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The Role of Taungya System in Afforestation of Atbara River Forests

Hafiz Mohammed Al-Habib Hamad[1], Osman Elbousairi Mohammed[1], Madani Ibrahim Adlan[2], and Haidar Salaheldeen Abdalla[2]

1Faculty of Agriculture, Nile Valley University.
2Agricultural Research Corporation (ARC), Hudeiba Research Station
Correspondent author: hafiz19784@gmail .com

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Abstract

The Taungya system is an agroforestry approach designed to combine agricultural production with forest establishment and restoration. A case study of five forests along the Atbara River showed that, despite its long-term application, the system has largely failed to restore forest cover. Extensive areas remain under cultivation without trees, with treeless cultivated land ranging from 13.3% to 67.4% across the studied forests. Although 82.1% of respondents practiced cultivation under the Taungya system and depended on forest land for both food security and income, compliance with tree planting and maintenance requirements was generally poor. Farmers mainly cultivated sorghum with other crops and planted drought-tolerant Acacia species, but tree establishment relied primarily on direct seeding, while seedling survival was very low, with 43.3% of respondents reporting survival rates below 10%. The main constraints were uncontrolled grazing, lack of irrigation, repeated plowing and land clearing, the short cultivation period, and inadequate post-planting management. Overall, the findings demonstrate that weak implementation, poor monitoring, and inadequate farmer compliance have limited the effectiveness of the Taungya system in restoring forest cover, highlighting the need for improved management, stronger institutional support, and greater community participation.

Keywords:Taungya system, reforestation, forest establishment, agroforestry, forest rehabilitation, sustainable forestry

نظام التونجيا في إعادة اعمارغابات نهرعطبرة

حافظ محمد الحبيب حماد[1]و عثمان البوصيري محمد[1] و مدني ابراهيم عدلان[2] و حيدر صلاح الدين عبدالله[2]

1كلية الزراعة جامعة وادي النيل

2هيئة البحوث الزراعية / السودان

ممثل المؤلفين : حافظ محمد الحبيب حماد hafiz19784@gmail.com **تلفون +249912828415**

المستخلص

يعد نظام التونجيا أحد النظم التي صممت للجمع بين الانتاج الزراعي وانشاء وتعمير الغابات ولقد اظهرت الدراسة التي اجريت في 5 غابات في نهر عطبرة ان نسبة الأراضي الخالية من الاشجار ما بين 13.3% الي 67.4% داخل أراضي الغابات محل الدراسة. وأوضحت النتائج أن 82.1% من المشاركين يمارسون نظام التونجيا يعتمدون علي أراضي الغابات لتوفير الامن الغذائي إلا ان الالتزام بزراعة الأشجار ورعايتها كانت ضعيفة. هم يعتمدون علي محصول الذرة الرفيعة بصوره رئيسة إلي جانب المحاصيل الأخرى وعلي زراعة الأشجار الشوكية المقاومة للجفاف بطريقة البذر المباشر للبذور داخل الحفر إلا ان نسبة النجاح لم تتعدي ال10%. ومعظم العوائق الرئيسة تمثلت في عدم السيطرة علي الرعي ونقصان الري في فترة الجفاف والإعتماد علي الحراثة والنظافة المتكررة وقصر فترة الزراعة وعدم تناسب إدارة ما بعد الإستزراع. عموماً اوضحت الدراسة ان ضعف التطبيق وضعف المراقبة وعدم تناسبية إدارة المزارع في النظام أدت الي محدودية نظام التونجيا في إعادة إعمار الغطاء الغابي مما أبرزت الحاجة إلي تحسين الإدارة والدعم المؤسسي القوي والمشاركة المجتمعية الفعالة.

الكلمات المفتاحية: *نظام "تاونغيا"، إعادة التشجير، إنشاء الغابات، الزراعة الغابية، تأهيل الغابات، غابات مستدامة*

Introduction:

Global forest ecosystems continue to experience severe degradation due to agricultural expansion, illegal logging, infrastructure development, mining, wildfires, and climate change (Food and Agriculture Organization [FAO], 2020). According to the FAO (2020), approximately 420 million hectares of forest have been lost globally since 1990, highlighting the urgent need for effective forest restoration strategies.

Forest restoration has become a major international priority under the United Nations Decade on Ecosystem Restoration (2021–2030), which promotes sustainable approaches capable of restoring degraded landscapes while improving local livelihoods (United Nations Environment Programme [UNEP] and FAO, 2021).

In this era of climate change, environmental degradation and socio-economic challenges, forest landscape restoration is advocated to be a normative ecological practice. Forest restoration is a planned process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded landscapes (Narh,2024)

Among these approaches, the Taungya system has proven to be an effective agroforestry practice that simultaneously supports forest establishment and agricultural production (Nair, 1993). By integrating tree planting with temporary cultivation of annual crops, the system reduces reforestation costs and encourages local communities to participate actively in forest management (Evans and Turnbull, 2004).

The term *Taungya* originates from the Burmese language, where "Taung" means hill and "Ya" means cultivation (Nair, 1993). The system was first officially introduced in Myanmar during the 1850s to establish teak (*Tectona grandis*) plantations while providing local farmers with temporary agricultural land (Evans and Turnbull, 2004).

Its success led to adoption throughout tropical Asia, Africa, and Latin America, particularly in India, Bangladesh, Nigeria, Ghana, Indonesia, Thailand, and several East African countries (Lamb, 2011).

