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Evaluation of legume shrubs improved fallow for abandoned agricultural land rehabilitation

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ABSTRACT

The experiment was conducted on abandoned agricultural land at Bena-Tsemay District, Southern Ethiopia. It was designed to evaluate legume shrubs growth performance, and its potential for soil fertility enhancement through improved fallow practice. The results of the current study showed that the growth performance of legume species reveals variation in different growth parameters. The mean height of *Sesbania sesban* was significantly higher than the other species except for *Senna siamea*. *Senna siamea* recorded the highest mean stem diameter followed by *Sesbania sesban*, 3.47 cm, and 2.86 cm, respectively. Legume shrub species for soil fertility enhancement under improved fallow showed an increase in soil pH, organic carbon, organic matter, phosphorus level, available potassium, and total nitrogen during the growth period. *Sesbania* provides a large amount of nitrogen (2.91 t ha^{-1}) within two years fallow period, linked with the carbon to nitrogen ratio (11.22) having better mineralization potential. The growing of promising legume shrub species as an improved fallow practice has an important contribution in the restoration process of abandoned agricultural land and used as an option to grow crops in a rotational cropping system.

Keywords: Agroforestry, Leafy biomass, Rehabilitation practices, Shrub species.

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Introduction

The rapidly growing population puts considerable pressure on scarce natural resources, and there is an urgent need to develop more efficient and sustainable agricultural production systems to feed the growing population. However, in Sub-Saharan Africa (SSA) agricultural productivity has been stagnant for many decades and the increase of production due to expanded areas under cultivation (Conway, 2012). The tradition of continuous cultivations results in natural resources degradation and soil fertility loss in agricultural landscapes. Improving soil fertility and applying an adequate supply of nutrients in agricultural land have major implications for meeting food security.

Legume shrubs species can fix atmospheric nitrogen by symbiotic bacterial (i.e. rhizobial) nodulation in their roots. An improved fallow is the planting of fast-growing legume tree/shrub species as a substitute to natural fallow to achieve benefits of the latter in a shorter time (Prinz, 1986; Young, 1997). Short-duration planted fallows using a wide range of legume shrub/tree species such as *Sesbania sesban, Gliricidia sepium, Tephrosia vogelii,* and *Cajanus cajan* have been found to replenish soil fertility and to increase subsequent maize yields (Kwesiga *et al.*, 1999). Legume shrub species are characterized as fixes nitrogen, vigorous, fast-growing, and deep-rooted, tolerant of drought, and they can accumulate atmospheric nitrogen (Hairiah *et al.*, 2006).

Nitrogen supply to be larger in improved fallow than in cropped land because the plants accumulate nitrogen from the air and deep layers of the soil, and drop their leaf litter to enrich the soil and conserve moisture (Styger and Fernandes, 2006). The off-season cultivation of fallow legumes and their subsequent incorporation as green manure has been own to enhance soil productivity by adding N and organic C and by suppressing the problem of weeds.

Improved fallows, in which leguminous trees and shrubs are grown in association with crops, have the potential to mitigate climate change by sequestering C in soils and biota, protecting existing natural forests, and conserving soil productivity (Sileshi *et al*., 2007; Schoeneberger, 2008).

In Ethiopia, agricultural production is intensively monoculture type either on large scale or in small-scale farmlands. The productivity declines from time to time due to soil fertility loss and insufficient supply of plant nutrients. The tradition of agricultural production in small-scale farm face a series of challenges from agricultural input application, specific fertilizer due to its cost increment and affordability problem. To address this problem agroforestry practices play a significant role in sustainable agricultural production and soil fertility improvement. This study mainly intended to evaluate the rehabilitation potential of degraded agricultural land through the integration of legume shrubs under improved fallow practice.

Materials and Methods

Study area description

The field experiment was conducted from July 2016 to October 2019 at continually cultivated land in the Bena-Tsemay district of South Omo Zone, Southern Ethiopia. It is located between the lower reaches of the Omo River in the West and the Woito and Sagan Rivers in the East. The district receives bimodal rainfall; the first peak, from mid-March to the end of April, which is important for crop production and the second peak, from mid-October to the beginning of November, which is short and important only for pasture establishments. Biophysically characterized as elevation ranges from 567–1,800 m above sea level, annual temperature between 16°C to 40°C (Admasu *et al*., 2010) and the major soil type of the area is Chromic Cambisols (Soromessa *et al*., 2004). The communities are practicing both types of crop and animal production systems.

