Shrubs and trees to enhance agroecosystem productivity and counter land degradation in semi-arid West Africa

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Background

Due to reduced land availability, continuous cultivation has gradually replaced previous shifting cultivation in semi-arid West Africa. This increasing pressure led to soil degradation and organic matter depletion, undermining food provision of local farm communities. Local manure and compost are options to regenerate soils but they are often limited by availability of organic material. We explored use of native woody resources to provide renewable organic amendments to enhance soil fertility and crop productivity, a practice that originates from local farmer creativity.

Research questions

1. How much woody material is available in a Sudano-Sahelian landscape?
2. What is driving soil quality heterogeneity around shrubs?
3. How much material is needed and to what extent is crop productivity improved through use of shrub material as mulch on soils?
4. What is the contribution of wild edible plants (including products from shrubs and trees) to local diets?

Main project findings

- Woody amendments alone have a limited potential for restoring soil carbon and soil fertility, unless used at input rates much larger than resource availability.
- Conversely, woody mulch applied at locally available rates in the vicinity of coppiced shrubs or on termite mounds induces significant localised fertility enhancement.
- Communities have been exploring these and other practices for soil protection for decades, they integrate within the numerous relationships that populations develop with woody stands. All these are taken into account for innovative system co-design.

Figure 1. Weathered soils like those of Yilou, ideally require protection with surface mulch. After harvest, livestock are allowed to roam on agricultural fields to feed on remaining sorghum stalks, leaving little left organic matter or soils to regenerate for next planting season. WASSA and CONNESSA projects study agroecological options to soil rehabilitation, based on local farmer innovations in Burkina Faso and Senegal. Photo: G. Félix

1. Woody resource availability

Figure 2. During the dry season, shrubs and trees are virtually the only vegetation left on agricultural fields (upper left). Woody perennials may represent 6 to 10 t.ha^{-1} of carbon-rich biomass in certain zones of Yilou. Nevertheless, not more than 800 kg.ha^{-1} could be readily available as woody amendments (material <2 cm in diameter). Shrubs also shape soil fertility by accumulating wind-driven sediments and leaves, allowing for termites and other soil organisms to dwell within their influence radius (upper right). By the end of the cropping season, slashed shrubs have grown back into so-called 'fertility islands' (bottom). Photos: G. Félix