Today, Taungya is recognized as an important agroforestry system that combines ecological restoration with rural development objectives (FAO, 2018).Making sure we use forest resources today; however, in a way that doesn't prevent future generations from using them too. It involveskeeping forests healthy and productive by using them wisely, planting new treesand protecting them.

Objective

The main goal of this study is to assess the effectiveness of taungay system in reforestation maintenance of Atbara River forests.

Material and Methods:

Area of study

The study was conducted in the Atbara River in River Nile state, Sudan, which covers an area of approximately 124,000 km² and extends between latitudes 16° - 22° N and longitudes 31° - 34° E. More specifically, the present study focuses on the Atbara River area, which lies between latitudes 16° - 18° N and longitudes 34° - 35° E, within the southeastern part of River Nile State (Adam, 2008). The Atbara River area is a part of Adammer locality and considered one of the most fertile agricultural areas in River Nile State.To assess the current status of forest vegetation, the relationship between local communities and forest resources was investigated, where a sample of five forests was taken, examining the Taungya system and mixed farming within these

forests, the extent of adherence to and application of the Taungya system in forest restoration, and whether the Taungya system was successful in restoring these forests or not, this forests are:

1- Um Al-Debea Forest, with an area of 1,751 fed (FNC, 2013), surveyed as part of this study. The field survey revealed that 52.5% of the forest area consists of agricultural land completely devoid of trees. These lands are leased annually by the Forests National Corporation under the Taungya system.
2- Umm Handhal Forest, covering an area of 2,090 feddan (NFC, 2013), which was included in the field survey conducted for this study. The sample-based field assessment showed that 67.4% of the forest area consists of agricultural land within the forest that is completely devoid of trees. Furthermore, the questionnaire survey revealed that thevast majority of local residents have been cultivating land within Umm Handhal Forest under the Taungya system since the 1980s. This indicates that they have practiced cultivation in the forest for more than 40 years, yet no trees have been established within the areas they cultivate.
3- Umm Ba'ashim Forest, with an area of 661 feddan (according to the reports of the Forests National Corporation), was also investigated in this study. The field survey revealed that 20.7% of the forest area is leased under the Taungya system through contractual agreements with the Forests National Corporation. Although the leased area is relatively small, interviews with local residents indicated that cultivation within the forest began in the early 2000s. The findings also revealed a lack of compliance with the Taungya system's requirements, as farmers generally failed to plant tree seedlings or seeds and did not provide adequate care for the planted seedlings.
4- Ashoul Forest, with an area of 363feddan according to the reports of the Forests National Corporation, was also assessed during the field survey conducted for this study. The survey showed that 13.3%of the forest area is occupied by agricultural land. A considerable amount of natural regeneration of Acacia trees was observed within the forest. However, most of these naturally regenerated seedlings disappear by the end of the growing season. If cultivation under the Taungya system had been properly managed and the naturally regenerated seedlings had been protected and maintained, the forest would likely have had no vacant or treeless areas.
5- Al-Barnawit Forest, covering an area of 633 feddan according to the reports of the Forests National Corporation, was also assessed in this study. Based on the field survey and sample-based area estimation, approximately 24% of the forest area is cultivated under the Taungya system through lease agreements with the Forests National Corporation. According to the questionnaire survey, local residents have been cultivating land within the forest since the **1990s**. The intensity of cultivation varies depending on the extent of seasonal flooding, as some parts of the forest remain inundated for more than one month during the flood season. Despite being cultivated under the Taungya and leasing systems for many years, these areas remain completely devoid of trees.

Study Design and Data Collection

A descriptive cross-sectional field **survey** was adopted to collect primary data from the selected communities. Data were obtained using three complementary methods: field surveys and observations, personal interviews, and a structured questionnaire.

Questionnaire Design

A structured questionnaire consisting of 112 questions was developed and administered to respondents in the seven selected villages. The questionnaire was designed to collect both ecological and socioeconomic information related to the forests and their surrounding communities. These area include: The current condition of forest vegetation and vegetation cover and it's changes over time as well as vegetation cover has increased or decreased compared with the past; changes in the abundance and distribution of plant and grass species; the emergence of new plant and grass species; the disappearance or possible local extinction of previously occurring species; local people's relationship with and utilization of forest resources and their dependence on forests for livelihood activities; the contribution of forest resources to household income and sources of livelihood and household food security. Furthermore, the direct and indirect benefits provided by forests to local communities; and local people's perceptions of changes in forest resources and vegetation conditions.

Sample Size

It is well established that the precision of study estimates increases as sample size increases. That is because larger samples reduce sampling error and narrow confidence (Andred.2021). The authorstake a sample of 67 out of population of 536 households to represent study sample size (Census Department- the RNS, 2005). However, this represents approximately 13% of targeted group of forests' people.

Data Processing and Statistical Analysis

The collected questionnaire data were coded, entered, organized, and statistically analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistical techniques were primarily used to summarize the characteristics of the respondents and their responses to the questionnaire.

For categorical variables, frequencies and percentages were calculated to describe the distribution of responses. Where appropriate, other descriptive statistical measures and relevant statistical variables were calculated according to the nature and measurement level of each variable.

