Market Access and the Adoption of Integrated Soil Fertility Management in Mbeya Region, Tanzania

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Wageningen UR - May 2015

MSc Thesis for International Development Studies
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Abstract

During the 20th century, sub-Saharan Africa (SSA) has missed out on the widespread adoption of innovative agricultural technologies that tripled yields in regions that used to be considered a part of the 'third world' just as well. To achieve an African Green Revolution after all, the 'Alliance for a Green Revolution in Africa' (AGRA) promotes the use of 'Integrated Soil Fertility Management' (ISFM). This package of agricultural technologies is not only meant to make agriculture more sustainable, the conservation practices involved increase the efficiency of inputs used and decrease the capital and labor intensiveness of agricultural practice which are thought to be the main constraints for the SSA smallholders to modernize their practice. Another important pillar of AGRA's projects is the facilitation of market access, to enable profit maximization. There is a high amount of literature dedicated to explaining the adoption of agricultural technology, but there is a gap between universal economic studies and local context specific studies into factors that determine this adoption. This study uses double hurdle regressions to identify the relation between market access and the adoption and adoption intensity of ISFM in Mbeya region, Tanzania. It leads to the conclusion that access to markets can be beneficial to overcome asset constraints, as illustrated by the positive effect of credit access to overcome financial constraints. Other outcomes show that the amount of household members and land-ownership play a role, suggesting land- and labor market effects. However, the role of gender and education also show that market facilities cannot overcome empowerment issues that highly affect ISFM adoption and market access. More specific data on the transaction costs that determine market access, access to land markets, labor markets and access to knowledge on innovation are needed to reach a definite conclusion on the relation between market access, other than financial markets, gender and education, and the adoption of ISFM.

Key words: *Tanzania, Integrated Soil Fertility Management, Market Access, Green Revolution, Conservation Agriculture, Agricultural Technology Adoption.*

Abbreviations

AGR - African Green Revolution
AGRA - Alliance for a Green Revolution in Africa
CA - Conservation Agriculture
FO - Farmer Organization
GDP - Gross Domestic Product
GR - Green Revolution
HH - Household
HHH - Household Head
ISFM - Integrated Soil Fertility Management
Km - Kilometer
NT - No-Tillage
SSA - Sub-Saharan Africa
SG2000 - Sasakawa Global 2000
SLF - Sustainable Livelihoods Framework
SRI - System of Rice Intensification
Tsh - Tanzanian Shilling
USAID - The United States Agency for International Development
USD - United States Dollar

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1. Introduction

Settled agriculture could not take place until the first farmers developed the digging stick, a tool that evolved into the hoe, fork, spade and plow (Lal 2009). At least as revolutionary has been the development of agricultural technology over the 20th century. Not every farmer in the world uses the technologies that tripled yields over the 20th century. The desire to achieve a global revolutionary increase in production through modern technology is generally known as the desire for a Green Revolution (GR). It is a controversial topic, but many state that a Green Revolution has taken place successfully in Latin-America and South Asia following Europe and North-America. The fact that sub-Saharan African (SSA) agriculture is, in general, still a low-input low-output business is a painful fact for many, and it drives efforts to modernize African agriculture. Green Revolution advocates have spent decades of efforts trying to stimulate modernization of African agriculture through the promotion of external input use with limited success. After countries in Asia and Latin-America, which used to be 'developing' countries just as those in SSA went through different growth patterns, people have started to compare what went 'wrong' in Africa with what went 'right' elsewhere. The relative difference in food production is an important factor that separates SSA from the rest of the former 'third world', Africa has even witnessed periods of stagnation instead of the immense growth that parts of Asia and Latin-America went through (Frankema 2014).

The first recorded person that managed to escape from the closed nutrient cycle of agriculture was scientist Alexandre Cochet, who achieved high yield increases after treating soils with bird excrements gained from deep old layers of Peruvian islands halfway the 19th century. The exportation of these excrements, made possible through exploitation of foreign labour and steam driven transportation, enabled European sugar beet farmers to compensate for decreasing sugarcane imports and US farmers to increase tobacco and cotton yields. Only in 1913 the production of chemical fertilizer became possible making way for the abolishment of labour intensive mining practises. The high application of chemical fertilizer by farmers in the decades after World War II caused yields to increase so severely, that crops collapsed under the heavy seed heads. In response, Norman Borlaug developed new dwarf varieties that were capable of carrying more weight. It made him win the Nobel peace prize in 1970. This impressive scientific progress caused yields to triple over the second half of the 20th century. The first one to use the term 'Green Revolution' was the former director of the United States Agency for International Development (USAID) in 1968, when he referred to the spread of these technologies across the globe (Hazell 2009). He made reference to the 'Red Revolution' that took place in many developing countries when they switched from colonial rule to a socialist state. By presenting the green revolution as a peaceful capitalistic scientific process of agricultural development and economic growth as an alternative to the violent 'red' guerrilla movements supported by the Soviet Union, the 'West' attempted to keep developing countries from sympathizing with socialist propaganda (Frankema 2014).

A revolutionary increase in agricultural production caused by the adoption of modern technology is central in a Green Revolution. The achievement of such a revolution requires more than a technological approach though, the economic- and policy environment shape the context in which a revolution should be realized. The production increases in Europe in the post-war decades took place in a context of many economic development efforts, of which the Marshall Plan is most renowned. The same counts for the active government involvement in the Green Revolution that took place in Southern Asia between 1965 and 1990. A general trend in this revolution was the expansion of irrigation and the promotion of chemical fertilizers, improved varieties and pesticides parallel to strong public support making sure that the right technologies were developed, required infrastructure was present, input- and output-markets were functioning, farmers had the right knowledge and incentive to participate in modernized agriculture and the benefits of these developments were available to poor farmers just as well. South Asian countries spend 15.4% of their total government budget on agriculture by 1972, of which the real value doubled by 1980 (Hazell 2009).

In 2004, UN secretary Kofi Annan called for a uniquely African Green Revolution, causing GR advocates to start a renewed quest to modernize market-led agricultural production in sub-Saharan Africa. The fact that this internationally renowned African politician called for a *unique* revolution, shows that there is a general believe that a revolution in SSA requires a different approach than the efforts that have been made on other continents. As Toenniessen et al. (2008) argue, Africa needs a 'rainbow' of crop improvement revolutions, in which productivity growth for a diversity of crops is combined with more focus on farmer participation, local adaptation, strong institutions, and value chains that enable surplus production for markets. A central characteristic of current GR activities, of which AGRA (chaired by Kofi Annan) is currently a leading organisation, is the embracement of a new approach to fertilizer use: Integrated Soil Fertility Management (ISFM). This approach is based on three principles. First the principle that soil responsiveness to chemical fertilizer differs depending on the amount of organic matter applied to the soil. Second, asset constraints disable the average African farmer from successfully engaging in agriculture based on external inputs. Third, agricultural intensification, especially under the wrong application, climate change and population growth cause soil erosion which, threatens the sustainability of SSA's agriculture. ISFM is a package of technologies that necessarily include the use of chemical fertilizer and improved varieties, but they should be used in combination with practises that facilitate soil nutrient regeneration, soil organic matter incorporation and prevention of erosion which go hand in hand through conservation agriculture (Vanlauwe et al. 2010a; AGRA 2015; Bellwood-Howard 2014). Since poverty is the main constraint to African farm households, an approach is required that needs little extra labour and capital input and markets to facilitate the intensification process (Toenniessen et al. 2008). ISFM attracts renewed interests to farm adoption results. Green Revolution efforts follow a top-down approach, while the success depends on the adoption behaviour of farmers. Insights into the drivers and constraints of farmers to adopt ISFM are therefore required for an African Green Revolution to succeed.

