystems are often in poor condition (Mousavi et al. 2022). The effects include not only defoliation by animals but also severe soil damage such as compaction and destruction of plants by animal trampling, which decreases infiltration and thus increases runoff and, consequently, soil loss. (Centeri 2022; Alados et al. 2004). Previous studies have approved that agroforestry practices could contribute in a sustainable way to mitigate the conflict between farmers and nomads and hence mitigate the grazing impacts (Awazi and Avana-Tientcheu 2020). It was obvious through DFOs that overgrazing has been severe in NFR. This could be attributed to the location of the NFR as a seasonal grazing route followed by nomadic pastoralists as well as due to the degradation of rangeland in the study area, which directs the nomads' attention towards the NFR for

feeding their livestock. This has created continuous destruction of crops and tree regeneration and hence exacerbated the land use conflicts between farmers and nomads. It is worth mentioning that land-use conflicts between sedentary farmers and nomads are a dominant dilemma in different parts of Sudan, as noted by several scholars (Adam et al. 2015; Abdel-Rahim and Kodeal 2020; Broche 2022). However, to address this issue, Taungya farmers could use the live fences to protect their farms, and FNC could facilitate this by allowing farmers to use the branches of failed trees during the migration season of pastoralists. Adoption of cut and carry as a proper grazing system for fodder could also be examined. Furthermore, the land use policy in Sudan should be revised to provide pastoralists with rangeland.

Land size allocation and crop species restrictions have been recognized as additional barriers for Taungya farmers. Discussions with forestry officials in the study area indicated that the limited allocation of land plots to farmers is due to the nature of the rehabilitation program, which focuses on specific degraded plots within the NFR, which was less than the number of motivated farmers who expressed an interest in participating. So, to solve this problem and make sure farmers had equal access to land, an average of 1–4 Mukhamas was given to each farmer. This approach was found to be like several Taungya agroforestry schemes in developing countries (Adjei et al. 2020; Wiro and Ansa 2019).

Regarding crop species restrictions, while the FNC officials restricted farmers from growing specific crops in the Taungya system, the farmers had their own preference for crops. For instance, some of the interviewed farmers expressed a preference to planting the sorghum crop due to its importance as daily food consumption for their livelihood. One farmer explained that by saying:

> I and most of the farmers have no other land except NFR to grow subsistence crops. If we are not allowed to grow the sorghum inside the forest, we must buy it from the market at a very high price to feed our families.

On the other hand, FNC authorities argue that intercropping *Acacia senegal* trees with sorghum have a major impact on seedling survival and growth during the early stages of tree establishment. To address this issue, FNC in collaboration with the extension division could find an appropriate way to provide farmers with intercropping sorghum, such as by allocating them to some degraded plots under young or mature trees. In this respect it is recommended to pursue further study to investigate appropriate tree spacing that allow existence of farmers throughout and avoidance of canopy closure. This way, farmers would be able to have a steady supply of food and thus achieve the win–win outcomes of the Taungya program. Acheampong et al. (2016) reported a similar issue in Ghana, where farmers were prohibited from cultivating cassava crops under the modified Taungya program.

Conclusion

This paper initially assessed the Taungya agroforestry program practiced by farmers within Nabag Forest Reserve (NFR) in South Korofan State, Sudan. It covered the association between socio-economic characteristics of farmers and Tuangya practice, Taungya agroforestry contribution to income generation, as well as the incentives and constraints associated with them. The findings of this study indicated that Taungya practice was dominated by male farmers, and most of them have attained different levels of formal and informal education. Except for the chi-square results of gender, main occupation, and land size, all socioeconomic traits have a highly significant association with Taungya practice in the study area.

The study revealed that the majority of Taungya farmers cultivated both cash and subsistence crops as means of sustaining their livelihoods. Thus, there is no doubt that Taungya agroforestry program in the study area improved crop production and contributed significantly to farmers' income generation. This was more clearly confirmed through the focus group discussions, and interviews with FNC officials, who affirmed that most of the Taungya farmers obtained their livelihood needs and household income from selling their crops as well as harvesting the non-timber forest products from NRF, which helped improve their financial capital. Moreover, farmers have reported other benefits of Taungya program such as access to land (improving natural capital), income generation (improving financial capital), and improving their ability to achieve educational attainment (improving human capital).