The statistical analysis was used to identify patterns in respondents' perceptions of changes in forest vegetation, the occurrence and disappearance of plant species, the level of dependence on forest resources, the contribution of forests to household income and food security, and the benefits obtained from forests.

The results obtained from the statistical analysis were presented in the form of frequency tables, charts, percentages, and other appropriate statistical summaries, allowing comparisons among the surveyed communities, and providing an overall assessment of the ecological and socioeconomic importance of the forests in the Atbara River region.

Result and discussions

Agricultural Cultivation within Forest Land:

The respondents were asked whether the forests provide any benefits and whether these benefits have an impact on household income. The results showed that 97% of the respondents believed that the forests provide significant benefits to the communities living adjacent to them. One of the main benefits identified was the provision of agricultural land for cultivation.

Out of the 67 respondents, 12 reported that they are not been involved in cultivation within the forest, while 55 stated that they cultivated forest land under the Taungya system. These

respondents were further asked about the type of cultivation they practiced—whether they cultivated agricultural crops only, planted trees only, or practiced a combination of tree planting and crop cultivation. The dribution of their responses is presented in figure 1.

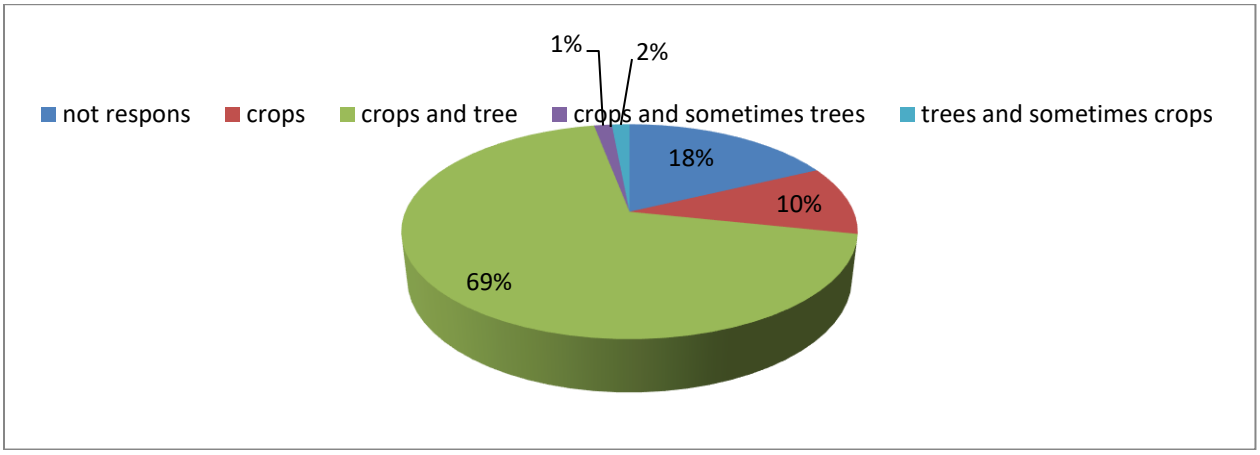


Figure1. Type of agriculture

Source: questionnaire surveys, 2025/ 2026

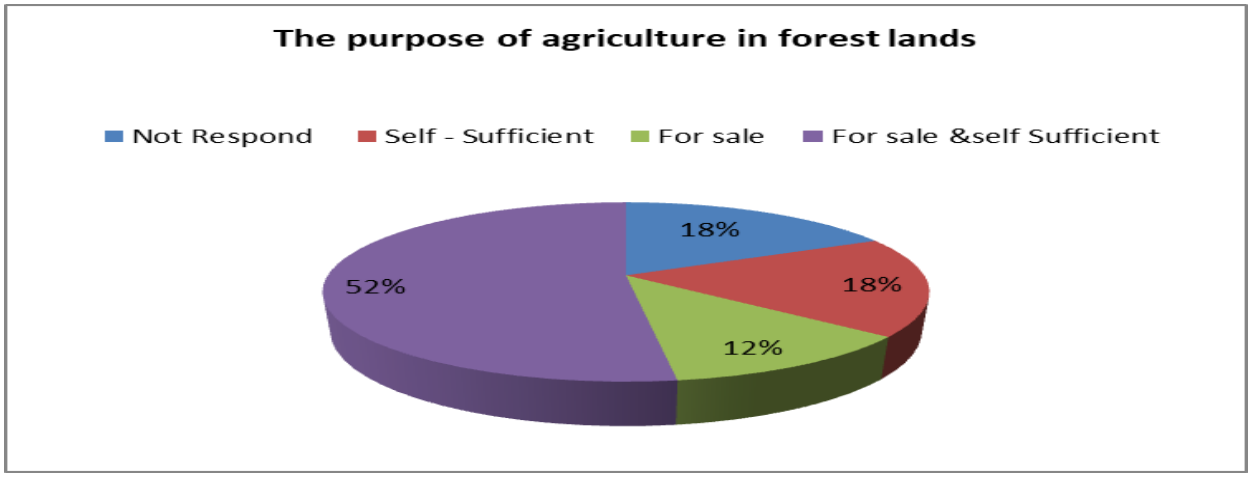
Twelve people in the sample did not respond or did not cultivate in the forest (18%), 7 people cultivated crops only within the forest (10%), 466 people in the sample cultivated trees along with crops (69%), one person in the sample cultivated crops and sometimes trees (1%), and one person cultivated trees and sometimes crops (2%). This indicates that the vast majority of the local population relies on the forest or forest land for agriculture.

