Phosphorus cycling within soil aggregate fractions of maize-pigeon pea intercropping systems of Malawi

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MAIZE PRODUCTION IN MALAWI

Maize is the principle staple crop of Malawi, and provides the livelihood for the majority of the population, both in terms of home consumption and income generation (Snapp et al., 2002). Over 70% of arable land is dedicated to maize production, and most farmers practice continuous maize cropping (Ngwira et al. 2012; Phiri et al. 2013). This practice, coupled with little to no fertilizer inputs, has depleted soil nutrient stores over the past several decades and significantly contributed to the low maize yields.

MAIN GOAL OF PROJECT

To determine if maize-pigeon pea intercropping systems can increase the accumulation of soil C, N and P pools via increases in soil aggregation, and if those changes can in turn increase maize yield.

WHY PIGEON PEA?

Biophysical benefits: Pigeon pea (*Cajanus cajan*) is a **nitrogen-fixing**, perennial leguminous shrub that grows well in poor soil conditions and can **thrive in low rainfall**. It can fix up to 60 kg N ha^{-1} and accumulate 6 kg P ha^{-1} (Myaka et al., 2006), thus providing a **nutrient-rich mulch** or green manure.

Social acceptance: It is **commonly grown and well-accepted** in Southern and Eastern Africa as a **good source of protein** (Bezner-Kerr et al., 2010; Mhango et al., 2012). Due to its slow growth rate, it can be planted at the same time as maize, yet harvested months after the maize, thus **providing an additional harvest** of edible crops at a time when available food is often scarce in Malawi.

EXPERIMENTAL APPROACH

Field Trial: Soils were collected from established field trials in northern and central Malawi in order to measure the effect of maize-pigeon pea intercropping on C, N, and P pools in bulk soil and soil aggregate fractions compared to sole maize plots (Fig. 1).

Fig. 1: Maize-pigeon pea intercropping trial in Linthipe, Malawi.

Fig. 2: Root barrier greenhouse trial in Eschikon, Switzerland.

Greenhouse Trial: A greenhouse trial was conducted in Eschikon, Switzerland to investigate mechanisms controlling nutrient dynamics of maize-pigeon pea interactions (Fig. 2).

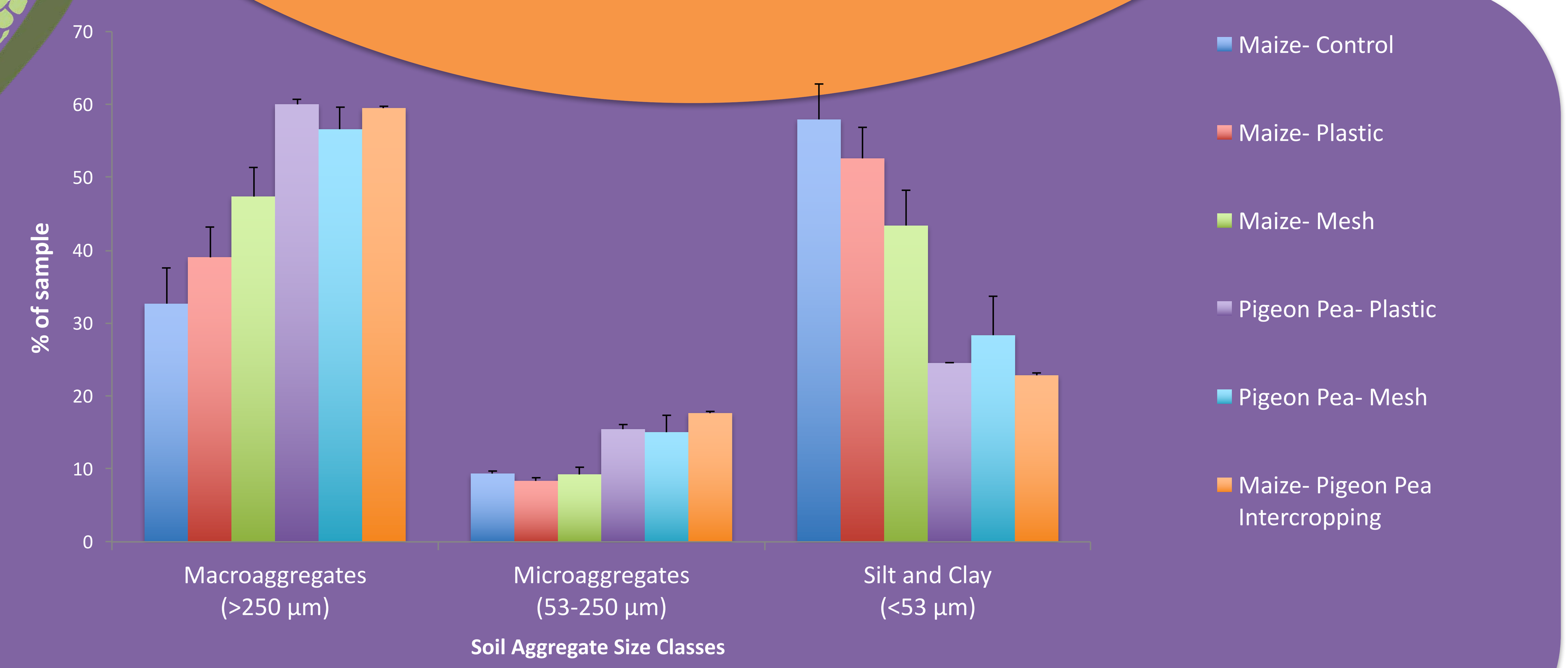

Fig. 3: In the root barrier greenhouse trial, the addition of pigeon pea increased the percentage of macroaggregates (>250 µm) and microaggregates (53-250 µm) by 53% and 111%, respectively,

