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INFLUENCE OF LEGUMINOUS TREES BIOMASS AND NITROGEN FERTILIZER ON GROWTH AND YIELD OF MAIZE

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ABSTRACT

The study was conducted to assess the influence of nitrogen fixing trees biomass and nitrogen fertilizer on growth and yield of maize. The experiment was laid out as 3 x 4 x 2 factorial in a split-split plot design with three replicates. The factors considered were: control and biomass species (*Albizia lebbeck* and *Parkia biglobosa*) as main plots, four rates of nitrogen (0, 40, 80, 120 kg N ha^{-1}) as sub-plots, and two maize varieties (DMR-ESR-7 and 2009 EVAT) as sub-sub plots. *A. lebbeck* (45.3, 46.0) attained early days to 50 % tasselling and silking than *P. biglobosa* (52.9, 53.9).*A. lebbeck* biomass had significantly higher influence on yield components like grain yield (1881.9 kg ha^{-1}) compared to *P. biglobosa*. Addition of nitrogen enhanced similar effects as nitrogen fixing trees on the growth and yield components of both maize varieties compared to control. Influence of biomass and nitrogen application on maize variety proved *A. lebbeck* with 120 kg N ha^{-1} rate of fertilizer to produce highest cob yield plant^{-1}, while 80 kg N ha^{-1} produced highest number of grains cob^{-1} with 2009 EVAT. It is therefore, concluded that incorporation of *A. lebbeck* with application of 120 kg N ha^{-1} fertilizer rate into the soil improved the grain yield of both 2009 EVAT and DMR-ESR-7 maize varieties.

Keywords: Leguminous trees; leafy biomass; fertilizer; growth; yield

INTRODUCTION

It has been discovered that food crisis, declining forest resources and environmental imbalance are the problems wide spread in Nigeria and the world today. Lack of soil fertility restoring resources, soil erosion and unequal soil fertility management have been reported to contribute to soil fertility depletion in arid Africa (Bationo *et al.*, 2007; Vanlauwe and Giller, 2006). Leguminous trees that are nitrogen fixing are known to play complementary or alternative role as source of organic fertilizer and have the potential to sustain soil fertility (Giller, 2001; Snapp *et al.*, 2003; Adjei-Nsiah *et al.*, 2004).

Biomass transfer using fertilizer-tree species such as *Albizia lebbeck* and *Parkia biglobosa* is a more sustainable means for maintaining nutrient balances in maize production systems, as the tree leafy materials are able to supply the soil N (Kuntashula *et al.,* 2004). Soil fertility research in recent years has shifted its attention towards the combined application of organic and inorganic nutrient sources to reverse the negative nutrient balances in cropping system in agriculture in sub-saharan Africa (Vanlauwe *et al.*, 2001a). Crop response to combined applications of organic inputs and chemical fertilizer can either be addictive or interactive (Vanlauwe *et al.*, 2001b). Rong*et al.* (2001) reported that reasonable application of combined inorganic and organic fertilizers decreased soil bulk density, increased soil moisture, soil fertility, growth and yield of maize and promoted grain quality.

Ploughed-in green material enriches soil with organic matter, which as a result of microbiological processes releases nutrients for plants (Ramroudi and Sharafi, 2013). The use of legume tree pruning as mulch in agroforestry system is a common practice to maintain soil organic matter and improve soil fertility in the tropics (Duguma *et al.,* 1988). In many tropical agricultural systems with limited access to fertilizers, tree biomass is often used to meet the N requirements of annual crops (Olujobi, 2012). A major challenge in this approach is to ensure that N in the applied biomass is efficiently utilized by crops. Synchronizing release of N from decomposing biomass with demand (uptake) by crop (Swift, 1987) will lead to increased N-use efficiency of the incorporated biomass (Becker *et al.,* 1994), and will in turn minimize the opportunity for N loss (Myers *et al.*, 1994)**.** One of the key limiting nutrients in these soils is nitrogen. The integration of green legumes as leaf biomass into the farming systems has the potential to enhance yields of subsequent crops, an effect which can be largely attributed to increase in plant available N in the soil as a result of N release from the decomposition of the legume residues. Incorporating plant residues into agricultural soils can sustain organic carbon (C) content, improve soil physical properties, enhance biological activities, and increase nutrient availability (Smith *et al.*, 1993; Hadas *et al.*, 2004; Cayuela *et al.*, 2009).

