Performance trials on different rates and ratios of N and P fertilisation in Ethiopia to inform field-specific Maize-Nutrient-Management advisory

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Table of contents

Short summary

This report of the Scaling Readiness of Nutrient Management decision Support Tools project focuses on agronomic trials that serve to inform the development of scalable, field-specific advisory for maize farmers in Ethiopia. These trials were conducted to generate additional information required to make a mobile phone-based nutrient decision support tool – Maize-Nutrient-Manager – more scalable in the context of institutional limitations in fertilizer availability and distribution in Ethiopia. The focus of the trials is on establishing proper N:P ratio's for different fertilization rates with the fertilizers available to farmers in West-Shewa and Jimma (two major maize belts in Ethiopia). The trials were conducted with additional funding from the TAMASA project and in collaboration with EIAR. As the latter institute is involved in conducting fertilizer trials and the development of recommendations, this collaboration also aimed at forming an appropriate entry point for institutionalization of the decision support tool that is being developed.

Keywords

Soil nutrients, decision support tools, scaling readiness, nutrient expert, agronomy, technology extrapolation domains, nutrient use efficiency, N:P ratio, landscape location

1. Introduction

Low yields are pervasive in the smallholder farming systems of sub-Saharan Africa (SSA). For the region to keep up with rapid population growth and cereal demand, cereal production must increase at least three-fold (van Ittersum et al. 2016). While increased fertilizer use seems indispensable to achieve this increase, current use is often inefficient, which limits productivity (growth) and contributes to greenhouse gas (GHG) emissions.

In order to improve fertilizer use efficiency, current blanket recommendations made at regional scale, may need to be replaced by more site-specific advisory which takes account of the heterogeneity among African smallholder farmers. Yet, government extension systems are often underfunded and lacking sufficient skills to provide more site-specific nutrient advisory. Mobile phone-based Nutrient Management Decision Support Tools (NM-DSTs) have been suggested to improve nutrient advice provision to African smallholders.

A scaling readiness evaluation of an existing decision support tool for field-specific nutrient management advice provision – Nutrient Expert® – revealed both operational problems and institutional constraints limiting the scalability of this advisory tool (Sida & Andersson 2018). For instance, as maize growing farmers in Ethiopia generally have only access to two fertilizer blends (NPS and Urea), the tool's focus on balanced N, P and K nutrient supply cannot be translated into fertiliser advice that builds on available blends. In addition, tool use requires expert knowledge, which limits its scalability.

Given the institutional limitations of fertilizer availability and distribution in Ethiopia, field-specific advisory can be simplified and made more scalable. However, current data of Nutrient Omissions Trials (NOT) conducted by the TAMASA project cannot be used to formulate such more simple, field-specific advice for different fertilization rates. To generate such field-specific advice, building on available fertilizer blends, requires a focus on N:P ratio's and an advisory tool that can be used by farmers using different fertilization rates.

As current fertiliser blends in Ethiopia only contain N and P, the most prominent decision on nutrient balance is the N:P ratio. We hypothesize that the optimum N:P ratio will most likely depend on agro-ecological conditions (slope, landscape position) and field conditions (soil organic matter, soil pH), the latter being shaped by past management. This study builds on about 20 trials in two main maize belts of Ethiopia. It focuses on nutrient responses within diverse agricultural landscapes, exploring the influence of landscape position, field slopes, and soil texture. Using this approach, we assess the influence of different agro-ecological and field conditions on the optimum N:P ratio .

This report summarizes initial findings from this N:P performance trial. Additional analyses, focusing on the economics of different fertilization rates and N:P ratios, or building on plant tissue analysis, will be reported upon later. The effects of different treatments (involving varying N:P ratios and fertilization rates) are presented in this report. This report also discusses implications for tool design and highlights ways forward in the remaining part of the project.

1.1. Diverse field conditions and field-specific nutrient advisory

Differences in soil fertility are a major factor shaping maize productivity in smallholder farming systems. Smallholder farmers' maize yields can vary substantially – even in the same location – and such differences cannot be explained by differences in fertiliser supply alone. The field's location in the landscape, the field's slope, agronomic management and notably, past agronomic management and input use, are important factors shaping the soil nutrient supply and uptake of nutrients by plants. As a result, nutrient management decision requires a field-specific approach.

