ADOPTION OF CONSERVATION AGRICULTURE IN MALAWI

by

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Duke University
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USAID/Malawi
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Abbreviations

CEC...Cation Exchange Capacity
GOM..Government of Malawi
MOA..Ministry of Agriculture
NGO..Non Governmental Organization
TLC ....Total Land Care, Inc.
USAID ....United States Agency for International Development
USG ....United States Government

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Abstract

There is need in Malawi to increase agricultural yields to feed the growing population. Concurrently, conventional agriculture techniques practiced by subsistence farmers steady depletes soil fertility thereby reducing the potential yield on the arable land. The practice of conservation agriculture may be a solution for rural farmers to improve the long-term soil health as well as increase yields and buffer potential losses due to drought, problems with the fertilizer import market and farmer health.

The non-governmental organization Total Land Care, LLC, with support from the United States Agency for International Development, manages the Chia Lagoon Project in the Nkhotakota and Ntchisi districts of Malawi. One part of this project teaches conservation agriculture and has had extraordinarily successful results—project managers have documented high yields, farmer involvement and requests from other farmers to be part of this project component.

This Masters Project involved a survey of conservation agriculture farmers in the Chia Lagoon Project to address the question of what indicators project managers should address in future conservation agriculture projects. The survey included questions on demographic information, agricultural practices and results, interaction with the Chia Lagoon Project, family and social relationships, and future agricultural plans.

The results found farmers required less labor in terms of time and greater profitability by practicing conservation agriculture. In fact, 82% of farmers indicated they would continue to practice conservation agriculture after the project has ended. A statistical classification model (CART) estimated leading indicators of adopting conservation agriculture after the project had ended, which was found to be the frequency of visits from agricultural extension agents.

The implications of these results are project managers should ensure adequate extension agent interaction for farmers in the conservation agriculture program. This practice will produce greater yields for farmers and require less time and work intensity than conventional agriculture. The time savings from these practices is particularly welcome to farmers with HIV or malaria.

Conservation agriculture should be officially adopted by the Malawian government as the form of agriculture taught by extension agents. Private industry and non-governmental organizations should work in cooperation with the government to spread this technology efficiently throughout the country.

Study Rationale

Malawi regularly experiences great difficulties feeding its exploding population. Harvests in 2006 and 2007 were very good due to adequate and consistent rainfall, but yet there is still hunger in the country. Compounding the problem, the population growth rate of Malawi is 2.4%, while available arable land is becoming scarcer. A comparison between Malawi, which has 14 million people with 6.5 million hectare of arable land, and Zambia, with 12 million people on 13.5 million acres of arable land (CIA World Factbook), points to heavy population density and the need to maximize agricultural yields. Greater pressure on current agricultural lands has leads to an increase in the amount of marginal and forested land converted to agriculture. In addition, conventional tillage methods have systematically reduced soil health and therefore potential yield of the soil (Derpsch 2004). As agriculture labor comprises 90% of the country's workforce, the agriculture comprises 1/3 of Malawi's GDP and agricultural accounts for 90% of total export revenue (CIA World Factbook), the economic success of individual Malawians and therefore the economy of Malawi are dependent on the success of agricultural practices. Therefore, a new paradigm is required to improve potential agricultural yield and stabilize agricultural yields. An increase in agricultural production increases not only food availability, but also economic activity that can set the stage for widespread development contingent on concurrent advances made in other sectors. A closer look at conservation agriculture is warranted as conservation agriculture may increase rural household incomes, one of the four focus areas of USAID/Malawi.

Conservation agriculture is a practice that has many positive benefits when compared to the conventional agriculture practices that are widely utilized in Malawi to date. This practice will reduce erosion, which will improve water quality of the Chia Lagoon over time. In addition, this practice improves soil health, decreasing the need for inputs and generally improves the health of crops, while improving total yields and decreasing the workload for the farmers.

Introduction

In a country where 90% of the workforce is involved in agriculture, productivity of crops has an overriding influence on the economic health. Beyond economics, the health of the agricultural sector reflects the quality of life for the vast majority of Malawians who are subsistence farmers. However, the hunger season of 2006 and 2007 demonstrated that even with what officials call bumper harvests, many Malawians are still unable to adequately feed themselves throughout the year. This demonstrates the shortcomings of conventional agriculture and the need to find an appropriate system of agriculture that stabilizes crop yields. Figure 1 demonstrates the recent extreme variability of crop yields in the last fifteen years, leading to the instability of rural families and the agricultural sector.

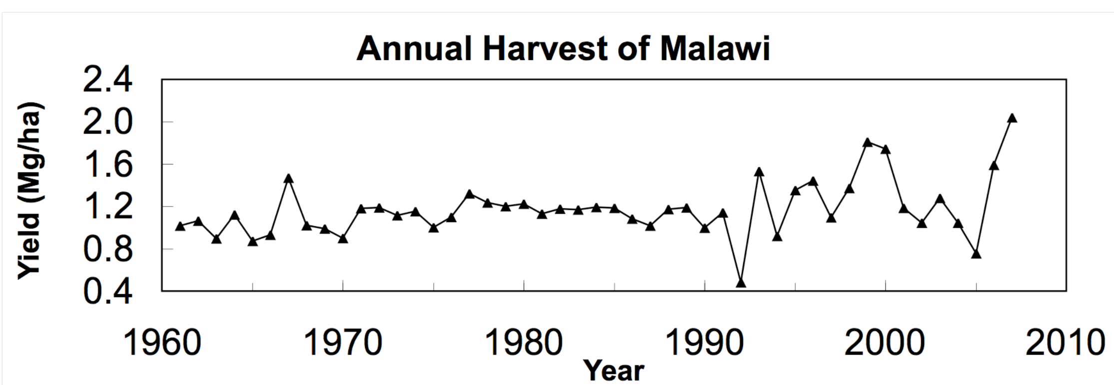

Figure 1. Yield graph of the harvest between 1960 and 2008. Source: FAOSTAT 2008.

There are four main environmental components in agriculture—air, soil, sun and water. Of these four components, soil is one that farmers can effectively manage and thus be able to adequately utilize other components, producing an optimal yield. Good soil management means that water can be more efficiently stored and utilized, and also incident solar energy can be better utilized because chemical inputs needed by crops are available in appropriate time and amount for photosynthesis due to healthy soil chemistry. This survey conducted in this project shows that 95% of the farmers interviewed own the land that they cultivate. Therefore the maintenance and improvement of soil health is in the long-term interest of the farmer. It is not an issue of neglect, but an issue of capacity to improve agricultural soil quality. Conventional agriculture has been found to be a destructive practice that causes a gradual degradation of chemical and water deficit buffering capacity of tropical soil (Brady and Weil 2002). Although the loss occurs in a long process, consequences of this process can dramatically reduce crop yield. In fact, because of long-term nature of this process, farmers do not immediately see the detrimental effects of their land management practices and therefore do not correct them.

The agricultural practices that have become conventional have exacted a serious toll on the soil and the people of Malawi. Agricultural soils are losing both water and nutrient buffering capacity due to high erosion caused by misguided soil management, which has lead to a decrease in crop yield. In Malawi, the population increases while agricultural yield and available arable land decreases. HIV/AIDS is gutting the most productive segment of society while other issues such as malaria and chronic hunger leave many Malawians unable to effectively cultivate their field—which is often a sole source of food and capital in the absence of aid. Current agricultural practices will lead to more famine and poverty if these practices are not altered before another year of inadequate rainfall in Malawi. Conservation agriculture has the potential to revolutionize Malawi's smallholder agricultural sector as it has in other parts of the world. Conservation agriculture has a myriad of benefits that have an effect on agricultural output, environmental health, and farmers' labor—truly a new *Green Revolution*.

Conservation agriculture has been successfully implemented in other parts of the developing world, which demonstrates the potential of agricultural conservation to become the new paradigm of agriculture in Malawi. Zambia and Brazil are examples of successful adoption of conservation techniques as these techniques have helped farmers realize sustainability, improved yields, increased profit, improved efficiency of agricultural inputs and less labor demand. Meanwhile, crop diversification is intrinsically encouraged via the tenet of crop rotation. The success of other countries should serve as an example and impetus for the adoption of conservation agriculture in Malawi.

Some organizations, such as Total Land Care, Inc. (TLC), have recognized the benefits of this method of agriculture and coordinate projects that have conservation agriculture as a component. Although adoption can never be one hundred percent, these organizations are realizing high adoption rates and farmer-to-farmer exchange. This study includes a survey of TLC's Chia Lagoon Project conservation agriculture component. The survey looks closely at what factors may indicate a greater willingness to adopt or try conservation agriculture, the affect of conservation agriculture on farmers' lives, actions by extension agents and the farmers' experience during the conservation agriculture project.