MATERIALS AND METHODS

Study Area

The study area was Makera, a village in Dutsin-ma Local Government Area of Katsina State. Dutsin-ma has an area of 527 km², it is located on Latitude $12^0$27’18”N and Longitude $07^0$29’29”E and it has an altitude of 605 m above sea level and a population of 169, 671 according to the 2006 census. The inhabitants of the area are farmers and they are predominantly Hausa and Fulani by tribe. Their main occupation is farming and animal rearing.

Experimental Field Design

The experiment was laid as 3 x 4 x 2 factorial in split-split plot design with three replicates. The plot dimensions were 4 x 3 m. Leafy biomass of *A. lebbeck* and *P. biglobosa* at 6 kg each were pruned and incorporated fresh into the soil biomass plots (B_1 and B_2) and control plots (B_0). The leafy biomass was incorporated into the soil for two cropping seasons (2014 and 2015). Four levels of N fertilizers were split applied as: $N_{0,}$ 0 kg N ha^{-1} (control); N_1, 40 kg N ha^{-1}; N_2, 80 kg N ha^{-1}; N_3, 120 kg N ha^{-1}.The first half was applied at

2 weeks after planting (WAP), while the remaining half was applied at 5 WAP. The two varieties of maize used (DMR- ESR- 7 (Yellow Maize) and 2009 EVAT (White Maize)) were obtained from Katsina State Agricultural and Rural Development Authority (KTARDA). Two maize seeds were planted per hole, at equal depth and it was later thinned to one by conventional spacing of 75 x 25 cm two weeks after incorporation of leafy biomass of *Albizia* and *Parkia* into the soil. Thinning was also done 2 WAP making the total plant population of 64 stands per plot.

Plant Tissue Analysis of Agroforestry Tree Species

Samples of harvested leaves were air dried at room temperature and ground and analysed for initial contents of N, C, lignin and polyphenols. Total N was analysed by Macro-Kjeldahl digestion, followed by distillation and titration (Anderson and Ingram, 1993; Brandstreet, 1965). Lignin was determined by the Acid Detergent Fibre (ADF) method as outlined in Anderson and Ingram (1993). The polyphenol was extracted in hot (80^0C) 50% aqueous methanol and determined calorimetrically with tannic acid as a standard measurement (Anderson and Ingram, 1993; Hagerman, 1988).

Data Collection

Five maize plants were randomly selected within each of the net plots 4 x 1.5 m (6 m^2) with a tag for periodic observations at 4, 6, 8 and 10 WAP during the crop growth cycle for pre- harvest data collection. At harvest, these same five tagged plants were used to obtain yield.

The number of days from sowing to 50% tasselling/silking of maize crop in each plot was recorded. Number of grains per cob of five randomly sampled cobs from each plot was counted and the mean number of grains per cob recorded. The grain yield was determined at harvest. The harvested cobs from the net plots were sun-dried, shelled, winnowed and the clean grains weighed. The total weight per plot was recorded and expressed in kilogram.

Data Analysis

Data collected on growth variables were subjected to Analysis of Variance (ANOVA) using Statistical Analysis System (SAS, 2000) computer package at 5 % level of significance to determine differences in the treatment effect. The Duncan's New Multiple Range Test (Duncan, 1955) was used to separate the means where significant differences exist among the treatments.

RESULTS

Chemical composition of *Albizia lebbeck* and *Parkia biglobosa* leafy biomass

The plant materials showed slight variations in comparison between *A. lebbeck* and *P. biglobosa* in their chemical compositions during 2014 and 2015 cropping seasons. The leaves of *A. lebbeck* contained more N (leading to lower C: N ratio) than *P. biglobosa*. *A. lebbeck* had the highest concentration of lignin with mean value of 11.06, while *P.*

biglobosa had highest concentration of C: N ratios with mean value of 6.30. The result (Table 1) showed that *P. biglobosa* had low N and C contents compared with *A. lebbeck*.