Although the current version of Nutrient Expert® for Ethiopia does not use different, area-specific calibrations of the underpinning QUEFTS model, results of Nutrient Omission Trials (NOTs) across maize growing areas of Ethiopia revealed considerable variability in soil nutrient supply and fertiliser responses. A pertinent question is therefore whether this variability is geo-spatially distributed – and at what scale – as this may inform the development of area-specific calibrations of any decision support tool.

Our earlier analysis of the geo-spatial dimensions in nutrient responses (soil supply and fertilizer response) has identified the relative contribution of field-, farm-, woreda-, and regional-level drivers of variability (Figure 1). While a considerable part of the variability originates at the regional scale, significant proportion of variability in total nutrient responses is predominantly shaped by farm/field-level factors. Regional and farm/field scale factors together explain more than three-fourths (77%) of the total variance in maize yield (regardless of the omitted nutrient). Field-scale factors were found to explain slightly more variance than regional scale factors – 43% and 34% respectively, of the total variability in yield in the NPK treatment. In addition, Figure 1 shows that maize response to N fertilizer is strongly dependent on region and field-scale factors, while responses to added P and K are mostly structured by farm/field scale factors. The large variability in soil nutrient supply and fertilizer responses at the farm/field scale legitimizes the development of a field-specific approach towards nutrient management advisory.
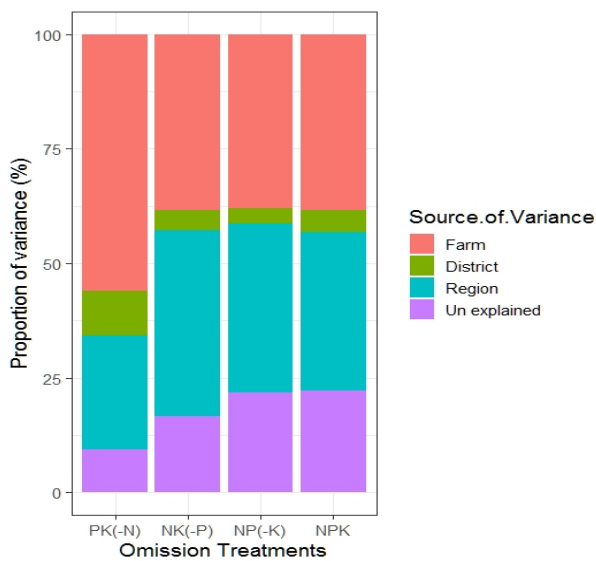

Figure 1: Proportion of variability in soil nutrient supplies explained by field-, district, and regional-level drivers (N = 492)

Figure 2, which focuses on yield responses to N, P and K, shows that almost all of the variability in yield responses to P and K originates at farm scale. Yield response to N are largely explained by regional-level differences (close to 50% of the variability), such as differences in climate (rainfall and temperature). These findings suggest that in order to improve fertilizer recommendations lower scale than the regional scale should be taken into account. It was on this basis that we designed on-farm experiments that allow for an exploration of lower scale factors shaping nutrient responses, in order to incorporate these into the field-specific nutrient management decision support tool under development.
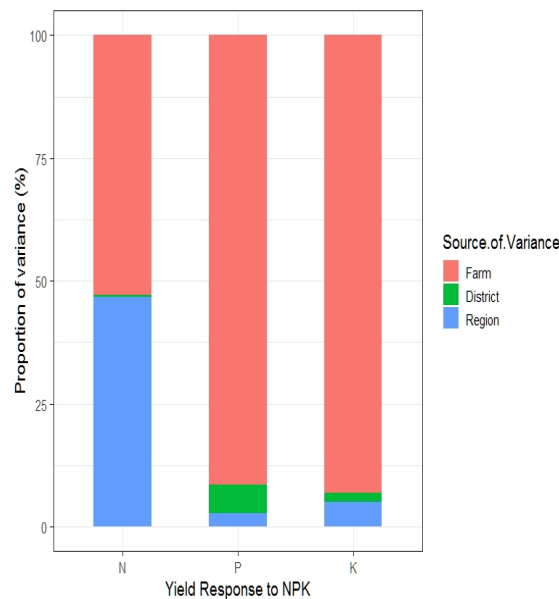
Figure 2 Fertilizer supply response in the NOT trials (N=492)

1.2. Identifying causes of field-level variability

The trial findings presented in this report focus on establishing appropriate N:P ratio's for different N and P rates. Yet, they are also informed by an appreciation of the limitations imposed by current availability of different fertilizer blends. This is reflected in two sets of treatments: the first one building on straight fertilizers (N and P) and a second one, making use of locally available fertilizer blends. Thus, the trials aim to simultaneously establish appropriate N:P ratio's for different fertiliser application rates, and the appropriate mix of fertilizers to be used by farmers, using available blends.