Based on the idea that the rate of uptake of agricultural technologies by poor farmers is positively related to market institutional development, AGRA's project include a wide range of market institutional development efforts. Lack of markets or failure of existing markets leads to adoption and productivity (Toenniessen et al. 2008). Researchers, however, are generally more concerned with the role of context specific factors in adoption behaviour. Studies show that household assets and the environment often play a determining role in the adoption of agricultural technology by farm household, but this does not lead to any conclusions on how excluded households can escape from a low input – low output trap. While there is ample evidence that the adoption of agricultural technology relates to household asset constraints and there is a general agreement that markets provide the incentive and the means to intensify production, there is little evidence that market access leads to the adoption of improved technology. This study makes these ends meet by studying the relation between market access and the adoption of ISFM. This will show if markets have the potential to include farm households that are constrained by poverty into the group of technology adopters. Since a lack of assets is a general characteristic of poverty, this research will be useful to understand how markets can play a role in including poor smallholders into an African Green Revolution. This will provide useful outcomes for current efforts by Green Revolution advocates such as AGRA, since ISFM and market access play central roles in the many projects that they represent.

Study Objectives and Research Question

This study will assess the adoption of ISFM and the role that market access plays in this process using a dataset from Mbeya region in Tanzania, one of the regions that AGRA has defined as having the potential for a uniquely African Green Revolution. None of the technologies of the ISFM package are completely new to the farmers in this region, a comparison of the characteristics of adopters and non-adopters will provide insight into the role of market constraints and asset constraints in adoption behaviour. This study will answer the following question:

Main question:
- *What is the relation between market access and household adoption of Integrated Soil Fertility Management in Mbeya region, Tanzania?*

Sub questions:
- *How does market access relate to the adoption of ISFM?*
- *How does market access relate to the adoption intensity of ISFM?*

This thesis starts with an elaboration on the research context in chapter 2 followed by an explanation of the analytical framework in chapter 3 which includes a review of relevant literature on technology adoption and market access. The methodology and data will be explained in chapter 4, the descriptive statistics will be presented in chapter 5. Chapter 6 will present the results followed by a conclusion, limitations of this study and a discussion in chapter 7.

2. Research Context

2.1 The African Green Revolution

The failure of modernized agricultural development in sub-Saharan Africa strengthens the conviction of those who have been sceptical of the GR. There have been many attempts to develop African agriculture from low input-low output to high input-high output production, but none have resulted in a continental nor a national revolution. Africa has few well navigable waterways and no continent is more land locked. The tropical climate challenges food storage, favouring day-to-day harvest of roots, tubers and starchy fruit for consumption. This same climate provides soils that are fertile but quickly exhausted. Livestock provided means to store capital, manage risks and raise land productivity in pre-industrial societies, but the tsetse fly and high temperatures make animal husbandry impossible on major parts of the African continent and difficult on the other parts. Those regions that are not home to the tsetse fly suffer from erratic rainfall patterns that make the crop season a yearly gamble for farmers. Risk causes them to adopt strategies that are not always consistent with commercial mind-set that the GR movement advocates. In the most arid regions of Africa, nomadic pastoralism is the only feasible livelihood strategy. However, to say that it is the environment that causes Africa to face a future of inescapable subsistence agricultural would derogate the potentials of this continent. No society in the world has shown such adaptive and responsive behaviour as African farmers, history shows that the African farmer has historically been better off than his counterparts elsewhere in the world and the technological developments of the past century have the potential to deal with many environmental barriers. The development of infrastructure can cut back transportation costs, machinery can compensate for the lack of animal power, chemical fertilizer can substitute for animal manure and improved varieties adapted to African circumstances have been developed (Frankema 2014).

2.2 Tanzania

The Republic of Tanzania is located in East-Africa, neighbouring Kenya, Uganda, Rwanda, Burundi, The Democratic Republic of Congo, Zambia, Malawi and Mozambique. Tanzania's mainland, spanning 942,800 km² of which 61,500 km² is water, is largely covered by woodland, bush land and wooden grassland. It has a warm climate with a short rainy season from October to December and a large rainy season from March to May, the large rainy season has more intense rains than the short one (Statistical Abstract 2011 2012). In 2013 Tanzania had a population of 49.25 million people of which 28.2% lived in poverty according to national poverty lines. Gross national income in 2013 was 2,430 in international dollars using purchasing power parity rates; in that same year GDP growth was about 7%, following a stable trend over the last decade. 70% of the Tanzanian population lives in rural areas, where agriculture is the main source of income and employment. Agriculture contributed to 28,4% of national GDP in 2013 (World Bank Open Data 2015).

When Tanzania became independent in 1961, Julius Nyerere, the leader of the revolution, chose for a one party state following a socialist model. This model, called 'Ujamaa Socialism' was based on freedom, self-reliance and family hood and proved to be successful in creating a united nation. The establishment of Swahili as the national language, instead of the colonial language, contributed to this transformation (Ibhawoh and Dibua 2003).

In 1991, Tanzania was the second poorest country in the world. Despite political stability and national unity, the economy declined from independence onwards. Price controls were a prominent feature of Nyerere's policy to protect low income groups from inflation and prevent price arbitrage among manufacturers and traders, but prices where set too low, marketing incentives did not stimulate the agricultural sector to behave market oriented anymore and the volume of marketed crops declined rapidly. Export crops were obliged to be sold to governmental marketing agencies, which operated inefficiently and were unable to offer producers prices that matched pre-colonial profits. Besides, exporters and importers had to surrender to increasingly complex regulations while foreign exchange also declined due to overvalued exchange rates. The effect of severe import and export restrictions increased by the lack of essential inputs and infrastructure. Tanzania's nominal GDP declined by 45% between 1976 and 1991, real income per capital fell by 15%. The Tanzanian economic collapse is one of the most severe in history without the factors war and/or natural disaster involved (Edwards 2012; Nord et al. 2009).

From 1991 onwards, Tanzania's national economy made a major comeback. Between 1990 and 2008, real GDP per capita increased by 64% which caused the country to return to its GDP per capita level of 1976. Not only economic, but also social indicators show improvement over this period. From 1995 the Tanzanian Human Development Index (HDI) increased from 10% under the African average, to 3% above the average. This process of improvement is said to have its roots in The Economic Recovery Program for a gradual liberalization that started in 1986 to end the cycle of economic degradation. The reforms began when the country was at the uttermost level of crisis, in 1986 there were no normal economic relations within formal sectors and especially peasants in the remote regions of the country lived under complete subsistence (Edwards 2012). According to Nord et al. (2009), of the International Monetary Fund (IMF), the reforms resulted in a vicious upwards cycle of economic recovery starting in 1995, in which committed ownership was the key. However, the success of liberalization in Tanzania remains a point of discussion especially when it comes to the development of rural areas (Cooksey 2011; Edwards 2012; Ibhawoh and Dibua 2003; Putterman 1995).

Due to liberalization, exports have increased significantly and Tanzania has regained some of its former global market share. The Liberalization process also included a transfer from a single state-owned bank sector, to a sector with dozens of commercial banks and financial institutions that deliver a range of financial services. There is room for improvement since the access to financial services needs to be broadened. Currently, banks operate almost exclusively in Dar Es Salaam and only involve in low-risk lending to high-value customers. Barriers to better access to finance are the inability to use land as collateral, underdeveloped leasing, equity and export finance markets, and low access to credit information (Nord et al. 2009). The effect of privatisation on the agricultural sector cannot be ignored. Devaluation put an end to decreasing farm incomes, import liberalisation made basic consumption goods available after long times of shortage, removal of state monopolies allowed national and international players to enter te market with varying degrees of competition, denationalized banks regained autonomy (some now provide crop loans) and inflation decreased to single-digit levels. Market liberalization ended decades of sate controlled agricultural input and output markets that resulted in an increase in subsistence agriculture and rural poverty. Also fertilizer subsidies were phased out creating room for private traders (Cooksey 2011). But even though 74% of the population lives in rural regions, agriculture has been lacking behind throughout the high growth period.