Table 1: Chemical composition of the leafy biomass of *Albizia lebbeck* and *Parkia biglobosa* in 2014 and 2015 seasons

Component	N %	C %	Lignin %	Polyphenol %	C: N
Albizia lebbeck					
2014	3.32[a]	18.62[a]	11.37[a]	0.65[b]	5.60[b]
2015	3.16[a]	18.65[a]	10.74[a]	0.48[b]	5.90[b]
Means	3.24[a]	18.64[a]	11.06[a]	0.57[b]	5.75[b]
Parkia biglobosa					
2014	2.85[b]	17.81[b]	8.35[b]	0.87[a]	6.20[a]
2015	2.44[b]	15.52[b]	8.13[b]	0.63[a]	6.40[a]
Means	2.65[b]	16.67[b]	8.24[b]	0.75[a]	6.30[a]

N= Nitrogen; C= Carbon; C: N= Carbon/N ratio *Means followed by the same letter(s) within the same column and treatment are not significantly different (P>0.05)

Days to 50 % Tasselling and Silking

Amended plots of *A. lebbeck* and *P.biglobosa* recorded no significant difference on days to 50% tasselling and silking in 2014 and 2015.

Table 2: Influence of leafy biomass and nitrogen rate on days of 50% tasselling and silking of two maize varieties in 2014, 2015 and combined analysis

	Days to 50% tasselling			Days to 50% silking		
Treatment	2014	2015	Combined	2014	2015	Combined
Biomass (B)						
Control	44.7[a]	43.4[a]	44.1[b]	54.1[a]	53.9[a]	54.0[a]
Albizia	45.0[a]	45.6[a]	45.3[ab]	52.6[a]	53.1[a]	52.9[b]
Parkia	45.6[a]	46.4[a]	46.0[a]	54.0[a]	53.8[a]	53.9[a]
SE±	0.47	0.94	0.53	0.36	0.31	0.24
Nitrogen (N) Kg ha^{-1}						
0	46.3[a]	44.3[a]	45.3[a]	54.0[a]	53.9[a]	54.0[a]
40	44.8[bc]	45.4[a]	45.1[a]	53.8[a]	53.5[a]	53.6[a]
80	45.6[ab]	45.7[a]	45.7[a]	53.3[a]	53.8[a]	53.5[a]
120	43.8[c]	45.0[a]	44.4[a]	53.3[a]	53.3[a]	53.3[a]
SE±	0.50	1.03	0.59	0.49	0.37	0.32
Variety (V)						
DMR- ESR-7	43.7[b]	43.4[b]	43.6[b]	53.1[a]	53.9[a]	53.5[a]
2009 EVAT	46.4[a]	46.8[a]	46.6[a]	54.0[a]	53.4[a]	53.7[a]
SE±	0.32	0.80	0.43	0.33	0.26	0.24

Means followed by the same letter(s) within the same column and treatment are not significantly (P>0.05)

The amended plots of *P. biglobosa* had significantly higher value on days to 50% tasselling compared with control and *A. lebbeck* had lower value on days to 50% silking in their combined means. In 2014, control treatment produced significantly higher value on Days to 50% tasselling than in other plots supplied with nitrogen except 80 kg N. However, there was no significant difference in 2015 and the combined means on days to 50% tasselling. Also, there was no significant difference in 2014, 2015 and there combined on days to 50% silking. Consequently in 2014, 2015 and combined means, 2009 EVAT had significant longer/higher days to 50% tasselling than DMR-ESR-7 while, there was no significant response on days to 50% silking (Table 2).

Grain Yield (kg ha^{-1})

Plots amended with *A.lebbeck* had significant higher values of grain yield than other treatments in the two cropping seasons and combined. In 2014, and combined means, the control treatments produced significant lower values of grain yield than plots supplied with other N rates. No significant response to N rates on grain yield in 2015. No significant difference was observed among varieties on grain yield in the two seasons and combined (Table 3).