Experimental design

Completely randomized block design (RCBD) was used in this experiment involving four legume shrub species with four replications. The continuously cultivated site was selected, which encounters a low fertility status. Experimental plot size of 4 m x 4 m was constructed. Seedlings were raised on the nursery site by using prepared pots filled with forest soil, FYM, and sand with the appropriate percentage (2:1:1 ratio), respectively. Seedlings of shrub species were planted onto the permanent plots with 50 cm x 50 cm spacing and their survival was monitored. Plant height, root collar diameter, diameter at breast height, and branch number was determined on five randomly selected plants of each shrub species. Measurement of the growth parameters was done within a six-month interval. All desirable tending and management activities were conducted throughout the experimentation period.

Collected data for legume shrubs

The treatments assigned for experimentation were legume species, named as *Sesbania sesban* (trt1), *Leucaena leucocephala* (trt2), *Senna siamea* (trt3) and *Chamaecytisus palmensis* (trt4). These leguminous plant species have the potential for restoring soil fertility through N2 fixation. The seedlings were grown in the nursery and were transplanted to the main trial plots. Legume shrubs growth parameters like tree height, root collar diameter (above ground 10 cm), DBH (diameter at breast height 1.3 m), branch number, leafy biomass (including leaf and green branches) to be incorporated into the soil, and wood products were collected from all experimental plots. These data are important to evaluate the adaptability of best performing plant species on continuously cultivated land and their potential to restore soil fertility.

Sample collection and nutrient analysis

Leaf samples were collected from each studied legume species for nutrient analysis at a fully mature stage. The leaves collected from each treatment were air-dried, grounded, labeled, and analyzed for N, P, K, C, and dry weight at Debre Brihan Agricultural Research Center. A composite soil sample before planting and soil samples after the experimentation for each treatment was collected, air-dried, and grounded for laboratory analysis. The pH of the soil was measured in 1: 2.5 (soil: water ratio). Soil texture was determined by the hydrometer method (Day, 1965). Organic C concentration of the soil was determined following the wet combustion method (Walkley and Black, 1934). The total N concentration of the soil was determined by wet-oxidation (wet digestion) procedure (Kjeldahl, 1883). The available phosphorus content of the soil was determined by using the BrayII method (Bray and Kurtz, 1965). Moreover, available potassium (K) was determined by using Morgan solution or sodium acetate extraction depicted in. Conversion of soil organic carbon (SOC) into soil organic matter (SOM) will be percentages= 1.72*percentage SOC.

Data analysis

The means values of the parameters were compared using the least significant difference (LSD) at a 5% level of significance using SAS statistical software (version 9.0) and for data organization, Microsoft Excel was used.

Results and Discussion

Growth performance and biomass production

Legume shrub species used in this study showed a significant difference ($p<0.05$) in growth parameters during the experimentation period (Tables 1, 2, 3, and 4). The heights of *Sesbania sesban* and *Senna siamea* has significantly higher than the other species (Table 3). *Senna siamea* recorded the highest mean stem diameter followed by *Sesbania sesban,* 3.47 cm, and 2.86 cm, respectively (Table 3). This result is in line with findings of Sjögren (2010) who reported that *Sesbania* showed a very high growth potential in terms of mean tree height (4.4 m and 7.9 m) and diameter (2.8 cm and 5.4 cm) in 6 and 18 months of improved fallows, respectively in Western Kenya. The findings also showed some variation in stem diameter among the shrub species. The highest mean number of branches was recorded from *Sesbania sesban* (49), while *Chamaecytisus palmensis* had the lowest (19) number of branches.

Table 1. The legume shrubs growth parameters data were taken in the first round.