TLC is a non-governmental organization that works in conjunction with Washington State University and specializes in environmental issues and development. The organization has worked to promote agroforestry and a market for local seeds and agroforestry tools, as well as capacity building in the areas of sustainable agriculture, fish farming, beekeeping, wood-lot creation and management, and irrigation. The success of this organization has lead to a close relationship with the United States Agency for International Development (USAID).

This paper addresses reasons for smallholder farmer adoption of agricultural conservation, adoption of conservation agriculture in the Chia Lagoon watershed, the internal and external effects on the smallholder system, and recommendations for scaling up in Malawi. These topics will give a clear picture of the current status, potential, and the way forward to increased adoption of agricultural conservation in Malawi. The intention of this study is to generate interest in agricultural conservation within organizations of all developmental sectors in Malawi and to stimulate an increase in collaboration between non-governmental organizations (NGOs), the United States Government (USG), the government of Malawi (GOM), the private sector and other organizations.

Reasons for Adoption

Agronomy, Economy and History

In order to understand the need for agricultural conservation in Malawi, it is important to know something about the history of agriculture in Malawi. Current agricultural methods in Malawi are a culmination of the effects of outside factors with few artifacts persisting—either practices or crops—from before contact with outside peoples. Possibly 3,000 different species of plants were prehistorically eaten in Africa, yet today's textbooks describe only 100 food plants, three of which are indigenous to Africa (National Research Council of the National Academies 2006). As trade began between Africa and external areas, crops from other parts of the world were introduced and were incorporated into African agriculture. Over time, farmers selected for external crops, such as sugar cane, because they had a higher value to the farmer due to trade potential. In addition, as Europeans began spreading to the area, exotic species were encouraged to a greater extent. Now, as the world looks to find a way to stimulate agriculture the continent of Africa, indigenous crops that were overlooked in favor of more economic, exotic crops are again overlooked as viable food crops. This is for three reasons, the first of which is the fact that much of the knowledge of these crops has atrophied. The knowledge of these crops that was passed down orally was forgotten. The second reason is that the crops that were previously known and extensively studied that westerners look to in order to solve the hunger problem. Thirdly, some crops, such as amaranth, are virtually ignored because they are considered inedible or a poor man's food. It is possible that these lost crops of Africa are better options for African farmers as these crops have evolved with the climate and soil of the region.

Economics still play an important role in agricultural production. For example, Malawi has traditionally been able to grow enough maize to feed itself and export maize to neighboring countries. Maize tends to have greater demand than other crops due to its versatility. In the world market, maize is bought for human consumption, livestock feed, and biofuels. Therefore, indigenous crops will not be adequately grown unless consumer recognition, consumer demand and research on the crop are increased.

Currently, the major crops grown in Malawi by smallholder farmers are tobacco, maize, peanuts, cassava, and cotton. Tobacco and cotton are the major cash crops of smallholder farmers. However, farmers sell maize, peanuts and cassava to supplement income if more cash is needed or if there is sufficient maize for the year. To a lesser extent, other vegetables are grown in the villages, such as mustard greens, cabbages, tomatoes, potatoes, sweet potatoes, rape, okra, and beans. The types and extent of what crops are grown vary widely on the region. Large plantations of tobacco, coffee and tea are large contributors to the Malawian economy. Staple food crops such as maize take priority in the minds of Malawian farmers and therefore when there is a shortage of inputs or time—it is the cash crops that suffer. This is exacerbated by the fact that these cash crops generally require more inputs than the staple crops.

Few farmers in Malawi keep work animals because of the high cost of keeping them. The cost of buying a large work animal is considerable considering the meager incomes realized by most smallholder farmers. Feed is also a major concern for farmers because the land is used to grow food and cash crops. Instead of feed, farmers graze their cattle on the brush growing on the sides of the road, forest reserves, and the few fields where there is sufficient amount of weeds and grass. In addition to the difficulty of keeping these animals, livestock are generally the first line of defense of smallholder farmers against poverty, i.e. cattle are the first things to be eaten or sold when times become hard.

Malawi's current largest economic sector is agriculture at 90 percent of the total workforce and 35.4 percent of the GDP (CIA World Factbook). Since agriculture is such a large part of the Gross Domestic Product (GDP), agricultural uncertainty, associated with the access to input markets, weather/pest patterns and farmer health, is coupled with the economic well being of the country as a whole. For example, a disruption in the supply of agricultural products that constitute the current 90% of export revenue (CIA World Factbook) would plunge Malawi further into poverty and further delay the emergence of Malawi as a self-sustaining country. In the absence of a significant amount of industry, the GOM must find a way to buffer itself against such disaster. In addition, agricultural uncertainty is increasing due to global warming.

Soils

Soils of the tropics can be supremely productive, however biogeochemical cycles are faster in tropical climates than in temperate regions due to increased daily and seasonal temperature. High productivity, even in the face of accelerated nutrient cycles is due to tight biogeochemical cycling, which retains and quickly uses available nutrients before leaching and excessive leaching can take place. Higher temperatures, and the high precipitation in some areas, impact biological and physical processes of weathering, erosion and soil formation. For example, warmer temperatures allow for year-round agriculture (in conjunction with higher precipitation or irrigation), which is not possible in temperate regions.

Soils of the tropics have long been over generalized and misunderstood—there is much more variation in the types of soils than previously thought (Richter and Babbar 1991). In fact, the US Department of Agriculture 1998 World Soil Resources map depicts Malawi as principally having three different series of soil—Oxisols, Ultisols and Mollisols. Good management depends on understanding the soil so that appropriate steps may be taken to optimize soil health.

Oxisols are the oldest, most weathered soils formed where there has been neither glaciations nor heavy erosion. These soils have an oxic B horizon where clay activity is low due to extreme weathering. They can be characterized by high clay content, and a deep, oxic subsurface horizon that is deeply homogenous and lacking stones. Aluminum and iron oxides are dominant in this system and most silica is leached from the system. Because the silica is leached, the clay has low activity and has a low CEC, low fertility and is moderately acidic. The good thing about this soil type is it may be resistant to compaction and erosion. Suitable uses for Oxisols are mixed canopy perennial crops, i.e. trees, which can restore the biogeochemical cycle (Brady and Weil 2002). This is because trees are able to deeply root themselves, reaching lower in the soil profile where more nutrients can be reintroduced into the cycle rather than being leached beyond the reach of biota. In agricultural systems, the use of agroforestry species is important to facilitate the biogeochemical processes for improved soil health.

Ultisols are also weathered, but not as extremely as Oxisols. Ultisols contain an E horizon and has acidic B horizon and are distinguished from Oxisols by the presence of rocks in the soil profile. The process that forms these soils is weathering and movement of clay materials through the soil profile in moist conditions. Ultisols are comprised of a kandic or argillic horizon where often there is an accumulation of aluminum and iron oxides, sometime forming an iron pan (Tewari 1963). These soils are low in plant nutrients and are at the most 35% CEC saturated in base-forming cations in their subsoils. The other sites on the clay particles are bound with hydrogen ions, which gives this soil its characteristically low pH. Management of these soils is straightforward yet intensive. These soils need to be limed in order to lower the pH of the soil, and make cation nutrients more available to plants. In addition, humus must be incorporated into the soil profile in order to increase CEC, especially since this kaolin clay, which already has a low CEC, is only 35% saturated at the most. Both Ultisols and Oxisols have a low amount of phosphorus, a nutrient that must be added because it cannot be fixed by biota or deposited by the atmosphere. Therefore, it is also important to manage the soil phosphorus in order to use the applied phosphorus more efficiently.

Mollisols are characterized by a rich, deep A horizon that tends to develop in semi-arid or moist grassland ecosystems—a savanna in the case of Malawi, however Mollisols in moist climatic regimes tend to have a greater amount of organic matter than their semi-arid counterparts. Mollisols develop due to an accumulation of organic matter with a high calcium content, such as grass, which give this soils a CEC that is more than 50% saturated with macronutrient cations like calcium and magnesium. The soil tends to form soft aggregates, which is good for aeration. This soil is a very good soil for agriculture, but as with other soils it must be well managed. Continuous cultivation of row crops causes serious deterioration of soil structure (Brady and Weil 2002). Mollisols lend themselves to agricultural purposes due to high humic composition, which provides cation exchange capacity and water retention potential. Oxidation is faster in the tropics than temperate areas, which means the organic matter is being lost at a faster rate and nutrients are being leached from the soil faster. A continual input of organic matter in order to maintain the biogeochemical cycling of these nutrients is an important management component of this soil series in the tropics.