Focusing on field conditions that may affect nutrient responses, such as field slope, the field's position in the landscape, soil texture, past fertiliser use and fertiliser use, these trials seek to identify field conditions that may improve nutrient use efficiency (NUE) by minimizing over-application in relatively fertile fields and under-application in fields with poor soil fertility conditions. Thus, with the current trial, we aimed:

1. To compare the performance of different N:P ratios and fertilization level (reflecting different investment capacities of farmers) with standard regional fertilizer recommendations. (The N:P ratio's used to translate to 50kg differences in fertilizer use per hectare).
2. To explore a pragmatic approach towards the estimation of the soils' indigenous nutrient supply, by locating the trials at different positions in the landscape, and by recording various field features that can serve as proxies for the field's soil nutrients supply (such as field slope, previous manure and fertiliser use, obtained yields, and past management practices)
3. To develop nutrient response and nutrient uptake datasets for the calibration of a QUEFTS-based, field-specific Nutrient Management Decision Support Tool for diverse soil fertility and climatic conditions in Ethiopia.

2. Methodology

2.1. Performance trials: Field selection

Trials were conducted in two sites (West-Shewa and Jimma) in two main maize production areas in Ethiopia. Trial site selection sought to ensure good representativeness of different field slopes (flat/moderate/steep), landscape positions (hilltop/hillside/valley), and soil texture types (clay/clay-loam/sand/etc.) in each area (Figure 3).
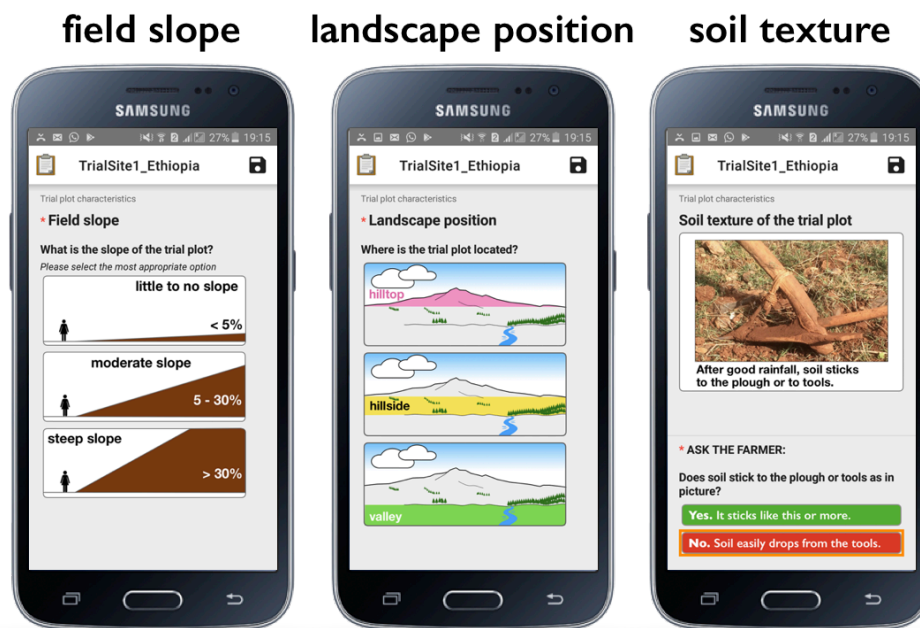

Figure 3: Trial sites were selected on different slopes, landscape positions and soil textures. Information was captured in ODK (Open Data Kit)

Ten experimental fields were selected in each area. Other criteria used for farm and field selection included:

- Farmers and fields that represent the main types of farmers and fields in the area;
- Commonly used cropping systems and farm management practices, and a range of socioeconomic conditions (low to high resource endowment);
- Uniform soil fertility throughout the trial plots as evidenced by uniform vegetation;
- Reasonable field size to accommodate all treatments (8 treatments of at least 5.1 x 4.5 meters each)
- Accessible fields to allow for frequent field visits.