The Ujamaa period and liberalization left national marks on agriculture. Before independence, Tanzania was home to a flourishing agricultural sector including a well-developed smallholder sector. Unions such as the Kilimanjaro Native Coffee Growers Union (KNCU) and the Victoria Federation of Cooperative Unions protected the profit margins of producers. Since these unions were largely autonomous, they were free to offer growers prices depending on local conditions. The early years of independence still saw grain exports exceeding imports and high growth rates in the production of coffee, cotton, cashew nuts, tobacco and tea.

During socialism, the National Price Commission controlled all prices at retail and wholesale level. Relative prices kept on declining though, a decline in capital accumulation also affected the sector. Between 1967 and 1981, real investment in agriculture declined by 37%. Eventually, crops could not reach their markets because infrastructure degraded. Peasants that used to be involved in market production withdrew into subsistence or produced for black markets. When it became clearer that government policy was failing, the policy became more aggressive at first. 'Villagization' became obligatory; cooperatives became prohibited and were replaced by inefficient and corrupt crop boards. Since villagization meant a forced replacement of peasant to often less fertile lands that were often kilometres away from their houses, agricultural output continued its decrease. Many believe that the high rate of subsistence agriculture and failure of cooperatives today in Tanzania, is a painful inheritance of government planning in the days of Ujamaa socialism (Cooksey 2011).

During the villagization process, unions were dismissed and Ujamaa-villages were assigned as multi-purpose unions instead. These unions had to equalize prices, regardless of local conditions. Any other trading channels were prohibited. Input supply was also a mandate of these unions, in return for crop sales (Putterman 1995). While prices lowered increasingly by the early 80s, farmers were pushed into participation in illegal trading channels or subsistence farming. By the end of Ujamaa, authorities seemed to acknowledge the ineffectiveness of bans on trade and slowly released constraints (Putterman 1995). Up to this day, staple crop exports are still heavily regulated. The Tanzanian government is known to close borders for maize in years of low productivity to protect the country's food security. In that sense, the idea of self-reliance, one of the pillars of Ujamaa, is still a value to the government. Since the closing of borders has a negative impact on labour income and productivity of land (Diao et al. 2013), it is likely that informal trading channels still play a role in the search of the agricultural sector for demand. The favourable population to land rate and fertility of Tanzania, creating potential to feed surrounding countries are therefore in conflict with national policy values.

Another inheritance of socialism is that the, once so important, unions lost favour of farmers. Before and after liberalization, farmers searched for alternative output channels causing the role of cooperatives to fade away in the 90s. The role of unions as publicly beneficial was unserved and the removal of regulations did not meet any resistance (Putterman 1995). Today the role of cooperatives is mixed; some play an active role whereas others are mere lists of members without any function or farmers even being aware of their membership.

Tanzania spans long distances, and the years of economic downfall have severely affected the quality of infrastructure. While only 1/3 of the required amount of money was budgeted for road maintenance, new roads were constructed making the situation increasingly unsustainable. Interesting though, is that the villagization process brought households much closer to the roads, which is currently still a reason for farm households to stay away from their places of origin. Also their central position around roads stimulated trade efficiency. Together with a consortium of international support, the government launched the Internal Roads Project (IRP) in 1991 aiming for an improvement of the degraded road system. These investment were not only aiming on restoration, but also at implementing more sustainable policy such as a road tax of which the benefits go straight to maintenance (Putterman 1995). Today, Tanzania has a comparatively good road system and is one of the few countries in the region that allocates adequate resources to maintenance (Tanzania's Infrastructure: A Continental Perspective 2010).

Figure 1 Tanzania's road system is now among the best in the region.

Overall, the economy of Tanzania made impressive improvements during the 90s. For those farmers who were favourably situated, new markets opened and access to consumption goods improved. The financial reforms generated an increase in food crop production, due to liberalized markets. Transportation facilities improved as the IRP continued and the Sasakawa Global 2000 (SG2000) project, the first Green Revolution-minded projects to take place in Tanzania, showed the capability of the Tanzanian extension system and farmers to spread and apply modern agricultural innovation. But those farmers, who were situated more remotely, lost market access due to the disappearance of unconditional marketing channels. The government did not supply inputs and did not buy food crops anymore and credit was only an option for the better-off export crop producers. Those farmers that were driven into subsistence during socialism remained so as there were no opportunities in the remote parts of the country to regain market positions. The export crop sector hardly profited from liberalization, which seemed to be a remedy only for public financial deficits. If there is one group of farmers that profited from liberalization, it is the small group of larger commercial farmers: individuals, who somehow managed to lay their hands on capital, either on- or off-farm, got access to additional land and input/output markets. One theory is that these large scale farmers could expand even under lacking economies of scale since they were the only ones able to buy harvests from the credit constraint smallholders. They could set the price and were therefore in a monopoly position. Also, they accessed a high supply of low-wage labour. However, if the distributional and social costs of these developments are taken into account, the liberalization reforms can by far not be considered a success for agriculture (Putterman 1995). It remains a question therefore, if liberalization has been the right way forward for the protection of smallholder agriculture in Tanzania.

2.3 A Tanzanian Green Revolution

AGRA is not the first organisation with the mission to provoke a Green Revolution in Tanzania. In 1989, just after the start of Tanzania's structural adjustment program, the SG2000 project started operating with the aim to demonstrate that GR inputs used in South-Asia could develop Tanzanian agriculture even in the absence of irrigation. Project participants reported to achieve tripled yields on demonstration plots in 1991 in the Northern and Southern Highlands. SG2000 spread technology through extension programs; they facilitated district government extension workers with motorized vehicles and appointed village level extension agents. Ten farmers in each village were selected for training in the first season, each farmer was asked to train nine other farmers in the next year and so on. Also SG2000 supported farmers through storage facilities, helping them to deal with the increased harvest stocks. Initially, inputs could be bought on a 100% interest free credit basis. SG2000 operated during Tanzania's structural reforms. One of these reforms was to shift the role of facilitating input and output market from crop boards and government cooperatives to private traders. Crop boards and government cooperatives operated nationwide under an equal pricing system. With the privatization of their mandate, transaction costs regained their role in national trade. As a consequence, remotely located farmers lost their access to input and output markets. Also, crop boards and cooperatives used to supply inputs on credit, to be repaid in harvest. Because they were the only credit supplier available, privatization led to a nationwide lack of credit. Although SG2000 managed to show the benefits of GR inputs in Tanzania's agriculture and the capacity of the national extension system and farmers to successfully spread and adopt modern agriculture, the project did not manage to set up a sustainable supply of inputs. The initial successes of the project were based on an artificial supply of inputs and credits, which could not be matched by private actors. Eventually the remote rural population remained excluded of access to input and output markets. A Tanzanian Green Revolution could not be achieved (Putterman 1995). It could be argued that the SG2000 project would have yielded more success in the days before structural adjustment, when nationwide market access could be realized through government planning.

Figure 2 Agro-dealer in Mbarali district, Mbeya receiving a new supply of fertilizer.

