Towards sustainable agriculture: the case of tea nutrient budgeting in the smallholder sub-sector in Kenya

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Abstract Sustainable agriculture in tea production has become a concern due to the pressures of the high fertilizer costs and increased focus on environmental protection. Greater attention is now being paid to efficient use of external inputs to avoid land degradation. Nitrogen phosphorus and potassium are the major nutrients in tea (Camellia sinensis) cultivation under commercial conditions. The smallholder tea sub-sector alone in Kenya on average imports an equivalent to 14,560 N metric tons, 2,800 P\textsubscript{2}O\textsubscript{5} metric tons and 2,800 K\textsubscript{2}O metric tons, and exports via processed made tea an equivalent of 9,618 N metric tons, 1,420 P\textsubscript{2}O\textsubscript{5} metric tons and 4,634 K\textsubscript{2}O metric tons. These figures are not sustainable and urgent efforts are necessary to develop threshold limits or symptoms of change that can serve as a wakeup call (before the effects become visible). Product diversification as in tea value addition factories that deal with extracts should be encouraged to avoid or reduce most of these unsustainable exports of NPK in processed tea, while the extracts are recycled. Similarly, increasing domestic consumption of our Kenyan teas will reduce the amounts of NPK exported out of the country by the black CTC teas.

Keywords Sustainable agriculture, Restorative management, Tea nutrient budgeting, Camellia sinensis

Introduction Sustainable Agriculture

In recent years, sustainable agriculture has become a concern due to the pressures of the increasing fertilizer costs and increased focus on environmental protection. There is greater attention being paid to the efficient use of external inputs, including fertilizers. The need to optimize fertilizer inputs to meet crop requirements have also increasingly been identified as priorities for research in feedback from tea stakeholders. Nitrogen phosphorus and potassium are the major nutrients of tea plant, Camellia sinensis required to achieve commercial levels of production. Land degradation sets in when the potential productivity associated with a land use system becomes non-sustainable, or when the land is not able to perform its environmental regulatory function.

Restorative management, including appropriate inputs and technology, can reverse the negative effects of over-exploitation by humans. But lacking the capability or incentives (tenure) to invest in land, small scale farmers tend to over-exploit their limited resources. In the process, soil, the key component of land, loses quality and becomes infertile, more erodible and compacted.

Sustainable land use implies harmony between man’s use of land and the land’s ability to maintain or renew its quality. Degradation sets in once this balance is upset. This damage can be manifested when soil loses life-sustaining topsoil (through erosion) and some essential nutrients (through nutrient leaching and export).

Nutrient Budgets

Whole farm budgets that compare the quantities of nutrient entering the farm with the outputs of products provide a relatively easy measure of likely changes in the nutrient status of farms and have been studied in many places and in different crops (Fleming, 2003; Smaling and Fresco, 1993; Surendran et al., 2005; Topp et al., 2001; Van der Werff et al., 1994) including
policy making (Roy, 2004; Scoones and Toulmin, 1999). They can provide early indication of potential problems arising from (i) nutrient surplus (inputs>outputs) leading to an accumulation of nutrients and increased risk of loss, or (ii) a deficit (outputs>inputs) depleting nutrient reserves and increasing the risk of deficiencies and decreased crop yields. These simple budgets help farmers and researchers to understand the factors influencing the farm nutrient status (Cuttle, 2002).

Nitrogen, phosphorus and potassium losses primarily arise from soil erosion, crop harvesting and, for nitrogen (N) and potassium (K), from leaching. An estimated 230 million tons of plant nutrients are removed from agricultural soils annually (Vlek et al., 1997). Balanced against this is the global fertilizer consumption of nitrogen (N), phosphorus oxide (P$_2$O$_5$) and potassium oxide (K$_2$O) of about 130 million tons. In the case of nitrogen the fertilizer supplements are augmented by an estimated 90 million tons from biological fixation. Thus, within the margin of error, the nutrient balance worldwide is in equilibrium. Regionally the story is quite different. Developing countries consume half the global fertilizer production, with most of it on cereal crops grown on the irrigated lands of Asia, or on cash crops. Low inputs and limited re-cycling of nutrients by poor smallholders in these areas lead to negative nutrient balances that render continued crop production unsustainable (Stoorvogel and Smaling, 1990). The negative nutrient balance, due to inadequate external inputs, and the inequitable distribution of nutrients between and within countries, is exacerbated by the transport of nutrients in harvested products. On a global scale, it has been reported that international trade in food commodities lead to a significant negative balance in exporting countries and accumulations in importing countries (Miwa, 1992). The environmental impacts of inter- and intra-national nutrient flows are commonly concentrated in the burgeoning cities. This negatively aggravates the ‘mining’ of rural soils where the products are produced. Nutrients can be re-cycled through the addition of the waste from the products to crops. In spite of the obvious benefits, the extent of re-cycling is limited in most cities as the transport costs are often prohibitive. These flows of nutrients today are greatly enhanced by human intervention in the natural ecosystem. Reversing these trends through better management is certainly within our reach, but there will be a price for it.