For these reasons, the importance of understanding the type of soil that one is managing for agriculture so that correct decisions can be made to cultivate the soil. In all three of these soils, the incorporation of organic matter is important to the system. The removal of vegetation has broken the natural biogeochemical cycle that has sustained the highest level of no-input production possible. Without care, agriculture in the tropics can take a heavy toll in an environment where there is no temperate winter to slow organic matter loss. Increased input of organic matter, or simply the retention of crop residue, will aid soil biogeochemistry and overall system sustainability.

Conventional Tillage

Humans have utilized the plow since 4000 BC in order to scratch the soil to loosen soil. In the 17th century, soil inversion plows were developed as a form of weed control. However, it was not until the 18th century, when quack grass (*Agropyron repens*) threatened to cause famine throughout Europe. At the time, the soil inversion plough was the only known tool that was able to control quack grass. Since then, it has become invaluable to cultivation and a symbol of modern agriculture (Derpsch 2001). The plough became such a vital tool in agriculture that European colonialists brought the plow with them as they built colonies across the world. When the English came to Malawi, then Nyasaland, they brought the plow.

In the early 18th century, English landlords claimed large swaths of land and required those living within to pay rent with three months of labor. Cotton was the crop the colonials had turned to for economic rents when no mineral deposits of worth were found in Nyasaland (Mandala 1990). These landlords assuredly used the trusted ridging method (emulated from European ploughed ridges) when planting the cotton crop. However, it was not until 1948 when P.M. Lewis, charged with the administration of the Port Herald District, now the Nsanje District, that Malawians were coerced to make ridges in their private fields. Lewis turned to coercion after he gave up on the traditional method of technical propagation via chiefs and headman and deemed it useless. To not follow this method of cultivation would result heavy punishment in the form of fines and incarceration (Mandala 1990). Little did the colonial government at the time know that while ridging may improve agriculture in Europe, ridging depletes soil fertility in tropical areas (Derpsch 2004). This technology spread throughout the colony and was rooted enough that when Malawi received its independence, the new government continued to enforce these agricultural requirements. Since the repeal of these laws, Malawians have been hesitant to change because it is the only technology that they know and some do not even know that ridging no longer compulsory (Banda 2007). The independent Malawian government discouraged traditional crops as well during the thirty-year rule of Hastings Banda. Cultivation of crops such as sorghum and millet was banned and the overwhelming focus of the agricultural sector was on maize production. The utilization of tradition and domesticated crops should both play a role in order to decrease risk and to improve food variety.

Nutrition plays an important role in agricultural yields as well. Wide crop diversity allows farmers to have a more nutritious diet. Instead, maize has become the main staple crop and meal constituent while other foods are all considered simply "ndiwo" or "side dishes". In addition, maize is processed by removing the bran, which is the part that contains most of the fiber, protein and vitamins. The resulting bran is often given to livestock for feed.

Malawian farmers are slow to change the agricultural legacy. Even with better technology, farmers are met often met with ridicule, jealousy and vandalism when attempting new technologies. The survey carried out in this project found that 68 percent of farmers have no other source of income other than farming. It follows then that farmers should be hesitant to take many risks in their fields in order to protect the yields that they expect. Showing farmers the benefits of other technologies via the use of small test plots in their field in order to compare outcomes of the agricultural methods. Further, successful conservation farmers are examples and potential mentors for neighboring farmers wanting to adopt different agricultural techniques as well.

Agriculture is a subject taught in secondary school and is included as a subject on the MSCE exams given at the end of secondary school. Under-funded schools do not have resources to neither buy current textbooks nor send teachers to training in order to encourage consistent and current information dissemination. In some cases, the subject is not taught at all due to a lack of qualified teachers. One of the major issues with agriculture in the developing world is that the people are farmers by default, not by interest or aptitude. In addition, farmers are conservative due to the inherent risk involved in agriculture—farmers are most likely to adopt practices that they have seen work and not expend effort in experimentation. For these reasons, conventional tillage has persisted in Malawi even as agriculture becomes more sensitive to drought and fertility drops.

Conventional tillage is done via three main methods. The method of conventional is using a moldboard plow to invert the soil 135 degrees. This is the method that was able to protect fields from the quack grass and other weeds in Europe. Second is minimum tillage, which incorporates the use of a ripper to dig through the field, which is used to sow seeds and apply a fertilizer basal dressing. These two methods are dependent on animal draft power or tractors, both of which are not readily available to Malawian farmers. Ridging is the most commonly practiced method of cultivation in Malawi. It consists of farmers digging and moving the previous year's ridges into the previous year's furrows to make new ridges. The construction of ridges is not only time consuming and difficult work, but it is detrimental to the agriculture system of the conventional farmer for a variety of reasons. To exacerbate the labor involved, it takes place during the hottest time of the year and when the family is at its weakest because of the onset of the hunger season. Maize is planted (30) cm apart, and 3-5 seeds are placed in each hole. The planting of multiple maize plants per hole makes the sowing process easier, but competition between these individuals is detrimental to the growth of all three because more energy is expended in competing than producing optimal growth. Also, yields decline with continual cultivation.

The common method of conventional tillage in Malawi proceeds predictably. First, farmers wait for the rains to arrive to begin field preparation. The first rains loosen the soil so that weeding and making ridges is considerably easier. Farmers clear the field of large weeds and small trees and burn the residue. Some farmers attempt to make contour ridges, however it is rarely done precisely with an a-frame or line-level. More common are ridges perpendicular to contour lines, which encourage and exacerbate erosion. Some farmers have had varying success with ridge tying, which is the practice of intermittently digging ridges perpendicular to the main ridges. Pesticides and herbicides are not widely used except for with crops that are grown with the aid of extension services that include the provision of the chemicals due to the high costs of the chemical and application devices—as is done by the cotton industry in Malawi. In general, there is a lack of capacity to effectively utilize these chemicals, specifically knowledge on the type, amount, method and timing of chemical application.

Fertilizer is the largest expense faced by Malawian farmers. The root of this problem is fertilizer must be imported into from neighboring countries. Since the availability of fertilizer is in the hands of another nation, prices and timing of delivery are often considerable issues. The government of Malawi has attempted to address the problem by "starter pack" distribution, which includes fertilizer and seed as well as distributing fertilizer subsidy coupons (Crawford et al. 2005). As with other chemicals, fertilizer is not applied efficiently due to improper timing, fertilizer types and amounts.

As land becomes scarcer, current agricultural land produces less, environment becomes more degraded, and the need to produce more food on less land in less time, Malawi must look to improve its agricultural productivity. It must do this not just to improve the economy of Malawi, but also to maintain the feasibility of the Malawian state. Conventional tillage has taken its toll on the environment of Malawi, created a decrease in agricultural production over time (Derpsch 2004). The population explosion caused by the greater availability of medicine has exacerbated the problem, and put more pressure on the environment as forest and marginal land is converted to agriculture.

Characteristics and Environmental Effects of Conventional Agriculture

Burning of most residual vegetation matter is widespread in tropical regions, and is practiced widely in Malawi because it is believed by farmers to be a good way to kill seeds of weeds, release nutrients back to the soil and remove debris that can get in the way of planting as well as attract termites. Conventional tillage in fact exacerbates all of these problems. Burning debris may kill some seeds, but those seeds that are buried more deeply in the soil are not affected by the burning, and become available as they are exposed when the ridges are dug. It is better to keep fields weeded so the seed bank remains at a low level, which makes weeding a smaller task. Burning does not make nutrients more available to crops. In fact, greater than 95% of nitrogen is lost via the process of burning. Of the remaining ash, 55% of phosphorus and 74 percent of nitrogen is lost via erosion (Giardina et al. 2000). However, if the residues had been left on the field, nutrients such as nitrogen and sulfur would have slowly been released during decomposition in a form that is easily used by the crops, further decreasing reliance on a large amount of fertilizer. Another popular reason for burning residues is that residues attract termites, which will then attack crops and lodge maize. Termites are present whether or not there is residue on the surface of the soil, therefore the leftover residue serves two functions. First of all, the residue serves as a food source for the termites, which would otherwise attack crops. Secondly, termites play an important role in agricultural ecosystem in that they increase field infiltration when they burrow tunnels in the field and they facilitate the incorporation of organic matter into the soil as they eat leftover crop residue (Conservation Farming Unit 2007).

