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Malawi

Topic #6

Improved soil management techniques for poverty reduction in Malawi

Malawi's population is the most rural in the world. Any attempt to understand and repair the problems of Malawi must begin with the agricultural smallholder. More than half of Malawi's population lives below the poverty line, and 22% of the population lives in ultra-poverty. (Republic of Malawi). People in the ultra-poor segment of the population can typically meet two thirds or less of their daily caloric needs through agriculture (Southern Africa Development Community 2007). Poverty is primarily concentrated in the northern and southern rural areas. The poor in these areas are nearly all agricultural smallholders, with just 8% of the population in rural areas relying on wages for income (Republic of Malawi). Malawi also has a very high rate of AIDS, which has contributed to substantial support from international donors (World Bank 2008). Humanitarian efforts account for roughly 20% of Malawi's GDP. Malnutrition is a major problem in Malawi. Maize is the staple crop of Malawi's subsistence farmers, and even when maize provides adequate calories, it lacks sufficient nutritive value. Malawi's other major crop is tobacco, which acts as a cash crop. The problem here is that both tobacco and corn heavily deplete the nutrients in the soil they are grown in, and over time they develop a very high need for fertilizer. Because fertilizer is expensive and soil management techniques are nonexistent, poor farmers are often left with land that cannot produce the crops it should be capable of producing. If crop rotation were implemented, it would provide both increased yields by maintaining the soil and decreased malnutrition by providing a new plant with a different nutrient profile. Another problem with soil management techniques is tilling soil, which allows the organic carbon content to decay. The introduction of home scale Biochar production could help alleviate this problem by providing a new stable source of soil carbon, which would improve yield and help the soil resist degradation. The problems of Malawi are severe, but the proper implementation of soil management could help reduce them in numerous ways.

A typical poor agricultural smallholder family in Malawi will have 6-7 members. These family members will manage less than an acre of soil, tilled by hand, on which they will most likely grow only maize. If they have another food source, it will likely be a goat or a pig and several chickens. Because they can generally only meet about two thirds of their calorie needs through their maize, they will often work with a better-off family to trade labor for food in a system called "Ganyu." The need for these jobs almost always exceeds their availability; even with the food they can acquire through Ganyu, poor families are generally unable to fully meet their calorie needs. A typical family in this category will be able to acquire only about 90% of their needed calories through these systems, leading to chronic problems with malnutrition (Southern African Development Community). The primary difference between a poor family and a better off one is ownership of cattle. A family that owns cattle will have a source of milk, and generally one or two oxen, enabling them to plow much larger areas of land; often more than 6 acres. In 2006, the government of Malawi conducted a study of the factors that contribute to poverty. This study found that one of the most significant indicators of poverty is household size. Better-off smallholder families are generally smaller, and can make up the difference in available labor by hiring laborers. Although the study found that members of female-headed households work longer on their own fields, they are generally poorer. They may find it more difficult to find employment outside of their farms, and they rarely grow cash crops. Education is another significant factor in determining household income. The change in income produced by completing primary education is approximately 12%, while the change in status produced by having completed secondary education is even larger-about 40% (Republic of Malawi).

Poor farmers generally subsist on a diet that consists solely of maize. This is because maize is carbohydrate rich and can ward off starvation. However, no single food source can adequately provide all of the 17 mineral nutrients, 13 vitamins and 9 amino acids that humans need to consume in order to survive (Grusak and DellaPenna 1999). The white maize commonly consumed by subsistence farmers in Malawi is devoid of Vitamin A, C, D, and B_{12} , and the amino acids lysine and tryptophan. It also contains inadequate amounts of niacin and zinc. This leads to severe problems with malnutrition. Malnutrition is most severe among children, and causes stunting, which is present in approximately 44% of the population (Republic of Malawi). This leads to an extremely low life expectancy, about 37 years, and high rates of infant, maternal, and childhood mortality. Better off families can produce cassava and sweet potatoes, which adds some diversity to their diets. Probably the best way to decrease malnutrition is to introduce the cultivation of legumes, which generally have a very different nutrient profile than maize. Because they are nutritionally different, the can complement each other to form a more balanced diet. Some possible legumes that are found in Malawi include groundnuts (peanuts), soyabeans (soybeans), and pigeonpeas. The introduction of these plants into effective crop rotation systems would substantially improve nutrition.