The main incentives for farmers to participate in the program were the high productivity inside the forest, access to free land, and highly fertile soil inside the forest, while the major constraints were the lack of extension services and supervision from FNC, overgrazing and crop destruction, land size allocation, and crop species restrictions. Recommendations to overcome these challenges include: (1) the priority budget allocation be given to the extension services that could empower farmers and guarantee to transfer and deliver the extension services adequately; (2) Taungya farmers could use the live fences to protect their farms and FNC could facilitate this by allowing farmers to use the branches of failed trees during the migration season of pastoralists; and (3) the FNC should reconsider farmers interest in having intercropping sorghum on their farms by revising tree spacing in the future. Alternatively, new degraded plots could be allocated to farmers for sorghum production to improve their livelihood.

Acknowledgements Authors are indebted to the Tempus Public Foundation, Hungary, and the Ministry of Higher Education, Sudan for the scholarship. Special thanks are due to farmers and the Forest Department in the study area for their kind support and cooperation.

Authors' contributions MH (conceptualization, methodology, data collection, data curation, data analysis, writing original draft); AV and ZMH (writing review and editing, supervision).

Funding Open access funding provided by University of Sopron. No funding was received to assist with the preparation of this manuscript.

Declarations

Conflict of interest The authors declare that there is no conflict of interest.

Consent for publication The authors declare that they consent to publish their manuscript "Socio-economic Traits and Constraints Associated with Smallholder Farmers in Taungya Agroforestry Program in Sudan'' in the journal of Agroforestry Systems.

References

Abdalla EA, Osman AK, Maki MA et al (2015) The response of sorghum, groundnut, sesame, and cowpea to seed priming and fertilizer micro-dosing in South Kordofan State, Sudan. Agronomy 5(4):476–490

Abdel-Rahim AO, Kodeal GAF (2020) Competition on rangelands utilizations conflict source among users in semi-arid areas at Eldebeibat, South Kordofan State-Sudan. J Rang Sci 10(2):149–161

Abdoun SOM (2020) Incentives for reforestation and forest's plantations option, under the national strategy of REDD+ program in Sudan. Advan Ecol Environ Res 5:53–85

Abu Zwaid, MM (2015) Development of a model for improving Nabag Forest reserve for participatory management and carbon development. In: Dissertation, University of Khartoum

Acheampong E, Insaidoo TFG, Ros-Tonen MAF (2016) Management of Ghana's modified taungya system: challenges and strategies for improvement. Agrofor Syst 90(4):659–674. https://doi.org/10.1007/s10457-016-9946-7

Acheampong EO, Agyeman KO, Amponsah O (2018) The motivation for community participation in forest management: the case of Sefwi-Wiawso forest district. Ghana Intern for Rev 20(1):1–17. https://doi.org/10.1505/146554818822824264

Acheampong EO, Sayer J, Macgregor C et al (2020) Application of landscape approach principles motivates forest fringe farmers to reforest Ghana's degraded reserves. Forests 11(4):411. https://doi.org/10.3390/f11040411

Adam YO, Bello ARS (2017) Relationship between local ecological knowledge and natural resources trade in Sudan. Int J Dev Sust 6(7):385–398

Adam YO, Pretzsch J, Darr D (2015) Land use conflicts in central Sudan: perception and local coping mechanisms. Land Use Policy 42:1–6. https://doi.org/10.1016/j.landusepol.2014.06.006

Adekunle VA, Bakare Y (2004) Rural livelihood benefits from participation in the taungya agroforestry system in Ondo State of Nigeria. Small-Scale for 3(1):131–138. https://doi.org/10.1007/s11842-004-0009-y

Adeoye IA et al (2015) Assessment of socio-economic impact of taungya planta-tion system in oluwa forest reserve, Ondo State. Nigeria J Appl Trop Agric 20(2):32–39

Adhikari S, Kingi T, Ganesh S (2014) Incentives for community participation in the governance and management of common property resources: the case of community forest management in Nepal. For Polic Econ 44:1–9. https://doi.org/10.1016/j.forpol.2014.04.003

Adjei POW, Agyei FK, Adjei JO (2020) Decentralized forest governance and community representation outcomes:

analysis of the modified taungya system in Ghana. Env Dev Sust 22(2):1187–1209. https://doi.org/10.1007/s10668-018-0243-7

Adolwa IS, Okoth PF, Mulwa RM et al (2012) Analysis of communication and dissemination channels influencing the adoption of integrated soil fertility management in western Kenya. J Agri Edu Exten 18(1):71–86. https://doi.org/10.1080/1389224X.2012.638782

