

Full Length Research Paper

Estimation of maize yield gap through soil analysis in small land holding fields at Livingstonia Plateau, Rumphi, Malawi

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The study was conducted at Livingstonia Plateau in Rumphi District, Northern Malawi to estimate maize yield gaps through the analysis of soil nutrients during the 2018/2019 growing season. Soil analysis was done for one hundred and fifty soil samples collected from the depth of 0 to 100 at an interval of 20 cm from the top, middle and bottom landscapes of the plateau. Soil nutrients analysis was done at the Ministry of Agriculture Lunyangwa Research Station following appropriate methods. Variables were weeding (no weeding and weeding twice) and application of N fertiliser (0 or 22.5 kg N ha⁻¹). Measurements for grain yield of maize were done in a uniform plot of 10 x 10 m from participating fields in each landscape position. Results showed that soil nutrients varied across the slopes, with the bottom slopes having higher values of the nitrogen (0.1 %) than those on the top (0.05 %). These variations showed varying maize grain yield responses of 0.8 and 0.5 t ha⁻¹ for no fertiliser but weeded and not weeded fields and 1.6 and 1 t ha⁻¹ for fertilised but weeded and not weeded fields, respectively. Maize grain yield gaps were higher (4.4 t ha⁻¹) in landscape position 1 than they were in landscape position 3 (4.0 t ha⁻¹) for the no fertiliser and weeded fields; whereas 3.6 and 3.1 t ha⁻¹ for the fertilised and weeded fields. Working closely with farmers on specific soil and fertiliser management practices for improved crop production is critical.

Key words: Lab quest, landscape, maize yield gap, nutrients, soil samples, slope.

INTRODUCTION

Land size has a great influence on species' diversity and composition (Bargali et al., 2018; Shahi et al., 2019; Vibhuti et al., 2019). Crop diversity is attributed to a broad range of known factors and ecological conditions, economic context and demands, taste, knowledge,

ethnicity, culture and special experiments of land owners (Zaldivar et al., 2002; Khoshbakht et al., 2006; Vibhuti et al., 2018). It is expected that with variation in size, density and compositional pattern, soil condition also varies and requires different management practices for improving

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the overall sustainability of the land-use systems (Bargali et al., 2004; 2009, 2019; Manral et al., 2020). In any land use system, when the original vegetation is replaced by the new one, the physico-chemical as well as the biological properties of soil also change with time (Bargali et al., 1993; Joshi et al., 1997; Padalia et al., 2018; Bargali and Bargali, 2020).

Small land holding agriculture is one of the driving forces of economic growth in Malawi. It contributes almost 40% to the GDP, accounting for more than 80% of export earnings; it supports 85 % of the total population living in rural areas (Government of Malawi, 2018). It is characterised by low levels of input and output (Julien et al., 2019). Small land holding production is highly subsistent (Zant, 2020). Small land holding agriculture produces about 80% of Malawi's food and 20% of its agricultural exports (Grow Africa, 2018), indicating the string dependency on the productivity of the small land holding agriculture for food production in Malawi. However, the sector is faced with a number of challenges such as loss of fertile soil that reduces its growth (Lindsjö et al., 2020). Soil loss is one of the major hindrances to small land holding crop productivity and the overall economic development of the country whose economy is dependent on agriculture (Ciceri and Allanore, 2018). Soil loss contributes to soil-fertility depletion which is the fundamental biophysical root cause of declining per capita food production in sub-Saharan Africa (Mugizi and Matsumoto, 2021; Mugwe et al., 2019). Besides soil loss, the human population is rapidly increasing reducing further the average farm sizes. At the moment, the average farm size is less than 0.7 hectares and about 60% of farmers with small land holding cultivate less than 1.0 ha of land (CCARDESA, 2021; Asfaw and Maggio, 2018); the average land per capita is 0.33 ha (GoM, 2010) and per capita land holding size of the poor is 0.23 hectare compared to the non-poor that hold 0.43 ha per capita (Benjamin, 2020; FAO, 2015).

The majority of farmers with small land holding have a low education qualification and are poor; management of soils and soil fertility in their farms leads to the declining agricultural productivity. Soil fertility is a major determinant of crop yields (Hörner and Wollni, 2021). Continued decline of soil fertility against the background of increasing rural poverty is threatening the farmers' long term food security and their source of livelihood (Kim, 2021). Fertiliser use is very low and extension services are almost minimal to non-existent in most parts of Malawi. Food insecurity is thus widespread among households with small land holding (Alpizar et al., 2020). In the face of the current situation of soil fertility management and increased food insecurity, Malawi is still faced with the need to keep pace with the growing demand for food; the need to ensure cash crop production for foreign exchange; and how to achieve these core objectives while ensuring that soil fertility is properly managed (Magreta et al., 2010).

Livingstonia plateau has not been spared with these limitations in its agricultural productivity. It has a fast growing population due to the existence of the university led development which has resulted into land holding sizes of less than a ha per person. Land that is supposed to be left for natural protection of the escarpment is now put under cultivation due to land scarcity. On average, over 90% of farmers with small land holding cultivated on land ranging from 13 – 60% slope (Clarkson, 2011) (Plate 1), facilitating heavy soil loss. Farmers' use of fertiliser is low and most fields have depleted soil fertility (Njoloma et al., 2016). The trend of declining yields at the plateau is increasingly providing evidence that soil fertility is declining due to continuous cultivation of fields with minimal fertility replenishment. The available land thus continues to have a lower production potential due to over exploitation (Ciceri and Allanore, 2018).