The survey results indicate that the majority of respondents practice agriculture within forest lands, either in association with forest trees (agroforestry) or in forest areas without tree cover. Their livelihoods are highly dependent on the use of forest land." These results agree with Elamin, et al. (2024) who found that 27% of Taungya farmers identified access to free land as a motivation, while farmers also reported the productivity and fertility of forest land.

The purpose of agriculture in forest lands

The results presented in the figure 2 regarding the purpose of farming among the study sample indicate variation in farmers' objectives for engaging in agricultural activities. The findings revealed that 12 respondents (18%) did not provide a response, while 12 respondents (18%) reported that their primary objective was self-sufficiency. In contrast, 8 respondents (12%) indicated that their main objective was selling agricultural products. The largest group, comprising 35 respondents (52%), stated that their objective was both selling their produce and achieving self-sufficiency. These findings suggest that the majority of the respondents rely on agriculture not only to meet their households' food needs but also as a source of income through the sale of part of their agricultural production. This reflects the economic and social importance of agriculture in improving household livelihoods. Furthermore, the results show that a considerable proportion of farmers engage in agriculture primarily to achieve self-sufficiency, whereas a smaller proportion focuses exclusively on production for commercial purposes."It can be observed that the main objectives of farming are subsistence, commercial production, or a combination of both. These findings highlight the importance of agriculture as a key source of livelihood, serving either as a means of ensuring household food security or as a source of household income through the marketing of agricultural produce. Frimpong and Titiati(2025)

cited that agriculture in forest lands contributes to food security and household nutrition also they found that agricultural activities in forest restoration areas can provide income and livelihood opportunities.



Source: questionnaire surveys, 2025/ 2026.

Figure2: The purpose of agriculture in forest lands

Type of crops Cultivated in side forests

The results presented in the table (1) show the different types of crops cultivated by the respondents within forest areas alongside trees. The findings indicate considerable diversity in crop production, reflecting the practice of integrating agricultural crops with forest trees.

Table (1): Different types of crops cultivated within forest areas alongside trees

Type of crops	Frequency	Percent	Cumulative %
No response	12	17.9	17.9
Sorghum	6	9.0	26.9
Vegetable	2	3.0	29.9
Cowpea	1	1.5	31.3
Sorghum and Beans	20	29.9	61.2
Sorghum and Onion	11	16.4	77.6
Sorghum and Vegetables	1	1.5	79.1
Sorghum and Watermelon	4	6.0	85.1
Chickpea and Onion	1	1.5	86.6
Beans and Onion	2	3.0	89.6
Sorghum, Chickpea, and Beans	1	1.5	91.0
Sorghum, Chickpea, and Onion	1	1.5	92.5
Sorghum, Beans, and Onion	2	3.0	95.5
Sorghum, Beans, and Cowpea	2	3.0	98.5
Sorghum, Beans, and Watermelon	1	1.5	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Out of the 67 respondents, 12 respondents (17.9%) did not provide a response regarding the types of crops they cultivate. Among those who responded, the most common cropping system

was the cultivation of sorghum and beans, reported by 20 respondents (29.9%), making it the dominant crop combination. This suggests that farmers prefer this combination because it provides both household food security and economic benefits while adapting well to agroforestry systems.

The second most common combination was sorghum and onion, cultivated by 11 respondents (16.4%). This indicates that onions are an important cash crop commonly intercropped with Sorghum, enabling farmers to diversify their production and increase household income.

In terms of single crops, sorghum alone was cultivated by 6 respondents (9.0%), making it the most common sole crop. This reflects the importance of sorghum as a staple food crop in the study area. Sorghum and watermelon were grown by 4 respondents (6.0%), while vegetables alone and beans with onion were each reported by 2 respondents (3.0%). Likewise, Sorghum with beans and onion and Sorghum with beans and cowpea were each cultivated by 2 respondents (3.0%).

Several crop combinations were less common, each reported by 1 respondent (1.5%). These included cowpea alone, Sorghum with vegetables, chickpea with onion, Sorghum with chickpea and beans, Sorghum with chickpea and onion, and Sorghum with beans and watermelon.

Overall, the results demonstrate that Sorghum is the dominant crop in the study area, appearing either as a sole crop or in combination with other crops in most farming systems. This highlights its central role in the agroforestry practices adopted by the respondents. The frequent integration of sorghum with beans, onions, vegetables, watermelon, chickpea, and cowpea reflects farmers' efforts to diversify production, improve food security, reduce production risks, maintain soil fertility through crop diversity, and generate additional income from the sale of different agricultural products.

In Sudan, a recent study conducted by Hemida, *et al*, (2024 the Taungya system in South Kordofan identified groundnut, sesame, cowpea, watermelon, and hibiscus as the five major crops cultivated by farmers. Groundnut and sesame were the dominant crops, cultivated by 79.5% and 75.5% of farmers, respectively, while cowpea, watermelon, and hibiscus were cultivated by 40.5%, 38%, and 17.5% of farmers.

Species of trees that planted with crops in the forests

The results presented in the table (3) show the tree species used in the taungya farming system within forests by the surveyed respondents (n = 67). A total of 20 respondents (29.9%) did not answer the question regarding the tree species associated with crop cultivation.