Akinwalere BO, Okunlola JO (2019) Roles of extension services in adoption of agroforestry practices among farmers in south West Nigeria. Int J Sust Agric Res 6(1):1–7. https://doi.org/10.18488/journal.70.2019.61.1.7

Alados CL, ElAich A, Papanastasis VP et al (2004) Change in plant spatial patterns and diversity along the successional gradient of Mediterranean grazing ecosystems. Eco Model 180(4):523–535

Ali AEM, Ali MA, Hamad MAA (2020) Assessment of the components that deliver agricultural extension services, at Gezira state-wad medani great locality. Sudan MOJ Eco Envi Sci 5(2):49–60

Amare D, Mekuria W et al (2016) Perception of local community and the willingness to pay to restore church forests: the case of Dera district, northwestern Ethiopia. Forests Trees Livelihoods 25(3):173–186. https://doi.org/10.1080/14728028.2015.1133330

Amare D, Wondie M, Mekuria W et al (2019) Agroforestry of smallholder farmers in Ethiopia: practices and benefits. Small-Scale for 18(1):39–56. https://doi.org/10.1007/s11842-018-9405-6

Appiah M, Yeboah B, Yeboah MA et al (2020) Community experiences in the use of modified taungya system for restoring degraded forests and improving livelihoods in Ghana. Env Manag Sust Dev 9(3):1–17. https://doi.org/10.5296/emsd.v9i3.17047

Aung KLN (2018) Review on reforestation management and socio-economic status of local taungya cultivators of Kaing reserved forest in Myanmar. In: The second myanmar national conference on Earth sciences, pp 1105–1119

Awazi NP, Avana-Tientcheu ML (2020) Agroforestry as a sustainable means to farmer–grazier conflict mitigation in Cameroon. Agroforest Syst 94:2147–2165. https://doi.org/10.1007/s10457-020-00537-y

Azeez IO, Popoola L, Shulamite IO (2017) An assessment of the forest regeneration potential of the taungya system of farming in Oyo State, south-western Nigeria. South Forest J for Sci 79(2):143–151. https://doi.org/10.2989/20702620.2016.1255425

Ballal ME, Salih NKE, Abdel Magid TD (2014) Ethno-botany of natural forests of Nuba Mountains, South Kordofan State, Sudan. J for Prod Indus 3(1):13–19

Bandi MM, Mahimba MB, Mbe Mpie PM et al (2022) Adoption of agroforestry practices in and around the Luki Biosphere reserve in the democratic Republic of the Congo. Sustainability 14(16):9841. https://doi.org/10.3390/su14169841

Basamba TA, Mayanja C, Kiiza B et al (2016) Enhancing adoption of agroforestry in the eastern agro ecological zone of Uganda. Int J Ecol Sci Environ Eng 3:20–31

Bello ARS, Allajabou HA, Baig MB (2015) Attitudes of rural youth towards agriculture as an occupation: a case study from Sudan. Int J Dev Sust 4(4):415–424

Brosché J (2022) Conflict over the commons: government bias and communal conflicts in Darfur and Eastern Sudan. Ethnopolitics. https://doi.org/10.1080/17449057.2021.2018221

Centeri C (2022) Effects of grazing on water erosion, compaction and infiltration on Grasslands. Hydrology 9(2):34. https://doi.org/10.3390/hydrology9020034

Coulibaly-Lingani P, Savadogo P, Tigabu M et al (2011) Factors influencing people's participation in the forest management program in Burkina Faso, West Africa. For Polic Econ 13(4):292–302. https://doi.org/10.1016/j.forpol.2011.02.005

Deafalla THH, Csaplovics E, El-Abbas MM (2019) Environmental change impacts and human security in semi-arid region, the case of Nuba Mountains of Sudan. In: Behnassi M, Gupta H, Pollmann O (eds) Human and environmental security in the era of global risks. Springer, Cham

Ebenezer AK, Ameka G, Annang TY (2018) The contribution of modified taungya system to forest cover and livelihoods of forest-fringe communities: a case study of Worobong South Forest Reserve in Ghana. Asian J Ethnos 1(1):15–30. https://doi.org/10.13057/asianjethnobiol/y010103

Eisawi KA, He H, Shaheen T, Yasin EH (2021) Assessment of Tree diversity and abundance in Rashad natural reserved forest, South Kordofan. Sudan Open J Fores 11(01):37–46. https://doi.org/10.4236/ojf.2021.111003

