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Programme: Environmental protection and nature conservation

The potentiality of agroforestry practices as essential land use option for
forest rehabilitation and livelihood improvement, case study of Nabag
reserved forest, South Kordofan State, Sudan

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1 Introduction

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 (Mohamed et al. 2021, Suleman – Ibrahim 2018). Nonetheless, Sudan's vegetation cover area has decreased dramatically from 40% to 10.3% with an annual removal rate of 1.6% (Abdoun 2020), resulted in deforestation and land degradation. Another factor of land degradation could be attributed to mechanized rain-fed agriculture and shifting cultivation (Biro et al. 2013). This has created renewed interest in adaptation and mitigation technologies that could reduce the impact of climate change on agro-ecosystems by introducing promising practice of land use systems. Agroforestry practices, where trees, crops, pasture and /or animal are integrating together for economic, social, and environmental benefits can help to reduce this tremendous pressure on natural forests and contribute to sustainable livelihood of rural people (Zamora et al. 2016).

During the last decade, the degree of research interest in agroforestry has been widespread, and the practice recognized and recommended as a feasible tool and cost-effective for forest rehabilitation (Gadallah et al. 2019, de Oliveira – Carylhaes, 2016) and improving livelihood for small-holder's farmers (Mondol et al. 2021, Do et al. 2020). Several studies have focused on forest rehabilitation and livelihood improvement under different agroforestry practices (Budiastuti et al. 2021, Miccolis et al. 2019, Agevi et al. 2016). In Sudan, however, the current research on tree cropping systems and its impact on forest rehabilitation and livelihood improvement is still not advance, but some conclusions can be drawn from a few studies (e.g., Fahmi et al. 2018, Fadl et al. 2015). However, to improve the livelihood of poor farmers in the rural areas of Sudan suffering from crop failure, drought and food insecurity,

as well as to rehabilitate the degraded forests there is urgent need to assess and quantify the prevailing agroforestry practice and its contribution to forest rehabilitation and livelihood improvement hence the information generated by this research will fill the gap of knowledge in understanding the inextricable linkage between agroforestry practices and add knowledge on the value of this practices in forests rehabilitation and livelihood improvement. 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 natural resource management, food security and rural livelihood improvement.

1.1 Aims of the research

The aim of the study was to assess the potentiality of Taungya agroforestry practice as essential land use option for forest rehabilitation and livelihood improvement.

The research attempt to address the following specific objectives:

- To quantify and map the forest rehabilitation under Taungya agroforestry program.
- To examine the socio-economic characteristics of Taungya farmers.
- To assess the program's contribution to farmers' income generation.
- To determine farmers' perceptions and attitudes towards participation in Taungya agroforestry program.
- To determine the socioeconomic factors influencing their perception of the benefits of the Taungya program.

- To highlight the major incentives and constraints associated with Tuangya farmers.

2 Literature review

The literature review includes the scientific articles regarding the main issues that have been addressed in the thesis, such as: concepts of agroforestry, Agroforestry practices in Sudan, role of agroforestry in forest rehabilitation, farmer's perception towards agroforestry systems, and remote sensing concepts and applications.

3 Material and Method

3.1 Study site

The study area Nabag Reserved Forest (NRF) lies in South Kordofan State, South central part of Sudan. The area was selected as a case study due to two reasons: Firstly, the area has experienced a long history of drought-prone and rainfall shortages, which have led to forest degradation and negatively affected many communities who rely heavily on this forest for their livelihoods. Secondly, an active Taungya agroforestry program has been applied to rehabilitate the study area.

The reserved forest lies between latitudes 12° 30' 0" N to 12° 36' 0" E and longitudes 29° 36' 0" N to 29° 58' 0" E. The forest has been reserved from 1961 as a state forest and is managed by the Forest National Corporation in Sudan (FNC). It covers an area of 4174.2 hectares. The dominant tree species is *Acacia senegal*. The other natural tree species include *Azadirachta indica*, *Balanites aegyptiaca*, *Sclerocarya birrea*, *Guiera senegalensis*, and *Ziziphus spina-christi*. The annual rainfall of the study area is between 350 – 850 mm, while the average temperature ranges from 20 – 35 °C (Adam – Bello 2017). Presently, at least nine villages are surrounding the forest and rely on agriculture mainly, cropping and livestock rearing, and natural forest products

as the main sources of their livelihood. It is worth mentioning that agricultural crop production is practiced inside the forest land area.