Among those who responded, the most common practice was the integration of three tree species together (*Acacia nilotica, Acacia seyal, and Acacia tortilis var. radiana),* reported by 15 respondents (22.4%), making it the most frequently adopted tree combination in the taungya system.

The use of Talh (*Acacia seyal*) alone ranked second, with 13 respondents (19.4%), followed by Sunt (*Acacia nilotica*) with 7 respondents (10.4%), and Taleh (*Acacia seyal*) with 6 respondents (9.0%).

Mixed combinations of two tree species were less common. Sunt and Seyal were reported by 4 respondents (6.0%), while Sunt and Taleh and Taleh and Seyal were each reported by 1 respondent (1.5%).

Overall, the findings indicate that respondents tended to prefer either cultivating crops with a mixture of the three dominant Acacia species or with Taleh alone. This suggests that these tree species are considered the most suitable for the taungya farming system, likely because of their adaptability to local environmental conditions and their compatibility with agricultural crops.

The relatively high proportion of non-responses (29.9%) may indicate that some respondents were uncertain about the tree species or were not practicing taungya cultivation with trees at the time of the survey.

Most of the dominant tree species along the Atbara River belong to the thorny acacias, which are well adapted to the prevailing climatic conditions of the region. Consequently, forest nurseries provide seeds of *Acacia nilotica* (Sunt), *Acacia tortilis* var raddiana (syal), and *Acacia seyal* (Taleh), as these species are highly suited to the local environment.

The area is characterized by seasonal flooding and a rainy season that begins at the end of July and continues until the end of September. This is followed by a cool winter extending until February, and then a long, hot summer lasting until the onset of the next rainy season in July. The summer is accompanied by prolonged drought, low relative humidity, and reduced soil moisture. These harsh environmental conditions require tree species that are well adapted to withstand drought, seasonal flooding, and other climatic stresses.

Table (2): Species of trees that planted with crops in the forests

Tree species	Frequency	Percent	Cumulative %
Not respond	20	29.9	29.9
Acacia Nilotic	7	10.4	40.3
Acacia tortilis var. raddiana	6	9.0	49.3
Acacia seyal	13	19.4	68.7
A.nilotica& A. tortilis var. raddiana	4	6.0	74.6
A.nilotica& A.seyal	1	1.5	76.1
A.seyal A. tortilis var raddiaan	1	1.5	77.6
A. nilotic, A. seyal, A. tortilis var radian	15	22.4	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

The period during which farmer cultivated land within forest

The results presented in Table (3) indicate that the majority of respondents were granted a single cropping season of six months for cultivating agricultural crops within forest areas under the taungya system. Specifically, 55 respondents (82.1%) reported that the Forest Administration allowed them to cultivate crops for one six-month season, while 12 respondents (17.9%) did not provide a response to this question.

El-Mahdy *et al*. (2024); suggest that the Forest Administration follows a standardized policy of granting local farmers temporary cultivation rights for one agricultural season during the early stages of forest plantation establishment. This practice is consistent with the objectives of the taungya system, which aims to support forest regeneration while providing short-term livelihood opportunities for local communities. The limited cultivation period ensures that agricultural activities do not interfere with the subsequent growth and management of forest trees once the It is worth noting that the Atbara River was formerly a seasonal river before the construction of the Setit Dam in the upper reaches of the river. At that time, agriculture depended primarily on the annual flood, with cultivation taking place on lands inundated by floodwaters.

Table (3): The period during which farmer cultivated land within forest

Period	Frequency	Percent	Cumulative %
No response	12	17.9	17.9
6 months	55	82.1	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

The length of time that target group cultivated in side of forest

Table (4) presents the distribution of respondents according to the number of years they have been cultivating crops within the forest under the taungya farming system. Of the total 67 respondents, 12 (17.9%) did not provide an answer to this question.

Among those who responded, the largest proportion of participants, 28 respondents (41.8%), cited that they had been cultivating in the forest for more than 30 years. This was followed by 17 respondents (25.4%) who had cultivated in the forest for 20–30 years, while 10 respondents (14.9%) mentioned 10 to 20 years of cultivation experience.

Table (4): The length of time that target group cultivated in side of forest

Length	Frequency	Percent	Cumulative %
No response	12	17.9	17.9
10-20 year	10	14.9	32.8
20-30 year	17	25.4	58.2
Over 30year	28	41.8	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Some studies found that the length during which farmers cultivated agricultural land within forest reserves varied according to the growth and development of the planted trees. Under the Taungya system, farmers are generally permitted to cultivate food and commercial crops during the early establishment stage of forest plantations. This period commonly ranges from three to five years, after which increasing tree canopy cover and competition for light make agricultural cultivation less productive (Hemida*et al*., 2023). In the Modified Taungya System in Ghana, farmers are generally allowed to cultivate permitted food crops for approximately three years until the developing trees form a canopy, after which crop cultivation is discontinued (Narh, 2024).

Methods of preparing land for cultivation

Table (5) presents the methods used by respondents to prepare land for crop cultivation within forest areas under the Taungya farming system. Out of the 67 respondents, 12 (17.9%) did not provide a response to this question.

The majority of respondents, 55 (82.1%), reported that land preparation was carried out through plowing using a tractor and moldboard plowing. No other land preparation methods were reported by the respondents.