Treatments (trees/shrubs species)	Measured parameters		
	RCD (cm)	H (m)	BN
Sesbania sesban	1.69^{b}	1.85^{a}	33.00^{a}
Leuceania leucocephala	1.17^{c}	0.99^{b}	9.86^{b}
Senna siamea	2.07^{a}	1.13^{b}	9.50^{b}
Chamaecytisus palmensis	0.97^{c}	1.07^{b}	8.00^{b}
LSD	0.315	0.61	5.10
CV(%)	14.42	33.50	23.27

Source: Own data, 2016- 2019

Means with the same letter are not significantly different within columns(P<0.05). Where: H =height, BN =branch number, RCD =root collar diameter, LSD(= least significant difference, CV =coefficient of variation.

Table 2. The legume shrubs growth performance parameters data were taken in the second-round.

Treatments (trees/shrubs species)	Measured parameters		
	H (m)	DBH (cm)	BN
Sesbania sesban	4.11^{a}	2.810^{a}	65.3^{a}
Leuceania leucocephala	2.72^{b}	1.420^{b}	37.5^{cb}
Senna siamea	4.57^{a}	3.270^{a}	45.5^{b}
Chamaecytisus palmensis	2.49^{b}	1.185^{b}	29.5^{c}
LSD	0.531	0.56	9.037
CV(%)	10.93	19.53	14.81

Source: Own data, 2016- 2019

Means with the same letter are not significantly different within columns (P<0.05). Where: H= height, BN =branch DBH=diameter at breast height

Table 3. The summarized mean of growth performance parameters of legume shrubs.

Treatments (trees/shrubs species)	Measured parameters		
	H (m)	DBH (cm)	Branch number
Sesbania sesban	3.59^{a}	2.86^{b}	49.25^{a}
Leuceania leucocephala	2.08^{b}	1.49^{c}	23.75cb
Senna siamea	3.44^{a}	3.47^{a}	28.00^{b}
Chamaecytisus palmensis	2.10^{b}	1.30c	19.00c
LSD	0.561	0.462	6.14
CV%	14.32	15.00	14.71

Source: Own data, 2016- 2019

Means with the same letter are not significantly different within columns (P<0.05). Where: H =height, BN =branch number, DBH =diameter at breast height, LSD =least significant difference, CV =coefficient of variation

The mean leafy green biomass produced through the legume species showed significant variation among the treatments used, for instance about 123.6 t ha^{-1} obtained from *S. sesban* followed by *S. siamea* (78.75 t ha^{-1}) and the lowest was recorded on *C. palmensis* (11.27 t ha^{-1}) are presented in Table 6 and Fig. 1. This plays a significant role in the release of important nutrients when incorporated as green manure during land preparation for subsequent cropping. From which

S. sesban and *S. siamea* record the highest value, this was the contribution of different growth parameters like branch number, height, and DBH. According to Torquebiau and Kwesiga (1996) reported about 18 t ha^{-1} for a 2-year *Sesbania* fallow in eastern Zambia and Ståhl *et al.* (2002) reported 31.5 t ha^{-1} after 22 months from a study in Eastern Kenya.

Although soil fertility amelioration is the primary objective of improved fallow practices, they have the potential to mitigate climate change through carbon sequestration. Abundantly high green leafy biomass production was obtained from *S. sesban* followed by *S. siamea,* under the improved fallow practice of the present study. This releases important nutrients, and it adheres with produced biomass amount and legume species used under improved fallow practice.

Under improved fallows practice, shrub species could provide biomass resources for fuel wood production at the end of the fallow phase. The result showed that there was an implication referring to the contribution of fuel wood production, through the use of *S. sesban* and *S. siamea* about 233.3 t ha^{-1} and 119.7 t ha^{-1} wood biomass obtained, respectively (Fig. 1). This in agreement with the findings of Kwesiga *et al.* (2005) who reported 15 and 21 t ha^{-1} of fuel wood material was harvested after two- and three-year fallows, respectively. Kwesiga and Coe (1994) also reported short rotation of *S. sesban* provided wood biomass after 1, 2, and 3 years fallow period was 8.3, 17.6, and 21.4 t ha^{-1} and 10.8, 14.5 and 21.2 t ha^{-1} for both provenances of Kakamega and Chipata, respectively.