Average maize yields per unit of land have fallen over the years to about 0.2 kg ha⁻¹ and food insecurity has crept in and threatening the survival of households. Although the area has a fairly natural production potential, the continuous use of the available encroached land for crop production leads to disproportionate nutrient loss (soil fertility loss). This is a much greater negative influence on maize yield in the area. Soil fertility is the most dominant limitation on yields of maize (McLeod et al., 2020) and the sustainability of maize-dominated agriculture at the plateau is difficult to achieve if no farmer led interventions such as integrated soil fertility management (ISFM) are involved. However, soil fertility management by farmers in the area is haphazard. Fewer farmers have adopted integrated soil fertility management practices. Maize remains the dominant food crop alongside cassava and plantains in the area. Unless soil nutrient losses are compensated for, the already poor production potential will be impaired by continued soil nutrient mining; food insecurity and rural poverty threaten to increase (Vidigal et al., 2019; Govers et al., 2017).

Management of the plateau soils is critical to food production and sustainability of the same. There is no doubt that the need to reverse the decline in soil fertility is becoming critical (Vidigal et al., 2019). This study was thus conducted to assess maize yield gaps in three landscape positions (dambo valleys (0 - 12% slope), dambo margins (0 - 12%) and steep slopes (> 12%) through soil nutrient analysis. The steep slopes are characteristics of Livingstonia Plateau and are prone to soil loss through erosion. The study is an attempt to respond to three critical issues in the area: 1. understanding the soil nutrient patterns as influenced by the landscape position and farmers management of the fields, 2. the need to understand the cause of the maize yield gaps, and 3. the need to understand the farmers' soil fertility management. The issues form preliminary steps in finding sustainable ways to urgently halt the yield declines and soil nutrient mining at the plateau. The study thus hypothesizes that landscape positions affect soil



Plate 1. Position of fields along the landscape at the Livingstonia plateau in 2018. The yellow marks indicate landscape positions and reddish colour show position of fields for maize grain yield measurement (Source: Google Earth, 2020).

nutrient patterns which in turn affect maize yields in farmers' fields.

MATERIALS AND METHODS

Study location

The study was conducted at Livingstonia Plateau (10.6028° S and 34.1059° E, elevation 2300 m asl) on the eastern side of Nyika Plateau from 2018 to 2019 growing season. The climate at the plateau is a humid subtropical one with hot and humid summers and cold to mild winters. The plateau has an average annual rainfall range of 1700 to 2200 mm with mean temperature of 18°C. The plateau is underlain by poorly-outcropping felsic gneisses of the Palaeoproterozoic Ubendian Belt which are covered by the thick clayey humus-rich soils (humic latosols in freely drained areas and organic hydromorphic peats on bogs or dambos (Master and Duane, 1998). The plateau soils are generally poor and acidic, with low soil organic carbon (C). Acidic tropical soils are low in inherent soil fertility, low cation exchange capacity, high levels of soluble aluminium and manganese, high fixation of phosphorus and low moisture retention capacity (Nanganoa et al., 2020). The plateau forms the landscape positions typified by tors with varying slopes that have perennial rivers with great potential for mini hydro power generation and irrigation for valuable horticultural crops in the dambos and wetlands (Plate 1). The main cropping system in the area is dominated by maize, with cassava forming a larger share of the staples consumed. Coffee has once been the main cash crop, although its production potential is still high. Besides these crops, bananas and other horticultural crops grow well in the area. It has a human population of about 10,000 (Kondowe, 2015) which poses so much pressure on land and other natural resources.

Soil sampling and management

The study categorised the landscape into three positions based on

slope: the dambo valleys (0 % slope), dambo margins (0 – 12 %) and steep slopes (> 12 %). Slope was determined by the Global Positioning System (GPS) (Chen et al., 2014). Within these landscape positions, several soil sampling points were georeferenced around the plateau. In this study, three sites were selected (Plate 1) for soil sampling giving ten soil sampling points in each landscape and 30 points across the landscape positions. Soil sampling point coordinates were obtained using the GPS for follow up research use. Each sampling point was cleared before sampling. Soil sampling was done using a soil auger at an interval depth of 20 to 100 cm. The soil samples were collected before the onset of rains in order to reduce the effects of leaching. At each sampling point, soil collected was mixed and quartered to come up with three 5 g representative samples from each sampling point.

Soil preparation for analysis

The composite samples were taken to the University of Livingstonia Laws Campus Chemistry Laboratory for immediate processing for moisture content, pH and bulk density. After measuring bulk density, the soil was then prepared by removing the lumps of the soil particles by beating the soil using a mortar and pestle in the laboratory, and the soil samples were then sieved to pass a 2.0 mm sieve to get manageable samples for nutrient analysis. The soil was then weighed to obtain 1 g of soil using a balance scale that was tared to bring it back to zero before weighing the soil. Tarring is done to prevent false measurement due to air pressure.

Moisture content, pH and bulk density analysis

Soil moisture was measured using a soil moisture sensor connected to a Vernier LabQuest (FAO, 2020) in the laboratory soon after soil sample collection from the field. Bulk density was calculated for each soil sample of different depth and different sites. Oven dry method was used to determine bulk density. Soil pH was

measured using pH sensors for the Vernier LabQuest equipment (OUAT, 2017) in the laboratory. Since the Vernier equipment could not analyze nutrients, soil samples were taken to the Ministry of Agriculture Lunyangwa Agricultural Research Station laboratory in Mzuzu for complete nutrient analysis.

Nutrient analysis

The nutrient analysis was done to understand the available nutrient concentrations in the field soils. This information was used to help estimation of the nutritional values needed for crop production and also evaluate the fertility status of soils of Livingstonia Plateau fields. Nitrogen, organic carbon and organic matter were analysed using a modified Walkley-Black (MWB) based on spectrophotometric procedure (FAO, 2019; Bahadori and Tofighi, 2016). This method is simple and rapid, and thus, widely used for determination of soil organic carbon (SOC). Phosphorous and potassium were analysed using the Mehlich 3 method following the commonly used Mehlich 3 extractant: a mixture of 0.2 N acetic acid (HOAc), 0.25 N ammonium nitrate (HNO_3), 0.015 N ammonium fluoride (NH_4F), 0.013 N nitric acid (HNO_3), and 0.001M of the chelating agent ethylenediaminetetraacetic acid (EDTA) at pH 0.25 \pm 0.05 (Wendt, 1993; Anderson and Ingram, 1994). Mehlich 3 method is commonly used for the determination of macronutrients (phosphorous, calcium, magnesium and potassium) and micronutrients (copper, zinc, manganese and iron). Mehlich 3 is highly correlated with plant phosphorus uptake and, is therefore, considered as a standard method for available phosphorus determination (Zemědělský et al., 2018; AgroEcoLab, 2016).

