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# Geographical determinants of inorganic fertiliser sales and of resale prices in north Ethiopia

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ABSTRACT

Low mineral fertiliser use received much attention in Africa over the last decades. As fertiliser sales have exponentially grown in Ethiopia, and evidence exists of a supply that is beyond the demand in the drier northern parts of the country, we investigated the geographical determinants of inorganic fertiliser sales and its resale prices in north Ethiopia. Quantitative data on fertiliser provision and prices on the black market in 2016 were obtained from official statistics and from key informants in each of the 35 studied districts and in all municipalities of the Raya area. Environmental variables were collected from spatial databases. To promote inorganic fertiliser, agricultural experts use incentives, and also barter the purchase of fertiliser by a farmer against food aid or other advantages from the authorities. The high application rate that is aimed at (200 kg ha$^{-1}$) contrasts with the dominance of less-responsive soils in the study area, for which inorganic fertiliser application does not result in higher crop yields, or even leads to root burn. The quantitative analysis shows that 40.7 $10^3$ Mg of fertiliser were officially sold in the study area in 2016, which corresponds to 52 kg ha$^{-1}$. This is notably different from the application rate, as reselling widely occurs, at 50% of the official price for diammonium phosphate (DAP) and 54% for urea, mostly to users outside the community. By accepting the opportunity offered by agricultural companies and traders, smallholders save themselves from greater losses. The black market rate is strongly and positively correlated to monthly rainfall at sowing time (July 2016) ($R^2 = 0.44$; $n = 31$; $p < 0.01$). In the four districts with spate irrigation, black market prices for inorganic fertiliser are low (35% of the official rate) and small quantities are sold officially (32 kg ha$^{-1}$). This corresponds to the farmers' saying that there "nobody needs inorganic fertiliser since the spate irrigation adds organic and inorganic nutrients yearly". We found similarities to the 'Green Revolution' in Mexico: the forced delivery of high-cost fertiliser, and the reselling at half price in the black market. Inorganic fertilisers are one of the elements that have allowed boosting agricultural production in Ethiopia; our findings indicate however that in the study area, the fertiliser policy needs to be much fine-tuned so that it is led by agronomic needs, rather than by statistics of inorganic fertiliser consumption, that hide complex environmental variability and socio-political relations.

## 1. Introduction

Sanchez (2002) stated that to overcome soil nutrient depletion in Africa, inorganic fertilisers need to be used. This author, as well as Morris et al. (2007) and Sommer et al. (2013) explain the limited use of inorganic fertiliser in smallholder agriculture in Africa South of the Sahara by (1) the high level of fertiliser prices relative to crop prices, hence a low benefit-cost ratio, (2) the low level and high variability of crop yields, (3) the lack of market information about the availability and cost of inorganic fertiliser, (4) the inability of many farmers to raise the resources needed to purchase fertiliser, (5) the lack of knowledge on the part of many farmers about use of fertiliser, (6) blanket fertiliser recommendations that ignore differences between soils, (7) untimely availability of fertiliser on the market in relation to regulations and

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procedures, (8) high rent seeking by fertiliser distribution companies, (9) the weak and dispersed nature of demand and the small market size, and (10) high transportation costs.

Geographical determinants of inorganic fertiliser application were studied at a global scale by Potter et al. (2010) who found significantly higher application rates in the northern hemisphere, with maxima centred on areas with intensive cropland. Such hot spots, approximately 10% of the treated land, receive over 50% of the global use of fertilisers. At subcontinental scale, Li et al. (2003) examined the spatial distribution of inorganic fertiliser consumption in China, where over- and underutilisation of different minerals was made spatially explicit, based on sales data. In India, Jha and Sarin (1980) used statistical data and found linkages between districts' fertiliser consumption and the share of irrigated land.

At the scale of East Africa, Guo et al. (2009) simulated and mapped inorganic fertiliser prices based on transportation costs, land cover, slope gradient, imported fertiliser price at port, storing, handling and regulation fees. A scenario analysis showed that there are opportunities to reduce farm-gate fertiliser price if an appropriate policy is made to lower transportation costs, such as improving road conditions, and to decrease handling fees. A price reduction would increase farmers' demand for fertiliser and make its application profitable. More specifically, for Kenya, Wanzala et al. (2002) identified the zones with high inorganic fertiliser consumption, linking sales statistics to agricultural potential. Low fertiliser use in Ethiopia has however been particularly attributed to market-based constraints (its relatively high cost) before factors pertaining to farming communities or agricultural potential that are important elsewhere in Africa South of the Sahara (Dercon and Christiaensen, 2011; Agbahey et al., 2015). Like in many developing countries, in Ethiopia, fertiliser distribution is strongly controlled by the Ministry of Agriculture, parastatals and cooperatives. Potential reasons for such involvement include (1) making economic input and infrastructure available which could not be mobilised by private investors, (2) monitoring agricultural development in line with national policies, (3) promoting uniform development so as to include geographical spheres that do not attract private operators, (4) effectively using land and labour by efficient allocation of scarce resources, and (5) enhancing food price stability (Timmer, 1989; Maheswaran, 2014).

