Could African farmers slash their reliance on mineral fertilizers by growing legumes?

April 28 2023, by Lalaina Ranaivoson, Aude Ripoche, François Affholder, Gatien Falconnier and Louise Leroux

Credit: CC0 Public Domain

Ending hunger by 2030 is one of the Sustainable Development Goals set by the UN. This is a huge challenge in sub-Saharan Africa, where one

third of all households are still exposed to food insecurity. To meet the demand of the rapidly growing African population, there is widespread consensus that farmers need to boost cereal crop yields.

Crop yields in the region are severely limited by depleted soils, following decades of relentless cropping with insufficient fertilization. This is because African farmers struggle to access affordable mineral fertilizers, while a lack of biomass also places organic fertilizers out of reach.

Currently, the quantity of nitrogen input would need to increase 15-fold to produce the cereal crop yields required for food security.

The precious nutrients in green manure

Mineral fertilizers provide one solution to inject nitrogen into crops. Although they are crucial for improving cereal crop yields, they can nevertheless harm the environment if used in excess, and are often too expensive for farmers. The war in Ukraine has only worsened the region's fertilizer shortage, though prices have stabilized since their peak in 2022.

Another fertilizing method seeks to harness the nitrogen from legumes. Through symbiotic bacteria, these plants have the unique ability to fix nitrogen present in the atmosphere to their tissues. To secure it for cereals cultures, farmers can adopt a technique consisting in growing legumes and pushing their residues into the soil prior to sowing cereals seeds.

This effect is well known in temperate and tropical systems, but can vary considerably from one year to another. In cases where there is an abrupt temperature increase, legume residues will decompose more rapidly, while heavy rains can cause the nitrogen obtained by residue decomposition to leach.

Fertilizers, climate and rice growth in Madagascar

For more than 20 years, FOFIFA (institute of agronomic research in Madagascar) and CIRAD have been exploring different avenues aimed at sustainably intensifying agricultural production in Madagascar and alleviating poverty.

In a recent study, we looked at the possibility of boosting the yields of a rain-fed rice fields in Madagascar by replacing some of the mineral fertilizers with green manure. The country's state policy provides for an increased in rice production in order to ensure food self-sufficiency in the country.

Both the saturation of the floodplains used for irrigated rice and the emergence of upland rice varieties have led many farmers to take up rain-fed rice cultivation in Madagascar's highlands.

However, they currently obtain an average yield of 1.6 t/ha, which is well below the maximum yield of around 4 to 6 t/ha that can be obtained in research stations under experimental conditions, in other words when nutrients are not limited and when pests—insects, diseases, weeds—are controlled.

Mucuna and Crotalaria

In our experiment, the green manure grown was a combination of "Mucuna" and "Crotalaria" legumes. Thanks to their complementary growth and above-ground structures, these two plants can produce a large quantity of plant biomass and thereby fix atmospheric nitrogen. This green manure was grown during the rainy season in the first year of a two-year rotation based on rain-fed rice, and residues were then incorporated into the soil, before tillage and rice sowing for the

following crop season.

The rotation was repeated twice for the purposes of the experiment and compared to rice monoculture. We conducted in-depth monitoring of this experiment, measuring the quantity of nitrogen in soil and plants, the dynamics of rice growth, the biomass produced and the grain yield. The data collected enabled us to adapt a crop simulation model to the case of rain-fed rice in Madagascar, in order to reproduce the impact of green manure incorporation and decomposition on rice growth.

A promising model

The model then enabled us to explore the potential advantages of green manure for rice growth, for 24 hypothetical rice growing seasons, built using climate measurements corresponding to our study region, for the period from 1994 to 2018. In this virtual experiment, we set the quantity of green manure incorporated into the soil prior to rice cultivation at 6 t/ha (or 140 kg of nitrogen), based on results obtained in the field.

Our findings showed that the cultivation and integration of green manure made it possible to reduce the mineral fertilizers required to improve rice yields. We set the target yield at 3.7 t/ha, or 75% of the maximum yield obtained in the on-station experiments. We achieved this with 40 kg/ha of nitrogen provided by mineral fertilizers when green manure was added to the soil. By way of comparison, more than double this quantity or 100 kg/ha, was necessary without the use of green manure.

Trade-offs to be made

This promising practice nevertheless requires considerable adjustments to make it appealing to family farms in Madagascar. Three key aspects need to be taken into consideration.

First, and as previously noted, heavy rainfall will dampen the benefits of green manure on rice productivity. To tackle this, farmers will have to dynamically manage residues and fertilizers and tailor them to individual crops.

Next, the gains linked to the use green manure do not entirely offset the losses resulting from its cultivation. In the process, farmers have to use a part of the land that would otherwise serve to grow rice for self-sufficiency. Crop rotation remedy this problem, as well as helping (control pests, nematodes and weeds, higher soil fertility over time and maintain biodiversity).

Finally, crop residues are typically left on the land to be grazed by cattle in the region. Alternative solutions are therefore required to feed cattle, and suitable value chains need to be developed to guarantee supplies for these farmers, who often live a long way from any infrastructure. It is also essential to once again ensure that mechanisms exist to offset this additional spending for farms, the majority of which live on less than 540 euros per year per agricultural worker.

Dual purpose legumes

Obstacles linked to rainfall can be overcome by adjusting the dates at which green manure is incorporated and rice is sown. The model that we have calibrated can help to make this type of assessment in silico.

Likewise, farmers needn't have to make the choice between food security and fertilizers. Certain pulse crops, such as groundnuts, can be both used as green manure and sustenance for farmers. Experiments in Southern Africa are currently focusing on the assessment of these "dual" legume crop rotations. However, it is important to ensure a market exists for these products with a sufficiently high price.

Time is short, but we are convinced that a change can occur rapidly to transform the current cereal production system toward greater productivity and sustainability. Solutions exist, including green manure, but extension officers, researchers, value chain actors and policymakers need to help farmers to invest in these techniques that will maximize production in the short term, but will be more sustainable in the long term.

Recent decades have seen the emergence of many talented African researchers. Now it is up to the leaders to make decisions.

Provided by The Conversation