INCREASED NUTRIENT STORAGE CAPACITY

	Total C (g C kg^{-1} bulk soil)			Total N (mg N kg^{-1} bulk soil)			Total P (mg P kg^{-1} bulk soil)			Organic P (mg P kg^{-1} bulk soil)		
	Macro	Micro	S+C	Macro	Micro	S+C	Macro	Micro	S+C	Macro	Micro	S+C
M	10.5 (±1.2)	4.2 (±0.3)	14.7 (±1.3)	535.3 (±66.5)	210.3 (±16.3)	781.8 (±79.2)	248.1 (±19.6)	69.4 (±5.3)	353.5 (±30.0)	31.8 (±3.5)	6.27 (±0.6)	57.7 (±3.2)
PP	**15.8 (±0.5)**	**6.0 (±0.3)**	6.8 (0.1)	**809.9 (±64.9)**	**378.7 (±36.6)**	269.1 (±104.5)	**379.6 (±10.7)**	**117.5 (±6.2)**	155.8 (±2.7)	**53.1 (±2.1)**	**19.2 (1.4)**	23.9 (±0.8)
M-PP	**16.1 (±0.5)**	**6.8 (±0.2)**	6.3 (0.1)	**786.5 (±72.8)**	**419.2 (±74.3)**	290.1 (±62.3)	**375.9 (±12.8)**	**132.4 (±3.2)**	130.1 (±8.7)	**51.6 (±0.7)**	**23.1 (±1.2)**	23.3 (±0.5)

Table 1: Overview of in which soil aggregate size classes the total C, N, P, and organic P are stored within the soil profile of three cropping systems comparing sole maize (M), sole pigeonpea (PP), and maize-pigeonpea intercropping (M-PP).

INCREASED CROP PRODUCTION AND DIVERSIFICATION

	Maize		Pigeon pea		Total	
	Biomass	Grain	Biomass	Grain	Biomass	Grain
	Kg ha^{-1}		*Kg ha^{-1}*		*Kg ha^{-1}*	
M	1590	692			1590	692
M-PP	1702	874	1453	206	**3155**	**1080**

Table 2: Biomass and grain yield from a field trial in Ekwendeni, Malawi comparing sole maize (M) and maize-pigeon pea (M-PP) systems. The Land Equivalent Ratio for M-PP is 1.56 compared to sole maize, showing a more effective use of available resources.

CONCLUSIONS

Maize-pigeon pea intercropping systems:

- improved soil structure by increasing aggregation (Fig. 3). This has been shown to greatly improve nutrient retention and water infiltration, increase microbial community nutrient cycling, and reduce runoff and leaching, all of which has a significant positive impact on crop growth.
- increased accumulation of total C, N, P, and organic P. Furthermore, these nutrients are stored primarily in the macro- and microaggregates (Table 1), which is thought to be more stable and therefore less likely to be lost from the plant-soil system by erosion and sorption to soil particles.
- increased total grain yield and biomass production compared to sole maize (Table 2). Not only does this provide an additional nutritious crop to the staple maize diet, it also opens the possibility for increased income from pigeon pea sales. Furthermore, the nearly double biomass production can be used as a nutrient-rich green manure for additional fertilizer inputs to the field, potentially adding to soil fertility and crop yield over time.

REFERENCES

- Snapp S, Rohrbach DD, Simtowe F, Freeman HA (2002) Sustainable soil management options for Malawi: can smallholder farmers grow more legumes? Agriculture, Ecosystems and Environment 91:159-174.
- Myaka F, Sakala WD, Adu-Gyamfi JJ, Kamalongo D, Ngwira A, Odgaard R, Nielsen NE, Høgh-Jensen H (2006) Yields and accumulations of N and P in farmer-managed intercrops of maize-pigeonpea in semi-arid Africa. Plant and Soil 285:207-220.
- Bezner-Kerr R, Snapp S, Chirwa M, Shumba L, Msachi R (2007) Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility. Experimental Agriculture 43, 4:437-453.
- Mhango WG, Snapp SS, Phiri GYK (2012) Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. Renewable Agriculture and Food Systems 28(3): 234-244.
- Ngwira AR, Kabambe VH, Kambauwa G, Mhango WG, Mwale CD, Chimphero L, Chimbizi A, Mapfumo P (2012) Scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi. African Journal of Agricultural Research 7(6):918-928.
- Phiri AT, Msaky JJ, Mrema J, Kanyama-Phiri GY, Harawa R (2013) Assessment of nutrient and biomass yield of medium and long duration pigeon pea in a pigeon pea-groundnut intercropping system in Malawi. Journal of Sustainable Society 2(1):36-48.