The current absence of effective soil management strategies leads to serious problems in terms of soil fertility and degradation. Before a forest area is cleared, the soil is fertile and useful. Organic carbon and nitrogen exist in high enough levels to maintain fertility. After clearing, monoculture cultivation of maize rapidly depletes soil nitrogen, as does the cultivation of tobacco, a key cash crop. Without new sources of nitrogen, fertility falls drastically, as soil nitrogen levels stagnate at around 50% of their original value (Walker and Desankker 2004). In order to increase the level of nitrogen in soil, the government of Malawi has recently instituted subsidies for inorganic fertilizers. The problem with these strategies is that they do nothing to sustainably and permanently improve soil fertility. The farmer must continue buying fertilizer year after year, which is an economic strain. In addition, these programs are often short-lived, and when they stop, they leave the farmer in the same situation they were in when the program started. As a result, it is necessary for sustainable ways to improve soil nitrogen to be implemented.

The first strategy is crop rotation or intercropping with a legume. Legumes fix nitrogen in the soil, improving soil fertility without the addition of inorganic fertilizer. The legumes already grown in Malawi would likely work effectively. In addition to improving yield, crop rotation would provide some element of risk mitigation to smallholders. If one crop fails due to a pest or weather event, the other crop may survive and yield, allowing farmers to continue to have a food source even in the face of a total loss in one crop. Rotation can also reduce the prevalence of pests, which may survive in the soil during monoculture cultivation but could be mitigated if the plant that is planted during that year is not one that they are capable of feeding on.

Another major barrier to soil productivity in Malawi is the decay of soil organic carbon that occurs after forest areas are cleared. Cultivation requires plowing, which exposes the plow layer to air and leads to degradation. Sustained cultivation also substantially reduces the input of organic matter to the soil, as there is no litter to fall off trees or other plants and resupply lost carbon. During cultivation, the soil plow layer can lose 55% of its useful organic carbon (Walker and Desankker 2004). Organic carbon maintains soil cation exchange capacity (CEC). When a soil's CEC falls, it becomes unable to hold nutrients, which then leach out of the soil with rainfall or become unavailable. If a soil has low CEC, attempts to return nitrogen to the soil are effectively useless; the soil may already be holding its entire capacity for nutrients, and new nutrient input may have no effect. Current strategies for increasing the input of carbon to soil have centered on returning litter from the crops, such as corn stover and the litter from legumes. While beneficial, this strategy is not as useful as it could be because the carbon that is added back to the soil in this form decays very quickly-within a matter of a few years. A strategy that could substantially increase the half-life of carbon in the soil is the addition of Biochar.

Biochar is a soil amendment produced through the pyrolosis of biomass. It is similar to charcoal, although it is produced at higher temperatures (around 400° C) and ideally contains very little ash. It has gained attention recently for a variety of reasons. First, it generally has a very high cation exchange capacity, so adding it to soil increases the soils ability to hold nutrients. As a result, it has been shown to improve productivity even beyond that of soils generally regarded as highly fertile. The other reason it has gained attention is its high carbon content, combined with its stability in soil. The carbon in Biochar has the greatest average age in soil of any C fraction. Although the exact half-life is debated, and somewhat dependant on the conditions and type of char, the carbon it contains has a half-life of at least 300 years in soil, although some studies have estimated the half-life may be as high as 6,623 years, and charcoal has been found from forest fires over 10,000 years ago (Lehmann and Joseph 2010). For the practical purpose of agriculture, the carbon is bound there effectively permanently. This property of Biochar has gained attention recently due to concerns about global warming and its potential to sequester carbon.

The discovery of Biochar by modern scientists has occurred relatively recently. The initial interest in it actually originated in the Amazon rainforest. Amazonian soil, known as ferralsol, is surprisingly poor. It is toxic for most agricultural plants because it has high levels of available aluminum, combined with low levels of available nutrients; most crops cannot survive in them. However, in 1871, Charles Hartt remarked that there were small areas of extremely fertile soil, now known as terra preta; Portuguese for black soil (Lehmann and Joseph 2010). For most of the next century, various theories were debated about their origin. Recently, it has been found that these soils contain very high levels of charcoal, and their distribution suggests an anthropogenic origin. In an attempt to attempt to recreate the production of these highly fertile soils, Biochar was created. Because the creation of terra preta stopped when the Portuguese arrived more than 500 years ago and the soils are still highly fertile, soils amended with Biochar are considered permanently improved. If smallholders in Malawi could recreate the fertility of terra preta, they would be able to completely eliminate hunger.

