Ecosystem services for West African farming families: the role of woody shrub mulch

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1 Introduction

Woody vegetation in semi-arid West Africa provides ecosystem services that benefit local livelihoods through provision and regulation of natural resources (Sinare and Gordon, 2015). Use of traditional fallows to restore soil productive capacity via organic matter accruement has been compromised by population growth in West Africa and increased land degradation (Bonetti and Jouve, 1999). Continued crop cultivation and insufficient fallow periods have thus, led to severe soil organic matter depletion and subsequent soil degradation in semi-arid West Africa. This situation ultimately undermines food provision of local farm communities and may affect irreversibly ecosystem provision and regulation services within these landscapes. Improved use of local manure and compost as options to regenerate soils may be limited by availability (usually in homestead enclosures), transport constraints (dependent on donkey cart access and distance to fields), and labour requirements (harvest and application effort). As crop residues are vastly collected for livestock forage during the dry season, farming families in certain dryland areas are left with little sources of organic matter to regenerate soils. Innovative farmers in Burkina Faso have developed spatial and temporal shrub-crop arrangements by switching from a strategy of slash-and-burn to a strategy of slash-and-mulch to optimize services provided by *in situ* native woody shrub biomass (Félix, 2015). Increasingly, scientific evidence supports key roles that shrub vegetation types have in sustaining crop productivity and enhancing soil quality in the sub-region (Dossa et al., 2013; Hernandez et al., 2015; Lahmar et al., 2012; Yélémou et al., 2013). Event though woody shrub-based farming systems may have heterogeneous shrub densities, these provide soil water regulation services (Kizito et al., 2007) and nutrient provision services through organic matter from branches and leaves (Ba et al., 2014). In this context, if 100% available woody shrub biomass is the usual application by farmers as mulch, then two questions arise: (1) To what extent is crop productivity affected by *in situ* available mulch application? and (2) What is the effect of twice that dose of application on crop productivity?

2 Materials and Methods

Our study was located in Yilou, Burkina Faso (13°01' N, 01°32' W), where rainfall pattern is unimodal, with a rainy (and cropping) season usually occurring between June and September and total rainfall of 615 mm in 2013 and 653 mm in 2014. Eight on-farm plots of 300-900 m^2 were established in areas with homogeneous distribution of *Piliostigma reticulatum* DC. Hoscht shrub types, following a randomized complete block experimental setup (n=4 in 2013; n=8 in 2014, two of which were on the same piece of land as in 2013). These plots were divided in three equivalent sections where standing woody shrub biomass was cleared, weighed, and applied as three fresh mulch treatments: no mulch (M0), 100% standing biomass (M1; one-third), and 200% standing biomass (M2; two thirds). Mulch application rates varied among plots since total standing biomass was heterogeneous between plots (Fig. 1). Planting dates varied from mid-June to mid-July during both years; sorghum (0.80 x 0.40 m) was intercropped with cowpea (0.80 x 0.40 m) using reduced tillage techniques and fertilizer application 21 days after sowing at 100 kg.ha-1 NPK (23-10-5). Sorghum (grain, straw) and cowpea (grain) yields were measured on three 8 m^2 sized sub-plots per treatment at harvest (November 2013 and 2014). Two-sample inference Student paired *t*-test was conducted to analyse significance of treatment effects on crop yields.

3 Results - Discussion

Numerically, average results from 2013 and 2014 on-farm trials show that yields were highest when 200% biomass mulch (M2) was applied than with treatments of 100 (M1) and 0% (M0) available biomass application (Table 1). Highly significant statistical differences ($p<0.005$) were found for sorghum grain for treatment M2 compared to both M0 (73% yield increase) and M1 (35% yield increase). Significant statistical differences ($p<0.05$) were found for sorghum straw production for treatment M2 compared to M0 (50% increase) and M1 (24% increase). No statistical differences were perceived for cowpea production even though M2 presented 38% and 35% yield increases as compared to M0 and M1, respectively. Overall, these results evidence that woody mulch may contribute to increased crop yields (M2>M1>M0) as related to enhanced soil water use efficiency and reduced water losses (Yélémou et al., 2014). Moreover, the contribution of biological activity (*i.e.* termites, fungi, bacteria) to enhance soil productive capacity and nutrient retention as drivers for chemical soil fertility increases may be evoked (Diedhiou-Sall et al., 2013) and should be explored in further studies.

Table 1. Average yield results (kg.ha^{-1}) from 2013 and 2014 and yield differences amongst treatments for on-farm trials with mulch applications of 0, 100, and 200% available woody shrub (*Piliostigma*) biomass in Yilou, Burkina Faso

	Sorghum grain (n=12)	Sorghum straw (n=9)	Cowpea (n=10)
Treatment M0 (0% biomass)	526.4 (222.7) ^{a}	1124.9 (465.2) ^{a}	376.1 (341.5) ^{a}
Treatment M1 (100% biomass)	674.8 (321.7) ^{a}	1353.7 (566.3) ^{a}	384.0 (243.3) ^{a}
Treatment M2 (200% biomass)	912.0 (361.3) ^{b}	1688.9 (664.5) ^{b}	519.8 (397.0) ^{a}
Difference M1 - M0	148.4 (362.0)	228.8 (588.7)	7.9 (197.8)
Difference M2 - M1	** 237.2 (187.9)	* 335.2 (426.3)	135.7 (218.3)
Difference M2 - M0	** 385.6 (370.1)	* 564.0 (728.1)	143.7 (348.3)

Values are shown as Means (S.D.); Means within the same column followed by the same letter are not statistically different; (*) indicates differences are significant at $p<0.05$ and (**) indicates differences are significant at $p<0.005$, following two-samples paired Student *t*-test

Plotting sorghum grain yield increase (%) in function of actual *Piliostigma* dry matter application reveals increased yields with higher application of standing woody biomass availability and variability of crop response to mulching between fields (Fig. 1). These results suggest that there are no linear responses of sorghum to mulching with shrub branches and leaves and that increased crop productivity varies according to soil texture and landscape location (data not shown).