Maize yield measurement

Along the soil sampling sites, 18 small land holding fields were selected for yield analysis. Maize plots were assigned for without fertiliser and with fertiliser (22.5 kg N ha⁻¹). Management of these fields were done by the farmers, with strict observations that the demarcated plots followed the weeding regimes (no weeding and weeding twice). The plots for yield analysis were controlled to no or two weedings and 22.5 kg N ha⁻¹ of fertiliser applied at basal (23:24:0+4S) and top dressing (46 % N Urea). The fields had plant population densities of about 37, 000 plants ha⁻¹ following recommended plant spacing of 70 cm apart (Seed-Co, 2018). A gross plot of 100 m² was made at the middle of each selected field. This was done to reduce field border effects. Maize grain yields from net plots of 25 m² were harvested at maturity. A moisture meter was used to determine grain moisture content at harvest and maize grain yields were adjusted to 12% moisture content.

Justification for using one year data

Learning from farmers is a piecemeal, fragmented and iterative process requiring repeated interaction between researcher and farmer over an extended period (Harwood, 1979). However, production research planned and carried out by and with the farmers on their own fields with emphasis on flexibility and local adaptation as the key to success generates positive results (Harwood, 1979). The positive attitude of honest curiosity by the researchers generated confidence among farmers to react openly and frankly to what they saw and that helped the researchers to gain an understanding of the role of the variables studied as the participating farmers carried the operations with utmost responsibility. This confidence was adequate to trust the yield and soil analysis results from the growing season.

RESULTS AND DISCUSSION

The findings of this study, presented in the following sections include common practices that form part of the constraints to improve maize yields, soil nutrient contents and maize grain yields from small land holding fields and maize yield gaps along landscape positions (Table 1). Some of the identified common practices by farmers had various reasons for their existence. Improved maize variety seed use was higher than local and recycled seed use. This practice indicates positive response to the extension calls for use of improved maize seed due to several benefits they offer. However, poverty still pushes a considerable proportion of farmers to use of local and recycled seed. Use of local maize helps to maintain variety diversity and reduces genetic loss of the maize. Most farmers prefer local maize to hybrids because of its storability, poundability and taste. Local maize has low yield potential as its fertiliser use efficiency is low (Zhou et al., 2019). This finding suggests the need for seed companies to improve interactions with farmers with small land holding by providing simple packaged information about the variety attributes. Apart from small packs of seed, they should also consider affordability to the resource poor farmers.

Time of planting at Livingstonia plateau poses a constraint to increasing maize yield. According to farmers, it was very rare to plant with the first planting rains. Their main reasoning was based on the rotting of maize cobs due to prolonged rains after maturity. The patterns of high and prolonged rainfall have taught stallholder farmers at the plateau to defer planting maize to the second or third onset of planting rains. Although this type of planting does not take advantage of the “Birch effect” (Weil, 2019), planting is delayed to reduce rotting of maize cobs due to prolonged rainfall which has potential of over 20% yield loss (McCarthy et al., 2021). Those that planted with the first rains avoided the unpredictability of the rains and were in response to the advice from extension experts about early planting.

Fertiliser is one of the most needed inputs in improving maize yields by farmers with small land holding especially on the basis of soil infertility. Using enough fertilizer enables much higher yields (van Ittersum et al., 2016). Use of fertiliser as a component for soil improvement is very low with the majority using below 30 kg N ha⁻¹ for maize production. The plateau has lowest proportion of farmers producing tobacco which competes with maize for the hard to secure fertiliser and labour inputs. Low use of fertiliser results from the high levels of poverty at the plateau, although the majority of the farmers with small land holding are low paid employees of the institutions existing there. Low fertilizer use is one of the major constraints for increasing agricultural productivity in sub-Saharan Africa (World Bank, 2007). Achievement of the Sustainable Development Goal 2, end hunger, achieve food security and improved nutrition, and promote

Table 1. Selected farmer practices for improving maize yields at Livingstonia plateau in 2018. ($n = 140$).

S/N	Practices	% of farmers practising	Reason
Common maize varieties			
1	Monsanto varieties	31	High yielding
	SeedCo varieties	24	High yielding
	Panner varieties	13	High yielding
	Local maize	15	Lack of money to buy seed
	Recycled	17	Lack of improved seed
Planting time			
2	First planting rains	3	Rainfall is unpredictable
	Second / third rains	97	Avoid rotting of maize
Fertiliser use			
3	None (0 kg N ha^{-1})	17	Lack of capital
	Medium ($1 - 29 \text{ kg N ha}^{-1}$)	49	FISP not adequate
	High ($30 - 50 \text{ kg N ha}^{-1}$)	34	FISP and own
Weeding			
4	None	7	Lack of labour
	Once	31	Labour shortage
	Twice	51	Maximise yield
	> twice	11	Able to hire in labour
ISFM (apart from fertiliser use)			
5	None	23	Lack of resources
	Legume intercrop	21	Bean adds fertility
	Conservation agriculture	13	Increase yield
	Manure/ compost	9	Increase yield
	Burning	34	Quick way of land preparation

sustainable agriculture through Target 2.3 that requires to “double the agricultural productivity and the incomes of small-scale food producers, requires concerted efforts on increasing fertiliser use by farmers with small land holding as fertilisers play a pivotal role in achieving food self-sufficiency (Ciceri and Allanore 2018). Increased fertiliser use in an ISFM context is able to increase both land and labour productivity in a sustainable way.