According to Minot and Benson (2009), inorganic fertiliser subsidies in developing countries in the 1970s and 1980s were expensive and had limited effectiveness. Such subsidy programmes, and concomitant state monopolies in fertiliser marketing, undermined the emergence of efficient private input distribution networks. Rather than devoting public funds to subsidising inorganic fertiliser, Minot and Benson (2009) and Morris et al. (2007) argue that it is preferable for the state to invest in market development, agricultural research, or transportation infrastructure.

Due to shortages in supply, black markets for fertiliser are quite common in developing countries: they have been observed since the 1960s in India, Pakistan, Nigeria and Egypt (Merrett, 1972; Hamdani and Haque, 1978; Yapa and Mayfield, 1978; Balcet and Candler, 1981; Antle and Crissman, 1988; Chikwendu and Omotayo, 1993), and as of the 1980s additionally in China, Burkina Faso and Nepal (Oi, 1986; Matlon, 1990; Andersen, 2001). On the other hand, black markets with prices below the official rate set by the government may have various causes such as smuggling of highly subsidised fertiliser from Nigeria to Niger (McIntire, 1986), and massive reselling below officially imposed rate in Mexico in the framework of the "Green Revolution" programme of the 1950s-1960s (Hewitt de Alcántara, 1974). There, inorganic fertiliser was resold to the black market, immediately upon delivery at the cooperatives, which led to their indebtedness. The term "black market" usually refers to "those transactions which take place illegally at prices higher than a legal maximum. Essentially the same phenomenon is observed when the illegal transactions take place at prices below a legal minimum (e.g., in the case of contraventions of a minimum wage law)" (Boulding, 1947). In the latter case, a black market will develop if the official price is above the hypothetical free market price, so that at the legal price less fertiliser is demanded than will be supplied. That is on the condition that some buyers and sellers can be found who are willing to buy and sell at prices lower than the official price in spite of possible penalties involved.

As mineral fertiliser sales have exponentially grown in Ethiopia over the last decade (Sommer et al., 2013), and evidence exists of supply that locally is beyond the demand in the northern part of the country, we have investigated the geographical determinants of inorganic fertiliser sales and of its resale prices. The objectives were (1) to understand the spatio-temporal variability in fertiliser supply and demand in N Ethiopia; (2) to assess the genuine interest of farmers for fertiliser use through an analysis of sold volumes and prices on the parallel black market; (3) to link up fertiliser consumption with climatic, soil and land variables at a scale of 1600 $km^2$ districts; (4) to specifically investigate links between fertiliser consumption and access to spate and formal irrigation at a scale of 80 $km^2$ municipalities; (5) to draw conclusions that will benefit the fertiliser policy. In this way, we will illustrate complex environmental variability and socio-political relations that are not discernible when considering only the official statistics of inorganic fertiliser sales.

## 2. Materials and methods

### 2.1. Study area

The research was conducted in Ethiopia in 34 districts located in Tigray, as well as in the adjacent Kobo district (part of Amhara region). The latter was included in order to conduct a detailed analysis in the three adjacent districts that form the Raya graben, where biophysical variables are very contrasted along a topographical zonation that cuts across the three districts (Fig. 1). The study area is mainly located in the headwaters of the Tekeze/Atbara basin, with the water divide between Nile and Rift Valley near its eastern edge; the adjacent upper marginal grabens of the Danakil depression are also included in the study area. The major lithologies are Precambrian metamorphic rocks, Mesozoic sandstone and limestone and Tertiary volcanic rocks. Given the mountainous character of the study area, land characteristics are quite variable. Average elevation is 1811 m a.s.l. (which is considered as mid-altitude in Ethiopia); the highest district is Enda Mekhoni at 2604 m a.s.l. on average. The lowest district, Kafta-Humera at 848 m a.s.l. comprises extensive plains at the apex of a large alluvial fan of the Tekeze River. The mean annual rainfall ranges from 570 to 850 mm $yr^{-1}$, with a unimodal pattern (northern hemisphere summer rains), except in the southern part of the study area, where a second (shorter) rainy season in spring locally allows for the growth of two successive crops within one year (Frankl et al., 2013). Rains in the study year 2016 were slightly above average, following an exceptionally dry year 2015. In these mountainous landscapes, Leptosols are present in all districts (70% ± 22%), together with associated (cumulic) Regosols and Cambisols. On the other hand, in vast plains, frequently tectonic depressions, large Vertisol areas occur (Kobo, Kafta-Humera, Wolkait, Tselemti, Raya-Azebo and Alamata districts); Vertic Cambisols in Hintalo Wajirat form extensive plains in the central part of the district and as such are very characteristic. In Ofla, limited areas with Vertisols occur in the lacustrine Lake Ashenge plain, but these are mostly occupied by grasslands, hence have no influence on fertiliser consumption; for the rest, Ofla is dominated by Leptosols, according to the Soil Atlas of Africa (ESDAC, 2014). Detailed maps of soil fertility status and recommended fertiliser blends have been prepared with a resolution of 250 m for the whole Tigray region, based on the analysis of 4200 topsoil samples (MoA and ATA, 2014). Overall, soils have low organic matter content, high pH and generally are salt-free. This soil fertility atlas includes detailed maps at the scale of districts which is quite unique (Mamo, 2014). However, the document is either not known to local experts or at least not used in the field. Obviously, the resolution