Exposure of soil by burning can lead to surface sealing because the soil is no longer protected from the impact of raindrops, which break up soil aggregates and redistributes them according to physical, chemical and suction forces which can arrange the clay particles in a such a way the soil surface becomes impermeable to water. The size and intensity of the raindrops have a significant affect on the degree and rate of sealing that takes place. Structural crust is another way the soil structure itself can limit crop production. Structural crust ranges in thickness from a few millimeters to a few centimeters, and is cause by physical compression of the soil—usually from livestock, machinery or people putting weight on the soil. In the case of conventional tillage, the hard pan that forms due to hand hoe cultivation is a type of structural crust. The hard pan is formed by repetitious hand tilling to the same soil depth every year, which compacts the soil at this depth. This mechanism is simply an increase in the bulk density due to compaction. The third type is depositional crust, which occurs when transient soil particles infiltrate the soil after being carried to another place by water and is deposited when that water evaporates leaving the particles behind. The particles involved are small clay and silt particles that constitute runoff turbidity due to erosion. These crusts and seals hurt crop production in that the plants are forced to expend energy to or attempt to break through the dense layers of the soil in order to emerge above the soil surface or to adequately expand the root system which is necessary to mine nutrients and tap enough soil moisture to avoid desiccation during the growing period. Without a large and complex root structure, crops will unavoidably be stunted and not have an optimal yield. In addition to plants not being able to penetrate these sealed or crusted soil layers, water cannot penetrate as well, which leads to a loss of potential soil moisture and an increase in surface runoff velocity and therefore erosion.

The impact of raindrops cause over 90 percent of erosion, which is why soil cover is essential. The use of residue to protects against the impact of raindrops, but also encourages infiltration and disperses runoff kinetic energy. Even though erosion via scouring, if the velocity of surface runoff doubles, the effects of scouring increase from the 5^{th} to 6^{th} power (Agriculture Department 1993). The problem with erosion is three-fold. Firstly, it is the topsoil and humus that are the first to wash away during precipitation events (Derpsch 1998). Without the topsoil and humus, the crops are more susceptible desiccation and a shortage of nutrients. Soil texture and structure itself are altered and affects the ability of soil to hold water and nutrients. Secondly, the eroded soil causes sedimentation in the streams and rivers that lead to Lake Malawi. The turbidity decreases the plant life of the waterways that provide not only food but also oxygen to fish and macroinvertebrates—which are also a primary source of food for fish. The resulting decrease in fisheries, in addition to over-fishing, drastically reduces the fish populations to unsustainable levels further exacerbating poverty and malnutrition. Thirdly, as erosion increases, so does the size of the streams, rivers and newly formed gullies adjacent to fields due to the greater amount of overland flow and surface runoff velocity. The net effect of this is that fields become physically smaller and less of the fields are available for cultivation.

Soil fertility in general begins to break down quickly due to conventional agriculture. Erosion tends to take silt, clay and nutrients, leaving little behind. The soil that remains does not allow much infiltration of water nor does it hold the water that infiltrates. It also does not retain nutrients well—nutrients are quickly mineralized or leached out of the soil (Cleveland and Townsend 2006). Phosphorus is the limiting nutrient in soils of the tropics (Cleveland and Townsend 2006) and this is true in the soils in the Chia Lagoon watershed. Without adequate organic matter in the soil, phosphorous and nitrogen are easily leached from the system.

The deforestation rate is high in Malawi partly because farmers are cutting forest to increase agricultural land area. This is coupled with the growing demand for firewood—the main source of fuel for Malawi and the lack of sustainable forest management. During the rule of Dr. Banda, the regime controlled the natural resources, such as the forests very closely. The period following the elections that triggered a multi-party democracy in Malawi marked a steep decline in both the community forest areas and the national forest reserves. Unsustainable deforestation decreases the resource base that many Malawians count on for food, medicine and building materials. Deforestation has another consequence in that it promotes leaching of nutrients from soils. When forests are converted to agricultural land, the feedback loops that maintained nutrient availability for biota is drastically altered, and many of the nutrients are lost due to leaching. Nutrient depletion from cropping without inputs has lead to a general depletion of phosphorus in sub-Saharan Africa in general (Buresh et al. 1997).

Conservation Tillage

Conservation tillage is a fusion of minimal tillage (ripping) and the retention of crop residue. By retaining crop residue and planning for the next agricultural season, farmers realize many benefits in addition to what has already been previously detailed. Farmers are able to begin the work of preparing for next season. Ripping during the dry season utilizes the energy of the farmer and the draft animals before they are weakened by the onset of the hunger season, and allows the work to be spread out over a longer period of time. In addition, by having the field prepared before the first rains, planting can be done after the first rains, and therefore the crops will benefit from both the utilization of the entire growing season and the pulse of nutrients that is coupled with the first rains of the season (Lodge et al. 1994).

One downside to minimal tillage is that because only a strip is ripped in the ground, the process is not an effective means to remove weeds. The retention of crop residue provides a partial, physical block that shades and keeps weed seedlings from growing. Another type of management is necessary in order to effectively weed the field. One option is to weed early and frequently, before weeds can grow too large to be easily removed. This way is effective, yet can be time consuming. Another option is the use of herbicides to kill weeds. This is a more expensive option and may be out of reach of farmers that do not have liquid capital to expend on chemicals.

Conservation Farming

Conservation farming, which is a combination of no till, which is the practice of planting a seed in the soil without tilling the soil, and the incorporation of intercropped annual species planted with the main crop for various reasons such as nitrogen fixation, soil protection and crop diversity. No till can be practiced in a variety of ways, including small basins (as practiced by the Conservation Farming Unit of Zambia (CFU)), large permanent basins, permanent ridges (as practiced by TLC), and making a small hole in the soil for the seed. This method has the benefit of minimizing erosion and organic matter loss by not disturbing as much soil. This method also has the benefit of no requirement for a plough or draft animals.

Crops planted between the crops are generally nitrogen fixers such as pigeon pea (Cajanus cajan) and tephrosia (*Tephrosia spp.*). Plants that are intercropped vary widely from non-utilized to utilized plants, some left for only one year and some for more. Not directly compete with the main crop, but grow in tandem providing some benefits as these species may provide nutrients, suppress weed growth and maintain soil stability in addition to adding organic matter.

Conservation Agriculture

Conservation agriculture can be thought of as a culmination of all these types of agriculture. It incorporates conservation farming and perennial or tree species into the agrosystem. The incorporation of perennial species not only provides more permanent stability for the soil, but the trees are able to recycle nutrients that have leached further into the soil profile than can be reached by traditional crops. Different species, such as jatropha (*Jatropha curacus*) and gliricida (*Gliricidia sepium*) are often utilized as complementary tree species. Jatropha is used as a cash crop as the seeds can be crushed to produce biodiesel. Gliricidia is used as a green manure that can be incorporated into the soil because it fixes nitrogen vigorously. The three main tenets of conservation agriculture are (1) permanent soil cover, (2) minimal soil disturbance, and (3) crop rotations (Conservation Farming Unit 2007). These are all vitally important because of the direct effect that they have on soil chemistry and structure.
The benefits of conservation agriculture include (Agriculture Department 1993):

- Savings hiring of draft animal or machinery
- Increased and stable yields, where crops are buffered against acute drought and other climate problems
- Time saving
- Labor saving
- Crop diversification
- Improvement in water quality
- Increased soil fertility
- Improved biotic activity in soil
- Improved food security

HIV/AIDS and Agriculture

Even as population is ballooning in Malawi, death also plays a detrimental role. Diseases such as HIV/AIDS and malaria decrease the productivity of Malawians. HIV/AIDS is an especially important topic of discussion because the sickness because 14% of Malawian are infected, and this disease often affects people in the most productive time in the lives—their late 20s, 30s and 40s. The Malawi Micronutrient Survey in Malawi in 2001 estimated that 12.1% of men 20-55 years old are infected with the malaria parasitaemia. The same survey estimated a childhood (<12 years old) rate of 47.4%. This high rate of infection influences farmers' effort, pointing to the fact that an agricultural system that requires less time in the field and the ability to work in the field when feeling well is an important technology to develop and employ. The significant amount of time required to practice traditional agriculture in Malawi makes it difficult for families who have relatives that are ailing, have a large amount of orphaned relatives to care for or have few family members within the most productive age group to carry out the work.

Conservation Agriculture in Brazil

Brazil is the flagship example of the success of conservation agriculture in the developing world. Thanks to the initial efforts of the Brazilian NGO, ZTAT, Brazil now has the second greatest amount of land managed under conservation agriculture, just behind the United States. ZTAT was able to accomplish this mostly due to a great number of partnerships with government and private sectors, as well as the enlistment of a group of local farmers' clubs. It was the sole job of the local farmers' clubs to disseminate information about conservation agriculture, and touting the advantages—and it is because of these farmers' clubs that conservation agriculture has been so successful in Brazil (2001).