Apart from fertiliser use, weeding is another constraint that reduces maize yields (Holden, 2018). Weeds outcompetes maize from nutrients and leads to low yields and consequently food insecurity. The results in Table 1 show that labour plays a role in reduced weeding of the maize fields. Although more than half of the farmers weeded twice, the majority that weeded once or with no weeding at all formed a considerable proportion of farmers at risk of food insecurity. Use of ISFM was lower than expected. ISFM is very important to farmers with small land holding especially in the face of exhausted soils that have low fertility to support high yields. Intercropping with legumes was cited to common bean only, defeating the intensive research activities by the

Government of Malawi agricultural research teams promoting the benefits of legumes to maize production (Silberg et al., 2017). With a sense of integrated soil fertility management practices by fewer farmers, fertilizer would turn out to be much more effective on such fields enriched by the ISFM than on fields with none (Mutuku et al., 2020). In fact, fertilizer use effectiveness and profitability increase with soil fertility (Bremana et al., 2019). The low fertiliser use in the area and weeding call for extension work to focus on increasing adoption of ISFM which has a high potential to improve maize yields in the area as food production increases directly proportional with fertiliser use (Bremana et al., 2019).

Soil moisture and pH

Soil moisture is the quantity of water the soil contains at a particular time. It is one of the main factors influencing soil nutrients and also plays a role in understanding the behaviour of soils. Soil moisture showed the degree of compaction of a particular soil. Soil pH is a measure of

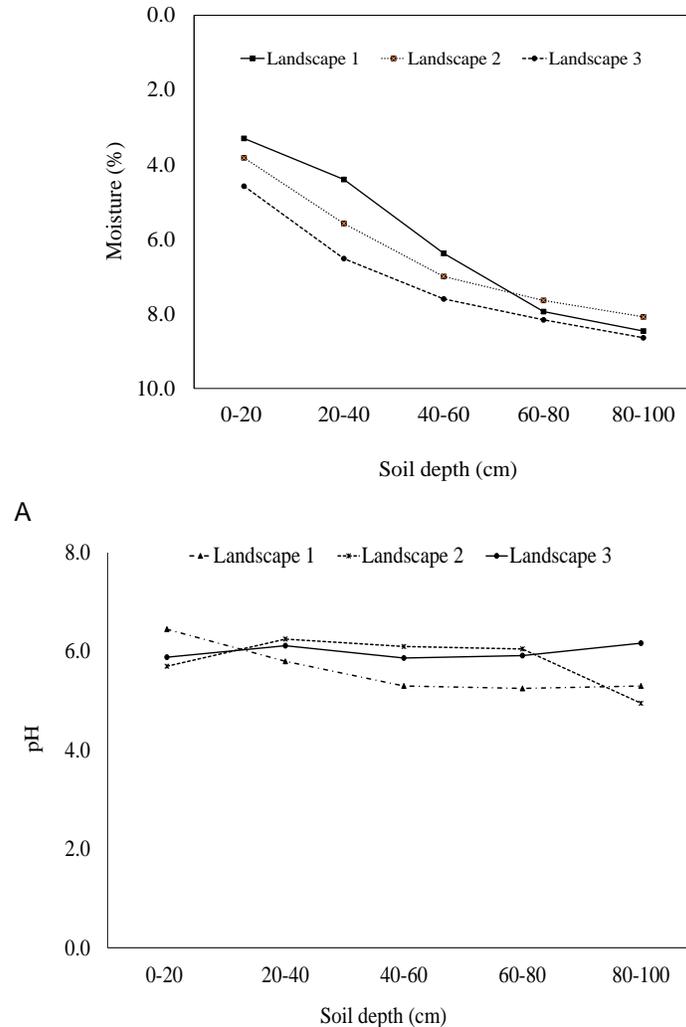


Figure 1. A. Soil moisture content (x 10 %). **B.** pH of soils for fields at Livingstonia plateau in 2018.

acidity or basicity (alkalinity) of a soil and it is important for determining the level of micro flora and fauna in the soils and influences the availability of essential nutrients.

Results for soil moisture and pH along soil depths are presented in Figure 1. The results showed that soil moisture content was within the range of 10 - 45% of a dry soil for soil depths of 0 - 20 cm. Soil moisture content increased with soil depth. Landscape 3 had higher moisture content. The results suggested that soils were not compact since the moisture content was within the moisture ranges for most dry soils (Kang et al., 2000) which also depend on the topography and location. Soil pH did not show much variations across the soil depths. The values averaged pH 6. Plant growth and most soil processes are favoured by a soil pH range of 5.5 – 6.5 (Neina, 2019). Maize grows best within the pH values of 5.8 - 6.8 and it is reasonably tolerant to soil acidity

(Timmer, 2019). Aluminium levels were not analysed because with the soil pH obtained, there might not be much worry about aluminium toxicity in the field especially where soil pH drops as aluminium becomes soluble. A small drop in pH can result in a large increase in soluble aluminium which retards root growth, restricting access to water and nutrients (Silva, 2012).

Soil nutrient analysis

Table 2 presents results of the soil nutrient analysis conducted at Lunyangwa Research Station in 2018. These are % nitrogen, % organic carbon, % organic matter, phosphorus and potassium. Nitrogen (N), phosphorus (P) and potassium (K) are the macro nutrients for most Malawian soils and are prescribed for

Table 2. Nutrient content of soils for 0 – 40 cm soil profile in small land holding fields by landscape position at Livingstonia plateau in 2018.