3.2 Data collection

Remote sensing data and socioeconomic survey were implemented in this study. Satellite images of Landsat 5 Thematic Mapper, and Landsat 8 Operational Land Imager/Thermal Infrared Sensor of 1991, 2001, 2011, and 2021 were used to generate forest cover maps. Both unsupervised and supervised classifications, as well as ground truth points, were applied to classify the vegetation cover in the study site.

The socio-economic data was collected using semi-structured questionnaires, focus group discussions, key informants' interviews, and direct field observations. The study applied purposive sampling technique to select the respondents. Two hundred farmers representing 50% of those who participated in the Taungya program were selected from nine villages surrounding the reserved forest. The exact numbers of respondents in the specified villages were, 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 selection of the villages was based on the recommendations provided by the forestry officials in the study area, while the selection of the farmers was made randomly according to their availability and willingness to participate. Prior to the interview, verbal consent was obtained from the farmers to take part in the interview.

3.3 Analysis

Forest cover changes were analyzed for different periods of satellite images between 1991-2001 and 2011-2021 using QGIS software. Percentage changes of land cover categories were calculated for the period times before and after the implementation of *Taungya* program in the study area. Socioeconomic data was analyzed using the Statistical Package for Social Science (SPSS)

version 22 with the aid of Microsoft Excel version 2013. Both descriptive and inferential statistics including means, standard deviations, frequencies, percentages, paired sample t-test, Likert scale rating, and ordinal logistic regression model were applied.

4 New scientific results

4.1 Taungya agroforestry program in the study area plays a vital role in forest rehabilitation

Before the implementation of the Taungya agroforestry program in the period between 1991 and 2001, the research site has witnessed a massive reduction in forest cover classes (dense forest and light forest), followed by a significant increase in bare land and agricultural field classes. While the Taungya agroforestry program was implemented between 2011 and 2021, a substantial increase in forest cover has been detected. However, within the study period of analysis (1991-2021), results indicated that forest cover classes (dense forest and light forest) were increased by 1041.68 ha (24.95%) and 2.72 ha (0.07%), respectively, due to the establishment of Taungya agroforestry program. As a result, bare land and agricultural field areas decreased by 409.83 ha (9.81%) and 634.57 ha (15.20%), respectively. According to the findings, every bare land covered by an agricultural field will most likely be successfully converted to forest cover in the future. Hence the study concluded that Taungya agroforestry could be a successful, suitable, and viable land-use option for forest rehabilitation in the drylands of Sudan. It is recommended that the FNC in Sudan should sustain the Taungya agroforestry program at NRF and imitate it in areas where forest rehabilitation is needed.

4.2 Taungya agroforestry program in the study area contributed significantly to farmer's income

Taungya agroforestry program contributed significantly to farmers' income. Evidence to that was the sharp reduction in mean annual costs from SDG 32851.75 to SDG 25107.50, and a substantial increase in the mean annual net

incomes of the farmers from SDG 35298.52 to SDG 91839.50 before and after participation in the program, respectively. Most farmers (61.5%) earned net income between (SDG 0 – 20000) before joining the Taungya program. This percentage was reduced sharply to (21.5%) after joining the program. In contrast, the number of farmers (11%) who earned net income (SDG > 100000) significantly increased to (30%).

4.3 Taungya farmers in the study area have different socio-economic characteristics

Statistical analysis showed that there was variety in the socioeconomic traits of the framers in the study area. However, Taungya practiced in the study area was dominated mainly by male farmers, and most of them were above youthful age but still considered within an economically active age range, meaning that they could effectively participate in the agricultural activities. Taungya's farmers had attained different levels of education, ranging from Khalwa to university, 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. Farmers cultivated an average of five mukhamas of land. However, the limitation of the land area could be explained by the nature of the agroforestry rehabilitation program, which targets specific land areas inside the reserved forest and the intension of FNC to distribute land to large number of farmers for benefit sharing. The average number of years of participation in the Taungya program was 6.70 years. Most of the farmers, 57.5%, had Taungya experience ranging between 1 and 5 years. This implies that farmers accept Taungya agroforestry practices and that the number of adopters is growing, while 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 participating in the Taungya program.

4.4 Taungya farmers have a positive perceptions of the benefits of participation in Taungya agroforestry program

Likert scale analysis showed that farmers in the study area have expressed strong positive perceptions ($MS > 2.5$) toward four out of five items, bordering on the benefits of Taungya agroforestry program, including the provision of land, improving income, help during times of hardship, and contribution to education expenses. However, only one item, “Taungya help in purchasing livestock” was perceived by farmers negatively ($MS < 2.5$).