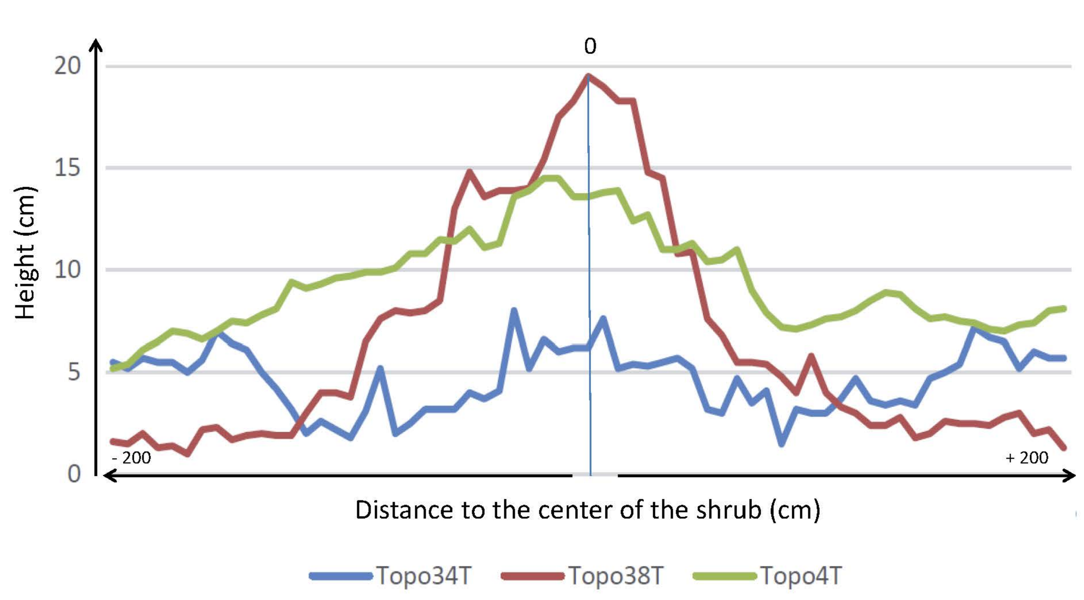
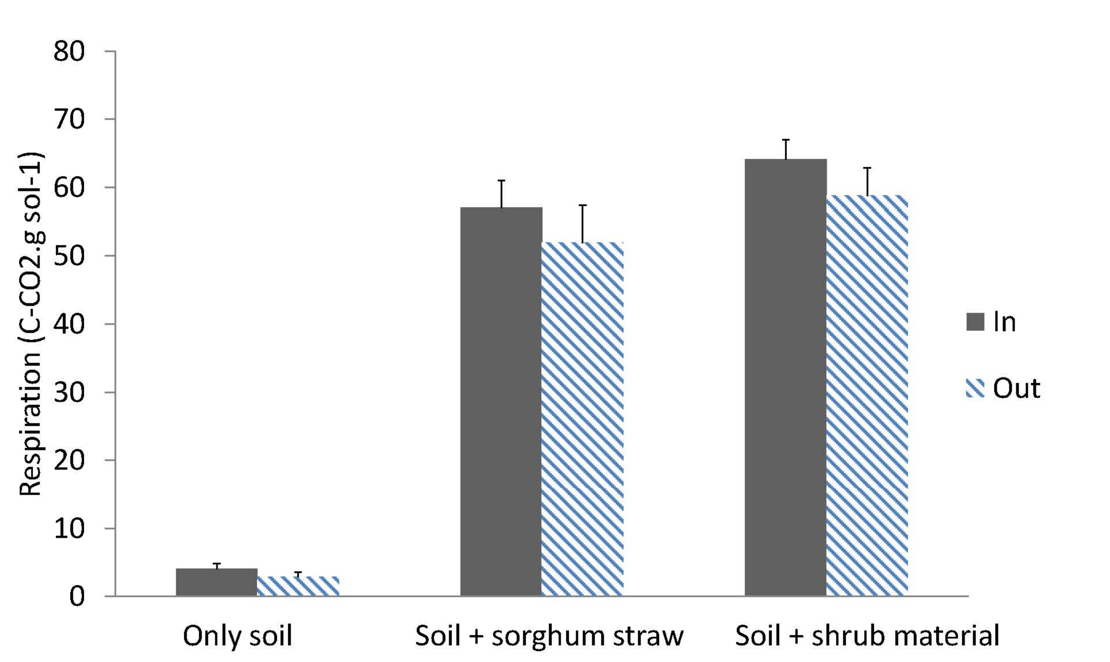


Figure 3. At the shrub scale, soil particles, water-driven sediments and organic matter accumulation lead to formation of micro-topographies within fields. North to South transects across *Piliostigma* shrubs reveal diversity of shapes, from steep shapes (red) to more flattened-out structures (blue). Volumes range from 0.08 to 0.34 m^3 for the extreme values with average value of 0.13 m^3 (±0.05 SD). This represent a consequent amount of soil accumulation underneath shrubs. For each 100 shrubs per hectare, an average of accumulated soil would therefore be 13 m^3 per hectare (equivalent to 1.3 mm of 'fine' soil).

2. Soil fertility - Key biological factors

Figure 4. Mean microbial respiration over 30 days-trial for soils within (In) or outside (Out) shrub influence area (2 m from center) and incubated with either sorghum straw or *Piliostigma* leaves and branches. Organic matter activates soil microbial activity, here evidenced through CO^2 respiration in laboratory conditions, with a clear stimulation of OM recycling in shrub-influenced soil, in line with 'fertility island' effect.