Table 3: Influence of leafy biomass and nitrogen rate on grain yield (kg ha^{-1}) of two maize varieties in 2014, 2015 and combined analysis

	Grain yield (kg ha^{-1})		
Treatment	2014	2015	Combined
Biomass (B)			
Control	1388.9^{b}	1395.8^{ab}	1392.4^{b}
Albizia	2097.2^{a}	1666.7^{a}	1881.9^{a}
Parkia	1413.2^{b}	930.6^{b}	1171.9^{b}
SE±	210.71	162.49	136.18
Nitrogen (N) Kg ha-^{1}			
0	833.3^{b}	990.7^{a}	912.0^{b}
40	1875.0^{a}	1250.0^{a}	1562.5^{a}
80	1652.8^{a}	1509.3^{a}	1581.0^{a}
120	2171.3^{a}	1574.1^{a}	1872.7^{a}
SE±	221.33	201.49	152.62
Variety (V)			
DMR- ESR-7	1569.4^{a}	1245.4^{a}	1407.4^{a}
2009 EVAT	1696.8^{a}	1416.7^{a}	1556.7^{a}
SE±	180.69	147.99	117.56
Interaction			
B x N	S*	S*	S*
B x V	S*	S*	S*
V x N	S*	S*	S*

Means followed by the same letter(s) within the same column and treatment are not significantly different (P>0.05)

Biomass and nitrogen interaction on grain yield

All plots (Albizia, Parkia and Control) treated with Nitrogen fertilizer from 40 to 120 kg N ha^{-1}significantly gave higher grain yield except control plot at 40 kg N ha^{-1}and *P. biglobosa* at 80 kg N ha^{-1} (Table 4).

Table 4: Interaction between biomass and nitrogen rate on grain yield (kg ha^{-1}) in combined analysis

	Nitrogen (Kg ha^{-1})			
Treatment	0	40	80	120
Biomass (B)				
Control	763.9^{d}	1236.1^{bcd}	1652.8^{abc}	1916.7^{ab}
Albizia	1277.8^{bcd}	1986.1^{ab}	2090.3^{ab}	2173.6^{a}
Parkia	694.4^{d}	1465.3^{abcd}	1000.0^{cd}	1527.8^{abcd}
SE±		243.99		

Means followed by the same letter(s) are not significantly different (P>0.05)

Biomass and Variety Interaction on Grain Yield

Comparable values of grain yield were obtained in the biomass treatments, where *A. lebbeck* amended plots and 2009 EVAT and DMR- ESR-7 had significantly higher value of grain yield than *P. biglobosa* and control in combined means (Table 5).

Table 5: Interaction between biomass and variety on grain yield (kg ha^{-1}) in combined analysis

	Variety	
Treatment	DMR- ESR-7	2009 EVAT
Biomass (B)		
Control	1444.4^{b}	1340.3^{b}
Albizia	1656.3^{ab}	2107.6^{a}
Parkia	1121.5^{b}	1222.2^{b}
SE±	100.01	

Means followed by the same letter(s) within the same column and treatment are not significantly different (P>0.05)

Variety and Nitrogen Interaction on Grain Yield

Table 6: Interaction between variety and nitrogen rate on grain yield (kg ha^{-1}) in combined analysis

	Nitrogen (Kg ha-^{1})			
Treatment	0	40	80	120
Variety (V)				
DMR- ESR- 7	777.8^{c}	1569.4^{ab}	1588.0^{ab}	1694.4^{ab}
2009 EVAT	1046.3^{bc}	1555.6^{ab}	1574.1^{ab}	2050.9^{a}
SE±		215.12		

Means followed by the same letter(s) within the same column and treatment are not significantly different (P>0.05)

Maize varieties were comparable both at 40to 120 kg N ha^{-1}, where 2009 EVAT produced significantly higher value of grain yield at 120 kg N ha^{-1} than DMR-ESR-7 and 2009 EVAT at 0 kg N rates in combined means (Table 6).

DISCUSSION

The study revealed that plots incorporated with *Albizia lebbeck* biomass performed better due to its better quality materials which contain higher average N content (3.24 %) and C (18.64 %) and lower average C: N (5.75) than *Parkia biglobosa* materials. Giller and Wilson (1991) reported that plant residues with a smaller C: N (< 30:1) are liable to decompose more rapidly with a net mineralization of N after incorporation into the soil. Hence, N is rapidly released and made readily available for crops.