Nutrient	Landscape position	Soil profile depth (cm)		Standard deviation		SEM	Critical values*
		0 - 20	20 - 40	0 - 20	20 - 40		
% N	1	0.08	0.06	0.006	0.026	0.005	> 0.2
	2	0.10	0.08	0.043	0.039	0.005	
	3	0.08	0.08	0.018	0.014	0.013	
%OC	1	1.16	0.70	0.072	0.303	0.051	> 2.7
	2	1.12	0.92	0.502	0.450	0.059	
	3	0.96	0.95	0.201	0.140	0.142	
%OM	1	1.25	1.05	0.123	0.523	0.087	na
	2	1.94	1.58	0.866	0.775	0.101	
	3	1.66	1.64	0.347	0.281	0.246	
P (ug/g)	1	44.00	8.66	26.194	4.5375	18.522	> 30
	2	15.08	7.61	9.837	10.077	1.700	
	3	9.20	4.50	6.9315	2.8575	4.901	
K (Cmol/kg)	1	0.11	0.12	0.098	0.0605	0.069	> 74
	2	0.07	0.07	0.143	0.145	0.054	
	3	0.16	0.16	0.013	0.023	0.009	

*Critical values (Snapp, 1998; FAO, 2007; NAAIAP, 2014) indicate extractable nutrient concentration in soil above which an economic yield response to added nutrient is unlikely.

the main fertilisers used by farmers with small land holding for cereal production.

The availability of P is considered to be a fairly good indicator of the P supplying capacity of a particular soil (Bargali, 1995). Knowledge of the available phosphorus content of soil is important for determining the critical limit (Karki et al., 2021; Bargali and Singh, 1997). The evaluation of a soil critical limit of nutrients helps in developing fertility classes for effective fertiliser recommending schedule and management.

The general picture in the study is that nutrient contents decreased with depth of the soil profile at each landscape position (Table 2 and Figure 2). A similar trend is observed for % N, % OC and P but this was different with the rest of the nutrients where they were increasing with landscape positions suggesting that nitrogen limited the maize yields at the plateau. Values of % N between 0.1 and 0.2 % are described as low and below 0.1 % are very low for tropical soils (Landon, 1991). The results supported the finding by Rütting et al. (2018) indicating that soil N is the most limiting factor for crop production.

This difference could be attributed to efforts by farmers with small land holding in application of ISFM in some fields which may lead to accumulation of nitrogen. The decrease in the nutrients might also have resulted from soil mining due to continuous use of the fields for the

maize. The increase in % OM and K was expected because the lower landscape positions are points of accumulation of residues washed from the higher positions. Decomposition is higher in such positions and thus may lead to higher levels of nutrients.

Landscape position had an influence on the nutrient accumulation in the fields for farmers with small land holding (Figure 2). Nutrient contents decreased with landscape positions. For instance, % N was lowest at landscape position 1 and highest at landscape position 3. Similar trends were observed for % OM. K and P showed variations especially with landscape position 3 which had higher values with increasing depth of soil profile for P and lowest values for K at landscape position 3. P status above the critical value of 15 mg kg was sufficient for small land holding maize production levels (Snapp, 1998) but below this level is described as low (Landon, 1991). Landscape position 1 had fields with P concentrations above the critical values which indicate potential for maize production if other factors that affect yields are well managed. All nutrient values found in Livingstonia plateau (landscape position 1 to 3) showed lower nutrient concentrations below the critical values for maize growth, suggesting that nutrient supply was inadequate to support maize development. Hence there is high probability of farmers with small land holding running into