Current GR projects in Tanzania, such as the breadbasket project in the Southern Highlands, but also other projects that take place under AGRA such as the seeds programs, market programs, FO support programs and soil health programs all over the country, are still based on the idea that agriculture can improve using fertilizer and improved seeds. However, the technology got more integrated into a wider range of interventions that facilitate the development of assets that smallholders generally lack. Also, market access receives more attention. On the field level, GR technology got more integrated into a wider range of technologies that should apply better to the farmer. Acknowledging that the responsiveness of fertilizer and improved seeds increases when more organic matter is incorporated into the soil, that soil erosion is a serious drawback of GR technology and that a sustainable approach to soil health will eventually lift the burden of external input dependency that asset constraint farmers cannot conform to, integrated soil fertility management has been introduced as the GR package that is fit for the African farmer. Considering twenty years of economic development since the SG2000 project and the efforts made to create a uniquely African GR approach, the question is if ISFM will become a sustainable way of agriculture in Tanzania.

2.4 Integrated Soil Fertility Management

The introduction of herbicides, fertilizer and improved varieties were revolutionary in the development of modern agriculture, reducing the need for tillage and even making it redundant. The efficiency of fertilizer use can be increased by using practises that increase the fertility of the soil by other means. A farmer can choose from a wide range of practises that all have their potential benefits and drawbacks. Governments, the private sector, but also many philanthropic and academic actors, give most attention to practises that, when applied in the 'right' way, should increase farm production. GR advocates have always been concerned with modernized intensification of agriculture; AGRA has now also incorporated conservation agriculture into their projects to increase the efficiency of input use. ISFM, as promoted by AGRA in Tanzania, consists of nine practises in the categories of external inputs and conservation practises. The promoted inputs are fertilizer, improved seeds and herbicides. The promoted conservation practises are no-tillage, leaving crop residues in the field, mulching, using cover crops, intercropping and crop rotation. An agronomic perspective brings a slightly different definition to ISFM, Vanlauwe et al. (2010b, p. 19) define ISFM as: "A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm, combined with the knowledge of how to adapt these practices to local conditions, aimed at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles." This definition puts more emphasis on the combination of fertilizer, improved seeds and organic matter to optimize the use of nutrients, though acknowledging the need for additional practises to optimize efficiency of nutrient use. This study will not redefine ISFM, but rather investigate the adoption of different combinations of practises. These practises are the use of chemical and organic fertilizer, improved seeds, herbicides, no-tillage, crop residues, mulching, cover crops, intercropping and rotation. There is a high diversity in opinions on the benefits of conservational agriculture among academics; much seems to be unclear about the true consequences of certain practises and the context specificity of their benefits. Since there is still a lot of debate among agronomists, the confusion among farmers cannot be expected to be lower. The following section will provide explanations on the conservation practises.

No-tillage is not a practise, but rather 'not a practise'. Since the positive aspects of tillage are substitutable with external inputs, the negative effect, which is soil erosion, can be prevented by abandoning the practise. Critique on the use of no-tillage goes hand in hand with critique on the use of herbicides and chemical fertilizer as these are required to compensate for the omitted benefits of tillage. Tillage requires labour inputs where crop external inputs require physical and financial capital of a farmer, smallholders are therefore not easily convinced. This assumes though, that soil nutrient content and weed plagues are the central reason to adopt tillage in the first place. Farmers in Ethiopia, however, indicate that the reason why they till is to improve water infiltration (Giller et al. 2009). There are also voices that stress the negative impact of NT on gender division, as ploughing is generally a male's task whereas weeding is a female's task. NT could increase the often already unequal labour division between men and women. Lal (2009) calls the promotion of improved stoves, which do not burn organic matter, as a step towards stimulating NT farming in sub-Saharan Africa. No-tillage increases yields but needs organic matter to infiltrate to the soil.

Figure 3 Tillage using oxen in Tanzania. The soil is inverted and ripped to fight weeds (Steiner 2002).

Crop rotation and Intercropping are practises that can decrease soil nutrient depletion. Monoculture can result in the apparent depletion of soils because the recurrent cultivation of one crop will deplete those nutrients that this crop uses most. When different crops are grown on one plot at the same time or over consecutive seasons, this depletion process can be decreased because different crops have a different nutrient uptake. Also the use of some crops has beneficial effects on soil nutrients, the roots of legumes, for example, are known to fixate nitrogen. Crop rotation refers to the differentiation of crops per plot in consecutive seasons while intercropping refers to the combination of different crops per plot per season. Another benefit of crop rotation is that it disrupts the transmission of pests. Since pests are often crop specific, they are disturbed by the cultivation of different crops per season. You can also rotate cropping with cattle grazing, to maintain economic benefits while restoring soil nutrients, or fallow periods (leaving a plot to rest to restore nutrients). The difficulty of intercropping/crop rotation is to identify the right combination of crops. Well know combinations/rotations are maize-legume systems. Others systems could also involve non-value crops, such as glover which is also known to fix nitrogen. The drawback of the last strategy is that the land provides no income for a whole season, which is a disincentive when there is poverty, food scarcity or land scarcity. Intercropping and crop rotation can be combined. Farmers in Zambia, Zimbabwe, Malawi and Mozambique prefer to continuously grow maize as a risk mitigation strategy according to Thierfelder et al. (2012). Since farmers in SSA often have few land, rotation means taking a big risk in self-sufficiency of food production. Maize is a main staple crop for own consumption but has markets for surpluses as well. In anticipation of food shortages, households prefer the cultivation of maize even though rotation will restore more soil nutrients. Therefore, intercropping is more popular than crop rotation. Farmers estimate that the crop penalty of intercropping is low. Whether this is true or not is questionable, since legumes suffer a growth penalty from the sunlight that the higher maize crops block. Mpepereki et al. (2000) show from studies in Zimbabwe that rotations using improved legume varieties have only acquired a central role in farming system where a secure access to markets was present. This shows that farmers were not willing to adopt a crop merely for conservation purposes.

Figure 4: Maize intercropped with beans in Tanzania (Kiboko 2006).

A *mulch* is a layer of any material covering the soil. It is mainly used to reduce soil erosion, but also beneficial to reduce evaporation, improve water infiltration, reduce temperatures in the upper soil layers and increase aggregate stability and soil porosity. Covering 30% of the land should reduce erosion by 80%. A mulch can be made out of many materials, plastic sheets for example, but also organic material. When live crops are planted for their mulching function, they are called *cover crops*. Cover cropping is and old practise that has regained attention due to its range of benefits. Cover crops used to be grown for animals to feed on, or to till into the ground as green manure. Cover crops are now found to be useful in no-till systems as slow breakdown residues, organic mulches, weed suppressors, for soil protection, for maintaining soil hydration and for their positive impact on the soil nutrition balance. Often, legumes are used as cover crops for their ability to fix high amounts of nitrogen. However, in contrast to intercropping systems, cover crops mainly prove their usefulness off-season or during fallow periods. Cover crops can also be used during the cropping season, but they should be cultivated with a sufficient delay so that they emerge only when the main crop is already maturing. A cover crop should not compete with the main crop. Cover crops can

Figure 5: Dolichos as a cover crop in Kenya (ACT-Africa 2015).

absorb nutrients that would have been washed away by rain otherwise. Crops that compete highly with weeds by stealing nutrients and blocking sunlight can substitute for herbicides without disturbing soils as tillage does. Cover crops cannot be used to substitute for herbicides during the crop season. The ways in which cover crops contribute to soil water management are the absorption of water in organic matter, protecting the soil from physical impact of raindrops and blocking sunshine to prevent evaporation. Covered soils are also more accessible after heavy rains for men and machinery. Cover crops contribute to pest management when they host predator insects that feed on the insects that are a plague to farms. However, cover crops can also be a host to pest and therefore they need careful selection based on a thorough knowledge of pests and predators. Land ownership is an important aspect in the usefulness of cover crops; land rental can prevent a farmer from controlling off-season soil treatment. Besides, land renters are generally not so interested in conservation agriculture since the long term productivity of the land is not in their interest. Cover crops work best in combination with no-tillage systems because tillage would disrupt its structure as a mulch (Lu et al. 2000). Cowpea, sweet potato and pumpkin are suitable cover crops in East-Africa since they spread fast. Other cover crops for this region are sun hemp, velvet bean and lablab. Farmers are generally reluctant to grow crops that are not valuable for consumption or markets, therefore legumes have the most potential even though they do not provide a maximum amount of biomass and are removed at harvest time (Steiner 2002).