3. Experimental results

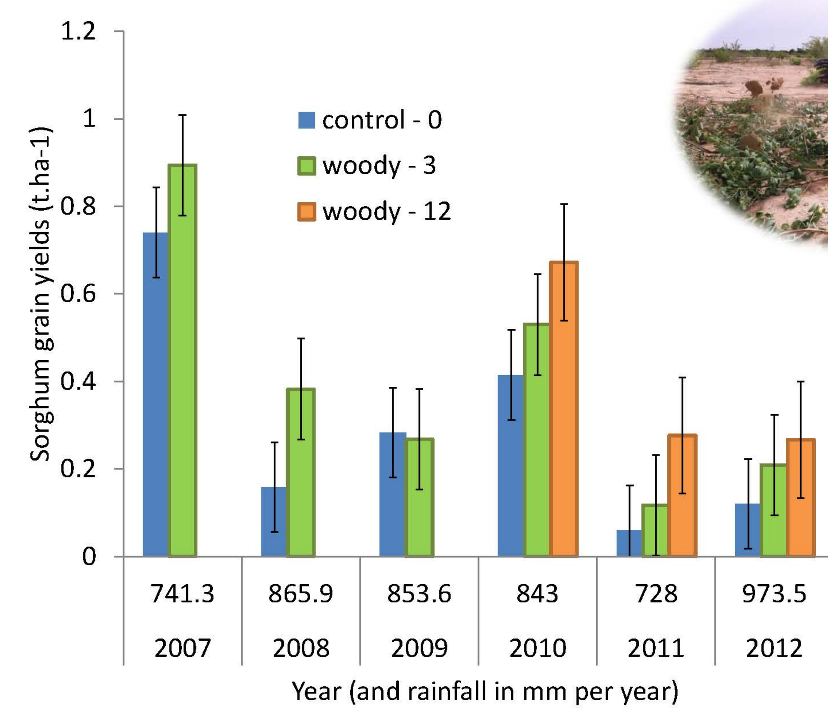
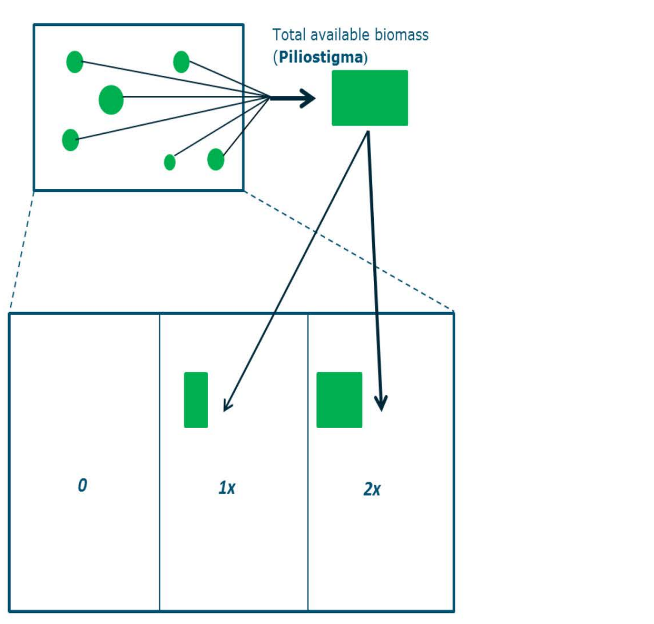


Figure 5. At Gampéla experimental station, results show that under continuous cultivation without fertilizer, grain yields decrease globally, regardless of rainfall patterns. Nevertheless, *Piliostigma*–based woody shrub material addition mitigates losses at application rates of 3 t.ha^{-1}. From 2010 through 2012 we also tested 12 t.ha^{-1} woody mulch with significant yield increases compared to no mulch.



	Sorghum grain yield (kg DW/ha)		Sorghum straw yield (kg DM/ha)	
0	511.4	± 273.1	1053.3	± 673.2
1x	610.4	± 379.3	1217.3	± 862.0
2x	778.2	± 431.4	1483.3	± 801.2

Figure 6. Experiments on farmer fields of Yilou, were kept simple. Total fresh available shrub biomass on plots of 10x20m was divided in three (0, 1x, 2x) and sorghum was planted in a homogeneous way. Significant crop yields enhancement are found when mulch is applied at locally available rate, and further enhancement when rate is doubled.

