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Short Communication

Nutrient status of sandy soils in smallholder areas of Zimbabwe and the need to develop site-specific fertiliser recommendations for sustainable crop intensification

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Sustainable crop intensification in sub-Saharan Africa cannot be achieved if farmers cultivate inherently infertile soils that are deficient in key essential nutrients, such as nitrogen and phosphorus. Most smallholder farmers in sub-Saharan Africa are resource-constrained and apply suboptimal fertiliser amounts, which cannot support optimal plant growth and replenish depleted soil reserves, resulting in food insecurity and soil nutrient mining. Conversely, farmers who can afford adequate fertiliser amounts use outdated recommendations, which are blanket in nature, and which ignore spatial variability in soil nutrients across fields and farms, resulting in inefficient nutrient uptake and consequently depressed crop yields. There is a need to revise the blanket fertiliser recommendations in order to develop site-specific recommendations that are based on soil nutrient status and production system. This can be achieved through systematic soil sampling and analysis, and integration of soil analysis data with GIS in order to develop soil fertility maps that can be used to target fertiliser application. Data from identified soil fertility units can be extrapolated to similar soil units in areas where soil analytical data are not available.

Keywords: blanket fertiliser recommendations, geographic information systems, nutrient status, sandy soils, site-specific fertiliser recommendations

The increasing human population in sub-Saharan Africa (SSA) requires sustainable crop intensification to meet the increasing food demand (Chikowo et al. 2014). However, sustainable crop intensification cannot be successful if farmers rely on infertile soils with inherent deficiencies of essential nutrients and undergoing nutrient mining for crop production (Smaling et al. 1997; Vanlauwe et al. 2015). For example, in Zimbabwe about two-thirds of soils are sands derived from granitic parent material and are inherently infertile with low concentrations of organic carbon (C), nitrogen (N), phosphorus (P) and sulphur (S) to support plant growth (Nyamangara et al. 2000; Ncube 2007). Soil acidity and deficiencies of secondary nutrients, such as calcium (Ca) and magnesium (Mg), and micronutrients, such as zinc (Zn), copper (Cu) and boron (B), are also common in high potential areas (Zingore et al. 2007) where leaching is high and use of lime and manure is limited.

Nutrient deficiencies in SSA are more acute in smallholder sectors where farmers apply suboptimal fertiliser rates to their crops due to poverty and other constraints, such as limited access to input credit, inadequate policies and institutional support, inappropriate fertiliser packaging sizes, and high and increasing fertiliser prices (Chianu et al. 2012; Tadele 2017). Moreover, these deficiencies are

exacerbated by the cultivation of high-yielding crop cultivars that quickly deplete the limited nutrients naturally present in the soil and the meagre fertiliser nutrients applied by farmers (Sserunkuuma 2005; Kihara et al. 2016). In an effort to increase effectiveness of the limited fertiliser amounts, the majority of smallholder farmers concentrate their fertiliser resources on the most productive fields, which are normally nearest to their homes (homefields) at the expense of less productive and normally distant fields (outfields), thereby creating permanent soil fertility gradients (Giller et al. 1997; Tittonel et al. 2007; Masvaya et al. 2010; Kurwakumire et al. 2014).

The common fertiliser types used in Zimbabwe are NPKS and single nutrient source fertilisers (FAO 2006; Minde et al. 2010). Farmers who afford these fertilisers use outdated blanket recommendations that have not been updated since their development in the 1970s to take into account the apparent nutrient mining that has been taking place in the smallholder sector (Zingore 2016), the long-term leaching effect of rainfall and introduction of cultivars with higher yield potential (Sserunkuuma 2005). For example, there is rarely a response to potassium (K) on the granite soils in smallholder farming areas of Zimbabwe (Kurwakumire et al. 2014), yet the common recommended compound fertiliser

Table 1: General recommended fertiliser rates for maize according to agro-ecological zones of Zimbabwe. Source: AGRITEX (2010)

| Agro-ecological Region | Fertiliser recommended rate (kg ha ⁻¹) | | Expected yield level (t ha ⁻¹) |
|------------------------|--|--|--|
| | Basal (Compound D) (7% N: 6% P: 6% K: 8.5% S) | Topdressing (ammonium nitrate) (34.5% N) | |
| I, IIa, IIb | 300–350 | 250–300 | 6 |
| III | 200–300 | 150–200 | 4 |
| IV, V | 150–200 | 100–150 | 3 |

(Compound D) for maize contains NPKS in the percentage ratios of 7:6:6:8.5, respectively (Minde et al. 2010). To increase nutrient use efficiency a better option would be to apply N and P and nil or maintenance levels of K to avoid depleting K reserves over time. Table 1 shows the general fertiliser recommendations for maize used in Zimbabwe that were developed mainly using experiments from research stations and commercial farmers and then extrapolated to surrounding smallholder areas (AGRITEX 2010; Mutezo 2013). The recommendations are therefore not cost effective in smallholder areas and very few farmers use them without modifications (Piha 1993; Mafongoya et al. 2006).

There is a need to revise the current fertiliser recommendations so that they are responsive to the fertility status of the different soil types, crop types and cultivars, and management level and history in order to optimise fertiliser use and increase crop yield and quality. This can be achieved by developing site-specific fertiliser formulations for specific crops based on soil nutrient status knowledge and production system. This requires systematic soil analysis so that the main soil types and fertility status can be determined. Systematic soil sampling, analysis and mapping for development of site-specific and balanced fertiliser recommendations has been done in other countries in SSA and therefore is a feasible proposition for Zimbabwe. For example, in Ethiopia, the project Ethiopian Soil Information System (EthioSIS) completed the fertility mapping and fertiliser recommendations for the majority of the country's agricultural land (<http://www.ata.gov.et/highlighted-deliverables/ethiosis/>). The project showed that besides N and P, which were the major focus in earlier recommended fertiliser types, deficiencies of K, S, Zn, B and Cu were common in some Ethiopian soils. The project has since recommended the use of at least 12 different fertiliser formulations that can be used to address nutrient deficiencies depending on status of the soil in Ethiopia. In Malawi, a team from the Department of Agricultural Research Service developed soil fertility maps and produced fertiliser recommendations that addressed deficiencies of other nutrients besides N and P catered for by the standard national recommendations (Chilimba and Nkosi 2014, cited by Mutega et al. 2015). The group noted widespread maize responses to S and Zn across the country and recommended widespread application of S- and Zn-containing fertilisers.

However, adoption of site-specific fertiliser recommendations following soil testing requires extensive soil sampling and analysis, which can be a challenge in SSA considering the limitations in soil testing infrastructure (Satyanarayana

et al. 2011) and high cost of soil analysis. Geographical information system (GIS) and global positioning system (GPS) based soil fertility mapping can provide an alternative that is cost effective for precise and efficient nutrient management (Lelago et al. 2016). In the last two decades, these techniques have been applied widely in soil science to explore spatial variability of physical and chemical properties of soils under grain crops and pasture in developed countries (Dobermann et al. 1997; Antwi et al. 2016). The developed soil fertility maps highlight the nutrient needs, based on fertility status of soils and adverse soil conditions, which need improvement to realise good crop yields (Verma et al. 2005). Site-specific fertiliser recommendations can then be developed to address identified soil nutrient imbalances in those specific areas.

Geolocation information

Chinhoyi, Zimbabwe: 17.36° S, 30.19° E

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Disclosure statement

No potential conflict of interest was reported by the authors.

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