Evaluation of phosphorus dynamics from renewable sources to meet crop demand and minimise environmental pollution in Malawi.

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Research background

A rapidly increasing global population will come with an increasing demand for food. In order to meet this demand, without expanding the area used for agriculture, it must become more intense, which means increased fertiliser inputs. One of the essential components of fertiliser is phosphate, which is mined, and its reserves are being depleted.

Over 70% of people in Malawi live on less than $1.9 a day. Almost 80% of Malawian farmers practice subsistence farming; their major food crop is maize though a few farmers grow legumes like soybean, pigeon peas, common beans and groundnuts for income. As in most tropical countries, the soils in Malawi are infertile and highly weathered. Farmers must apply chemical fertilisers to harvest enough food to feed their families, but only less than 50 % of smallholder farmers use fertiliser. Malawi imports almost all fertilisers it needs, and being a landlocked country, import costs mean that the price of chemical fertilisers is too high for most smallholder farmers, and prices are expected to continue rising. Malawian farmers are also negatively affected by climate change: severe droughts, floods and extreme temperatures combined with the farmers' dependence on a few crops increase their vulnerability even more.

Using organic fertilisers (market waste compost, faecal sludge compost, etc.) is a cheap and sustainable alternative to inorganic phosphate. Unlike expensive inorganic fertilisers, organic fertilisers also add organic matter to the soils, which improves the soil's ability to supply other nutrients to crops and improves water holding capacity, increasing the crop's survival chance during drought periods.

Besides, recycling organic waste and faecal matter into fertilisers offers a sanitation solution and reduces water contamination. The use of faecal sludge as fertiliser encourages the proper discharge of faecal materials from pit latrines and septic tanks and creates business opportunities for those involved in the production of organic fertilisers.

The objectives of this research are:

1. To characterise and quantify the sources, the flows, and the sinks of phosphorus in Malawi to determine options for waste minimisation, recovery potential, and chemical fertiliser reduction
2. To evaluate phosphorus mineralisation and crop uptake from recycled sources in different soils
3. To evaluate the impact of using recycled fertiliser products on soil health status and crop yield.

Methodology summary and results for each objective

In order to achieve the set objectives, two different studies were conducted. The first study was the phosphorus flow analysis for Malawi and the second one was field studies to evaluate the performance of organic fertilisers after applying to maize.

Objective 1

The phosphorus flow analysis used data from, Food and Agriculture Organisation (FAO) database, Malawi National Statistical office, Journal articles, and interviews were collected for objective one. The data were on exports and imports of chemical fertilisers and food products, human population, the phosphorus content of food items consumed in Malawi, phosphorus content in soils, and types of sanitation facilities. All these data were entered in STAN software to produce a flow diagram showing the phosphorus flows, sinks/stocks and quantities. It was from this flow diagram that points and areas where phosphorus can be recovered were identified

The results showed that there are 35000 Mg of recyclable organic P annually, which is over two times Malawi's annual P fertiliser demand (14000 Mg). Currently, only 16% of the organic P is recycled to agriculture. Chemical P fertiliser represents 66 % of the P fertiliser used for crop production. Manure is the most recycled organic P source (38 % recycled), followed by organic solid waste (6%), and crop residues (5%). Annually, 9000 Mg of P is transferred to faecal matter, but none is recycled. Overall, Malawian soils have a negative P balance of -4000 Mg. Malawi can reduce its dependence on imported chemical P if recycling of organic P source is adopted. However, regulations should be put in place to control the quality of organic fertilisers. Countries like Uganda have policies governing the quality of organic fertilisers ranging from nutrient content to pathogens. So Malawi, through the Malawi bureau of standards, should set guidelines that all organic fertilisers should follow to make sure that consumers are protected from diseases while providing the best fertilisers for crop production.

These results were published in Resources, Conservation and Recycling Journal.

Objectives 2 and 3

The faecal sludge and organic waste from flow the phosphorus flow analysis were made into two organic fertilisers (compost). There was pure organic waste compost and a mixture of organic waste and faecal sludge compost. Maize was used as a test crop. These organic fertilisers were evaluated for their ability to release and maintain phosphorus concentration in the soil for plant uptake (objective 2), and their impact on soil health status and crop yield (objective 3) compared to chemical fertilisers. The field experiments were conducted in two sites for two years.

For the second objective, the results showed that available P in the soil from three weeks after planting to nine weeks was the same regardless of the fertiliser used. In Malawi, the available soil phosphorus should be more than 18 mg/kg for maize production, and the organic fertilisers had 25 mg/kg P in the soil throughout the growing period of maize. The phosphorus source did not affect the maize PUE (Phosphorus Use Efficiency). The results indicate that organic phosphorus sources could be used as alternative P sources for maize production in Malawi since they could maintain the concentration of P in soil solution just like NPK fertiliser.

The results for the third objective showed that soil organic matter, Soil pH, and earthworms selected as soil health indicators, increased when organic fertilisers were applied. In addition, the maize yield was the same regardless of the type of fertiliser used.

The individual studies conducted as part of this research have been completed and the results and analyses have been compiled into a complete PhD thesis and submitted to the School of Water, Energy, and Environment at Cranfield University.

Impact on the community and my career

The results obtained show that there are enough organic P sources in Malawi that can be applied to crops. Organic fertilisers made from organic market waste and faecal sludge are potential sources of organic P. The field studies conducted using these sources of organic P affirmed that using organic fertilisers as a source of phosphorus produces the same results as the chemical phosphate fertilisers and in addition, improve soil health. Malawi can reduce the import cost and protect itself from fertiliser price changes on the international market by recycling phosphorus from within the country. Recycling phosphorus from waste materials will reduce production costs for smallholder farmers, ensure household and national food security, and improve soil health status, leading to sustainable crop production. Furthermore, the use of faecal sludge, manure, and organic market waste as fertiliser reduces water contamination from pathogens, e.g. *Salmonella sp* and phosphorus, as the materials are adequately treated and utilised.

The research was conducted in conjunction with the Department of Agricultural Research Services (DARS) in the Ministry of Agriculture. Each year (for two years), a field day was held at both experimental sites for the people to see how the organic fertilisers were performing against the chemical fertilisers. The people were also given detailed explanations on the organic fertilisers' application rates and application time for better results. Furthermore, DARS technicians are teaching other farmers on organic farms with some information from this research.

The opportunity to do this PhD through the support of the Sue White Fund is a big step in my career. I have gained relevant knowledge, skills and experience, which will open more opportunities for me. This PhD has enabled me to secure a job at a local university (Mzuzu University) as a lecturer. Through this job, I will share the knowledge I have acquired with students, and I will be able to proceed with research in my area of focus. It is also my intention to look for post-doctor opportunities to enhance my research skills.

Lastly, let me thank Sue White Fund for giving me this opportunity to do my PhD at Cranfield. You have given me a chance to contribute to my country and the world.