Frimpong, A.and Titiati, A. (2025) cited that depending on local practices and forest-management regulations, farmers may use manual tools such as hoes, cutlasses and axes for slashing and clearing vegetation, followed by soil preparation for crop planting.

Table (5): Methods of preparing land for cultivation

Methods of preparing	Frequency	Percent	Cumulative %
No response	12	17.9	17.9
Moldboard plowing	55	82.1	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Irrigation methods

Table (6) illustrate that pump irrigation was the predominant irrigation method among the respondents, accounting for 36 respondents (53.7%), followed by flood irrigation, which was reported by 16 respondents (23.9%). A further 3 respondents (4.5%) used a combination of flood and pump irrigation. This finding is consistent with recent evidence from smallholder irrigation systems in sub-Saharan Africa, where pump-based technologies have become an important means of accessing irrigation water. For example, Hagos *et al*. (2024) reported considerable use of pump irrigation across different smallholder irrigation management systems in Ethiopia, while flood irrigation was also identified as one of the major methods of applying water to agricultural fields. Similarly, Ahmed and Tilaye (2024), in their assessment of smallholder irrigation pump users in Ethiopia, identified pump irrigation as an important technology used by farmers, although its adoption and continued use were constrained by factors such as pump costs, fuel requirements and equipment damage. The predominance of pump irrigation in the present study may therefore be associated with farmers' need for a reliable means of lifting water from available surface-water or groundwater sources, particularly where rainfall is inadequate or unreliable.

Table (6): Methods of Irrigation

Methods of irrigation	Frequency	Percent	Cumulative %
No response	12	17.9	17.9
Flood irrigation	16	23.9	41.8
Pumped irrigation	36	53.7	95.5
Flood and pumped	3	4.5	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Source of trees that planted in forest by farmer

Table (7) presents that seeds were the most commonly used source of tree planting materials among the respondents, accounting for 37 respondents (55.2%). Seedlings were used by 6 respondents (9.0%), while 5 respondents (7.5%) reported using both seeds and seedlings. The predominance of seeds in the present study is consistent with evidence that smallholder farmers commonly obtain tree planting materials through locally available seed sources and self-collection. Recent evidence from agroforestry systems indicates that farmers use both seeds and seedlings and rely on diverse local networks for obtaining planting materials (Mariel *et al.*, 2024). Similarly, CIFOR-ICRAF (2024) identified self-collection and supply through seed and seedling networks as important components of tree planting-material systems. The relatively greater use of seeds in the present study may be associated with their lower cost, local availability and farmers' familiarity with direct sowing. However, this finding differs from some recent agroforestry initiatives where seedlings produced through community nurseries are increasingly promoted to improve tree establishment and survival. For example, recent agroforestry activities in Cameroon have relied extensively on community-produced tree seedlings for landscape restoration and farm establishment.

Table (7):Sources of tree planting materials

Source of trees	Frequency	Percent	Cumulative %
No response	19	28.4	28.4
Seeds	37	55.2	83.6
Seedling	6	9.0	92.5
Seeds & seedling	5	7.5	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Percentage of success seedling

Table (8) presents the perceived success rates of tree seedlings as reported by farmers practicing the Taungya farming system within forest areas. Out of the total 67 respondents, 19 respondents (28.4%) did not provide a response regarding the success rate of planted seedlings.

Among the respondents who provided information, the majority (29 respondents, 43.3%) indicated that the success rate of seedlings was less than 10%. Meanwhile, about 19.4% of them estimated the success rate to be between 10% and 50%, while only 9 % reported a seedling success rate of more than 50%.

These findings reveal that farmers generally perceive the survival and establishment rate of tree seedlings within forest areas to be relatively low. The high proportion of respondents reporting success rates below 10% suggests the presence of challenges affecting seedling establishment, which may include limited water availability, harsh environmental conditions, grazing pressure, pests, or inadequate management practices during the early stages of tree growth.

This finding is consistent with Fané *et al*. (2024), who examined agroforestry adoption among 279 farmers in Mali and Burkina Faso. They found that although agroforestry has substantial potential for improving livelihoods and ecosystem services, its targeted adoption remained low in the study areas. Their findings suggest that the potential of agroforestry does not automatically translate into widespread adoption or successful implementation, which is consistent with the relatively low success perceived by your respondents.

Similarly, a 2024 systematic review of agroforestry technologies in Africa found that their adoption and widespread use remain below anticipated levels. The review identified several barriers, including limited access to inputs, inadequate technical support, land-tenure problems, lack of incentives and socioeconomic constraints. These factors can contribute to poor implementation and consequently low perceived success of agroforestry initiatives (Kpoviwanou, *et al*., 2024).

Table (8): success rate of initiatives

Success rate of initiatives	Frequency	Percent	Cumulative %
No response	19	28.4	28.4
Less than10%	29	43.3	71.6
10- 50 %	13	19.4	91.0
Over 50%	6	9.0	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026,

Methods of planting trees

Table (9) presents the methods used by farmers for planting trees by seeds within forest areas under the Taungya farming system. Out of the total 67 respondents, 19 respondents (28.4%) did not provide information regarding the method of seed planting.

Among the respondents who reported their planting methods, the most common technique was planting seeds in prepared holes with specific dimensions, reported by 32 respondents (47.8%). This was followed by broadcasting seeds, practiced by 13 respondents (19.4%), while 3 respondents (4.5%) used the furrow (ridge) planting method.