Crop residuals are also often used as a mulch, since they are surpluses and ready to use in the field. Another benefit of these residuals is that they eventually decompose and reincorporate nutrients in the soil. A main critique on the use of crop residuals in the field is that they are widely used as high value inputs in other activities such as animal feed or fuel for stoves. In regions where livestock keeping is uncommon, farmers often burn crop residuals to enhance soil fertility, destroy weeds and other pests such a rodents. Leaving crop residuals also enhances plagues since it attracts rodents and transfers diseases (Giller et al. 2009). In a case from Mozambique, Giller et al. (2009) explain how residuals disappear from the field within weeks carried away by termites, whereas they should remain there much longer to fulfil their benefits. Many rural communities in sub-Saharan Africa rely on communal use of land, often including grazing patterns in which off season land is available to anyone's cattle. If farmers want to leave a mulch on their fields, they would have to fence their land to protect it from animals or others who might take the often valuable crop residuals away. This would require them to re-negotiate local communal laws, a reasonable constraint to implementation of this technique. Chivenge et al. (2007) stress, based on their research in Zimbabwe, that the use of crop residues for animal feed and the off-season communal grazing of lands are more pertinent issues that constrain the retention of crop residuals. Also, they state that the soils already have a low level of organic matter which is highly related to the low-productivity of the soil. Also, the need for fertilizer and herbicides are just as pertinent, and these inputs are not highly adopted in SSA.

Figure 6 Maize residue as a mulch in Tanzania (Shetto and Owenya 2007).

2.5 Mbeya Region

Mbeya region, in the Southern Highlands of Tanzania, is well suited to supply Tanzania from their crop production, a lot of agriculture, however, takes place on subsistence level. Farmers indicate to be struggling with market access (National Sample Census of Agriculture 2007/2008 Volume VI: Regional Report: Mbeya Region 2012). AGRA has identified Mbeya as a bread basket region that needs market development to stimulate growth and food security. Without markets, farmers do not access cash which limits them to their own household's assets since they cannot invest. The theory of AGRA is that facilitating market production will decrease transaction costs and increase cash in the region, allowing production to move to elsewhere in the country where food is more scarce (SNV 2013). This problem of remoteness and financial exclusion was already an issue in the post-independence decades that Nyerere tried to solve through its unions, who bought output under unconditionally equal prices and provided inputs on credit. This policy was effective but as the unions struggled with the public financial policy, liberalization reforms had to abandon the planned protection of remote farmers (Cooksey 2011; Edwards 2012; Ibhawoh and Dibua 2003; Jerven 2011; Nord et al. 2009; Putterman 1995). The liberalization reforms have yet not managed to solve the problems of remoteness in agriculture, leaving Mbeya to produce far under its potential.

Mbeya region is nationally known for its high agricultural production. A relatively cool climate and sufficient rainfall create suitable circumstances to grow food crops for (inter)national demand or cash crops. The region is bordering Zambia and Malawi. In 2008, when the most recent agricultural census took place, the population of Mbeya was 2,707,41, it is therefore one of the most densely populated region of the country with 45 people per km². 93% of the population ranks annual crop farming as the main source of income. Widely grown food crops are maize, rice, beans, sorghum, Irish potatoes and sweet potatoes. Popular cash crops are coffee, tea, and pyrethrum. Livestock keeping is also a common activity. 46% of households in Mbeya have off-farm income generating activities. 74% of the land in Mbeya is arable. Of the total available land for agriculture, 80.9% is utilized. Households use 1.5 ha on average, which is below the national average of 2 ha. 10.3% of the land was, during the census, under permanent crop whereas 52% was under temporary crop and 10.6% under fallow. The majority of the cultivated land was covered with cereals (67%) whereas pulses covered 15.7%, oil seeds and nuts 11.6% and cash crops only 1.4%.
The most important crop is Maize, followed by beans, rice and groundnuts, they reach out above a high variety of other crops (National Sample Census of Agriculture 2007/2008 Volume VI: Regional Report: Mbeya Region 2012).

Figure 8 Mbeya Region

154,055 Of the total crop area, which is 26.7%, was planted with fertilizer of which 85% was planted with inorganic- and 15% with organic fertilizer. 20% of the land was planted with improved seeds, 19% with pesticides of which half were herbicides. 5.9% of the land in Mbeya was under irrigation, of which 54.5% concerned the district Mbarali which is home to an advanced irrigation scheme. 27% of the irrigated land was in Mbozi

Figure 7 Mbeya Region

whereas the rest of Mbeya had only a minor access to irrigation, a constraint that is common across Tanzania. 78.2% Of the cropping households in the regions received agricultural extension of which 83.5% came from government agents, 32.8% from neighbours, 17,3% from media, 10.5% from NGOs, 5.3% from large scale farmers and 4.7% from cooperatives (National Sample Census of Agriculture 2007/2008 Volume VI: Regional Report: Mbeya Region 2012).

Of the 519,454 households reporting to use store crops, 2,235 use ‘modern stores’ whereas the majority uses sacks/open drum and a smaller part uses ‘traditional structures’. 76.5% of the households reported to sell at least a part of their crops. They report various problems: too low prices in the open market, remoteness from markets, too high transport costs, lack of market information and a lack of buyers. Very few household had access to credit. The main providers are cooperatives, followed by savings and credit societies and family friends or relatives, to a smaller extend credit is provided by private individuals, banks, NGOs and traders (National Sample Census of Agriculture 2007/2008 Volume VI: Regional Report: Mbeya Region 2012).

3. Analytical Framework

3.1 Defining Adoption

There is an extensive amount of literature dedicated to explaining farm adoption of agricultural practises. A broad definition of 'adoption' is provided by Rogers (1962) as "the mental process an individual passes from first hearing about an innovation to final adoption" (Feder et al. 1985, p. 17). The term adoption gets more complex in practise, where many factors such as incentive, rational, religion, assets, environment, coincidence and experimental behaviour all have their impact on eventual farm practises.

Adoption studies on the use of external inputs usually focus on one input only, studies on the adoption of herbicides are hardly available. There is a lot of literature on the combined adoption of conservation practises.

There is a high variability in the ways in which the concept of adoption is approached. Many studies use a binary model for adoption (Kassie et al. 2013; Kassie et al. 2015; Teklewold et al. 2013). This is most likely due to the limitations of available datasets, because a closer look at the adoption process will provide more complex dynamics than just a simple distinction between 'adopter' and 'non-adopter'.

When adoption is a binary variable, this often means that adoption is defined as 'using a technology now', which practically means the survey season. Richards (1993) argues that a snapshot of a farmer's practise in time is limited. He argues for the important distinction between knowledge and performance, in which performance refers to the practical outcome of cultivation, which does not necessarily have to be based on knowledge and neither does it have to be a permanent way of cultivation. Experimentation is an example of performance in contrast to action based on knowledge. These kinds of approaches to adoption are difficult to frame in research, especially when the methodology is quantitative.