4.5 Different factors are influencing farmer’s perception of the benefits of Taungya program

Several factors were found to have positive and negative influence on farmer’s perception. The ordinal logistic model analysis showed that farmers’ perceptions of Taungya agroforestry benefits are affected by several socio-economic factors at a 5% level of significance. Out of eight explanatory variables included in the model, six variables were found to have a positive influence on farmers’ perceptions towards the benefits of Taungya agroforestry practice. These include extension services ($\beta = 0.771, P = 0.013$), family size ($\beta = 0.043, P = 0.345$), educational level ($\beta = 0.065, P = 0.583$), land size ($\beta = 0.056, P = 0.11$), Taungya experience ($\beta = 0.126, P = 0.002$), and gum Arabic production ($\beta = 0.032, P = 0.92$). Farmer’s gender ($\beta = -0.43, P = 0.182$) and age ($\beta = -0.028, P = 0.03$), on the other hand, had a negative association with their perception. This implies that farmers’ perceptions were strongly correlated with their socioeconomic factors. Therefore, a better understanding of these factors is crucial for the planning and implementation of such agroforestry programs in different farming communities in the future.

4.6 Several incentives and challenges are associated with Taungya farmers in the study area

Taungya farmers in the study area had different incentives and constraints confronting their participation in the program. The main incentives for farmers to participate in the program were the high productivity inside the forest,

access to free land, and the 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. Therefore, prioritizing extension services, providing live fences, and reconsidering farmers' interest in intercropping sorghum on their farms to improve their sustenance will overcome the constraints and further boost farmers' productivity.

5 References

- ABDOUN, S.O.M. (2020): Incentives for Reforestation and Forest's Plantations Option, under the National Strategy of REDD+ Program in Sudan. *Advances in Ecology and Environmental Research* 5: 53–85
- ADAM, Y.O. – BELLO, A.R.S. (2017): Relationship between local ecological knowledge and natural resources trade in Sudan. *International Journal of Development and Sustainability* 6(7):385–398
- AGEVI, H. ADAMBA, M.K. – HILLARY, K. – CALORYNE, M. CALVINCE, K.R. – KIPRUTO, D.K. – MOSES, W. – MERCY, K. – STANELY, J. (2016): PELIS Forestry Programme as a Strategy for Increasing Forest Cover and Improving Community Livelihoods: Case of Malava Forest, Western Kenya. *American Journal of Agriculture and Forestry* 4:128–135. <https://doi.org/10.11648/j.ajaf.20160405.13>
- BIRO, K. – PRADHAN, B. – BUCHROITHNER, M. – MAKESCHIN, F. (2013): Land Use/Land Cover Change Analysis and Its Impact on Soil Properties in The Northern Part of Gadarif Region, Sudan. *Land Degradation & Development* 24:90–102.
- BUDIASTUTI, M.T.S. – PURNOMO, D. SETYANINGRUM, D. (2021): Agroforestry System as the Best Vegetation Management to Face Forest Degradation in Indonesia. *Reviews in Agricultural Science* 10:14–23. https://doi.org/10.7831/ras.10.0_14
- DE OLIVEIRA, R.E. – CARVALHAES, M.A. (2016): Agroforestry as a tool for restoration in atlantic forest: Can we find multi-purpose species? *Oecologia Australis* 20(4): 425–435.
- DO, V.H. – LA, N. – MULIA, R. – BERGKVIST, G. – DAHLIN, A.S. – NGUYEN, V.T. – PHAM, H.T. – ÖBORN, I. (2020): Fruit tree-based agroforestry systems for smallholder farmers in Northwest Vietnam – A quantitative and qualitative assessment. *Land* 9(11): 1–23