2.2. Performance trials: Experimental layout

Ten experimental fields were selected in each area, making a total of 20 fields, with 8 treatments, each replicated three times. The varying P rates in the treatments were determined based on two criteria. First, rates were determined so that straight fertilizers could be easily converted into bags (or half bags) of available fertilizer blends. For instance, 62 kg TSP (46% P_2O_5) translates into 12.5 kg P, and 75kg NPS, a locally available fertilizer blend. Second, varying N:P ratios were used as to establish nutrient efficient N:P ratios. Table 1 outlines the different treatments (in kg/ha) and the timing of application.

Table 1: Amounts of fertilizers and nutrients for each treatment and timing of application (on a per hectare basis). (N and P contents of NPS: 19% N, 38% P_2O_5; TSP: 38% P_2O_5 ; Urea: 46% N).

Code	Treatment description	Basal dressing (kg/ha)					Top dressing (kg/ha)				Total (kg/ha)		N:P ratio
		NPS	TSP	Urea	N	P	(1) Urea	(2) Urea	N	P	N	P	
1	Regional N and 0% P (control 1)	0	0	62	28.5	0	100	100	92	0	120.5	0	--
2	Regional N and 50% less P_2O_5	0	62	62	28.5	12.5	100	100	92	0	120.5	12.5	9.6
3	Regional N and regional P (EIAR)	0	124	62	28.5	25.1	100	100	92	0	120.5	25.1	4.8
4	Regional N and 50% more P_2O_5	0	186	62	28.5	37.6	100	100	92	0	120.5	37.6	3.2
5	0% N and Regional P_2O_5 (control 2)	0	124	0	0	25.1	0	0	0	0	0	25.1	0
6	Common practice (50% less NPS)	100	0	0	19	16.7	100	100	92	0	111	16.7	6.6
7	Regional N and regional P (EIAR)	150	0	0	28.5	25.1	100	100	92	0	120.5	25.1	4.8
8	Regional N and 100% more NPS	200	0	0	38	33.4	100	100	92	0	130	33.4	3.9

(1) Top-dressing fertiliser (1st split)
(2) Top-dressing fertilizer (2nd split)

3. Results and Discussion

3.1. Maize productivity under different treatments

Figure 4 shows the effect of the different fertilizer treatments on maize yield. In Figure 4a, where only the rate of P was progressively increased (respectively 0, 12.5, 25, 37.8 kg/ha P) and the rate of N kept constant at 120.5 kg/ha, there was a gradual increase in maize yield. Increases in nutrient supply resulted in larger yield increases in Jimma than in West-Shewa.

Figure 4b shows the performance of different N:P ratio's and input rate treatments, as can be achieved with the available fertilizer blends, NPS and Urea. Although these figures show that although the current regional recommendations (3 bags NPS and 4 bags Urea per ha; treatment 7) the benefit of additional NPS basal fertilizer may be limited – the differences between treatments 6, 7 and 8 (representing steps of one 50 bag increases in NPS) are not significant in both Jimma and West-Shewa. This suggests that higher rates of P may only result in significant yield increases when accompanied by substantially higher rates of N, as suggested by treatments 3 and 4 (Figure 4a). Economic analyses will need to show under what price situations investment in such additional inputs are profitable. Farmers might thus save on fertilizer costs by applying less NPS than the regional recommendation, especially in the West Shewa area. Another tentative conclusion that may be drawn from these findings is that the N:P ratio in applied fertilizers may range between 3.9 and 6.6.