Biomass treated plots especially *Albizia lebbeck* performed better in terms of growth and yield because it has the capacity to improve soil nitrogen content (Pushpavalli *et al.*, 1994). The response of maize to nitrogen application agrees with Daudu (2004) and Cherr *et al.* (2006) who reported that biomass or litter used and the rate of nitrogen fertilizer applied has significant effect on maize growth. The significant shortening in days to 50 % tasselling and silking in *Parkia biglobosa* was as a result of the incorporation of biomass that improved and increase soil nitrogen and organic matter which led to rapid growth of maize plants and quickened various parts of maize plants. The increase in yield components was possible due to incorporation of biomass which invariably contributed to significant increase observed in the growth parameters. Incorporation of *A.lebbeck* biomass brought about higher increase in grain yield of maize due to increased total soil N from biological fixed N and mineralized N from decomposed litter materials. This agrees with Lelei *et al.* (2009) who reported that the supply of N through mineralization of the high quality residues usually lead to higher maize grain yield.Incorporation of *A. lebbeck* with application of 120 kg N ha^{-1} fertilizer rate into the soil improved the yield of both 2009 EVAT and DMR-ESR-7 maize varieties.

Significant interaction between biomass and nitrogen rate, and variety on grain yield revealed that the combination of *Albizia lebbeck* with N rate at 120 kg N ha^{-1}, and 2009 EVAT was the best interaction combination. Whereas, the significant interaction between variety and nitrogen on grain yield showed that N rate at 120 kg N ha^{-1} produced higher yield of 2009 EVAT maize variety. Therefore, the combined effects of *Albizia lebbeck* and 120 kg N ha^{-1} gave maximum yield than 40 and 80 kg N ha^{-1} respectively. This is in agreement with the recommended rate of 120 kg N ha^{-1} for maize production in Nigeria's Savanna and Semi-Arid regions as reported by Buah *et al.* (2009).

CONCLUSION

The soil is sandy and acidic in nature. Incorporation of *A.lebbeck* into the soil improved the soil quality for better grain yield. Application of 120 kg N ha^{-1} is agronomically the best and suitable rate for 2009 EVAT maize production. The use of plant biomass alone can also give increase in grain yield, but when combined with nitrogen fertilizer, it produces better and higher grain yield.

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REFERENCES

Adjei-Nsiah, S, Leeuwis, C. and Giller, K.E. (2004). Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implications for interdisciplinary action research, NJAS-Wageningen.*Journal of Life Sciences,* 52(3 and 4): 331–348.

Anderson, J.M. and Ingram, J.S. (1993).*Tropical Soil Biology and Fertility*. A Handbook of Methods. CAB International, Wallingford. 221pp.

Bationo, A., Waswa, B, Kihara, J. and Kimetu, J. (2007).*Advances in Integrated Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities*. Dordrecht, Netherlands: Springer, Science +Business Media p. 1.

Becker, M., Ladha, K.J. and Ottow, J.C.G. (1994). Nitrogen losses and lowland rice yield as affected by residue nitrogen release. *Soil Science Society of America Journal* 58: 1660-1665.

Brandstreet, R.D. (1965). Kjeldahl Method for Organic N. Academic Press. London. 85 pp.

Buah, S.S., Abatania, I.N. and Aflakpui, G.K.S. (2009). Quality protein maize response to nitrogen rate and plant density in the Guinea Savannah Zone of Ghana. *West African Journal of Applied Ecology*, 16:9-21.

Cayuela, M.L., Sinicco, T. and Mondini, C., (2009).Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil.*Applied Soil Ecology,* 41: 118-127.

Cherr, C.M., Scholberg, J.M.S. and Mcsorley R. (2006). Green manure Approaches to crop production; A synthesis.*Agronomy Journal*.98:302 – 319.

Daudu, C.K. (2004). An evaluation of different sources of organic matter on the fertility and productivity of alfisol in the Nigerian savannah.PhD. Dissertation, Ahmadu Bello University, Zaria, Nigeria.173pp.

Duguma, B., Kang, B.T. and Okali, D.V.V. (1988).Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an Alfisol. *Agroforestry Systems.*6:19-35.

Duncan, D. B. (1955). Multiple Range and Multiple F- test. *Biometrics.*11:1-42.