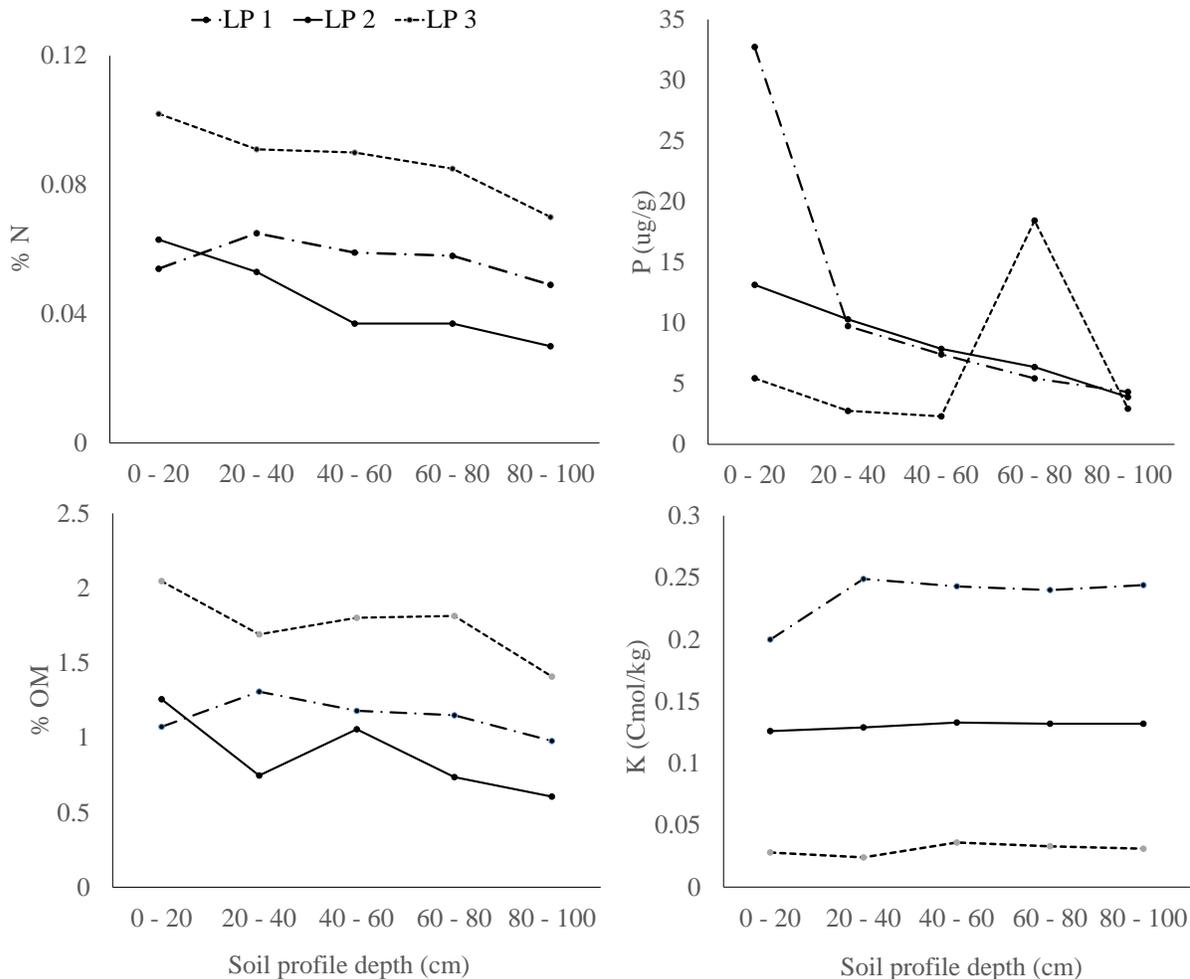


Figure 2. Nutrient content of soils in small land holding fields by soil depth at Livingstonia plateau by landscape position in 2018. SE: % N = 0.004; % OM = 0.084; P(ug/g) = 0.111; K (Cmol/kg) = 0.04.

food insecurity since maize is the largest source of staple food supply, if no external input supply is made.

These results support the findings by Snapp (1998) on nutrient concentration in small land holding fields. Therefore, the call for external inputs, without which food insecurity shall be the order of the day, is justified. The Farm Input Subsidy Programme (FISP) now the Affordable Inputs Programme (AIP) requires flaking off from political influence because its better management would directly translate to improved maize grain yields among farmers with small land holding in Malawi. The amounts of fertiliser the AIP provide mean good crop yields where farmers with small land holding are encouraged to observe other agronomic operations including weeding and timely plantation. The nutrient concentrations also call for the promotion of ISFM at all cost in order to increase the nutrient use efficiencies of the small land holding fields. Access to fertiliser is low in Malawi especially among the rural farmers with small land holding and is one of the main constraints to

increased maize production. A combination of AIP and ISFM would have positive impact on food security.

Maize grain yield analysis

Figure 3 shows maize grain yield as measured from the net plots in the farmers with small land holding fields along landscape positions at the plateau. Weeding and fertiliser use were variables controlled alongside the landscape affecting maize grain yield. For the weeded fields, maize grain yields were higher than non-weeded fields. In the weeded fields, medium (22.5 kg ha^{-1}) use of fertiliser almost doubled maize grain yields from 1 to 2 t ha^{-1} giving a strong evidence that weeding combined with small or medium amount of fertiliser would be a silver opportunity to improve maize yields for farmers with small land holding (Holden, 2018).

The inherent soil fertility as indicated by the soil analysis has an impact on maize yield in each landscape

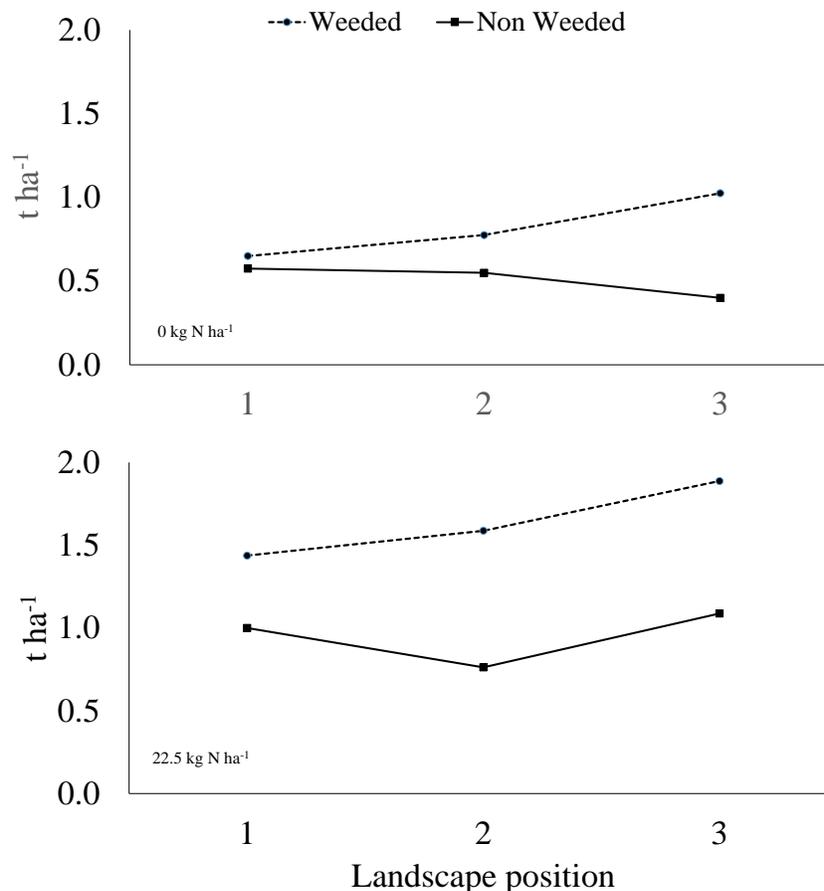


Figure 3. Maize grain yield (kg ha⁻¹) from farmers with small land holding along landscape positions at Livingstonia plateau in 2018. SE = 0.5.

position. However, the impact on maize grain yield was observed to be higher on landscape 3 as one observes the trend of maize grain yield in fields without fertiliser (Figures 2 and 3).