- FADL, K.E.M. – MAHMOUD, S.E. – HAMAD, Z.M. (2015): Farmers' perceptions towards agroforestry systems in North and South Kordofan states, Sudan. *International Journal of Environment* 4(2): 53–67.
- FAHMI, M.K.M. – DAFA-ALLA, D.A.M. – KANNINEN, M. – LUUKKANEN, O. (2018): Impact of agroforestry parklands on crop yield and income generation: case study of rainfed farming in the semi-arid zone of Sudan. *Agroforestry Systems* 92:785–800.
- GADALLAH, N.A. – ADEWOLE, N.A. – AJAYI, D.D. (2019): Potential of agroforestry as forest landscape restoration tool to solve forest cover loss cum food security in Sennar and Gedaref States, Sudan. *International Journal of Development and Sustainability* 8: 199–210.
- MICCOLIS, A. – PENEIREIRO, F.M. – VIEIRA, D.L.M. – MARQUES, H.R. – HOFFMANN, M.R.M. (2019): Restoration through agroforestry: options for reconciling livelihoods with conservation in the Cerrado and Caatinga biomes in Brazil. *Experimental Agriculture* 55(1):208–225. <https://doi.org/10.1017/S0014479717000138>
- MOHAMMED, E.M. – HASSAN, T.T. – IDRIS, E.A. – ABDEL-MAGID, T.D. (2021): Tree population structure, diversity, regeneration status, and potential disturbances in Abu Gadaf natural reserved forest, Sudan. *Environmental Challenges* 5:
- MONDOL, M.A. – ALAM, N.E.K. – ISLAM, K.K. (2021): Contribution of traditional Date palm (*Phoenix sylvestris*) agroforestry in income generation and livelihood improvements: A case of Jashore district, Bangladesh. *International Journal of Environment, Agriculture and Biotechnology* 6(1): 261–269. <https://doi.org/10.22161/ijeab.61.33>
- SULEMAN, S.S. – IBRAHIM, G. (2018): The Importance of Non-Wood Forest Products In improving of Livelihoods of Rural Communities in WadiSaleh Locality-Central Darfur State-Sudan. *Journal of Agriculture and Veterinary Sciences* 11(6): 69-73
- ZAMORA, D. – UDAWATTA, R.P. (2016): Agroforestry as a catalyst for on-farm conservation and diversification. *Agroforestry Systems* 90(5):711–714. <https://doi.org/10.1007/s10457-016-0013-1>

6. Bibliography of personal publications

6.1 Peer reviewed journals:

- Hemida, M., Vityi, A. & Hammad, Z.M.** Socio-economic traits and constraints associated with smallholder farmers in Taungya

- agroforestry program in Sudan. *Agroforest Syst* (2023). <https://doi.org/10.1007/s10457-023-00855-x>
- Hemida, M.,** Yasin, E., Kheiry, M., Hammad, Z. and Vityi, A. 2023. Assessment of Taungya agroforestry system in dryland forests rehabilitation in Sudan. *Journal of Degraded and Mining Lands Management*10(3):1001-101. doi:10.15243/jdmlm.2023.103.0000
- Hemida M,** Mulyana B, Vityi A. 2022. Determinant of farmers' participation and biodiversity status in the program of agroforestry rehabilitation in Sudan. *Biodiversitas* 23 (11): 5638-5645. DOI: 10.13057/biodiv/d231113
- Mohamed Hemida,** Andrea Vityi, Zeinab Hammad. Monitoring of Forest Recovery Under Taungya Agroforestry Program in Sudan. In: Czimer, K.; Heil, B. (eds.) *Az Erdőmérnöki Kar Tudományos Kiadványa Sopron, Hungary: University of Sopron Press* (2022) 297 p. pp. 116-122. Paper: 7,7 p.
- Mohamed Hemida,** Zeinab Hammad, Andrea Vityi. Socio-economic Condition and Income Generation of Taungya Farmers in Dryland of Sudan. In: Czimer, Kornél; Heil, Bálint (eds.) *Az Erdőmérnöki Kar Tudományos Kiadványa. Sopron, Hungary: University of Sopron Press* (2023).

6.2 Conference papers

- Hemida, M.,** Vityi, A. Hammad, Z.M., (2022). Taungya Agroforestry program in Dryland of Sudan: Incentives, Challenges and Strategies for Improvement. Can agroecological farming feed the world? Farmers' and academia's views. Conference on International Research on Food Security, Natural Resource Management and Rural Development (Tropentag) September 14 - 16, 2022, Czech Republic Prague,
- Hemida, M.,** Vityi, A. (2022). Forest cover changes under agroforestry program in dryland of Sudan. *Proceedings of the 6th European Agroforestry Conference: Agroforestry for the Green Deal transition. Research and innovation towards the sustainable development of agriculture and forestry.* Neuro, Italy: European Agroforestry Federation, (2022) pp. 195-196
- Kovács K. – Czupy I – **Hemida M.** – Vityi A. (2020): POTENTIAL CONTRIBUTION OF AGROFORESTRY PRACTICES USED IN AGRICULTURAL AREAS TO MEET FUTURE WOOD DEMANDS IN HUNGARY. *Proceedings of the Miskolc IPW – IV. Sustainable Raw Materials International Project Week, 25-27th November 2020, Miskolc, Hungary*