Giller, K.E. (2001).*Nitrogen Fixation in Tropical Cropping Systems*. CAB International, Wallingford, UK, 2nd edition, 423p.

Giller, K.E. and Wilson, K. J. (1991).*Nitrogen Fixation in Tropical Cropping Systems*.CAB International, Wallingford, U. K. 1st edition.189p.

Hadas, A., Kautsky, L., Goek, M.and Kara, E.E. (2004). Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover.*Soil Biology and Biochemistry*.36: 255-266.

Hagerman, A. (1988). Extraction of tannin from fresh and preserved leaves. *Journal of Chemical Ecology*, 2(2): 95- 121.

Kuntashula, E., Mafongoya, P. L., Sileshi, G. and Lungu, S. (2004). Potential of biomass transfer technologies in sustaining vegetable production in the wetlands (dambos) of eastern Zambia. *Experimental Agriculture*, 40: 37-51.

Lelei, J. J., Onwonga, R. N. and Freyer, B. (2009). Organic based nutrient management strategies: Effect on soil nutrient availability and maize *(Zea mays*L.) performance in Njoro, Kenya. *African Journal of Agricultural Research*, 4(2): 92-99.

Myers, R.J.K., Palm, C.A., Cuevas, E., Gunatilleke, J.U.N. and Brossard, M. (1994).The sysnchronization of nutrient mineralization and plant nutrient demand. 81-116. *In*: Woomer, P. L and swift, M. J (eds.). The biological management of tropical soil fertility. Tropical Soil Biology and Fertility Programme (TSBF), Nairobi, Kenya.

Olujobi, O.J. (2012). Effect of application regime of *Gliricidia sepium* leaf litter on the growth and yield of maize (*Zea mays* L.).*Journal of Agriculture and Veterinary Sciences*, 4**:** 34-39.

Pushpavalli, R.K., Natarajan and Palaniappan, S.P. (1994).Effect of green manure on ammonia release pattern in rice soils. *International Rice Research Notes*, 19:16-17.

Ramroudi, M. and Sharafi, S. (2013). Roll of cover crops in enhance ecological services. *International Journal of Farming and Allied Sciences*, 23(2): 1076-1082.

Rong, X. M., J. J. Rong, Z. H., Liu Quang, L. J. and Y. Z. Hua, (2001). Effect of application of inorganic fertilizer in combination with Organic fertilizer to red upland soil. *Journal Human Agriculture University*, 27: 453-456.

SAS Institute (2000). Statistical Analysis Systems, Users Guild, Cary, N.C USA. 949 pp.

Smith, J.L., Papendick, R.I., Bezdicek, D.F. and Lynch, J.M. (1993).Soil organic matter dynamics and crop residue management.*In*: Metting, Jr., F.B. (ed.), *Soil Microbial Ecology: Application in Agricultural and Environmental Management*. Marcel Dekker, New York, pp. 65-94.

Snapp, S.S., Jones, R.B., Minja, E.M., Rusike, J. and Silim, S.N. (2003). "Pigeon Pea for africa: a versatile vegetable—and more," *Hort. Science.* 38(6): 1073–1079.

Swift, M.J. (1987). Tropical Soil Biology and Fertility: Interregional Research Planning Workshop. Special Issue 13, Biology International. Paris France: IUBS (ed). System for the tropics. *Natural Resources Forum*, 24: 137-151.

Vanlauwe, B. and Giller, K.E. (2006).Popular myths around soil fertility management in Sub-Saharan Africa.*Agriculture, Ecosystems and Environment*, 116:34–46.

Vanlauwe, B., Wendt, J. and Diels, J. (2001a). Combined application of organic matter fertilizer.*In*: Tian, G., Ishida, F. and Keatinge, J. D. H. (eds), Sustaining Soil Fertility in West Africa, SSSA Special publication no. 58, *Soil Science Society of America*, Madison, Wisconsin, U.S.A., Pp. 247-279.

Vanlauwe, B., Aihou, K., Aman, S., Tossah, B.K., Diels, J., Sanginga, N. and Merckx, R. (2001b).Leaf quality of selected hedgerow species at two canopy ages in the derived savanna zone of West Africa. *Agroforestry Systems*, 53: 21-30.