Reversibility of productivity decline with organic inputs of different quality and stability

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Introduction

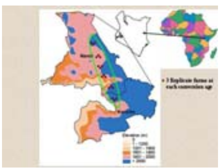
For several decades, in most parts of the developing world, increased production has been attained through conversion of natural ecosystems to agriculture instead of increased production per unit area. The anthropogenic perturbations through continuous cultivation and land tillage cause an immediate and rapid loss of carbon due to the disruption of the physical, biochemical and chemical mechanisms of soil organic matter (SOM) stabilization exposing it to microbial degradation. SOM decline leads to reduced cation exchange capacity (CEC) resulting in weakening of the nutrient retention capacity of the soil.

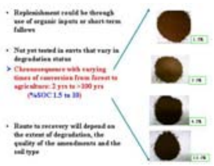
Thus improving SOM contents is indispensable in realizing a sustained and long term solution for increased agroecosystem productivity.

The main aim of this study was to investigate the reversibility of agroecosystem productivity decline using organic inputs of differing quality and stability.

Approach

To soils that had been under continuous cultivation for 5, 20, 35, 80 and 105 years, four OM sources; Tithonia diversifolia, Hemsley A. Gray, cattle manure, biochar and sawdust were incorporated at the rate of 6 tons C ha^{-1}, for 3 seasons over a 2-year period.





Treatment	N	P	K	Ca	Mg
	(kg ha^{-1} yr^{-1})				
Biochar	31.0	4.2	38.1	138.2	22.6
Sawdust	25.0	2.3	9.1	34.1	2.3
Manure	689.3	122.2	726.9	285.1	150.4
T. diversifolia	1294.4	83.6	954.6	631.0	83.6
Control	240	200	200	nd	nd

Note: NPK amounts added through organic resources are in addition to the blanket applications of the same nutrients through mineral fertilizers

Results

Years of continuous cultivation	Treatment	Carbon content (g kg^{-1})	% C derived from added OM	Net CO_2-C loss (g m^{-2})	$\delta^{13}C$
105	Biochar	30.5^a	30.0	-422	-20.6^a
	Tithonia	26.8^b	19.4	329	-20.4^a
	Control	21.1^c	-	-	-18.3^b
	$Lsd_{0.05}$	1.6	-	-	1.3
5	Biochar	65.2^a	32.2	83	-24.6^a
	Tithonia	60.2^a	9.7	292	-24.5^a
	Control	59.9^a	-	-	-24.0^a
	$Lsd_{0.05}$	6.4	-	-	1.2

Organic C content increased significantly ($P < 0.05$) with the application of organic amendments in highly degraded soil. Biochar application increased whole SOC by about 45% while tithonia increased SOC by 27% above a fully fertilized (N, P, K) control treatment

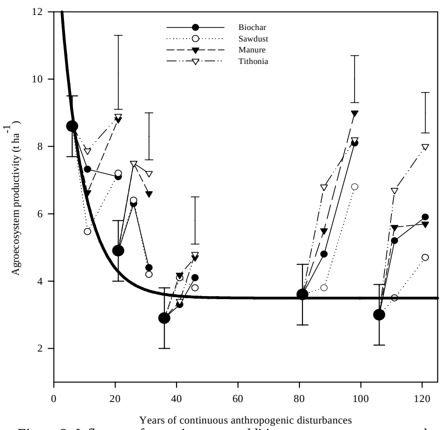


Figure 2: Influence of organic matter additions on agroecosystem productivity (maize grain yield) across a chronosequence of soil degradation in 2005-06

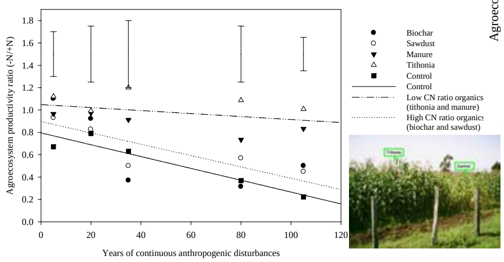


Figure 4: Nitrogen additions and cumulative ecosystem productivity as a function of the length of continuous anthropogenic soil degradation

Across the entire degradation range, OM additions decreased the need for N irrespective of the quality of the organic matter (**Figure 4**). For low quality organic resources (biochar and sawdust), N was needed to a greater extent with increasing soil degradation. N additions into the system did not have any significant influence on the improvement of agroecosystem productivity when high quality organic inputs (Tithonia and manure) were applied (**Figure 4**)

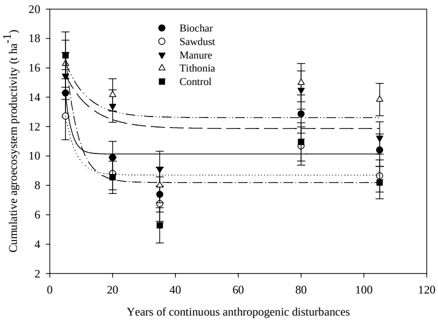


Figure 1: Cumulative agroecosystem productivity (over two cropping seasons) with organic matter additions of different quality as a function of the length of continuous cropping

Agroecosystem productivity declined by 66% with full fertilization during the first 35 years of continuous cropping and remained at a low level of 3.0 Mg grain ha^{-1} over the study period of 100 years (**Figure 1**). The use of organic resources was able to revert productivity decline by 57-167% with 110% greater short-term increases through the use of nutrient-rich green manure in comparison to nutrient poor organic resources (**Figure 1** and **Figure 2**)

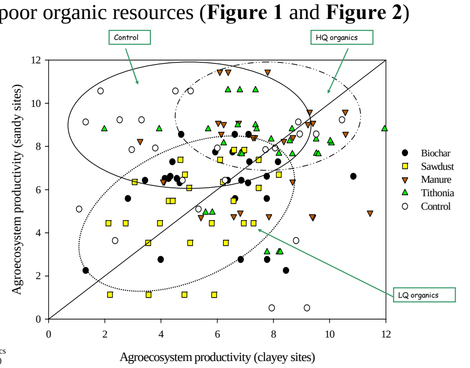


Figure 3: Organic matter additions and agroecosystem productivity in both clayey and sandy site

No detectable influence of texture (soils with either 84 or 61% clay+silt) when low quality OM was applied (sawdust, manure, biochar), whereas productivity was greater on sandier than heavier textured soils with high quality OM (Tithonia) or only inorganic nutrient additions (**Figure 3**)

Conclusions

Resource allocation for securing or restoring agroecosystem productivity is more effective in the most degraded sites. Short term gains in productivity were evident with high quality amendments whereas long term SOM stabilization was greatest with low quality amendments

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References: McLauchlan K. 2006. The nature and longevity of agricultural impacts on soil carbon and nutrients: A Review. Ecosystems 9:1364-1382.
Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418:671-677