The effect of landscape position on maize grain yield was the increase in yields from landscape position 1 to landscape position 3. This was very clear with fertiliser amendments and weeding. The maize that was not weeded and did not receive any dose of fertiliser, growing on the inherent nutrients in the soil, had its yields decreasing from landscape position 1 to landscape position 3. Weeding alone had an impact on maize yields with better yield increment at landscape position 3. Accumulation of organic matter at the lower slopes (landscape position 3) could explain the differences in yields. It is also evident to say that farmers with small land holding who receive AIP inputs have an opportunity to double their yields when attention is paid to some simple agronomic practices including weeding. Small amounts of fertiliser with inherent soil nutrients produce wonders to farmers with small land holding especially where ISFM is practiced (Holden, 2018).

Correlation for % N and maize grain yields (t ha⁻¹) in Figure 4 showed a general increase in maize grain yields as % N increases with highest increments in fields that received both weeding and fertiliser. The increase was also evident for the landscape position. Landscape position 3 had better yield increase in both weeded and not weeded plots. The plots that neither received fertiliser nor weeding performed poorly even at the landscape position 3 where yields seemed to be generally better. However, the maize grain yield increase seemed to correlate to the levels of inherent soil nutrients at different landscape positions as inherent nitrogen influences maize yield response (Gotosa et al., 2019).

Maize yield gaps

Maize is the major staple food at the plateau with visibly little competition from secondary staples such as cassava, rice and banana. Despite the importance of maize at the plateau, yields remain consistently low and food insecurity has become a chronic problem.

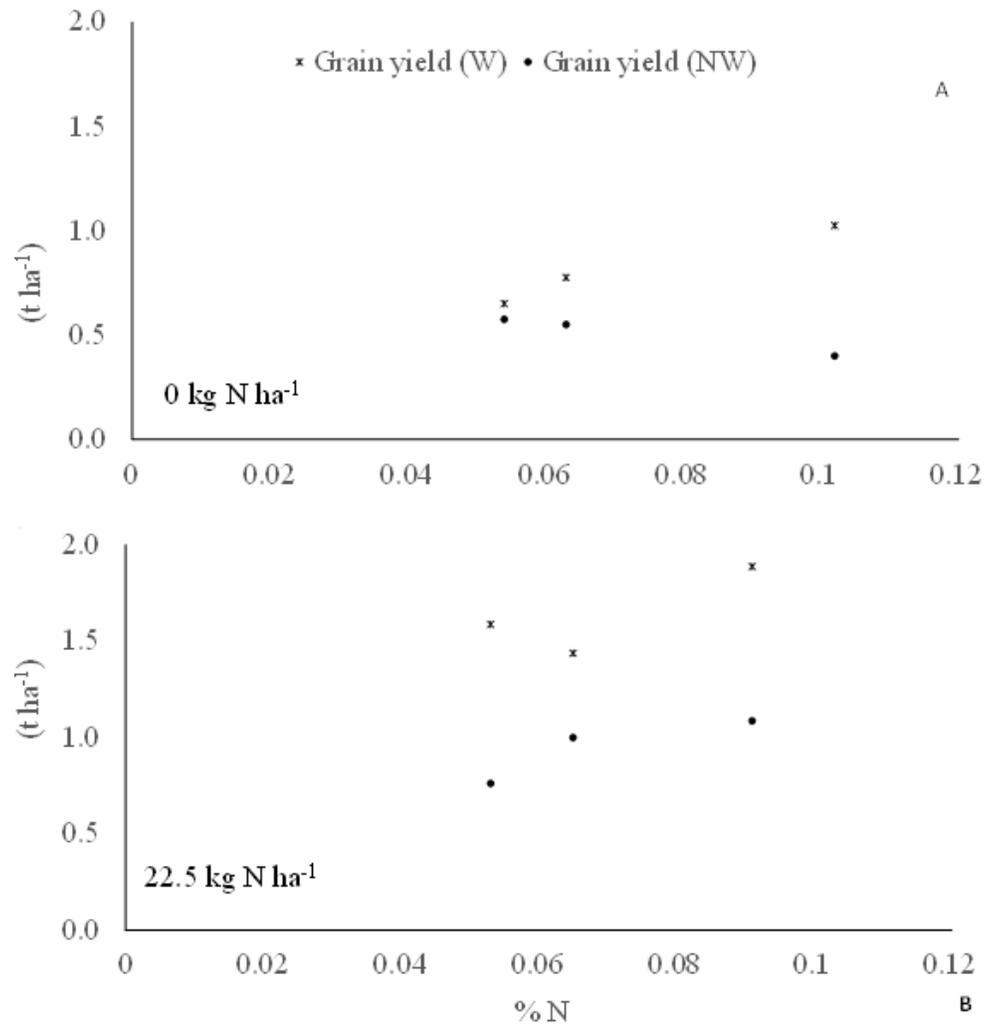


Figure 4. Correlation of maize grain yield (kg ha^{-1}) and % soil N in small land holding fields: (a.) no fertiliser and (b) with fertiliser along landscape position at Livingstonia plateau in 2018. SE = 0.16.

Livingstonia plateau had large maize yield gaps among fields at different landscape positions in the area. These yield gaps can become poverty traps (Tittonell and Giller, 2013) especially to vulnerable households at the plateau. The maize yield gaps observed seem to correlate well with the poor economic growth and livelihoods of the farmers in the area, and may likely explain the high poverty levels observed at the plateau.

The gaps in maize yields between fields that were weeded and not weeded increased with landscape position. Landscape position 3 had the highest increase in both situations (Figure 4). There was grain yield increase on fields that received fertiliser in general but the increase was clear on fields that had received weeding. This implies the importance of weeding which reduces competition for nutrients between weeds and the maize crop from the soil nutrients.