El Tahir BA, Vishwanath A (2015) Estimation of economic value of agroforestry systems at the local scale in Eastern Sudan. J Geosci Env Protect 3(09):38–44. https://doi.org/10.4236/gep.2015.39005

Fadl KEM, Mahmoud SE, Hamad ZM (2015) Farmers' perceptions towards agroforestry systems in North and South Kordofanstates. Sudan Int J of Env 4(2):53–67

Fahmi MKM, Mohamed ES, Kanninen M et al (2015) Determinants and constraints of integrating natural acacias into mechanised rain-fed agricultural schemes Sennar State. Sudan Geojournal 80(4):555–567. https://doi.org/10.1007/s10708-014-9563-9

FAO (2020) Global forest resources assessment 2020: Main report. Rome.

Gadallah NA, Hano A, Yagoub Y (2020) Characterizing forest cover changes based on satellite images cum forest dependents' data. Agr for J 4(2):63–70

Ibrahim IE (2018) Economic of sorghum production in traditional rainfed sector, case study Kadugli locality of South Kordofan State, Sudan. Int J Agr Env Sci 3(2):24–29

Ibrahim GA, Abdalla NI, Fangama IM (2015) Contributions of non-wood forest products to household food security and income generation in South Kordofan State, Sudan. Int J Curr Microb Appli Sci 4(6):828–832

Ibrahim AO, Abdullahi HA, Lateef BO et al (2021) Assessment of the effect of rice smuggling on well-being of smallholder farmers in Ogun State, Nigeria. Glob J Health Rela Res 3(2):157–165

Irshad M, Asadullah K, Mitsuhiro I et al (2011) Identifying factors affecting agroforestry system in Swat, Pakistan. Afric J Agric Res 6(11):2586–2593. https://doi.org/10.5897/AJAR11.485

Kalame FB, Aidoo R, Nkem J et al (2011) Modified taungya system in Ghana: a win–win practice for forestry and adaptation to climate change? Env Sci & Polic 14(5):519–530. https://doi.org/10.1016/j.envsci.2011.03.011

Kalu C, Oboho EG, Ihama OE (2011) Economic potential of taungya farming system in Edo State, Nigeria. J Agr Soci Res 11(1):49–57

Kansanga MM, Luginaah I (2019) Agrarian livelihoods under siege: carbon forestry, tenure constraints and the rise of capitalist forest enclosures in Ghana. World Dev 113:131–142. https://doi.org/10.1016/j.worlddev.2018.09.002

Mahmood MI, Zubair M (2020) Farmer's perception of and factors influencing agroforestry practices in the Indus River Basin, Pakistan. Small-Scale for 19(1):107–122. https://doi.org/10.1007/s11842-020-09434-9

Martey E, Wiredu AN, Etwire PM et al (2014) Fertilizer adoption and use intensity among smallholder farmers in Northern Ghana: a case study of the AGRA soil health project. Sust Agric Res 3(1):24

Mbwiga J (2016) Classification of chagga agroforestry homegardens and their contributions to food, income and wood energy to communities of Rombo District. Ph.D. Thesis, Sokoine University of Agriculture, Morogoro, Tanzania.

Meaza H, Tsegaye D, Nyssen J (2016) Allocation of degraded hillsides to landless farmers and improved livelihoods in Tigray, Ethiopia. Norsk Geografisk Tidsskrift-Norwegian J Geogr 70(1):1–12. https://doi.org/10.1080/00291951.2015.1091033

Mohammed EM, Hassan TT, Idris EA et al (2021) Tree population structure, diversity, regeneration status, and potential disturbances in Abu Gadaf natural reserved forest, Sudan. Env Chall 5:100366. https://doi.org/10.1016/j.envc.2021.100366

Mousavi SA, Ghahfarokhi MS, Koupaei SS (2020) Negative impacts of nomadic livestock grazing on common rangelands' function in soil and water conservation. Eco Indicat 110:105946. https://doi.org/10.1016/j.ecolind.2019.105946

Mugi-Ngenga EW, Mucheru-Muna MW, Mugwe JN et al (2016) Household's socio-economic factors influencing the level of adaptation to climate variability in the dry zones of Eastern Kenya. J of Rur Stud 43:49–60. https://doi.org/10.1016/j.jrurstud.2015.11.004

Mwase W, Sefasi A, Njoloma J et al (2015) Factors affecting adoption of agroforestry and evergreen agriculture in Southern Africa. Env Nat Resour Res 5(2):148–157

