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Agricultural waste utilisation strategies and demand for urban waste compost: Evidence from smallholder farmers in Ethiopia

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ABSTRACT

The use of agricultural waste for soil amendment is limited in developing countries. Competition between fuel and feed is the major cause for the insufficient application of agricultural waste on cropland. The aims of this study were therefore (i) to investigate variation in agricultural waste allocation between groups of farmers with different livelihood strategies and link this allocation with the nutrient balances of their production systems, (ii) to identify farm characteristics that influence utilisation of agricultural waste for soil amendment, and (iii) to assess demand for urban waste compost. A total of 220 farmers were selected randomly and interviewed using standardised semi-structured questionnaires. Four groups of farmers, namely (i) field crop farmers, (ii) vegetable producers, (iii) ornamental-plant growers, and (iv) farmers practising mixed farming, were identified using categorical principal component and two-step cluster analyses. Field crop farmers produced the largest quantity of agricultural waste, but they allocated 80% of manure to fuel and 85% of crop residues to feed. Only <10% of manure and crop residues were applied on soils. Farmers also sold manure and crop residues, and this generated 5–10% of their annual income. Vegetable and ornamental-plant growers allocated over 40% of manure and crop residues to soil amendment. Hence, nutrient balances were less negative in vegetable production systems. Education, farm size, land tenure and access to extension services were the variables that impeded allocation of agricultural waste to soil amendment. Replacement of fuel and feed through sustainable means is a viable option for soil fertility management. Urban waste compost should also be used as alternative option for soil amendment. Our results showed variation in compost demand between farmers. Education, landownership, experience with compost and access to extension services explained variation in compost demand. We also demonstrated that labour availability should be used to estimate compost demand beside cash.

1. Introduction

Urban and peri-urban agroecosystems are common in many countries, and they are often characterised by a surplus nutrient balance due to the intensive use of fertilisers and heavy irrigation with waste water (Khai et al., 2007; Wang et al., 2008; Diogo et al., 2010; Abdulkadir et al., 2013). In contrast, some studies showed negative nutrient balances and hence declining soil fertility in urban and peri-urban farming systems (Tewodros et al., 2007). Mineral fertilisers have been used to improve and maintain soil fertility and crop production; however, this is a challenge for many smallholder farmers because mineral fertilisers are expensive (Kassie et al., 2009; Dercon and Christiaensen, 2011). Hence, the integration of mineral fertilisers with organic amendments (e.g. animal manure and compost) has been recommended to increase crop production (Negassa et al., 2005). Organic amendments could also increase or maintain soil organic matter contents and thereby contribute to enhanced fertiliser use efficiency.

The use of organic amendments in cropping systems is the most viable option for farmers to maintain their field in a productive state. The benefit of organic amendments is not new for many farmers. However, only small fractions of animal manure and crop residues are retained on farmlands in many developing countries due to the low production of manure, the limited availability of labour and the inefficient collection of manure (Tittonell et al., 2005; Kassie et al., 2009; Baudron et al., 2014). In addition to this, high competition of agricultural waste with other uses (e.g. feed and fuel) results in insufficient application of organic amendments in soils, and this competition has become a major concern. For example, utilisation

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of agricultural waste for feed and fuel has been identified as a major cause for the slow adoption of conservation agriculture in sub-Saharan Africa and South Asia (Mekonnen and Köhlin, 2009; Baudron et al., 2014; Valbuena et al., 2015). Nevertheless, more than 10 t ha^{-1} of organic amendment are still recommended for resource-poor farmers in many developing counties (Negassa et al., 2005; Hou et al., 2011) but such recommendations do not consider competition in the utilisation of agricultural waste.

It is important to identify the current uses of agricultural waste across different farmers groups and livelihood strategies because it explains the causes for minimum application of organic amendments for cropping systems. It is also essential to determine the farm characteristics that impede farmers using agricultural waste for soil amendment. Baudron et al. (2014), Rimhanen and Kahiluoto (2014), Valbuena et al. (2015) found that most of the crop residues are fed to livestock in sub-Saharan Africa and South Asia countries. In contrast, the majority of farmers in Western Kenya, India and Bangladesh retain over 80% of crop residues on farmland (Baudron et al., 2014; Valbuena et al., 2015). This variation could be due to the difference in degree of agricultural intensification and high competition of agricultural waste with other uses such as feed or fuel (Baudron et al., 2014). Another reason could be differences in terms of farm characteristics and livelihood strategies. Therefore, we hypothesized that farmers with different production goals, degree of intensification and socioeconomic status have different agricultural waste utilisation strategies. For example, subsistence field crop farmers may prefer to utilise agricultural waste for feed or fuel. In contrast, vegetable producers might apply more manure and retain more crop residues on fields than cereal producers because vegetable production demands a high nutrient input and generates a rapid economic return (Abdulkadir et al., 2013). Similarly, land entitlement might encourage farmers to allocate large quantities of agricultural waste to soil amendment. Availability of labour, farm size and distance could also determine farmers' decisions to allocate agricultural waste for soil amendment since investment is required to transport agricultural waste (Tittonell et al., 2010). However, no studies have been conducted to explain variation in utilisation of agricultural waste across different livelihood strategies and production goals.