Maize grain yield gaps measured on the average small land holding maize yield of 5 t ha^{-1} are presented in Figure 5. The gaps are overwhelming. Lack of fertiliser use increased maize grain yield gaps but weeding alone was observed to narrow the gaps especially at the landscape position 3. This was also observed from fields that had received medium fertiliser. Yield gaps narrowed more towards landscape position 3 but more so from fields that had received weeding and fertiliser. The results suggest that use of FISP inputs would bear positive impact in increasing farmers with small land holding yields where farmers adopt weeding and fertiliser use. Maize yield gaps have been reported to be higher in small land holding fields elsewhere (Leitner et al., 2020) which call for adjustments in soil and crop management measures to increase yield (Munialo et al., 2020). In addition, Munialo et al. (2020) indicated that the high

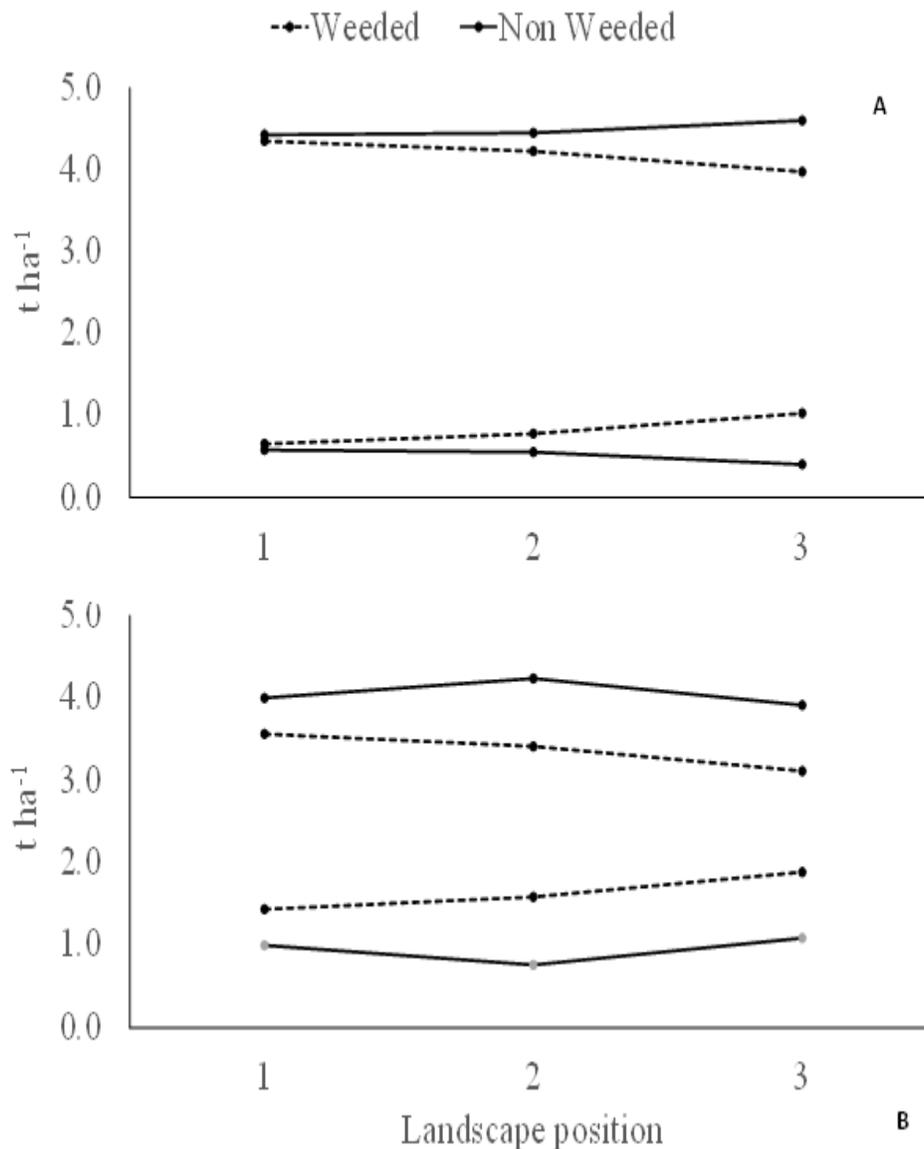


Figure 5. Maize yield gap analysis in small land holding fields: (a) no fertiliser and (b) with fertiliser at Livingstonia plateau by landscape position in 2018.

observed maize yield gaps show potential to increase yield at small land holding level. The plateau is one of the areas with high agro-ecological potential and the maize yield gaps indicated that potential to be achieved.

Conclusion

The levels of nutrient concentrations in small land holding fields at the plateau were low and producing maize without fertiliser use remains a poor decision especially when weeding is not prioritised. Weeding plus medium use of fertiliser showed promising improvements in maize grain yields. A farmer with small land holding who has no

fertiliser but potentially invest in weeding would be better off than one who gives up weeding on the basis of no fertiliser. Landscape position influences maize grain yields suggesting that the fields on top of the slope require more intensive use of ISFM to improve maize grain yields than on the lower slopes. All fields in the landscape positions would produce better yields following a combination of inherent nutrient levels, fertiliser use and weeding. These factors increase the nutrient use efficiency of the fields.

The study showed how soil nutrient analysis can be used to estimate maize yields and the analysis of maize yield gaps. These results can provide complementary findings that are of wider relevance on small land holding

farms (Munialo et al., 2020) in similar landscape positions and agro-ecology within Malawi and beyond. The analysis also revealed the area specific factors influencing maize yield gaps on small land holding farms. The high difference in yields suggests that soil factors and management related variables are important in influencing maize yield gaps.

The findings of this study suggest several discussion points: 1. The need for an investment in educating farmers in appropriate fertilizer use; 2. The need for an investment in promoting the integrated soil fertility management which is not adopted by farmers across landscape positions; 3. The evaluation of the small land holding farming practices in order to increase land use efficiency and reduce use of land with slope above 60 % and 4. The need to invest in extension services to farmers with small land holding.

COMPLIANCE WITH ETHICAL STANDARDS

This research formed part of the student research activities as the requirements of the University of Livingstonia. It was thus conducted in line with the requirements of the University of Livingstonia Research and Ethics Committee (NCST/RTT/2/6), established by the National Council of Science and Technology in Malawi.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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