A comparison of Figure 4a and Figure 4b shows that equal N and P rate treatments with blended fertilizers tend to outperform straight fertilizers (treatment 3 and 7), although these treatments are probably not significantly different. Observed differences may be a result of different timing of nutrient supply – the blended fertilizer treatment (7) provides some N at planting.
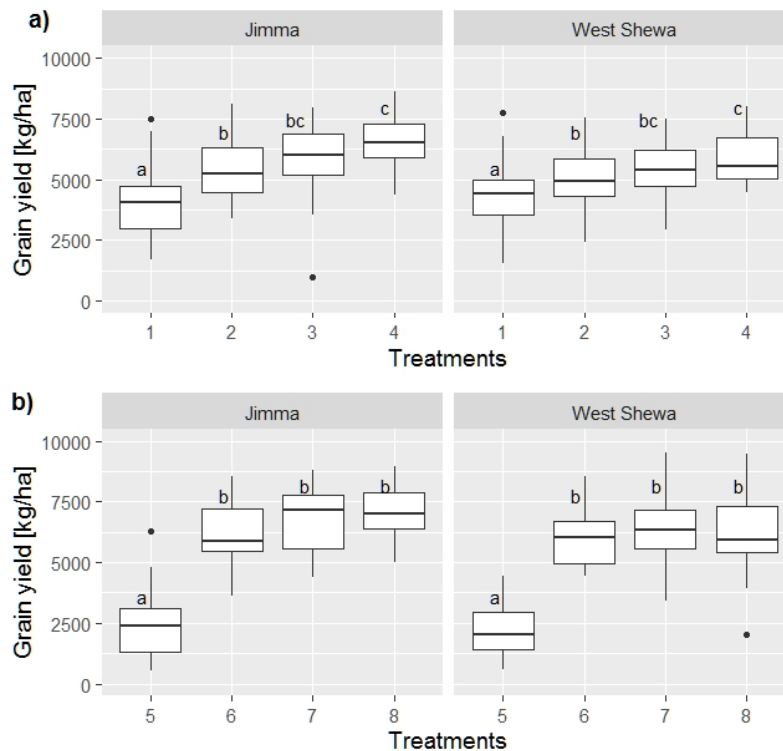

Figure 4: Effect of different fertilizer treatments on maize yield in Jimma and West Shewa, showing responses of maize to different P rates under constant N rate (a) and variable N rates (b) as resulting from the use of available fertilizer blends (NPS and Urea). The treatments 1-8 are explained in table 1. (N = 54 for each graph).

3.2. Maize productivity under different treatments and field conditions: West-Shewa

Figure 5 shows responses of maize yield to different N and P rates under different landscape positions in the West-Shewa zone[1]. These preliminary results suggest that the maize response to different rates of N and P depend on the field's position in the landscape (see Figure 3 on how landscape position was visually assessed) rather than to the rates per se. This finding underwrites the need for a field-specific approach to nutrient management advisory. For example, maize yield responses to different nutrient rates and ratio's on hillside fields (that are more prone to nutrient loss through erosion and leaching) was consistently below the site mean regardless of the slope. Hilltop and valley bottom fields were generally better yielding. In addition, hilltop and valley bottom fields showed better response to higher P rates even when the slopes were moderately steep.

The implication of this finding is that nutrient advisory needs to take account of the landscape position of the field; particularly hilltop fields appear to require relatively more P-fertilizer.
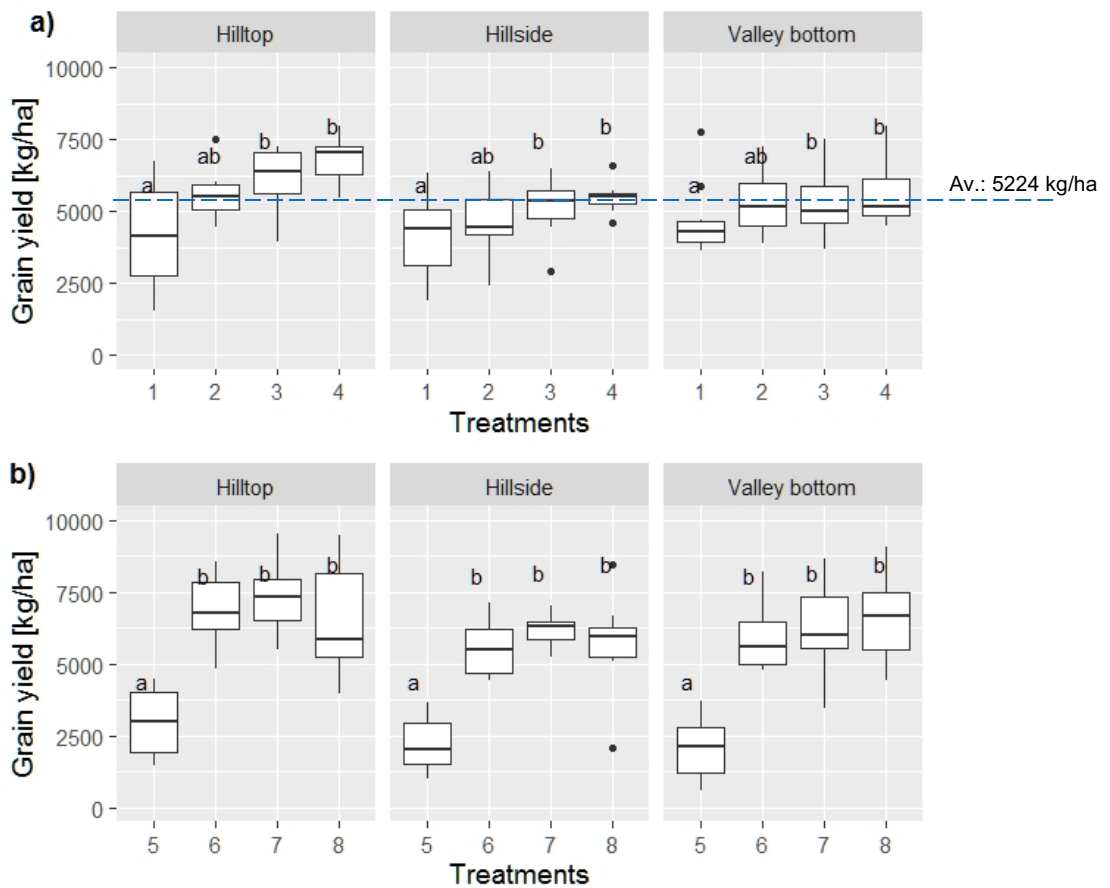