Wendland and Sills (2008) argue that there is an importance to account for adopters, non-adopters and dis-adopters. Dis-adopters are those who have adopted a technology, but do not use it anymore. Reasons for dis-adoption can be many, for example disappointing results or unexpected circumstances. Their methodology includes this category of adopters by asking whether someone has 'ever adopted the technology' and if he has 'ever abandoned the technology'. Another approach is used by Marenya and Barrett (2007) who use time-series data to study the development of ISFM adoption over five years. They find that farmers are not able to keep up the practises over longer periods due to financial constraints, even though they adopt them in the first place

Another limitation of a binary approach to adoption is that adoption does not necessarily mean that the practise is executed correctly. Since ISFM is a technological package developed by agronomists, it is easily misunderstood by farmers. There is an amount of literature that does not come from economic or anthropological scientist, but from agronomists. An agronomist can judge in how far a technology is implemented in the right way. These studies also come with field-level conclusions. Giller et al. (2009), show how the leaving crop residuals in the field is not possible in Mozambique due to termites who steal al residues within two weeks. Such a factor has crucial implications for adoption, but is usually not covered in a standard socio-economic questionnaire.

Besides quality, also the intensity of adoption can be studied. Murage et al. (2012) and Thuo et al. (2011) use tobit models to for this. It works well for inputs, since the quantity of inputs applied is an easily measurable variable. For non-input practises percentage of soil treated could be an indicator. Another approach to adoption intensity analysis is used by (Langyintuo and Mungoma 2008; Noltze et al. 2012; Tambo and Abdoulaye 2012). They use a double hurdle model, which is able to separate adoption and adoption intensity while a tobit model would combine the two of them. A double-hurdle model starts with a probit model to estimate the adoption probability, followed by a truncated normal model which estimates the intensity of adoption. Noltze et al. (2012) use a double hurdle model to study the adoption of SRI methods in Timor Leste using plot specific data. They collected plot level data on quality of adoption which they use to create a score; however it is likely that conducting such a survey amongst a sufficient sample requires a lot of effort. They measure the intensity of adoption in two ways: first they measure the acreage on which SRI is applied, consequently they use a variable that represents the amounts of SRI components that are adopted.

Thuo et al. (2011) study the crop specific adoption of chemical fertilizer on peanut, millet and peanut-millet intercropping. Their approach is unique for its crop specificity; they show that the use of fertilizer is related to different factors per crop. Some crops are produced for different reasons than others. Cash crops can provide a different incentive to farmers than subsistence crop for intensification practises. Some crops are mainly grown for their effects on soils, like legumes, even though they are consumable and have market value. Some crops are more risky than others; this can also influence the choice to treat them with certain technologies.

Many studies use quantitative approaches to agricultural technology adoption; they base their findings on questionnaires. The risk of questionnaires is that respondents do not present reality, because there is a political aspect involved, because of misunderstanding, impatience or other reasons. Observatory studies can define adoption by the observation of the technology in the field, such as (Glover 2011) advocates for the case of System Rice Intensification (SRI) which is a package of technologies applicable to rice farming. For this to work on a quantitative level, this needs obvious technologies such as the use of a private storage barn. But the detailed use of ISFM would only be observable when the farmer is joined several times per season and off-season on his plots to cover all the cultivation practises that are involved in ISFM. Such a qualitative and participatory approach cannot be realized in order to get quantitative outcomes since most research projects do not have enough capacity for this.

3.2 Explaining adoption

In order to quantitatively study the adoption of agricultural technology, one needs explanatory variables that have to be selected on forehand. The sustainable livelihood framework (SLF) as presented by Ellis (2000) is useful to frame these variables, since a household's assets provide the means to take action. Ellis (2000) defines five forms of household assets. The first is human capital, which is the value that one can create by mobilizing himself and others. Human capital that is beneficial for agricultural production is personal skill gained through education or experience and un-hired labour. Health is also a factor that determines the value of human capital. Human capital therefore refers to the quantity and quality of people that can support your livelihood. Physical capital refers to all physical assets that generate a future flow of income; they are therefore production goods and not consumer goods. For agriculture this refers to equipment and facilities. Financial capital refers to the amount money that a household can mobilize. Natural capital refers to the value that nature has to offer, for example through rainfall, land fertility and sunshine. Social capital refers to social claims that one accesses when being a part of a group or social network. A concrete example of social capital in agriculture is a farmers group. By being a member of a farmers group, farmers benefit from an increased social network. Social capital can be deployed to influence policy but also to gain other forms of capital, a credit cooperative can be used to gain financial capital while cooperatives also often serve their members with tools (physical capital). Together, these categories can be used to present a household's asset status.

The livelihood framework provides a more detailed definition of poverty by addressing the aspects involved. Instead of stating that a household is 'too poor' to take action, this framework can be used to identify what exactly poses the constraint. It recognizes people as actors with assets and capabilities instead of putting the poor in the position of passive victims (Adato and Meinzen-Dick 2002).

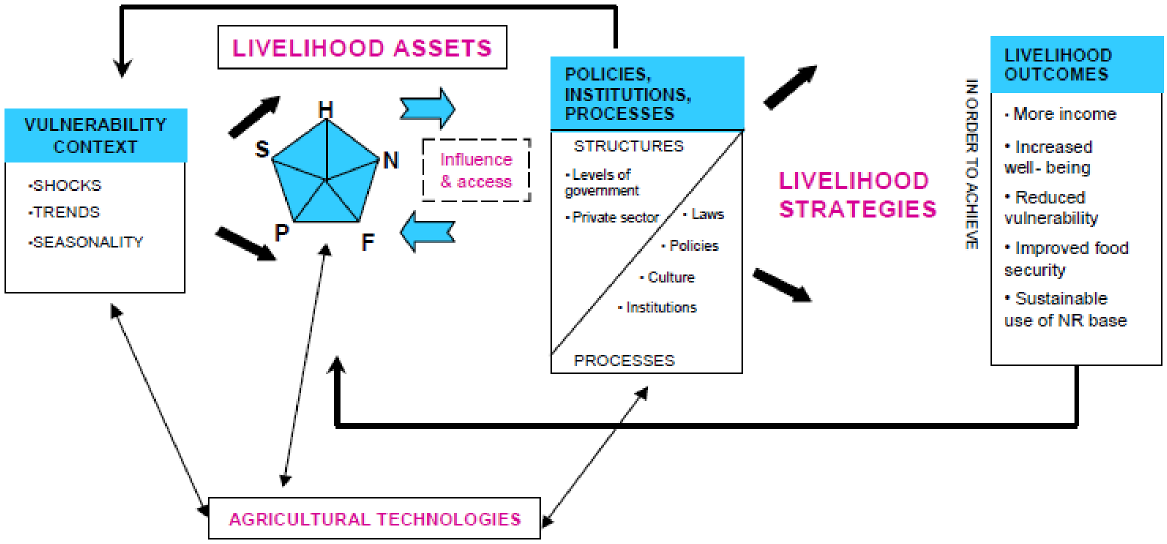

Figure 9: The Sustainable Livelihoods Framework with agricultural technologies (Adato and Meinzen-Dick 2002).