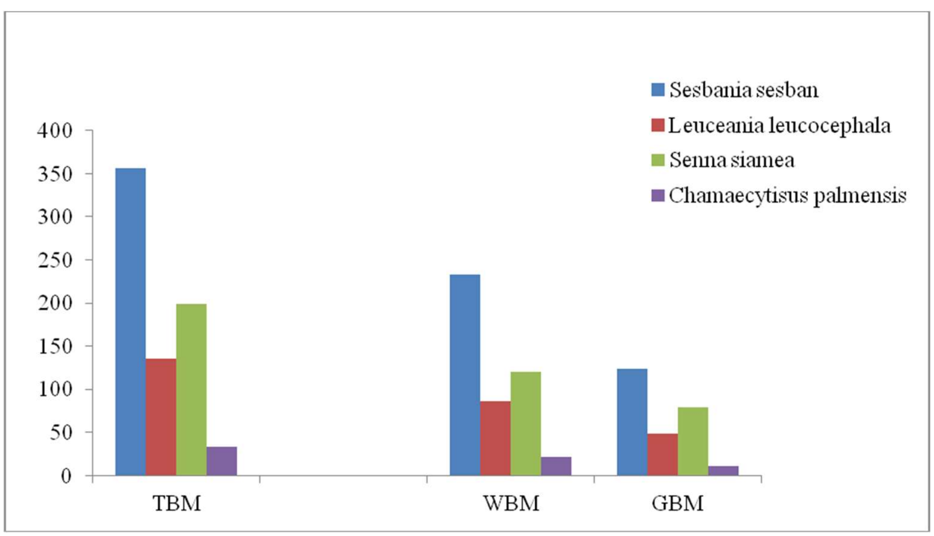
Table 4. Shrubs growth parameters at the end of the experimental period.

Treatments (trees/shrubs species)	Measured parameters		
	H (m)	DBH (cm)	Leafy BM (kg)
Sesbania sesban	4.82^{a}	2.91^{b}	197.75^{a}
Leuceania leucocephala	2.53^{b}	1.55^{c}	78.25^{bc}
Senna siamea	4.61^{a}	3.65^{a}	126.00^{ab}
Chamaecytisus palmensis	2.74^{b}	1.41^{c}	18.03^{c}
LSD	1.09	0.4402	84.688
CV%	21.57	13.44	64.207

Source: Own data, 2016- 2019

Means with the same letter are not significantly different within columns(P<0.05). Where: H= height, BN =branch number, DBH = diameter at breast height, LSD =least significant difference, CV= coefficient of variation

The figure below shows that biomass produced from each shrub species in terms of total biomass that was the combination of wood. This was a very appealing value of improved fallow system reduces the harvesting of fuel wood from natural forests and maintains environmental stability.



Source: own data 2016-2019.

Fig. 1. Total biomass (TBM), wood biomass (WBM), and leafy green biomass (GBM) production per species under improved fallow period (t ha^{-1}).

Soil fertility improvement under improved fallow

The current study conducted for the rehabilitation of abandoned agricultural land under improved fallow practice showed an increase in soil pH, organic C, phosphorus level, available K and total N comparing with before planting (P<0.05), as well as among legume species used in the experimentation (Table 5). The result of this study in line with findings of Young (1997), who reported the provision of plant-available N from decomposing *Sesbania* biomass, increased soil organic matter, improved nutrient, water retention in the soil. Kwesiga *et al.* (1999) also reported short-duration planted fallows using leguminous species have been found to replenish soil fertility and to increase subsequent maize yields at Eastern Zambia. Similarly, Rao *et al.* (1998) reported fertilizer tree fallows improve soil physically, chemically, and microbiologically. This practice has the advantage of soil nutrients improvement at the study site. Nutrients released from leaf determined by green biomass produced from legume species grown on experimentation site. The leaf analysis results showed that the amount of nutrient concentration varies from species to species (Table 6 and 7). The legume species improve the soil through biological nitrogen fixation whereby recycled nutrients are deposited through litter or when biomass is harvested at the end of the fallow period. Soil organic matter and organic carbon increased through legume species under improved fallow practice in the study site, this in line with the findings of Donahue *et al.* (1983) who reported that SOM was a major source of nutrients such as nitrogen, and available P and K in unfertilized soils. Besides, organic carbon is positively correlated with available N and K nutrients (Maiti and Ghose, 2005). The biomass produced by these species has wider importance in the composition of important soil nutrients and increased yield in sequential cropping period. The production of green leaf biomass has an ideal contribution in the release of important crop available nutrients through its decomposition and modifying the agricultural land either it is by improving physical, biological or chemical properties (Table 6 and 7). Similarly, Bekele-Tesemma (2007) who reported in most parts of SSA, farmers use improved fallows as a strategy for improving soil fertility within a shorter period.