The only other known way for smallholders in Malawi to maintain their soil organic matter is long-term fallowing (Hardy). Smallholders are incapable of leaving fields fallow for years at a time because this would decrease their calorie consumption in the years they did, and they are already on the brink of starvation. The application of carbon in the form of Biochar does not have this limitation, and is more suited to practical application. As it is applied, it will work with the crop rotation scheme to fix nitrogen and increase overall productivity, reducing the need for fertilizer.

The other major danger that Malawi agriculture faces is drought and flooding. These can cause sudden losses of yield that can tip even middle and well-off families into poverty. Biochar has a very high surface area, and thus tends to alter soil in such a way as to increase water holding capacity. Because of this high water holding capacity, soils to which Biochar is applied have the ability to resist fluctuations in moisture content, allowing them to better withstand drought. Thus, Biochar combined with a crop rotation strategy could substantially mitigate the risks that threaten smallholder agriculture.

The yield effect of Biochar is substantial. The addition of Biochar produced from various mixed green waste has been shown to increase crop yield by up to 266% in strained conditions, provided there is adequate nitrogen in the soil. Biochar produced from rice husks and applied at a more practical level has been shown to increase maize and soybean yield by 20-40%. Wood Biochar has been shown to be effective even at the very low application rate of .5t/ha (Lehman and Joseph 2010). This leaves the problem of determining what the source biomass for Biochar can practically be, what application rate is appropriate, and how this Biochar can be transported to smallholders.

One solution that has been tried is having large brick kilns at a central location produce enormous quantities of Biochar and then transport it to stores, where it could be sold. There are, however, several limitations to using this strategy in Malawi. First, there are few roads in Malawi (Republic of Malawi). In fact, one significant factor in a Malawi smallholder's livelihood is their proximity to a road. A road gives them a place to sell any surplus food or cash crops and gives them the ability to buy supplies. As a result, a central distribution system would give a substantial disadvantage to the ultra poor people in rural areas who would most benefit from the application of Biochar. Second, if it is distributed in any centralized fashion, it will cost money. This is a problem, given that one of the things that Biochar should be able to do is provide farmers with a way to improve their economic situation, not to provide the farmers with a new large expenditure that they cannot afford.

A better way to produce Biochar is on a household scale. This could be done through the introduction of top-lit updraft gasifiers, stoves that can be built from two one-gallon paint cans and a smaller can for under $10. Top-lit updraft gasifiers work by filling the bottom can with source biomass, which is then lit on fire. This creates a pyrolysis front, which moves downwards through the can. This alone would be smoky and inefficient. With the gasifier design, a concentrator (the other can with holes cut in the bottom and along the sides) is placed on top of this, and a chimney is placed above that. This creates negative pressure, which pulls air from the holes in the bottom of the first can up, providing oxygen to the flames and concentrating the smoke, which ignites. (Smoke is composed of pyrolysis gasses that have cooled and condensed around particles-it is flammable in the right air mixture.). This produces a considerable amount of heat, which could be used for cooking and water sanitation. It is also completely smokeless when operating properly, meaning it does not have a negative contribution to air quality. When the pyrolysis front reaches the bottom of the can, the can is full of Biochar. Because there are no more pyrolysis gasses, the heat output falls significantly, and the Biochar itself begins to burn. This is the point where it should be quenched (a lid can be put on the bottom can), as it will now begin producing ash which reduces the quality of the Biochar. A stove like this used to produce the heat needs of a household for cooking will produce about 1.5 kg of good Biochar per day (Lehman). This can then be added to the soil, giving the farmer a much needed boost to productivity.