Ellis (2000, p.10) defines a livelihood as 'the assets, the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by an individual or household'. Figure 8 shows how livelihood strategies are determined by policies institutions and processes that interact with livelihood assets. This takes place in a vulnerability context which refers to the processes that a household or individual cannot control. Agricultural technologies interact with this context, assets, policies, institutions and processes (Adato and Meinzen-Dick 2002). The SLF can either be used to measure how the household asset status relates to technology adoption but it can be used as well to control for the household asset status while measuring the relation to other variables. In the last way, you can explain adoption determinants regardless of whether the household is 'poor' or not.

Human Capital
To account for human capital, almost every study includes characteristics of the household head as determining variables. Education, gender, age/experience and health are recurrent variables. Martey et al. (2014) study the adoption and adoption intensity of chemical fertilizer use in the context of an AGRA project in Northern Nigeria. They find a significantly negative relation between adoption and having a male household head, the age of the household head and the nativity of the household head. The role of education and experience are often studied because technology adoption is easily associated with knowledge and intelligence, but also, such as Knight et al. (2010) show, with risk-taking behaviour. Risk perception on itself has long been a dominant explanation for adoption behaviour, and a popular subject of studies (Feder and Umali 1993). Parks et al. (2014) show how the access and perception of conservation agriculture differs between men and women, women are more constrained and their association with food differs for their position in the household. Therefore, adoption results are different when the decision taker's sex differs.

Financial Capital
Financial constraints are used, mainly in models on the adoption of inputs, as these are often more capital intensive technologies than labour intensive. Financial capital is usually measured by wealth indicators, since the amount of money possessed is sensitive information that cannot easily be gained from a survey. Besides, households in developing countries are often financially excluded, which means that they do not access financial facilities such as bank accounts. This means that they usually save financial capital in productive forms such as animals or housing material. Other ways of approaching financial capital is by looking at farm productivity and other sources of income (Knowler and Bradshaw 2007).

Physical Capital
Physical capital in agriculture refers to the tools used. The equipment used is therefore a straightforward and widely used way to measure this. Some use an aggregate variable for all tools used whereas some

distinct certain tools for their relevance. If certain technologies require certain tools, it is relevant to measure this equipment separately (Knowler and Bradshaw 2007).

Natural Capital
To account for natural capital; climate and farm biophysical factors are often found in studies on conservation practises. These factors are selected to point out the natural assets that a farmer accesses to achieve the adoption of technologies or that provide an incentive to adopt a certain technology. For example, rainy areas suffer from erosion through the washing away of soils. Conservation practises should prevent this from happening. If a rainy areas shows significantly more adopters, this can be interpreted as the motivation of farmers to adopt technology to solve this problem (Arslan et al. 2014). More detailed factors used are temperature, water quality, erosion, a soil quality index or the amount of clay (Knowler and Bradshaw 2007).

Social Capital
The role of social capital in adoption literature is in its infancy, likely since it is not easily measured (Knowler and Bradshaw 2007). The most approximate way is to use farmer organisation membership and the amount of members since these provide social capital. This variable is not a full indicator of social capital though; a socially influential individual might be making a much bigger difference than a farmer's group.

The amount of variables that studies identify as being significantly related to adoption is remarkable. An illustration of this heterogeneity of findings is provided by Knowler and Bradshaw (2007). In an attempt to find universal determinants of adoption of conservation agriculture practises they compare 31 peer-reviewed studies on adoption behaviour. They conclude that as the number of indices of a variable increases across studies, the likelihood of mixed positive/negative and significant/insignificant results increases. They explain the unconvincing pattern of explanatory variables as a consequence of the heterogeneous context of the used studies. Each study presents site-specific outcomes that cannot be used to provide universal insights. All too often these analyses take place without a theory that explains why specific variables have been selected for analysis and how measurements on their effects improve insight into the reality of adoption behaviour. The variables that could possibly play a role in adoption behaviour are countless; it is therefore difficult for researchers to give meaning to the outcomes of a regression of diverse variables that have no underlying theory. For example, Knowler and Bradshaw (2007) repeatedly find 'farm size' as a significant determinant, but the ways in which farm size could be related to technology adoption can be many. Perhaps the owners of small farms do not have the economies of scale to see the benefits of technologies, or the owners of large farms are richer and are therefore able to invest in technologies, or the land serves as collateral enabling them to access finance to invest in technology, or perhaps the size of the land disables them to adopt the practises because of a shortage of labour. Findings like this can mean a lot of things and causal relations are not necessarily direct, there can be effects related to omitted variables

Explaining adoption beyond poverty
Giller et al. (2009) argue that, given the complexities that a universal technology package encounters when applied in a local context, capacity building towards problem solving of local implementation issues should be an important activity of development agents. Failure to understand and involve farmers in problem definition and solving often results in the failure of technology transfers. Similarly, adoption will fail if the package does not meet the farmer's production objectives, does not deal with factors limiting production, the expected relative costs and benefits are locally not in the right balance and if the right institutions to provide the knowledge and inputs are not present (Giller et al. 2009). There are many studies into the determinants of adoption of agricultural technology, but a GR requires solutions to the problems that are identified as constraining adoption. From adoption literature can be concluded that agricultural adoption can often be related to the assets status of households, which comes down to an explanation based on poverty. A constructive approach to agricultural development would therefore identify solutions to overcome asset constraints.

Not only modern technology adoption, but also markets play a central role in the Green Revolution philosophy. Access to output markets should provide the incentive to intensify production, triggered by the desire to maximize profits. Access to input markets, including credit, should make demand and supply meet, since many sub-Saharan African farmers have the potential for productivity gains but not the capital to invest in modern technology. Finance institutions have no faith in the credit worthiness of

Africa’s smallholder farmer. As AGRA argues, many efforts to increase production have created ‘bread basket’ regions where production is high, but demand is low, driving prices down while many places on the continent still suffer from malnutrition due to a lack of purchasing power for food. Tanzania is one of the countries where AGRA has identified such a situation. The Southern Highlands are nationally known for their agricultural production, but are located at least a day’s drive from Dar Es Salaam. While farmers in the highlands have plenty of their own produce for subsistence, the urban population struggles for their daily meal. If market access would be improved, there would be an incentive for the highland farmers to increase production to meet national demands (SNV 2013; AGRA 2015). The question if farmers will respond to this incentive is left in the middle, farmers are assumed to be market oriented.

It is commonly believed in economics that a human being maximizes profits if conditions allow for it. Key et al. (2000) develop a model, based on this assumption that explains why some agricultural households do not intensify their agricultural production in contrast to others. They explain that market access is household specific, determined by fixed- and proportional transaction costs. Fixed costs refer to the costs involved in finding sellers or buyers, bargaining prices, monitoring business partners and other costs that are necessary to facilitate the overall trading process. Proportional transaction costs are the costs that increase with every unit traded, for example the transport costs per unit or the taxes paid per unit. The shadow price, which is a virtual price that represents the value that a household gives to its own product, determines the choice to become a net buyer or a net seller. If the shadow price is lower than the market price, the household will sell. If the shadow price is higher than the market price, the household will buy. Transaction costs create a price band around the market price, since they decrease the profits of selling while they increase the costs of buying. If the shadow price of a household falls within this price band, there is no profit in either buying or selling and no transaction will take place. In that case the household is a subsistence producer, it only produces for own consumption because there is no possibility to maximize profits on the markets (Key et al. 2000). Subsistence households only have a reason to increase production if their own food supply would be undermined. Based on this theory, it differs per household if market access is a requirement for the adoption of intensification practises. Since the Green Revolution is about vast production increases that go far beyond the consumption capacity of producers, market access is central in achieving revolutionary agricultural production increases through the adoption of modern technology.