Table 4. Analyzed soil Physico-chemical properties under each legume shrub species.

Treatments (trees/shrubs species)	Soil parameters				
	pH	%TN	%OC	P (ppm)	K (ppm)
Sesbania sesban	6.08a	0.096a	1.110a	8.8c	122.90a
Leuceania leucocephala	5.90b	0.087c	1.013d	8.4d	114.04d
Senna siamea	5.78c	0.082d	1.096b	10.8b	118.20b
Chamaecytisus palmensis	5.70d	0.091b	1.050c	11.2a	115.34c
Before planting	5.58e	0.066e	0.764e	7.5e	107.03e
LSD	0.0275	0.0019	0.0085	0.0357	0.195
CV%	0.31	1.44	0.549	0.248	0.1096

Source: Own data, 2016- 2019.
Means with the same letter are not significantly different within columns (P<0.05).

The average compositions of clay, sand, and silt percentages were 51, 30, and 19, respectively. Thus according to USDA soil textural classification of the experimental area was classified as clay.

Table 5. Analyzed leaf nutrients from legume shrub species.

Treatments (trees/shrubs species)	Nutrients released			LDW (g)	LGBM t ha^{-1}
	%N	%P	%K		
Sesbania sesban	4.71	0.59	4.31	96	123.6
Leuceania leucocephala	3.00	0.65	4.39	88.69	48.91
Senna siamea	2.33	0.65	3.3	90	78.75
Chamaecytisus palmensis	2.84	0.47	3.69	83.15	11.2

Source: Own data, 2016- 2019.

For nutrient analysis 0.3 g leaf sample for N, and 0.5 g leaf sample for P & K, used, Where BM =biomass, LDW =leaf dry weight, N =nitrogen, K =potassium, P =phosphorus.

Table 6. Contribution of green biomass for nutrient release.

Treatments (trees/shrubs species)	GBM kg plot^{-1}	N (from GBM) t ha^{-1}	P (from GBM) t ha^{-1}	K (from GBM) t ha^{-1}
Sesbania sesban	197.75	2.91	0.36	2.660
Leuceania leucocephala	78.25	0.73	0.16	1.073
Senna siamea	126.00	0.92	0.26	1.300
Chamaecytisus palmensis	18.03	0.16	0.04	0.21

Source: Own data, 2016- 2019.

Where: GBM = green biomass, kg =kilogram, ha =hectare, N =nitrogen, K = potassium, P =phosphorus.

The relation between organic matter and organic carbon obtained from green biomass

The present study result showed that the amount of organic matter depends on legume shrubs used in improved fallow and biomass produced by these species. The present study conducted in legume shrubs improved fallow on abandoned agricultural land, the shrub species offered with a better proportion of organic matter, organic carbon, and C: N ratio at which the mineralization process determined. For instance, the variation of C: N value for each species showed (Table 8) that the amount of carbon and nitrogen nutrients constituted in the organic biomass of the species. The C: N value described as 11.22, 17.68, 18.82, and 22.84 for *Sesbania sesban, Leucaena leucocephala, Senna siamea,* and *Chamaecytisus palmensis,* respectively. Mineralization of organic matter depends on this critical parameter at which the process is undertaken. The result of the present study in line with previous studies of Aerts and De Caluwe (1997) and Teklay *et al.* (2007) who reported the concentrations of nitrogen (N), phosphorus (P), and the ratios of C/N are recognized as the main organic biomass quality variables controlling rates of decomposition. Mineralization process occurs faster at lower C: N ratio (high nitrogen) at which the conversion of organic minerals into organic or mineral form and easily available for crop uptake. This in agreement with the findings of Baggie *et al.* (2000), who reported low C: N ratio and lignin indicating the high quality of leaves with a fast decomposition rate.

Table 7. Analyzed value of organic matter, organic carbon, and C: N ratio from shrub species.