Recent research on smallholder farmers participating in Taungya agroforestry in Sudan indicates that access to land, crop choices, and tree establishment are important components of the success of the system. The study also highlights the need for appropriate tree spacing and extension support to achieve a balance between agricultural production and tree growth. Therefore, extension services should focus on demonstrating the advantages of properly prepared planting holes, appropriate seed depth and spacing, suitable species selection, and post-planting protection. Farmers who use broadcasting or furrow planting could particularly benefit from practical demonstrations comparing germination and survival rates among different methods (Hemida *et al.*, 2024).

Table (9): Method of planting trees within forest areas under the Taungya farming system

Planting Methods	Frequency	Percent	Cumulative %
No respons	19	28.4	28.4
Sowing seeds	13	19.4	47.8
Planted in pit	32	47.8	95.5
Planted in stream	3	4.5	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Causes of low percentage of trees success and seedling mortality

Table (10) presents the respondents' perceptions of the main causes of the low success rate of natural regeneration. A total of 67 respondents were included in the analysis.

The largest proportion of respondents (28.4%) did not provide a specific reason for the low success rate. Among those who identified contributing factors, the most frequently reported cause was the combined effect of land grazing, irregular irrigation, insufficient six-month establishment period, and sand burial, which accounted for 17.9**%** of responses. This was followed by land grazing, lack of irrigation, plowing, cleaning operations, and the perception of six months is insufficient for seed germination and seedling establishment (13.4%).

Several other respondents (9.0%) indicated that the land is left for grazing after harvest before plowing, while 7.5% reported that leaving the land for grazing after harvest combined with an insufficient six-month period limits successful germination. Another 7.5% attributed the low success rate to the absence of irrigation after harvest until the following season, when land cleaning and plowing are carried out. Likewise, 7.5% identified a combination of grazing, land preparation, cleaning, and sand burial as major constraints.

Less frequently reported causes included the absence of irrigation after harvest, followed by grazing and plowing (4.5%), while only 1.5% of respondents cited each of the following individually: leaving the land after harvest for grazing or without irrigation, leaving the land for grazing with no irrigation until sand burial occurs, and grazing combined with land preparation, cleaning, and sand burial.

Overall, the findings indicate that poor post-harvest land management practices, particularly unrestricted grazing, inadequate or irregular irrigation, repeated land preparation activities (plowing and cleaning), sand burial, and an insufficient period for seed germination and seedling establishment, are perceived as the principal factors limiting regeneration success. These results suggest that improving grazing management, ensuring timely irrigation, minimizing disturbance

during the regeneration period, and extending the establishment period could substantially enhance regeneration success (Opoku Mensah *et al*. 2024).

Table (10): Causes of low percentage of trees success and seedling mortality

Causes of low success	Frequency	Percent	Cumulative %
No response	19	28.4	28.4
After harvest the land either left for grazing or not irrigated	1	1.5	29.9
After harvest the land left for grazing then plowing	6	9	38.8
After harvest the land left for grazing and 6 month in not enough to germinate	5	7.5	46.3
After harvest no irrigation till next season; then cleaning and plowing	5	7.5	53.7
After harvest the land left for grazing no irrigation till sand burial	1	1.5	55.2
After harvest no irrigation; the land left for grazing then plowing	3	4.5	59.7
The land is left for grazing, with preparation, cleaning, and sand burial	5	7.5	67.2
The land is left for grazing, with preparation, cleaning, and sand burial	1	1.5	68.7
Land grazing, no irrigation, plowing, cleaning, 6-six-month is insufficient	9	13.4	82.1
Land grazing, irrigation is irregular, 6-month is insufficient, and sand burial occurs	12	17.9	100.0
Total	67	100.0	

Source: questionnaire surveys, 2025/ 2026.

Recommendations

Based on the findings of this study, the following recommendations are proposed to improve the implementation and sustainability of the Taungya farming system and enhance forest regeneration in the study area:

1- Strengthen the implementation of the Taungya system. The Forest Administration should ensure that the Taungya system is implemented according to its intended objectives, where agricultural cultivation is integrated with tree establishment rather than replacing forest regeneration.

2- Improve seedling establishment and survival. Measures should be introduced to increase tree survival rates by using high-quality seeds and seedlings, improving nursery management, applying appropriate planting techniques, and providing regular monitoring during the early stages of tree growth.

3- Extend post-planting care. The current six-month cultivation period is insufficient for successful tree establishment. A mechanism should be developed to provide continued protection and maintenance of young seedlings after the cropping season until they become well established.

4- Control livestock grazing. Uncontrolled grazing after crop harvesting was identified as one of the major causes of seedling mortality.Controlled grazing systems, fencing of newly established plantations, or designated grazing areas should be introduced to protect young trees.