Figure 5: The effect of landscape position on the responses of maize to different P rates under constant and variable N rates. The treatments 1-8 are: 1 = Regional N and 0% P (control 1); 2 = Regional N and 50% less P205; 3 = Regional N and regional P (EIAR); 4 = Regional N and 50% more P2O5; 5 = 0% N and Regional P2O5 (control 2); 6 = Common practice (50% less NPS); 7 = Regional N and regional P (EIAR) and 8 = Regional N and 100% more NPS. A) Treatments to are variable P with constant N, b) while those variable P and N rates. The horizontal line indicates the mean for the site (N = 27).

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[1] Similar analyses will be made for the Jimma zone.

3.3. Maize PUE under different treatments and landscape positions: West Shewa

Figure 6 shows Phosphorus Use Efficiency (PUE) of maize under different field slopes and N and P rates. Figure 6 underwrites the findings presented in Figure 5. First, an increase in P rate does not necessarily lead to improved PUE, unless the N rate is also manipulated to match the increased P rate (Figure 6a). Second, PUE clearly varies with the location of the fields within the landscape; in fertilizer blend treatments (Figure 6b), we observed a declining PUE especially in hilltop and hillside fields.
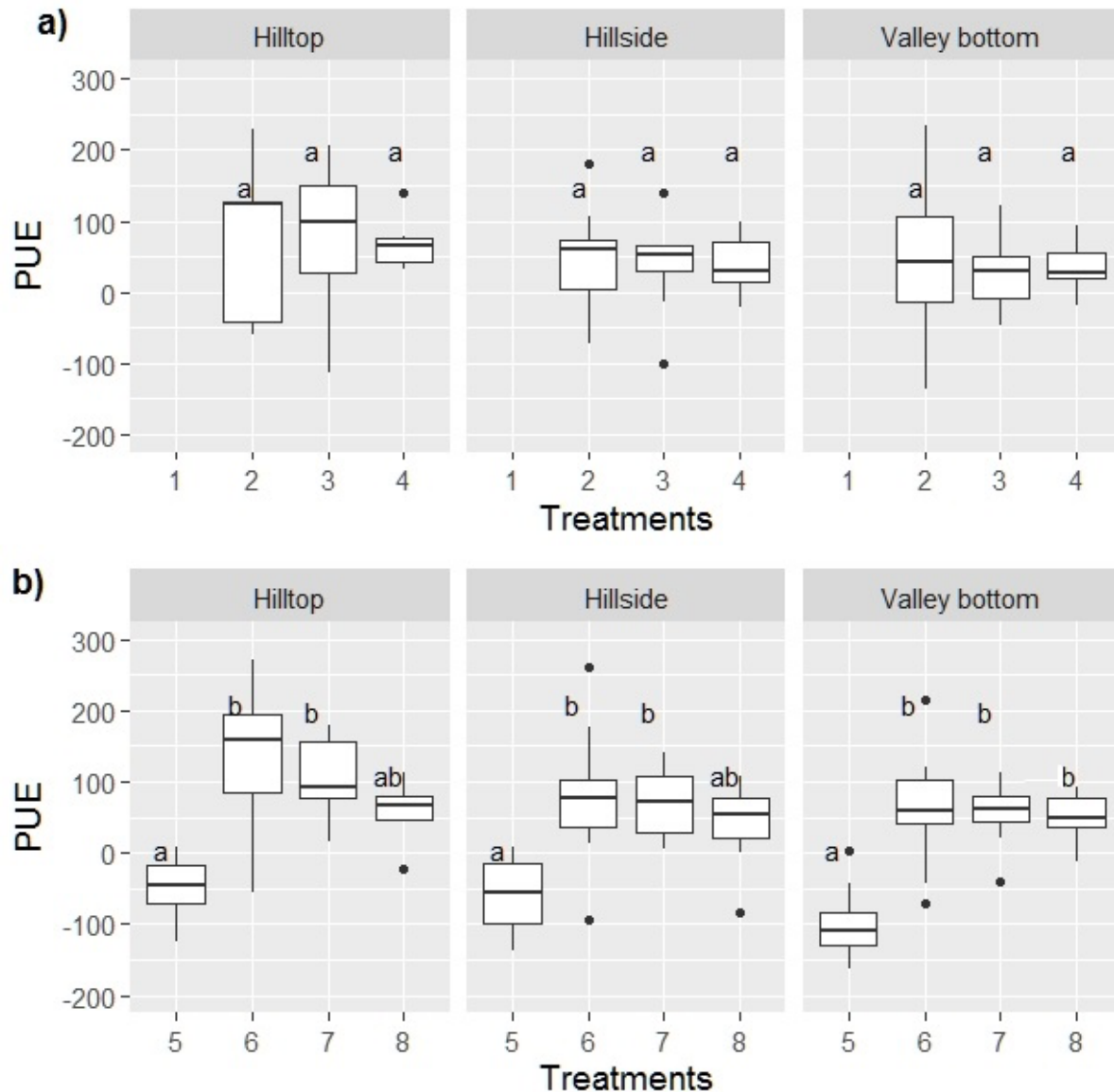