Treatments (trees/shrubs species)	%OM	%OC	%N	C:N ratio
Sesbania sesban	90.92	52.86	4.71	11.22
Leuceania leucocephala	90.94	52.87	2.99	17.68
Senna siamea	91.91	53.44	2.34	22.84
Chamaecytisus palmensis	91.92	53.44	2.84	18.82

Source: Own data, 2016- 2019.

Where: OM =Organic Matter, OC =Organic Carbon, N =Nitrogen, And C: N =Carbon to Nitrogen ratio.

Conclusion

The growing of promising legume shrub species as an improved fallow practice has an important contribution to the restoration process of abandoned agricultural land. On-farm evaluation of legume, shrubs provide desirable variations in different growth parameters, on soil properties and amount of leaf nutrient compositions respecting to the biomass produced by each species. The result of the present study showed that improved fallow agroforestry practice plays a significant role in the rehabilitation of degraded or continuously cultivated agricultural land through the incorporation of the green biomass (leaves, green twigs, and branches). *Sesbania* provides a large amount of nitrogen (2.91 t ha^{-1}) within two years fallow period, used as an option to grow crops in a rotational cropping system. Therefore, this solves soil fertility problem and it provides an opportunity to cultivate crop production.

Recommendation

Based on the findings of the present study, the following point is recommended

- Crop production largely hindered by soil fertility problem; it is improved through the integration of desirable legume tree/shrub species capable of providing decomposable biomass, able to fix nitrogen, fast-growing, and deep root system to access nutrients beyond the annual crop root zone.
- For instance, *Sesbania* has better adaptation, good growth performance, provide fuel wood, huge leafy green biomass adheres with a large amount of nitrogen nutrient composition in the study area, it is recommended as an important legume shrub to rehabilitate degraded agricultural within a short fallow period. Thus, this practice is an important way of improving the production potential of degraded agricultural land through the provision of nutrient-rich organic biomass and biological nitrogen fixation. This species has an appropriate proportion of carbon to nitrogen ratio; mineralization processes of organic compounds were done.
- Therefore, further research is important to evaluate the crop response after the green biomass incorporation at the end of the rotational fallow.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

Admasu, T., Abule, E. and Tessema, Z.K. 2010. Livestock-rangeland management practices and community perceptions towards rangeland degradation in the South Omo zone of Southern Ethiopia. *Livestock Res. Rural Dev*. 22(1): 1-17.

Aerts, R. and de Caluwe, H. 1997. Nutritional and plant-mediated controls on leaf litter decomposition of Carex species. *Ecol*. 78(1): 244-260. https://doi.org/10.1890/0012-9658(1997)078[0244:NAPMCO]2.0.CO;2

Baggie, I., Zapata, F., Sanginga, N. and Danso, S.K.A. 2000. Ameliorating acid infertile rice soil with organic residue from nitrogen-fixing trees. *Nutr. Cycling Agroecosyst*. 57(2): 183-190. https://doi.org/10.1023/A:1009844019424

Bekele-Tesemma, A. 2007. Profitable Agroforestry Innovations for Eastern Africa: Experience from 10 Agroclimatic Zones of Ethiopia, India, Kenya, Tanzania, and Uganda. World Agroforestry Centre (ICRAF), Eastern Africa Region. pp. 1-388.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, Organic, and available forms of Phosphorus in Soils. *Soil Sci.* 59(1): 39–46. https://doi.org/10.1097/00010694-194501000-00006

Conway, G. 2012. One billion hungry: can we feed the world? Cornell University Press. pp. 1-456.

Day, P.R. 1965. Particle fractionation and particle-size analysis. *In:* Black, C.A. *et al.* (eds.), Methods of Soil Analysis, Part I. Agronomy, 9, pp. 545–567, Madison: American Society of Agronomy, Wis. https://doi.org/10.2134/agronmonogr9.1.c43

Donahue, R.L., Miller, R.W. and Shickluna, J.C. 1983. Soils: An introduction to soils and plant growth. 5th Editon, Prentice-Hall, Inc. 667p.