4. Human communities

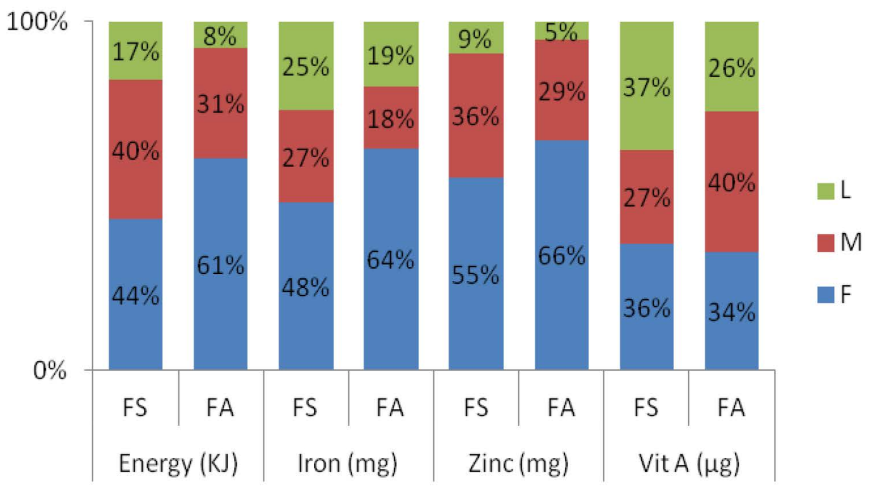


Figure 7. Wild edible plants (green) constitute an important part of diets, especially during periods of food shortage, just before harvests. Periods: FS=food shortage (Aug. 2015), FA=food abundance (Nov. 2015); Food sources: L=landscape, M=market, F=on-farm. Data collected amongst 4 households at Yilou, Burkina Faso, 2016

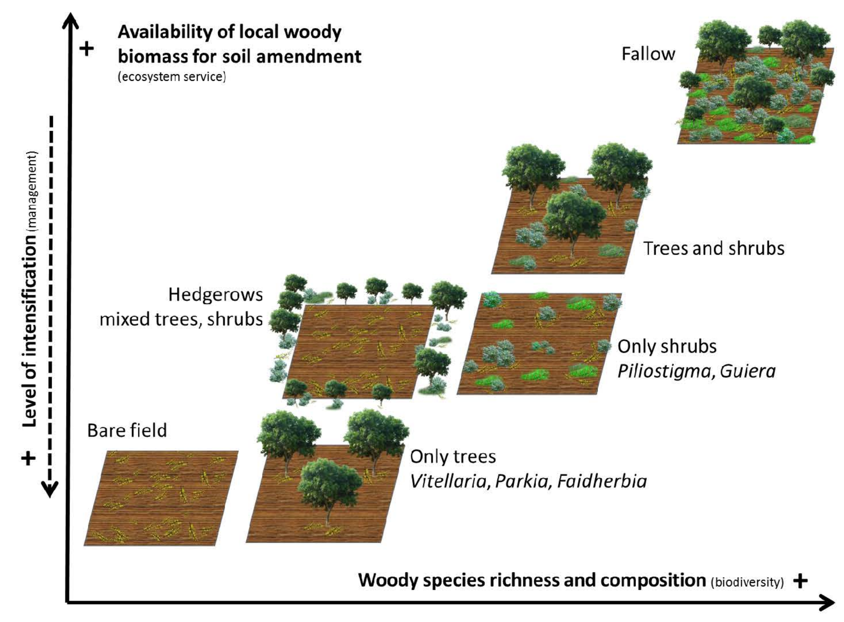


Figure 8. Possible agroecosystem designs for enhanced soil management through woody amendments. Trade-offs at landscape level may appear, requiring local stakeholders to engage in better informed decisions regarding collective and individual resource use and management.

Project-related publications

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*. Field Crops Research, 132: 158-167

Barthès B.G., Penche A., Hien E., Deleporte P., Clermont-Dauphin C., Cournac L., Manlay R. J. (2015) *Effect of ramial wood amendment on sorghum production and topsoil quality in a Sudano-Sahelian ecosystem (central Burkina Faso).* Agroforestry Systems, 89: 81-93

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