Figure 6: The effect of landscape position on the PUE of maize under different P rates with constant (a) and variable (b) N rates (For treatment labels, see table 1), n = 27.

3.4. Maize productivity under different treatments and field slopes: West-Shewa

In analogy to sections 3.2 and 3.3, we also assessed the effect of the field's slope on nutrient response. Findings suggest similar trends, particularly for steep field slopes (Figure 7); grain yields appear to start declining when the N:P ratio drops below 4.8 (treatment 3) (Figure 7a). However, this decline is not statistically significant (low numbers of observations may be a factor in this). Analyses of PUE (albeit also not significantly different) point in a similar direction; steep sloped fields may require higher N inputs.
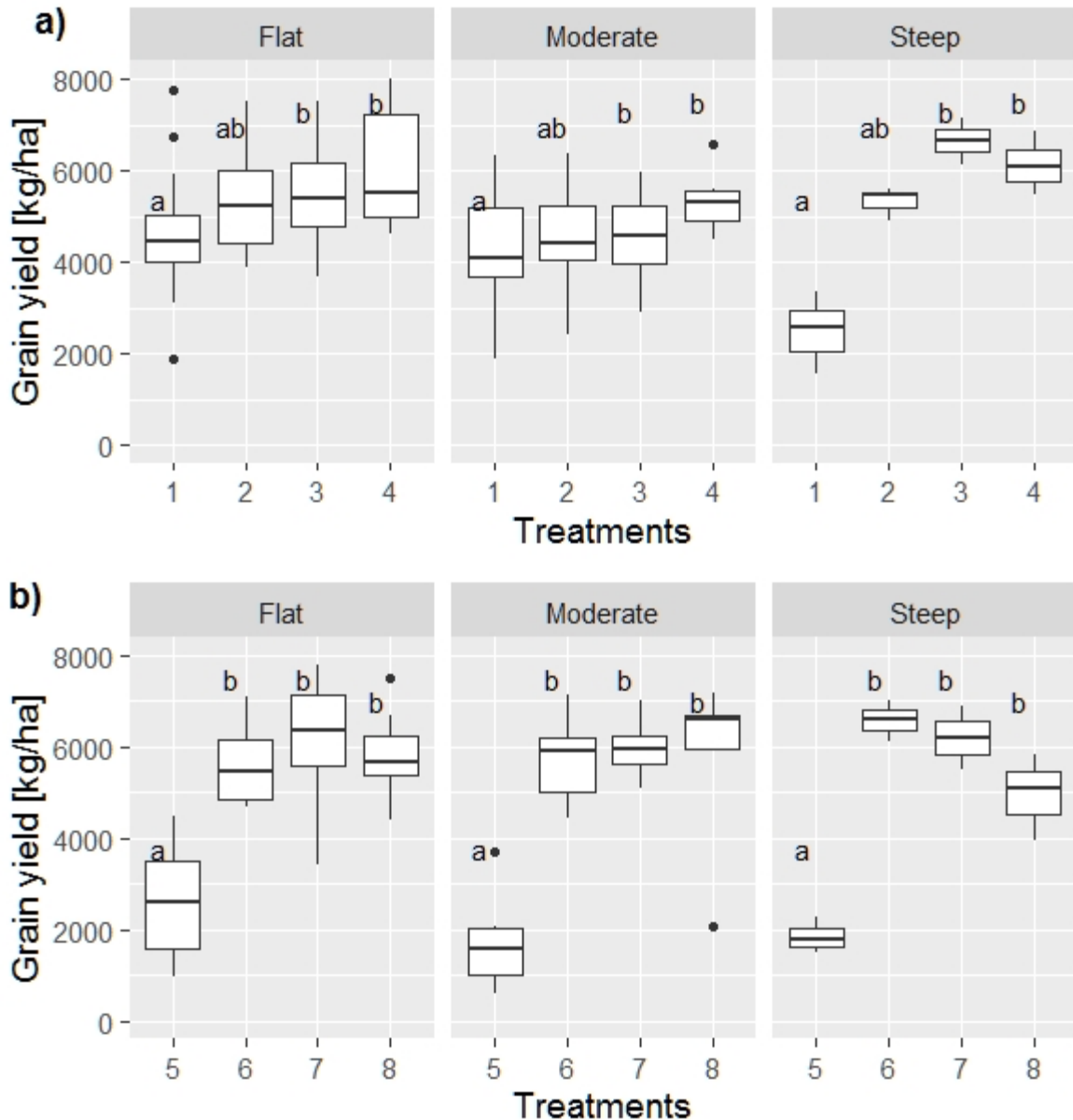