An interesting aspect of the development of conservation agriculture in Brazil was that it mirrored the development of adequate herbicides that were available to Brazilian farmers. The most notable herbicide produced was glyphoshate, which is more commonly known as RoundUp. This was an especially powerful weed desiccant that was surprisingly inexpensive. Some farmers who had begun to try conservation agriculture prior to the release of RoundUp were unable to spread the technology further because there was still a lot of work associated with conservation agriculture. Perhaps it was the idea of adding a medicine to the weeds that made it easier for farmers to deviate so far from the norm that they considered safe.

Van der Klinken, a man who was attempting to disseminate conservation agriculture via two-day training sessions, formed ZTAT. In order to facilitate the process of dissemination, he organized a group that was to oversee the farmers' clubs and their role as disseminators of information. Throughout the efforts of ZTAT, they found that the greatest resistance they faced was that of the researchers and academics who did not see immediate benefits of the practice. It was not until medium and large-scale farmers began to demand technologies associated with conservation agriculture that researchers and extension agents started to get on board. Thus, they were the impetus for a more rapid uptake of conservation agriculture as a practice. However, in the end it was the farmers' clubs that were the driving force to disseminate the knowledge into rural Brazil.

ZTAT serves as an example and hope that this technology can be adopted in the long-term in Malawi. ZTAT was an organization that took ownership of disseminating a non-biased and standard practice of conservation agriculture, and organized clubs to help get the word out. This is certainly possible in Malawi as well. As with the Brazilian farmers, Malawians will not adopt conservation agriculture wholesale, but focus on the practices that benefit and make sense to them the most.

Conservation Agriculture in Malawi

Chia Lagoon Project - TLC

To address these issues in agriculture and health, TLC's Chia Lagoon Project has a component that works with 68 farmers practicing conservation farming, which is similar to conservation agriculture without the incorporation of perennial tree crops. The project had the farmers set aside a small amount of land, which was consequently split into three sections. The first section is where the farmer does any practice he wishes—this is the reference area. In the second plot, the farmer practices conservation farming. Maize stovers are spread between permanent ridges and only hole are made for the seed at planting time. The third section is like the second, although it includes the intercropping of a legume—either pigeon pea or tephrosia. The three sections are side-by-side so that they can easily be compared. Maize was grown throughout the sections.

Objective

Because of the reports of high levels of satisfaction with this type of agriculture, and the interest piqued with those that lived nearby to the pilot farmers, a survey was run to look at what exactly was happening in the area, and what indicators could be applied to adoption and to see the extent of how fast this technology was spreading.

Survey Methods

Surveyor Training and Method

Two surveyors were trained July 2nd through July 3rd 2007 at the Chia Lagoon Project Office in the Nkhotakota boma. The surveyors were chosen and logistics were organized by Richard Maseka, the conservation agriculture lead extension worker for the Chia Lagoon Project. The surveyors were chosen from outside the project minimize bias in the way questions were asked nor record responses. The surveyors were:

M. H. Kalingumba
Veterinary Assistant, Nkhotakota
+265.9.359.603

Mr. Yunusu
Government Youth Officer, Nkhotakota

A training schedule was created and followed over two days. The students that aided the primary researcher to translate the questionnaire are from Bunda College of Agriculture and the Natural Resources College and were interns for TLC. Corrections and clarifications to this translation draft were the first things accomplished during the training. The discussion and edit of the translated copy created greater understanding for the surveyors within the questionnaire because each question was discussed in depth so that the intent and wording of the questions was clear.

In addition to editing the existing survey, space was provided so the surveyors could provide input to add and edit questions in a way they felt would enrich the survey results. This process had a dual purpose. Firstly, this would add a cultural perspective to the survey, allowing for cultural intricacies to be elucidated. Secondly, it created ownership of the survey for the surveyors, which aimed to encourage them to be accurate and thorough during data collection.

Also, the survey was reviewed after the final edits in order to make sure the survey was clear to the surveyors. A secondary document was created to be a guide to the questionnaire, describing the process of conducting the survey and describing each question, just in case there were any questions while in the field. There was also a discussion about possible issues that may arise and their solutions.

Training with a GPS was the third component of the surveyor training. TLC loaned the surveyors the GPS units. Since only the GPS coordinates were required, training was restricted to simply turning on and off the units and reading the correct numbers. The coordinates were used only as an indirect method of identification so follow-up is possible. The use of coordinates was preferred so that names were not associated with the surveys and therefore the respondent does not worry about consequences of their truthful answers.

Finally, the survey was run on a test sub-population. Six people were chosen, in both participant and non-participant populations. After the survey of the sub-population, issues were discussed and evaluated.

Statistics

Selected Frequency Tables

The survey was successfully carried out, statistics analyzed and formatted for display. Selected and pertinent frequency tables are displayed in this section along with interpretations.

Table 1: Frequency table of Chia Lagoon Project conservation agriculture (CA) farmers' satisfaction with the conservation technology.

Satisfaction with CA	Conservation Agriculture
Response	%
Satisfied	98%
Neutral	2%

Table 1 is a frequency table that shows how satisfied the farmers in the program are with the technology they are trying. No one in the program is unsatisfied and only one is neutral—the rest are satisfied. The fact that all the respondents are satisfied with the skill shows that there are other barriers to adoption rather than dissatisfaction with conservation agriculture. This table is interesting in the fact that the satisfaction rate for farmers practicing conservation agriculture is extremely high, which demonstrates the potential popularity of this technology.

Table 2: Frequency table quantifying the number of conservation agriculture farmers who have helped another try the technology.

Helped friends adopt CA	Conservation Agriculture	Adopting CA
Response	%	%
No	8%	4%
Yes	92%	96%

Table 2 depicts the frequency table of the number of conservation agriculture farmer in the Chia Lagoon Project that have assisted others in trying the practice. Over 92 percent of participants have passed on the knowledge they have learned to someone else! This statistic shows that there has been significant farmer-to-farmer spread of this technology—it is spreading due to its own accord. It is important then to have adequate support from extension agents—government and NGO—in order to maintain interest, quality, and success of conservation agriculture in the field. In other words, follow up is necessary to encourage the current trend of conservation agriculture methods spreading through the community.

Table 3: Frequency table that shows the number of people who have expressed interest in CA to current conservation farmers in the Chia Lagoon Project.

Number of farmers asking participants about CA	Conservation Agriculture	Adopting CA	First Year Chia	Multiple Year Chia
Response	%	%	%	%
1-5	64%	48%	61%	73%
6-10	36%	22%	39%	27%
11-15	15%	13%	19%	0%
>15	26%	17%	31%	9%

The numbers of people that have expressed interest to the Chia Lagoon participants are represented in Table 3. If the median number of people interested is taken from each of these categories there are no repeats and those greater than 15 are considered to be exactly 15, over 480 farmers have expressed interest in trying conservation agriculture. That is seven times the number of farmers in the Chia Lagoon Project conservation agricultural component, and over 150 farmers per year of the project. The purpose of these data is to demonstrate the shear volume of farmers outside of the program that express interest in this technology, demonstrating the potential for rapid grassroots level technology transfer.

Table 4: Frequencies of responses when asked about the differences between them and farmers that farmed in the other method.

Perceived difference between CA and conventional agriculture	All Farmers	Conservation Agriculture	Conventional Agriculture	Adopting CA	Wants to Try CA
Response	%	%	%	%	%
Time	41%	49%	21%	43%	23%
Soil Fertility	39%	46%	21%	46%	23%
Yield	75%	72%	82%	75%	81%
Labor	19%	21%	14%	23%	15%
Erosion	18%	12%	32%	11%	27%
Other	100%	100%	100%	100%	100%

One question in the survey asked about the differences between the respondent and farmers who practiced the opposite type of agriculture, i.e. how did conservation agriculture farmers view the difference between conservation and conventional tillage. The frequency results are represented in Table 4. The most common response by far was the yield realized by the conservation agriculture farmers. This frequency was even higher when looking at just the conventional farmers as well—yield was a response 82 percent of the time. This shows that the improved results of this agricultural technique are obvious to those who see it in the field. With the majority of the farmers in this project in their first year, the yield can be expected to increase next year as soil structure rebuilds. The next highest percentage of farmer responses was in regards to time.

Table 5: Average amount of time spent per acre in both convention tillage and the first and subsequent years in the conservation systems.