Mwaura GG, Kiboi MN, Mugwe JN et al (2021) Economic evaluation and socioeconomic drivers influencing farmers' perceptions on benefits of using organic inputs technologies in Upper Eastern Kenya. Env Chall 5:100282. https://doi.org/10.1016/j.envc.2021.100282

Ndomba OA, Bakengesa S, Petro R et al (2015) Perils of taungya to the productivity of forest plantations and need for modification: case study of Meru Forest plantation in Tanzania. Int J Agric Fores 5:267–275. https://doi.org/10.5923/j.ijaf.20150505.01

Nigussie Z, Tsunekawa A, Haregeweyn, N et al (2020) Economic and financial sustainability of an Acacia decurrens-based Taungya system for farmers in the Upper Blue Nile Basin, Ethiopia. Land Use Policy, 90, 104331. https://doi.org/10.1016/j.landusepol.2019.104331

Nketiah SK, Kumeh EM, Owusu-Addae O (2016) Functional forestry extension: amissing link in promoting forest plantation development in Ghana. J Glob Resou 3:89–96

Nyamweya JM, Moronge J (2019) Some socio-economic drivers of agroforestry adoption in Temiyotta Location, Nakuru County. Kenya J Sustain Environ Peace 2(1):9–14

Obiri BD, Obeng EA, Oduro KA et al (2021) Perceptions of herbicide usage in forest landscape restoration programs in Ghana. Sci Afric 11:e00672. https://doi.org/10.1016/j.sciaf.2020.e00672

Ojijo AL, Kibiwot SP, Kipkosgei MT (2022) Adoption and implementation of devolved farm forestry extension services from Kenya forest service to county governments: socio-economic wellbeing of rural communities and experiences from Homabay county, Kenya. East Afric J for Agrofor 5(1):9–21

Oluwadare OS (2014) Taungya farming- a strategy for sustainable land management and agricultural development in Nigeria. Advan for Lett 3:16–22

Pello K, Okinda C, Liu A et al (2021) Factors affecting adaptation to climate change through agroforestry in Kenya. Land 10(4):371. https://doi.org/10.3390/land10040371

Rahim M, Zeynab B, Javad S, Kamran A (2013) Factors affecting agroforestry acceptance level by framers in Lorestan. Iran J Agric Sci Dev 2(10):102–105

Rietveld T, van Hout R (2017) The paired t test and beyond: recommendations for testing the central tendencies of two paired samples in research on speech, language and hearing pathology. J Comm Disor 69:44–57. https://doi.org/10.1016/j.nedt.2019.05.023

Saha S, Sharmin A, Biswas R et al (2018) Farmers' perception and adoption of agroforestry practices in Faridpur district of Bangladesh. Int J Env Agri Biotec 3(6):1987–1994

Salih BA (2013) Rehabilitation of Nabag forest through Taungya system – ElQoz locality Southern Kordofan state. In: Dissertation, Sudan University of Science and Technology.

Saung T, Mizoue N, Ota T et al (2020) Differences in forest use strategies for cash income between households living outside and inside selectively logged production forests in Myanmar. Forests 11(12):1263. https://doi.org/10.3390/f11121263

Sharmin A, Rabbi SA (2016) Assessment of farmers' perception of agroforestry practices in Jhenaidah district of Bangladesh. J Agric Ecol Res Int 6(4):1–10. https://doi.org/10.9734/JAERI/2016/21760

Suleman SS, Ibrahim G (2018) The importance of non-wood forest products in improving of livelihoods of rural communities in WadiSaleh locality-central Darfur State-Sudan. J Agric Veteri Sci 11(6):69–73

Sulieman HM (2018) Exploring divers of forest degradation and fragmentation in Sudan: the case of Erawashda Forest and its surrounding community. Sci Total Env 621:895–904

Tani Y (2000) Ecological factors affecting Taungya farmers behavior in teak plantation projects: a case study in Bago Range, Union of Myanmar. Tropics 10(2):273–286

Ullah A, Khan A (2019) Effect of extension-farmers contact on farmers' knowledge of different pest management

practices in the rain-fed districts of Khyber Pakhtunkhwa, Pakistan. Sarhad J Agric 35(2):602–609. https://doi.org/10.17582/journal.sja/2019/35.2.602.609

Wiro KO, Ansa JEO (2019) Socio-economic potential of taungya farming system for sustainable food production in Nigeria. Int J Interdiscip Res Innov 7(4):13–21

Yamane T (1967) Statistics: an introductory analysis, 2nd edn. Harper & Row, New York