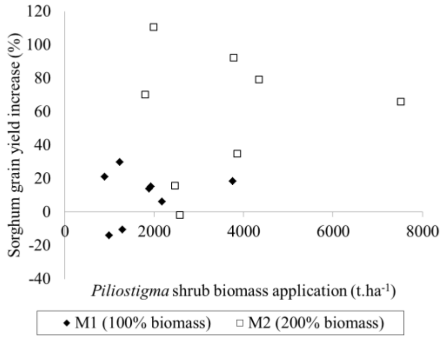

Fig. 1. Sorghum grain yield increase (%) as a function of *Piliostigma* shrub mulch application (n=8, 2014 yield data).

4 Conclusions

Woody shrub mulch, based on above-ground *Piliostigma* biomass, at rates corresponding to *in situ* availability, had clear positive effects on crop productivity. Doubling mulch application rates revealed increased crop production as compared to no mulch and 100% mulch application. However, recommendations for optimal application rates to return highest benefits, in form of ecosystem provisioning services to farming families, requires further study and context adaptation, especially in regards to soil type. Agroecosystem services to dryland farming systems through shrub vegetation types should be further explored, both on farmer fields and experimental stations across West Africa.

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References

Ba, M.F., Samba, S.A.N., Bassene, E., 2014. Influence des bois rameaux fragmentés (BRF) de Guiera senegalensis J . F . Gmel et de Piliostigma reticulatum (Dc) Hochst sur la productivité du mil , Pennisetum glaucum (L .). Int. J. Biol. Chem. Stud. 8, 1039–1048.

Bonetti, C., Jouve, P., 1999. Jachères et systèmes agraires en Afrique subsaharienne. CORAF, Union Européenne, Dakar, Senegal.

Diedhiou-Sall, S., Dossa, E.L., Diedhiou, I., Badiane, a N., Assigbetse, K.B., Samba, S. a N., Khouma, M., Sene, M., Dick, R.P., 2013. Microbiology and Macrofaunal Activity in Soil beneath Shrub Canopies during Residue Decomposition in Agroecosystems of the Sahel. Soil Sci. Soc. Am. J. 77, 501–511.

Dossa, E.L., Diedhiou, I., Khouma, M., Sene, M., Badiane, A.N., Ndiaye Samba, S. a., Assigbetse, K.B., Sall, S., Lufafa, A., Kizito, F., Dick, R.P., Saxena, J., 2013. Crop Productivity and Nutrient Dynamics in a Shrub-Based Farming System of the Sahel. Agron. J. 105, 1237.

Félix, G.F., 2015. From slash and burn to “slash and mulch.” Farming Matters 31.1, 14–17.

Hernandez, R.R., Debenport, S.J., Leewis, M.-C.C.E., Ndoye, F., Nkenmogne K., I.E., Soumare, A., Thuita, M., Gueye, M., Miambi, E., Chapuis-Lardy, L., Diedhiou, I., Dick, R.P., 2015. The native shrub, Piliostigma reticulatum, as an ecological “resource island” for mango trees in the Sahel. Agric. Ecosyst. Environ. 204, 51–61.

Kizito, F., Sène, M., Dragila, M.I., Lufafa, A., Diedhiou, I., Dossa, E., Cuenca, R., Selker, J., Dick, R.P., 2007. Soil water balance of annual crop–native shrub systems in Senegal’s Peanut Basin: The missing link. Agric. Water Manag. 90, 137–148.

Lahmar, R., Bationo, B.A., Dan Lamso, N., Guéro, Y., Tittonell, P., 2012. Tailoring conservation agriculture technologies to West Africa semi-arid zones: Building on traditional local practices for soil restoration. F. Crop. Res. 132, 158–167.

Sinare, H., Gordon, L.J., 2015. Ecosystem services from woody vegetation on agricultural lands in Sudano-Sahelian West Africa. Agric. Ecosyst. Environ. 200, 186–199.

Yélémou, B., Dayamba, S.D., Bambara, D., Yaméogo, G., Assimi, S., 2013. Soil carbon and nitrogen dynamics linked to Piliostigma species in ferugino-tropical soils in the Sudano-Sahelian zone of Burkina Faso, West Africa. J. For. Res. 24, 99–108.

Yélémou, B., Yaméogo, G., Koala, J., Bationo, B.A., Hien, V., 2014. Influence of the Leaf Biomass of Piliostigma reticulatum on Sorghum Production in North Sudanian Region of Burkina Faso. J. Plant Stud. 3, 80–90.