Time Spent Cultivating (household-days/acre)	All Farmers	Conservation Agriculture	Conventional Agriculture	Adopting CA	Wants to Try CA	First Year CA	More than First Year CA
Response							
Preparation	11.53	9	16.83	8.89	15.92	8.93	9.3
Weeding	18.43	12.86	30.12	12.6	22.89	13.72	8.62
Spreading stover	5.81	8.59	0	9.12	0	8.52	8.93

Table 5 a combination of three frequency charts that show the average amount of time (household-days per acre) spent in both conventional tillage and conservation agriculture farming systems. The literature often states that the first year weeding can be overwhelming for many farmers starting out—the weeds are worse when retaining crop residue. However, weeding takes two less weeks per acre than conventional tillage in the Chia Lagoon watershed and decreases by almost another week after the first year of practicing conservation agriculture. The average total time spent working in the garden after the first year is 60% of the time spent by practitioners of conventional tillage.

Table 6: Average amount of fertilizer used (50kg bags per acre) by farmers in the Chia Lagoon watershed.

Fertilizer Used (50kg bags/acre)	All Farmers	Conservation Agriculture	Traditional Agriculture	Adopting CA	Wants to Try CA	First Year CA	More than First Year CA
Response							
CAN	0.04	0.03	0.04	0.03	0.05	0.04	0.01
Compound D	0.03	0.01	0.07	0	0.08	0.01	0
Manure	0.21	0.3	0	0.36	0	0.37	0
NPK (23-21-0+4S)	0.67	0.77	0.45	0.68	0.43	0.82	0.57
Urea	0.68	0.74	0.55	0.68	0.57	0.77	0.61

In the examination of fertilizer use, Table 6 shows frequencies for average amount used (50 kilogram bags per acre) of the different types of fertilizer available. NPK and urea are the most popular types of fertilizer. Fertilizer input increased the first year of attempting conservation agriculture because the program helped farmers acquire fertilizer. In later years, less fertilizer was needed, so fertilizer use decreased demonstrating the ability for the soil to maintain nutrient levels due to higher organic matter content as well as less dependence on the import market of fertilizer.

Table 7: Comparison of this and last year's harvest for conventional and first year conservation agriculture farmers.

Harvest compared to last year	All Farmers	Conservation Agriculture	Traditional Agriculture	Adopting CA	Wants to Try CA	First Year CA	More than First Year CA
Response	%	%	%	%	%	%	%
More	66%	81%	35%	82%	38%	84%	67%
Same	3%	0%	10%	0%	10%	0%	0%
Less	31%	19%	55%	18%	52%	16%	33%

In Table 7, two frequency tables are compared—conventional tillage, and those who made the change to conservation agriculture. The majority of conventional farmers harvested less this year than last year, while 83 percent of first year conservation agriculture farmers harvested more this year than last.

Table 8: This frequency tables show neighbors' reactions of a neighbor trying conservation agriculture.

Neighbors' reaction before	All Farmers	Conservation Agriculture	Adopting CA	First Year CA	More than First Year CA
Response	%	%	%	%	%
interest	28%	28%	30%	23%	50%
jealousy	1%	1%	2%	2%	0%
no reaction	1%	1%	2%	0%	8%
ridicule	47%	47%	39%	50%	33%
support	19%	19%	23%	21%	8%
vandalism	1%	1%	2%	2%	0%
wait and see	1%	1%	2%	2%	0%

Neighbors' reaction after	All Farmers	Conservation Agriculture	Adopting CA	First Year CA	More than First Year CA
Response	%	%	%	%	%
Interest	84%	84%	84%	82%	92%
Jealousy	0%	0%	0%	0%	0%
No reaction	0%	0%	0%	0%	0%
Ridicule	1%	1%	0%	2%	0%
Support	15%	15%	16%	16%	8%
]Vandalism	0%	0%	0%	0%	0%
Wait and see	0%	0%	0%	0%	0%

Reaction of friends and neighbors, as seen in Table 8, is often an important factor in the level of participation for villagers, and can affect the choice for farmers to adopt the technology or not. An interesting point on in regards to the before frequency table is that almost 50 percent of the farmers trying conservation agriculture were met with ridicule from their peers. In the case of conservation agriculture farmers in the Chia Lagoon watershed, all but one negative and all neutral reaction became positive. As a side note, the farmer who remains with neighbors who ridicule has decided to adopt conservation agriculture after the project has finished nevertheless.

Table 9: Reasons why the surveyed conventional farmers did not try conservation agriculture last year.

Reasons not practicing CA	All Farmers	Traditional Farmer	Willing to Try CA
Response	%	%	%
Afraid of ridicule	6%	6%	7%
Missed extension	6%	6%	7%
No interest	29%	29%	28%
No project	39%	39%	38%
Not informed	3%	3%	3%
Not selected	10%	10%	10%
Plowed too early	3%	3%	3%
Too late	3%	3%	3%

Table 9 exhibits the data describing why farmers have not begun conservation agriculture. Most of these are either no project or no interest, but when looking at Table 8, it is seen that interest has been increased greatly because of the example set by those who practiced conservation agriculture.

Decision Tree Analysis

Besides frequency tables only, it is valuable to examine decision trees produced from this data to see which controllable variables may help predict the adoption of conservation agriculture by farmers. Using controllable variables to predict adoption of conservation agriculture, the decision tree shows which variables have the greatest effect on which farmers are most likely to adopt conservation agriculture. One problem with this method is that we are relying on the farmer self-reporting, but whether or not the farmer has actually adopted the practice is yet to be seen. Another problem with this data is that the sample size is very small, and the majority of these farmers are adopting conservation agriculture.

This CART model was run with all data collected included. This means demographics such as age and education level, agricultural practices, social relationships, previous project participation, etc. were included in the model. The analysis of the data shows the cross validation error becomes to great when going form one to three splits, so only one split in this model is significant. The significant split in this model was the frequency of visits the extension agents made to the farmer. This result shows that the extension agent must visit the farmer at least once a month to improve the propensity for the farmer to adopt conservation agriculture after the project has ended.

Criticisms of Conservation Agriculture

There is apparently still argument in some circles that conservation agriculture may not be appropriate to be incorporated into projects in Malawi. This section looks to evaluate some common criticisms.

Time and effort

Figure 2: Conservation agriculture in practice in Ntchisi District, Malawi. July 2007.

Some will say that weeding takes a considerable amount of time and effort and is so insurmountable that conservation agriculture cannot be adopted on the large scale. This cannot be further from the truth. Picture first the amount of work that goes into traditional agriculture methods. Digging the upper 20 centimeters of soil and moving it horizontally by nearly 50 centimeters each year is also an incredible amount of work! The foreword-thinking farmers that make their ridges before the first rains in order to maximize the growing season, when the ground is still dry and incredibly indurated exaggerate the amount of time and effort. If a farmer has been given the capacity and support to practice conservation agriculture, then the farmer understands that timely weeding is fundamental and will drastically reduce time and effort required to maintain their field. Also, the weed seed bank does not become exposed as fully without the annual inversion of soil in the field. If one walks through a field a month after harvest, it is clear that the weeds in conservation plots are significantly reduced in comparison with neighbor plots. In the Figure 2 the center photo is a conservation plot and the field beyond the conservation plot is a conventional plot, which can be seen with significant amount of weeds. In addition, it is common practice for farmers to apply herbicides to their fields in order to decrease the weed population. To quantify the time savings of this practice, the survey specifically asked farmers how much time was spent in their fields. This number was standardized by the size of their fields in order to determine the time spent on each activity in each acre of field. Table 5 shows that the conservation agriculture respondents on average spent 30 hours per acre in their fields while their counterparts practicing traditional methods spent 47 hours per acre in their field, and those who had been practicing CA for more than a year spent slightly even less—27 days.

High cost of herbicides

Another criticism of conservation agriculture is that the cost of herbicides makes it difficult for subsistence farmers to adopt conservation agriculture. This is another aspect where good support by extension agents and financial infrastructure is important. Some organizations such as I-Life are working with villagers to form savings clubs and they have been quite success in the places where there program has been implemented. These types of basic skills can be extrapolated to work with farmers to boost them to a higher agricultural economic level where their purchase of these inputs will significantly increase their harvest (7 to 8 fold increase), which will in turn increase their income. Monsanto has reported increasing sales of RoundUp, going from <8,000 L in 2004 to 21,000 L in 2005 to 90,000 L in 2006. This shows that farmers are taking herbicides seriously and are incorporating them into their agricultural production system.