This leaves the question of what the source biomass should be. The advantage to this stove design is that the updraft it creates can be used to burn things which would not ordinarily be quality fuel. This includes corn stover and the litter from legumes, both of which could be charred and returned to the soil. This would be a more effective use of the litter than simply dropping it back to the soil, where it would rapidly decay. Other potential sources include grass and firewood. Grass is a good candidate, because it is not currently used for anything. Firewood is frequently sold even now, and if the use of Biochar as a soil amendment increased the demand, smallholder farmers might sell it rather than use it themselves. For this reason, smallholders should concentrate on using the feedstocks that are not saleable, such as the grass, stover, and litter. This would enable them to produce Biochar cheaply and efficiently.

What would the actual yield improvement be if household scale Biochar usage were properly implemented? In *Biochar for Environmental Management* by Johannes Lehmann and Stephen Joseph, this question is examined. Charles Mwoshi, a smallholder farmer from a village in western Kenya, implemented a household-scale Biochar production system. The farmer already used a bean/maize rotation, and only added the use of Biochar. He used about 20% of the biomass available on his farm in a kitchen Biochar stove, which allowed him to add .5t/ha to his .62 ha (1.5 acre) maize and bean field per year. With this system and no application of fertilizer, he observed 25 to 67% increases in maize yield over the three growing seasons studied. Because agriculture in Kenya is similar to that of Malawi, this shows that the Biochar strategy alone increases yield substantially. Combined with the addition of crop rotation strategies, it can be expected that the introduction of these two improved soil management techniques in Malawi could reduce or eliminate hunger and malnutrition among smallholder farmers.

The challenge of getting new seeds equipment to Malawi and used is an important consideration. People may be resistant to implementing new techniques with no guarantee that they will work. As a result, efforts in a given area should begin with a demonstration by a local farmer. This farmer could build a reasonable quantity of Biochar in the soil before the test begins. The greater issue comes with getting the farmer access to the Biochar stove. The farmer must have some investment in it. However, it also cannot be sold for the cost of $5-10, as this would account for most of a poor farmer's monthly income. A more reasonable price is probably $1-2. The initial farmers should receive advice on the proper use of Biochar and crop rotation, and set up side-by-side plots to compare the crop with and without the new techniques. Pictures should be taken of the crops, and the yield advantage estimated. If the results are as profound as prior data indicates they should be, these pictures can then be used to convince others to implement improved techniques. The initial test trials will also give an opportunity to refine techniques (such as which legumes are most effective) for specific use in that region of Malawi before they are widely adopted.

The success of this effort will require the assistance of the government of Malawi, as well as international aid organizations. First, it will require that legume seeds become available in local stores in a quantity reasonable for the use of smallholder farms-the government might be able to help here. Second, financial resources will be needed to subsidize the cost of the Biochar stoves, especially once adoption extends beyond a few test farms. Third, it will require people on the ground from aid organizations to assist the farmers in the implementation of new techniques, and to take photographs and data that can then be applied elsewhere in Malawi and Africa. With the help of a large organization, the implementation of improved techniques should be successful.

The agricultural smallholder in Malawi faces many problems. The rate of AIDS is high, as is childhood and infant mortality and life expectancy. Malnutrition is commonplace, and the majority of the population lives in poverty. Even those who do not live in poverty must live in constant fear that a drought will destroy their crop or a disease kill their cattle. The monoculture cultivation of maize used by most poor farmers does not provide adequate nutrition, and degrades the soil to the point where it also rapidly fails to provide adequate calories. Fertilizer is too expensive a solution to the problems of the smallholder, and it is not sustainable. Malawi's problems with malnutrition and soil degradation would be greatly reduced if they were to introduce a strategy of crop rotation with a legume, which would provide them with a source of other essential nutrients while returning nitrogen to the soil and improving the yield of maize. However, this strategy cannot be fully effective, as it fails to address the low nutrient holding capacity of the soil caused by the degradation of organic carbon. The best way to improve the quality of the soil in a way that would complement the strategy of crop rotation is the addition of Biochar, a soil amendment that can be produced by smallholder farmers with the right equipment and knowledge. Biochar would provide a stable source of carbon in the soil, effectively permanently improving it. If these two sustainable soil management strategies were introduced, it can be expected that malnutrition and hunger would be substantially mitigated. Smallholders might even be able produce more food than they need to survive, enabling them to produce more cash crops, starting a virtuous cycle that could help to substantially reduce poverty in Malawi. With the proper strategies for improving soil fertility implemented, the future of Malawi would be much brighter.

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