Figure 7: The effect of field slope on the responses to different P rates and constant (a) and variable N rates (b). The treatments 1-8 are explained in table 1. n = 27.

4. Summary and way forward

The current multi-locational trials in Jimma and West-Shewa have been informed by an analysis of the TAMASA Nutrient Omission Trials (NOT), which showed that yield variability is often caused by farm or field-level factors. As this project found that institutional limitations in fertilizer distribution within Ethiopia – allowing only for variable fertilizer rates and N:P ratios – the trials explored the effects of landscape position and field slope on varying N and P rates and ratios. Field-specific advisory focused on balanced N-P-K fertiliser advice – as generated by Nutrient Expert® – may be sound from a soil nutrient replenishment perspective, but currently cannot be implemented in Ethiopia (Sida & Andersson, 2018).

The preliminary results from the current trials suggest that field-specific factors, such as the field's landscape position and slope may be important qualifiers to be included in field-specific advisory. Including these factors like these may go a long way in fine-tuning current regional scale-based fertilizer advisory, and reducing farmers' nutrient use efficiency. At the same time, such fine-tuning can assist in reducing greenhouse gas (GHG emissions) caused by maize production, although at present these effects cannot yet be quantified. The current trials identified timing of N-fertilizer, field slope and field location along the catena as potential sources of variability in the effectiveness of fertilizer use. These sources of variability can easily be modelled into mobile-based decision-support tools that can adjust advice depending on such field conditions. The next step in our project will be to:

1) Further explore the effects of field conditions (notably, soil texture and past management) on nutrient responses;
2) Perform economic analyses on the profitability of the different (fertilizer blend based) treatments;
3) Complete plant tissue analysis, which will enable us understand crop nutrient uptake and use efficiencies. Data analyses on soil nutrient supply, crop nutrient uptake, impact of past management (e.g. manuring, fertilizer residues, legume intercropping etc.), farmers' resource endowment (poor, medium, rich), on the benefits from different N and P fertilizer combinations. These analyses will enable us to better understand nutrient use efficiency;
4) Model the field-scale causes of variability into a simplified decision support tool – Maize-Nutrient-Manager – that is more user-friendly, building on locally available fertilizer blends and (therefore) more scalable;
5) Try to institutionalize the use of this Maize-Nutrient-Manager tool in Ethiopian government's agricultural extension system.

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