However, the use of herbicides is not necessary in this practice because herbicide application is merely a shortcut. Subsistence farmers do not need purchase this costly input if they but in the time and effort to weed by hand. Early and consistent weeding is an adequate substitute for chemicals when farmers have labor, not capital to spend on agricultural improvement. The conservation farmers in Chia Lagoon have shown that conservation agriculture is already significantly less work since ridging the entire field is no longer a necessary practice.

Tried before

Another thing that critics will point out is that CA has been approached before by development organizations, such as the EU PROSCARP Project. There are many components to projects that are variable depending on the organizing agency, the target population, timing, etc. that will lead to the success or failure of the project as a whole. In fact, some NGOs such as TLC are successful in the promotion of conservation agriculture throughout Malawi. Adoption cannot be one hundred percent, but if this technology will be successful in Malawi it will fall upon the ears of some farmers who will be successful and others will learn from their example, as we have learned from the results of this survey. Neighbors' perceptions will change, other farmers will ask what the positive deviants are doing differently and then the farmers will work together to spread conservation agriculture further—farmer-to-farmer.

Scaling up Conservation Agriculture

Conservation agriculture has had a degree of success in being adopted in Malawi, at least in the Chia Lagoon watershed. Conservation agriculture has also had success being scaled up in other countries. This shows that scaling up agricultural conservation in Malawi is certainly feasible.

Vision

Creating a detailed vision is the first step in effectively scaling up development projects. With a vision in mind, small, doable steps can be taken to achieve specific goals in order to realize this vision.

What should Malawi's agricultural sector look like? Agricultural practices should not be the same throughout Malawi as different areas have different agricultural requirement, different crops and different climates. Tailoring sustainable agricultural practices should be driven by both research at the university and government level, and by the rural farmers themselves. Researchers should be looking at the practical application of agricultural science and improving agricultural conservation techniques specifically applied to Malawi via field research and the synthesis of successes abroad. The focus of research needs to completely shift from conventional tillage methods to conservation methods. As theory is created and applied at the research level, there must be a clear and consistent bridge connecting research to agricultural colleges and rural extension agents.

Information exchange with agricultural colleges can be done by seminars and survey courses taught by the researchers themselves. Students from the colleges should be working hand in hand with the researchers to help develop agricultural conservation to build ownership and deep understanding of conservation methodologies and how they can be applied. Because these students have a keen understanding of these technologies because they helped develop them, they will become leaders and powerful proponents of improved methodology in their career, further spreading conservation techniques.

Periodic training of existing extension workers is also a necessary facet to widespread adoption of agricultural conservation. Annual workshops during the dry season that cover the basics of agricultural conservation and the newest results of that have come out of research that year would be an effective way to keep extension agents on the same page and to create a forum to discuss issues and give practical feedback to researchers. Researchers and extension agents alike would benefit from learning about the challenges and successes faced by extension agents in other parts of the country or region, and therefore applied to future research or extension.

The farmers themselves should be encouraged to systematically try different techniques in small plots within their own fields, as farmers know their climate, soil, and crops better than anyone. The practical insight of the farmers themselves will lead to localized improvements. Farmer clubs are an important supportive structure for farmers engaged in agricultural conservation. Farmer clubs provide a method for farmer-to-farmer interaction and dissemination of information. Farmers who have successful experiments can share their findings with neighbors. Groups of farmers also have more bargaining power and information to deal with buyers and traders. Farmer groups will have an umbrella organization to help guide and support them through trainings and newsletter, not unlike the direction that NASFAM is currently going.

A future Malawi where agricultural conservation is widespread requires a strong official policy on agricultural conservation. This policy should be backed up by an increased investment in the agricultural sector. On average, African governments only allocate 5 percent of public expenditure to MOA, even though 60 to 70 percent of the population works in the agricultural industry (Borlaug and Dowswell 2004)—but that number is 90 percent in Malawi (CIA World Factbook). A Malawi that has a thriving agricultural sector has a MOA that is well funded. The ministry will therefore be able to increase GDP and therefore government coffers, effectively paying for itself. Extension agent salary must be competitive with NGO and donor salaries in order to recruit, retain and motivate quality employees. Government and private enterprise will have aided in the creation of markets to accommodate the increased agricultural supply. This means the food processing industry will also have increased its production and export.

Large and medium scale commercial farmers will play a role as well in using their size and buying power to increase the markets for agricultural inputs and exports, similar to the situation in Brazil. They will also work with researchers and universities to increase agricultural research to increase their productivity, but will in turn produce technological spillover to smallholder farmers in Malawi.

Principles of Development

Address the Issue Systemically

The spread of conservation agriculture must be systemic. A blanket mechanism needs to be put place that is flexible enough to fit all of the areas and still meet the needs of technological adoption. The first hurtle to cross is to get everyone on the same page to work together rather than alone. Of the different methods that are currently being taught in the field, there are some overlapping of projects and the smallholder farmers do not know who to follow and look at projects as just a temporary support to give them inputs—not something serious to follow. Truly, collecting handouts is a vocation in Malawi. To put an end to this, development organizations need to be more consistent in their message, but the message should be dynamic.

In order to get all development organizations on the same page, GOM must make policy to advocate agricultural conservation. Policy must be created using the collaboration of researchers, agricultural colleges, and development organizations to pool information and technology. The role of NGOs would be altered slightly in that they would assist in extension, but would be working more closely with government and other organizations in order to keep extension more cohesive. Pooling of information, while working with the local research infrastructure such as the Chitedzi Research Station is the key to keep the extension message consistent and to build capacity.

One component suggested repeatedly in discussions with various partners is the value of partnerships with the GOM. This goes beyond the utilization of government extension agents and offices in the field. A positive and foreword-thinking relationship includes a corroborative component where NGOs and government work together to create clear policy and goals for where agriculture in Malawi. This includes appropriate policy that addresses all aspects of agriculture, including conservation agriculture. Many USAID/Malawi partners believe that a coherent opinion on conservation agriculture from the Ministry of Agriculture would have a significant effect on the success of future initiatives. Therefore, the NGOs, USAID/Malawi, politicians and chiefs, and the villagers whom wish to have a conservation agriculture program in their area should vigorously encourage petition their government in instigate this type of relationship.

Finally, a democratic process should be incorporated extension projects. This will help tailor the system to the area by using indigenous knowledge. One good example of this is how farmers worked with extension agents to determine pigeon pea was an inappropriate crop as it would attract goats. Instead, the project changed to utilizing tephrosia as a nitrogen-fixing intercrop. By incorporating locally generated ideals into a project creates ownership with the farmers involved and farmer commitment to the project strengthens. These farmers will be more likely to market their project and help others to adopt the practice.

The Solution is Demand Driven

Implementing a behavior-change project in an area is impossible without the creation of demand. Especially in the past, many projects created demand simply by paying participants—a practice which quickly caused more problems for all those working in the area. Today, many of USAID/Malawi partners are turning to more sustainable methods of creating demand—via demonstration plots, field days and movies, which can be shown in the village. However, these methods are mere educational tools. The stronger mechanisms to create demand lie in creating a greater economic incentive to adopt improved practices. This includes market augmentation, i.e. higher prices for farmers for their product and an investment in the agricultural value chain so the final good is more valuable, which improves value down the chain.

The Solution is Learning/Information Driven

The process of spreading conservation agriculture throughout Malawi absolutely must be driven by learning and information. It is vitally important to monitor and evaluate not only the success or failure of the spread of conservation agriculture in the focus area, but also the success or failure of the technology being utilized. Continual studies need to be undertaken to determine the true benefit of conservation for farmers. How does conservation agriculture vary over different types of soils? What about different type of crops or climate? These have to be evaluated and the results reincorporated into the methods taught. In addition, do the statistics of the survey suggest that some demographics are more likely to adopt conservation agriculture and than teach it to their friends than others? When learning is woven into the framework of a project, it allows for the project to focus more intensely and therefore become more efficient.

Different people and organizations can be utilized to realize this principle of development. A partnership with Chitedzi Research Center could possibly provide a valuable asset as their studies and extension workers will help tailor conservation agriculture to Malawi and the unique challenges that Malawian farmers face.

Creating the ideal situation is an important part of finding and implementing solutions to current agricultural issues, however information can easily be lost during the dissemination of information from the researchers to managers to extension agents to the farmers themselves. This needs to be a tight chain of learning so all may understand to the best of their ability, or researchers directly working with extension agents may considerably shorten the chain by cutting out middlemen who could muddle any main points. Researchers working on the cutting edge of conservation agriculture in Malawi should also work with the students who are the future extension workers.