It is clear that only very small fractions of agricultural waste are allocated to soil amendment in many developing countries (Tittonell et al., 2010; Baudron et al., 2014; Jaleta et al., 2014; Rimhanen and Kahiluoto, 2014). Therefore, other organic resources (e.g. urban waste) should be considered as an alternative option for soil amendment in urban and peri-urban farming systems in developing countries. Previous studies have suggested the use of urban waste compost to enhance urban agricultural production (Danso et al., 2006; Mary et al., 2010). However, there are very few studies on urban waste compost demand between different farmers groups and production goals using contingent valuation method (Danso et al., 2006). Contingent valuation method (CVM) is a widely used method to estimate the economic values of environmental services (Danso et al., 2006). Thus, the specific objectives of this study were: (i) to investigate the utilisation of agricultural waste between different urban farmers and link this use with partial nutrient balances, (ii) to identify farm characteristics that influence farmers' decisions to use agricultural waste as a soil amendment, and (iii) to assess the demand for non-agricultural waste (i.e. urban waste) compost.

2. Materials and methods

2.1. Study area

The study was conducted in Addis Ababa, the capital city of Ethiopia. Addis Ababa is located between 2400 and 3100 m above sea level and has a total land area of 530 km^2. The average low and high temperatures are 10 and 25 °C respectively. Annual precipitation is 1180 mm. It has a unimodal rainfall regime starting in June and lasting until September. The dominant soil type is Vertisol, and the parent material is olivine basalt (Tekalign et al., 1993). Urban farmers who grow crops in the study area are approximately 7000 (Mengistu, 2013). Teff (Eragrostis tef), wheat (*Triticum* sp.) and chickpea (*Cicer arietinum*) are the main crops grown in the area. Cabbage (*Brassica oleracea*), Ethiopian mustard (*Brassica carinata*), potato (*Solanum tuberosum*) and carrot (*Daucus carota*) are the main vegetables grown. Cattle, donkeys and sheeps are the main livestock types kept by farmers. The poor solid-waste management system is one of the main problems in the city. The current waste generation is about 1000 tons day^{-1}. The average daily waste generation is 32 kg $person^{-1}$ $year^{-1}$ (Guerrero et al., 2013). About 76% of the urban waste is household waste and over 50% of the urban waste consists of organic materials that can be recycled into compost (Regassa et al., 2011). From the total waste generated, only 65% is collected, and the remaining 35% is dumped on open sites, drainage channels, rivers and streets (Guerrero et al., 2013). Currently, less than 5% of the urban waste is composted (Mengistu, 2013).

2.2. Socioeconomic survey

Areas that represent the current agricultural systems and heterogeneities of livelihood strategies were selected using secondary sources and governmental and non-governmental organisations. Discussions were held with key informants who worked in agricultural offices in order to obtain information about the farmers, their locations and other relevant information. A total of 220 households were randomly selected, and individual farmers were interviewed using a standardised semi-structured questionnaire and informal conversation. The sample size was determined according to Israel (1992) who recommended a minimum of 200 samples for population size between 5000 and 10,000 at 95% confidence level and 7% precision level. The questionnaire was pre-tested with 12 respondents and modifications were made on the basis of this pre-test. Field observations and discussions with key informants, and governmental and non-governmental organisations (NGOs) were used to supplement the household interviews. The qualitative and quantitative variables used in the study are given in Table 1.

2.3. Sampling and laboratory analyses

Samples were collected from soil, plant, irrigation water, manure and compost to quantify partial balances of nitrogen (N), phosphorus (P), and potassium (K) across different farms. Three farms were selected from each farmers group after we identified different farmer categories. The farms which represent each category were selected through detailed observation, discussion with farmers and development agents. Three sub-plots (1 m^2) were prepared in each farm (Abdulkadir et al., 2012). Soil and plant samples were collected from these sub-plots. Composite soil samples were taken from the 0–25 cm layer and air-dried for laboratory analysis. The hydrometer method was used to determine soil texture, and pH-H_2O was measured in a 1:2.5 soil-to-water suspension. Soil carbon was analysed using the Walkley–Black method, total N using Kjeldahl digestion, available P using Olsen extraction and soil K using aqua Regia digestion (Van Reewijk, 1992). Plant, manure and compost samples were also collected and weighed immediately after sampling to determine fresh weight. Plant samples were oven-dried at 60 °C for three days, then ground and sieved for N, P and K analyses (Van Reewijk, 1992). Nitrogen in plant tissue was analysed using