The case of the smallholder tea sub-sector in Kenya

In 2010, Kenya Tea Development Agency (KTDA) imported 56,000 metric tons of NPK 26:5:5 for smallholder tea growers (KTDA, 2010-2011). This was equivalent to 14,560 metric tons of nitrogen (N), 2,800 metric tons of phosphorus oxide (P$_2$O$_5$) and 2,800 metric tons of potassium oxide (K$_2$O). Ironically, only farmers practicing Good Agricultural Practices (GAP), could expect the equivalent. The same year, 224,981 metric tons of processed tea was produced using the fertilizer and 95% were exported from Kenya. Assuming NPK contents in the young harvestable two leaves and a bud of 4.5%N, 0.29%P, and 1.8%K (Kamau, 2008), this was equivalent to 9,618 metric tons of N, 1,420 metric tons of phosphorus oxide (P$_2$O$_5$) and 4,634 metric tons of potassium oxide (K$_2$O). In other words, these high amounts of nutrients were mined from the smallholder tea farmers’ fields that do not optimize on GAP (Owuor, 2011). The difference between imported NPK in fertilizer and exported NPK in metric tons processed tea were 4,942 N, 1,380 P$_2$O$_5$, and negative 1834 K$_2$O (Figure 1). The finding would be much higher if the all the teas grown in Kenya (i.e. large estate and smallholder sub-sectors) were taken into consideration.

![Figure 1 NPK metric tons import as fertilizers & export as processed tea in KTDA](image-url)
When NPK use agronomic and apparent recovery efficiencies are taken into consideration, the difference between imported NPK in fertilizer and exported NPK in processed/made tea would be much higher. This hardly solves the problem of nutrient depletion in tea growing areas. If the nutrients imported in processed tea ends up as waste in the major cities, as would be expected, the rural lands suffer severe nutrient depletion. The result highlights the potential for nutrient re-cycling in peri-urban and urban agriculture. Vlek (1993) estimated that in 1987 the export of nitrogen (N), phosphorus oxide (P₂O₅) and potassium oxide (K₂O) in agricultural commodities from sub-Saharan Africa, mainly in cotton, tobacco, sugar, coffee, cocoa and tea, was 296,000 tons. The high exportation of nutrients in the form of cash crops from the sub-Saharan Africa, basically negates the positive balance due to food imports.

The total net global flows of nitrogen (N), phosphorus (P) and potassium (K) in the form of commodities, estimated in the study of Craswell et al. (2004), are 4.8 million tons in 1997 which will be 8.8 million tons in 2020. Nitrogen is the most dynamic nutrient and after transformation can move in the atmosphere, as well as in aquatic systems. The amounts of nitrogen (N) involved in transfers through trade are ecologically significant especially when the 2020 projections are considered. Potassium and phosphorus transfers are also significant and may provide opportunities for the eventual re-cycling of the important nutrients, especially given the high cost of potassium mining and transportation. It is therefore important for each country to consider the effects of nutrient flows in food trade on its own ecosystem. The economic impacts and implications of perturbations to nutrient cycles in tea are yet to be looked at.

Conclusions and Recommendations

Soil quality is the key to agricultural productivity where its loss is attributable in large part to the loss of nutrients from the system. There is an urgent need to monitor the fate of our land and soils, and to develop indicators that can predict the onset of soil depletion. The smallholder tea sub-sector alone in Kenya on average imports an equivalent to 14,560 N metric tons, 2,800 P₂O₅ metric tons and 2,800 K₂O metric tons, and exports via processed made tea an equivalent of 9,618 N metric tons, 1,420 P₂O₅ metric tons and 4,638 K₂O metric tons. These figures are not sustainable and urgent efforts are necessary to develop threshold limits or symptoms of change that can serve as a wakeup call (before the effects become visible). Product diversification as in tea value addition factories that deal with extracts should be encouraged to avoid or reduce most of these unsustainable exports of NPK in processed tea, while the extracts are recycled. Similarly, increasing domestic consumption of our Kenyan teas will reduce the amounts of NPK exported out of the country by the black CTC teas.

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