Problem Solving Includes Partnerships

Partnerships are important for spreading conservation agriculture. A close partnership with government leads to effective policy-making as well as an effective use of extension agents that are well trained and teach the same things throughout the country. Research institutions make good partners because they will help validate practices to technically fit in Malawi. Research institutions also prove to be a good doorway to working with other institutions within the government and the education sector. A relationship with research colleges in Malawi must be reached as well to assure that graduating extension agents have the correct knowledge and continuing education for practitioners is comprehensive. Supporting more conservation agriculture research and hiring faculty with responsibilities in both research and training current extension agents can encourage this relationship. Private agencies, and for profit organizations, are vital to work with on agricultural development projects. These entities are the ones who drive the economic vehicle to encourage and grow the agricultural sector. Without Cheetah buying paprika peppers, farmers would not be expanding the types of crops they grow, and this would not therefore increase larger economic trade inside and outside of Malawi. Private companies must be brought into partnerships so that they may grow with the agricultural sector.

Change Takes Place in a Hostile Environment

All development typically takes place in a hostile environment. Otherwise most development projects would have already been successful. This is especially true in Malawi as emotions of individuals entice people to act destructively towards their neighbors if the neighbors seem too well off. Jealousy is a significant problem in Malawian culture and there have been many tree nurseries, beehives, and agricultural fields burned, stolen and destroyed for this reason. Whether it is actually jealousy or not, tradition is also often cited as a reason for destructive behavior. Poverty as well can be the impetus for vastly destructive behavior. One great example of this is the fire that burned much of the Zomba Plateau a few years ago that was started by the same men that were hired to plant the trees on the plateau. As their work neared completion, their need for income pushed them to attempt to get more money out of their employers via destruction of the trees that they had previously been paid to plant. These same issues are easily applied to the extension of conservation agriculture to new areas. If some farmers take up and be successful with this practice before their peers, destruction, no matter what the impetus, may find that farmer and bring him back down to where he was previously. This is why great care must be taken to properly introduce the conservation agriculture project to a community in an transparent and inclusive way.

Change Requires Facilitation

The process of getting conservation off the ground in Malawi will undoubtedly require a substantial input of facilitation. This specifically means that a large, knowledgeable base of extension workers is required to teach and support conservation agriculture throughout Malawi. These extension agents require support themselves, which must come from either a fully funded Ministry of Agriculture, donor agencies or a combination of the two. However, a strong extension agent base is a vital component to the success of the adoption of conservation agriculture.

There Are No Magic Bullets

An authoritarian interpretation of conservation agriculture preached to the farmers of Malawi cannot solve the problem of declining agricultural yield. Each district, village and farmer must decide what type of management will work the best for their household with the help of a knowledgeable extension agent. For example, in areas with steep slopes, conservation agriculture must be dealt with differently to protect the soil from greater erosion potential. The extension agent must help farmers to recognize and make management decisions about problems with the farmers' agricultural regime. A "magic bullet" technique will not fit all places where conservation agriculture can be applied. If one applies this technology as a "magic bullet", the concept as a whole is easily discarded as impractical as it cannot fit wholesale in every situation.

Conclusion

Conservation agriculture has the potential to revolutionize agriculture in Malawi as it has in other parts of the world. We have seen that in cases such as Brazil that conservation agriculture has significantly improved agriculture. Although the paradigm of adoption of conservation agriculture that Brazil has developed cannot be directly applied to Malawi, many of the lessons could guide Malawi as the country moves towards more widespread practice.

However, the wide spread adoption of conservation agriculture in Malawi is far from realized. Tradition, personalities, and old habits will change in the long run if conservation agriculture can gain a foothold as the survey presented in the paper suggests is the current situation in the Chia Lagoon watershed. Conservation agriculture in Malawi promises to improve agricultural output and farmers' way of life. Farmers are saving time, growing greater yields, and rebuilding their soil, which will create even greater returns in the future. In addition, not only is the adoption rate extraordinarily high, but also the number of farmers learning of and beginning to practice conservation agriculture. It is therefore important to look forward to how to foster the successes of conservation agriculture and determine how to scale up these successes to other parts of Malawi.

Way Forward

Government partnership is the first thing that needs to happen in order for conservation to take off to a great extent in Malawi. Many people are still tentative on working with conservation agriculture because the government has no official agricultural policy that incorporates this technology.

Another crucial step to support the farmers who are beginning to work with conservation agriculture is to ensure adequate extension services are available to the farmers. Conservation farming does involve a lot of technical knowledge of agronomics, which the average farmer is not likely to have a grasp on. Therefore it is important for there to be an adequate number of extension agents to work with farmers as to effectively teach a completely different agricultural management style contrary to what they know. This is a difficult transition for anyone, especially for subsistence farmers whose entire income and food stock is determined by agricultural yield. It is important for these farmers to have a knowledgeable and accessible extension agent.

Finally, after making sure the current farmers are stable and experienced, we can look to scaling up and plan the implementation of conservation agriculture throughout the rest of the country. A clear vision of what conservation agriculture should look like in Malawi is the first step, then a plan that addresses the principles of development should be compiled. This is not a simple process, and should be done in conjunction with all partners and input from farmers themselves—if this process belongs to a single person, it is intrinsically doomed to fail.

Final Remarks

In all the research I have done and all the discussions I have had with partners and farmers in Malawi, I feel confident suggesting conservation agriculture is a practice that will benefit the farmers of Malawi. In addition to the improvement directly to the farmer, the decrease in erosion means less sediment load in the streams—further translating to more productive fisheries in the water bodies where these streams flow. Conservation agriculture is an obtainable practice in which farmers simply need support from extension agents in order to learn the practice.

References

The World Factbook. Central Intelligence Agency.

Agriculture Department. 1993. Soil Tillage in Africa: Needs and Challenges.*in* F. a. A. Organization, editor. Food and Agriculture Organization.

Banda, M. 2007. Agricultural History of Malawi.*in* J. Williams, editor., Lilongwe, Malawi.

Borlaug, N. and C. R. Dowswell. 2004. Achieving Sustainable Agricultural Growth in Africa: Lessons from Experience. Assuring Food and Nutrition Security in Africa by 2020: Prioritizing Action, Strengthening Actors, and Facilitating Partnerships, Kampala, Uganda.

Brady, N. C. and R. R. Weil. 2002. The Nature and Properties of Soils. 13 edition. Prentice Hall, Upper Saddle River, New Jersey.

Buresh, R. J., P. C. Smithson, D. T. Hellums, P. A. Sanchez, and F. Calhoun. 1997. Building soil phosphorus capital in Africa. Replenishing Soil Fertility in Africa:111–149.

Cleveland, C. C. and A. R. Townsend. 2006. Nutrient additions to a tropical rain forest drive substantial soil carbon dioxide losses to the atmosphere. PNAS **103**:10316-10321.

Conservation Farming Unit. 2007. Conservation Farming & Conservation Agriculture Handbook for HOE Farmers in Agro-Ecological Regions I & IIa - Flat Culture. CF Handbook, Lusaka, Zambia.

Crawford, E. W., T. S. Jayne, and V. Kelly. 2005. Alternative Approaches for Promoting Fertilizer Use in Africa, with Particular Reference to the Role of Fertilizer Subsidies. Dept. of Agricultural Economics, Michigan State University.

Derpsch, R. 1998. Historical review of no-tillage cultivation of crops. JIRCAS Working Rep:1-18.

Derpsch, R. 2001. Conservation tillage, no-tillage and related technologies. Conservation Agriculture, A Worldwide Challenge **1**:161-170.

Derpsch, R. 2004. History of Crop Production, With & Without Tillage. Leading Edge. March:150–154.

Giardina, C. P., R. L. Sanford, Jr., and I. C. Dockersmith. 2000. Changes in Soil Phosphorus and Nitrogen During Slash-and-Burn Clearing of a Dry Tropical Forest. Soil Sci Soc Am J **64**:399-405.

Lodge, D. J., W. H. McDowell, and C. P. McSwiney. 1994. The importance of nutrient pulses in tropical forests. TREE **9**:384-387.

Mandala, E. C. 1990. Work and Control in a Peasant Economy, A History of the Lower Tchiri Valley in Malawi. The University of Wisconsin Press, Madison, Wisconsin.

National Research Council of the National Academies. 2006. Vegetables. The National Academies Press, Washington, DC.

Richter, D. D. and L. I. Babbar. 1991. Soil diversity in the tropics. Advances in Ecological Research **21**:315-389.

Tewari, G. P. 1963. Occurrence of Kaolinite in Association with Iron-pan. Nature **198**:1019-1019.