Hairiah, K., Sulistyani, H., Suprayogo, D., Purnomosidhi, P., Widodo, R.H. and Van Noordwijk, M. 2006. Litter layer residence time in forest and coffee agroforestry systems in Sumberjaya, West Lampung. *Forest Ecol. Manage.* 224(1-2): 45-57. https://doi.org/10.1016/j.foreco.2005.12.007

Kjeldahl, J. 1883. A new method for the estimation of nitrogen in organic compounds. *Z. Anal. Chem*. 22(1): 366-382. https://doi.org/10.1007/BF01338151

Kwesiga, F. and Coe, R. 1994. The effect of short rotation *Sesbania sesban* planted fallows on maize yield. *Forest Ecol. Manage*. 64(2-3): 199-208. https://doi.org/10.1016/0378-1127(94)90294-1

Kwesiga, F., Franzel, S., Mafongoya, P., Ajayi, O.C., Phiri, D., Katanga, R., Kuntashula, E. and Chirwa, T. 2005. Successes in African agriculture: Case study of improved fallows in Eastern Zambia. Environment and Production Technology Division (EPTD) Discussion Paper, 130. International Food Policy Research Institute (IEPRI). pp. 1-87.

Kwesiga, F.R., Franzel, S., Place, F., Phiri, D. and Simwanza, C.P. 1999. *Sesbania sesban* improved fallows in eastern Zambia: Their inception, development and farmer enthusiasm. *Agrofor. Syst*. 47(1-3): 49-66. https://doi.org/10.1023/A:1006256323647

Maiti, S.K. and Ghose, M.K. 2005. Ecological restoration of acidic coalmine overburden dumps- an Indian case study. *Land Contam. Reclam*. 13(4): 361-369. https://doi.org/10.2462/09670513.637

Prinz, D. 1986. Increasing the productivity of smallholder farming systems by introduction of planted fallows. *Plant Res. Dev*. 24: 31-56.

Rao, M.R., Nair, P.K.R. and Ong, C.K. 1997. Biophysical interactions in tropical agroforestry systems. *Agrofor. Syst*. 38(1-3): 3-50. https://doi.org/10.1023/A:1005971525590

Schoeneberger, M.M. 2008. Agroforestry: working trees for sequestering carbon on agricultural lands. *Agrofor. Syst*. 75(1): 27-37. https://doi.org/10.1007/s10457-008-9123-8

Sileshi, G., Akinnifesi, F.K., Ajayi, O.C., Chakeredza, S., Kaonga, M. and Matakala, P.W. 2007. Contributions of agroforestry to ecosystem services in the Miombo eco-region of eastern and southern Africa. *African J. Environ. Sci. Tech.* 1(4):68-80.

Sjögren, H. 2010. Agroforestry systems with trees for biomass production in western Kenya. PhD Thesis, Faculty of Forest Sciences Department of Forest Ecology and Management Umeå, Swedish University of Agricultural Sciences. 43p.

Soromessa, T., Teketay, D. and Demissew, S. 2004. Ecological study of the vegetation in Gamo Gofa zone, southern Ethiopia. *Trop. Ecol.* 45(2): 209-222.

Ståhl, L., Nyberg, G., Högberg, P. and Buresh, R.J. 2002. Effects of planted tree fallows on soil nitrogen dynamics, above-ground and root biomass, N2-fixation and subsequent maize crop productivity in Kenya. *Plant Soil*. 243(1): 103-117. https://doi.org/10.1023/A:1019937408919

Styger, E. and Fernandes, E.C. 2006. Contributions of managed fallows to soil fertility recovery. *Biol. Appr. Sust. Soil Syst.* 425-437. https://doi.org/10.1201/9781420017113.ch29

Teklay, T., Nordgren, A., Nyberg, G. and Malmer, A. 2007. Carbon mineralization of leaves from four Ethiopian agroforestry species under laboratory and field conditions. *Appl. Soil Ecol*. 35(1): 193-202. https://doi.org/10.1016/j.apsoil.2006.04.002

Torquebiau, E.F. and Kwesiga, F. 1996. Root development in a *Sesbania sesban* fallow-maize system in Eastern Zambia. *Agrofor. Syst*. 34(2): 193-211. https://doi.org/10.1007/BF00148162

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci*. 37(1):29-38. https://doi.org/10.1097/00010694-193401000-00003

Young, A. 1997. Agroforestry for soil management (No. Ed. 2). CAB International. 320p.