5- Improve irrigation management. Since many farmers depend on pump irrigation after floodwater recedes, efforts should be made to improve access to affordable irrigation facilities, reduce pumping costs, and encourage efficient water-use technologies to support both crop production and tree establishment.
6- Promote sustainable land preparation practices. The use of tractors, moldboard ploughs, and burning of crop residues can damage naturally regenerated seedlings. Conservation-oriented land preparation methods that minimize disturbance to young trees should be encouraged.
7- Enhance farmer training and extension services. Regular training programs should be organized to improve farmers' knowledge of agroforestry practices, tree planting techniques, seedling management, soil conservation, and sustainable forest management.
8- Promote agroforestry and crop diversification. Farmers should continue integrating agricultural crops with suitable indigenous tree species while expanding crop diversification to improve household food security, reduce production risks, and increase income.
9- Strengthen community participation in forest management. Local communities should be actively involved in planning, implementing, and monitoring forest management activities to encourage ownership, improve compliance with forest regulations, and enhance the long-term sustainability of the Taungya system.
10- Support forest restoration through appropriate tree species. The continued use of indigenous species such as Acacia nilotica, Acacia seyal, and Acacia tortilis var. raddiana should be promoted because of their adaptation to the environmental conditions of the study area and their compatibility with agroforestry systems.
11- Review land-use policies within forest reserves. The Forest Administration should periodically assess the duration of land allocation and ensure that cultivated areas are successfully converted into forest plantations before new cultivation sites are allocated.
12- Conduct further research. Additional studies should investigate the ecological, economic, and social impacts of the Taungya system, including long-term tree survival, household income, biodiversity conservation, and the effectiveness of different management interventions under changing climatic conditions.

References

Adam, A.K. (2008). “Change in land use in Lower Atbara River Area”. Nile Valley University, MSc. Dissertation (Arabic source).

Ahmed, B.; Tilaye, A. (2024). Assessment and technical constraint identification of smallholder irrigation pump in Arsi and East Shewa Zone, Oromia. International Journal of Engineering Science Technologies, 8(4). 24-36 https://doi.org/10.29121/ijoest.v8.i5.2024.641

Census Department in the River Nile State (2005). An estimation to general census of population by localities, *Report, 2005*.

CIFOR-ICRAF. (2024). Tree seed and seedling supplier and planter surveys: Guidance *for understanding tree planting material systems*. CIFOR-ICRAF Info-brief No. 407.

Deribe, BR.; Dawit, M.; Ringler, C.; Jeuland, M.(2024). Irrigation technologies and managment and their environmental consequences: Empirical evidence from Ethiopia. Agricultural Water. Management**.** https://essp.ifpri.info/2024/08/26/irrigation-technologies-and-management- and-their-environmental-consequences-empirical-evidence from- ethiopia/Accessed 2 Sep. 2026.

El-Mahdy, M. E.-S.;Abdel-Monsef, M.; Abo-Elella, S.; Shahba, M. (2024). *Impact of climate change on the water resources of the Atbara River using novel hydrological models*. Water Science & Technology, 89(6), 1419–1440. https: doi.org/ 10.2166/wst.2024.070

Evans, J.; Turnbull, J. W. (2004). *Plantation Forestry in the Tropics* (3rd ed.). Oxford University Press. PP 484.

Fané, S.; Agbotui, D.K.; Graefe, S.; Sanou, L.; Sanogo, S., & Buerkert, A. (2024). Adoption of agroforestry systems by smallholders' farmers in the Sudano- Sahelian zones of Mali and Burkina Faso, West Africa. *Agroforestry Systems, 98*(7), 2385–2396.

FAO (2018). *The State of the World's Forests 2018*. FAO.

FAO (2020). *Global Forest Resources Assessment 2020*. FAO.

Frimpong, A.; Titiati, A. (2025). Enhancing food security, nutrition, and livelihoods through the Modified Taungya System in Ghana: A sustainable path forward. *UNDP Ghana*.

Hemida, M., Vityi, A.; Hammad, Z.M. (2023). Socio-economic traits and constraints associated with smallholder farmers in Taungya agroforestry program in Sudan. *Agroforest Syst* 97, 1169–1184 (2023). https://doi.org/10.1007/s10457-02300855- x.

Kpoviwanou, M.R. J.H.; Sourou, B.N.K.; Ouinsavi, C.A.I.N. (2024). Challenges in adoption and wide use of agroforestry technologies in Africa and pathways for improvement: A systematic review. (2024). *Trees, Forests and People, 17*, 100642. https://doi.org/10.1016/j.tfp.2024.100642.

Lumb, D. (2011). Regreening the bare hills: Tropical forest restoration in the Asia-Pacific region. Springer.

Mariel, J.; Sanchez, I.; Verzelen, N.; Massol, F.; Carrière, S. M.; Labeyrie, V. (2024). The role of farmers' networks in sourcing planting material and information in a context of agroforestry transition in Madagascar. Agricultural Systems, 217, 103906. https://doi.org/10.1016/j.agsy.2024.103906.

Nair, P. K. R. (1993). *An introduction to agroforestry*. Kluwer Academic Publishers. Chapter 6: (Nair, 1993, pp. 75–83)

Narh, J. (2024). Progress, challenges and prospects of the modified Taungya system in Ghana. Agroforestry Systems, 98, 767–782**.** *DOI: 10.1007/s10457-023-00947-8.*NFC, National Forestry Corporation. (2013). *Inventory map booklet of River Nile State: Delineation of state forest boundaries and forest areas*. National Forestry Corporation, Sudan.

Opoku Mensah, S.; Ibrahim, S.K.; Jacobs, B.; Cunningham, R.; Owusu-Ansah, D., & Adjei, E. (2024). Benefits of farmer managed natural regeneration to food security in semi-arid Ghana. *Agriculture and Human Values, 41*(3), 1177–1193.