Early studies specify the term transaction costs, which is useful because it includes all barriers to market access in terms of extra costs. However, the emphasis of remoteness has much been on transportation costs (von Thünen 1960; Fafchamps and Gabre-Madhin 2006). This would suggest that every household in the same place would have equal market access. Janvry et al. (1991) show that household specific factors play a role in generating transaction costs as well, explaining the differences in market oriented production within the same location. They apply this to labour and food markets. Carter and Yao (2002) show how households specific market access also play a role in land market failures. Also Key et al. (2000) show that every households has a unique price band created by transaction costs.

Goetz (1992) shows that the decision of Senegalese farmers to participate in a market is separated from the decision on how intensively to participate in markets. While improved market information relates to the participation in markets, access to technology influences quantities produced for markets. He does not consider technology access here as being a part of market access. Technology is an input however, and the use of inputs is a consequence of input market access. It is likely, that access to input and output markets are largely depending on the same circumstances. It could just as well be that technology access is a consequence of high market production.

Many studies focus on the quality of infrastructure as an important aspect of market access. Infrastructure is often interpreted as the quality of roads (Khandker et al. 2006; Mu and van de Walle 2007; Escobal and Ponce 2002), although infrastructure refers to more than just transportation means. Pinstrup-Anderson and Shinokawa (2006) count irrigation, energy, telecommunications, water supply, sanitation and transportation as physical infrastructure. Chamberlin and Jayne (2013) argue that, with the rise of mobile communication, remoteness is becoming less of a constraint in market access. Telecommunications are mainly useful for fixed transaction costs such as the costs of finding market information and business partners, monitoring and bargaining. What telecommunications do not solve are the proportional transaction costs of transportation, physical infrastructure such as roads or canals therefore remain of importance in facilitating market access.

There appears to be consensus on the role of transaction costs in determining the access of agricultural households to markets, but measurement of market access proves to be complex and subject to different interpretations of the phenomenon. The most accurate way of measuring market access is based on the idea that transactions costs are reflected in market prices. For every study, it is likely that the kind of information that is available determines how market access is measured.

Ample studies cover the subject of market access just as studies that cover the subject of agricultural technology adoption; the specific link between the two of these has rarely been studied.

Staal et al. (2002) use a spatial approach to the relation between adoption of a range of individual agricultural technologies in Kenya, market access and agro-climate based on geographical information. They find that estimates of distance prove to be useful in spatially predicting adoption, although the specific roles of factors are difficult to unravel. Variables based on distances, such as distance to the nearest market, distance to the capital or distance to the nearest ago-dealer, often behave in common patterns. Differently stated, distance based variables are often commonly related to 'remoteness' in general. It is therefore questionable whether it is useful to use a range of distance variables or a single one that serves best as a proxy for remoteness.

Zeller et al. (1998) find that the adoption of hybrid maize and tobacco (a new crop in the study region) is positively related to the access to agricultural credit whereas this access relates negative to the use of traditional maize varieties. They also use a measure of travel costs to agricultural markets which significantly matters for this crop decision. Also the price of fertilizers has a negative relation to the use of fertilizer intensive crops.

Katungi et al. (2011) show that market access contributes to intensification using external fertilizer but not the use of improved seeds among common bean farmers in Ethiopia. They base their findings on a spatial measurement of market access. They use a variable for distance the nearest urban centre.

Teklewold et al. (2013) use a measure of distance the input market in minutes walking and the means of transport to the output market to measure the relation to the adoption of input- and conservation practise adoption. They find significantly negative relations to the use of improved seed and fertilizer. If the means of transport to the market improves, the farmer is also more likely to use tillage. Distance to the input market has a positive relation to the use of tillage though.

Tanzania
There are few studies on adoption behaviour of farmers in the Southern Highlands of Tanzania. Kassie et al. (2013) use data from four unspecified districts of Tanzania to find determinants of adoption of rotation, intercropping, animal manure, conservation tillage, soil and water conservation practises, chemical fertilizer and improved seeds. They find that rainfall, insects/disease shocks, government extension effectiveness, tenure status of plots, social capital, location of plots, size of plots and household assets influence adoption of these SIPs. Kahimba et al. (2014) study the adoption of terraces, no-tillage, cover crop, ridges and large pits in Northern Tanzania. They find that low labour intensiveness of the technology, subsidies, training, extension visits, extension efficiency, presence of input and equipment suppliers, policies and bylaws promote adoption of CA whereas high labour intensiveness, lack of training, lack of capital, a lack of credit, a lack of equipment, limited promotion, no land ownership, lack of interest, lack of incentives, a lack of time, no availability of inputs, implementation costs, low returns, a lack of immediate returns and a lack of land constraint adoption. Mwaseba et al. (2006) study the adoption of rice related innovations in Kyela district and Kilombero district. They find that apart from the age and education level of the household head, determinants of adoption vary between the study areas. There is a discontinuity in adoption behaviour across Tanzania. Northern regions may show different adoption behaviour than Southern regions.

3.3 The Role of Market Access in Technology Adoption

De Haan (2000) argues that capital does not necessarily have to be privately owned, it is access to capital that counts. Even though globalization diminishes the sense of geographical distance, many sustainable livelihood studies still neglect the role of macro-economic policies and institutions. Kanji and Barrientos (2002) confirm to this view by stating that both universal economic studies and context specific studies prove to be useful, but that the gap that separates these approaches needs to be bridged to understand the link between trade and poverty.

This thesis will bring together the study of agricultural technology adoption with dominant ideas about the role of markets in facilitating and incentivizing intensification practises. Figure 8 shows how agricultural technology adoption interacts with structures, processes and the vulnerability context. Market access is an example of a factor that does not only affect household assets, but also provides an incentive for action. Structures and processes determine access to credit, knowledge, inputs and infrastructure whereas the vulnerability context determines trends such as prices and knowledge diffusion. The expected relationship between markets and adoption is based on the widespread idea that markets provide the possibility to maximize profits, with this possibility comes the incentive to engage in this maximization process.

It is important to take household assets into consideration. Human capital, physical capital, financial capital, natural capital and social capital provide a checklist to identify household constraints. Consequently, actions can be identified that remove these constraints (Ellis 2000). Asset constraints can trap a household in poverty; the household lacks the assets to take action to escape from this trap. This study is based on the idea that markets provide the means to escape from a poverty trap, no matter how big the asset constraint is. This requires all forms of capital to be available through market facilities. For agriculture, this means that market facilities should provide the assets needed to intensify agricultural production. Human capital could be gained through agricultural extension and labour markets, physical capital through agro-dealers, financial capital through finance institutions, natural capital through land markets and irrigation systems and social capital through cooperatives. The GR movement is based on the idea that modern technology can deal with any environmental constraint. Factors such as climate change or soil depletion can be faced through a conservation approach to modern input use (Vanlauwe et al. 2010a).

Financial capital plays the leading role in market-led production. Many regions in SSA of which the agricultural potential is high, do not suffer from food security in the sense that there is direct hunger. One might therefore argue that farmers do not have any reason to switch from subsistence agriculture to market production. However, subsistence farming often leads to homogenous diets, since farm diversity does not allow diverse consumption. Also, subsistence farmers lack the cash to consume goods that they cannot produce themselves. Therefore, it is likely that farm households see benefits in maximizing profits through market production which provides them with cash to spend on goods that increase their quality of life. This implies that choosing for agricultural intensification is to choose for market production.

However, just like Key et al. (2000) argue that there is a dynamic range between 'no market access' and 'full market access', there is a dynamic range between 'full adoption' and 'no adoption'. Even when a household has chosen for agricultural intensification, constraints can limit the engagement in full technology adoption. It is a well-known fact, that SSA farmers generally apply insufficient quantities of fertilizer to their crops which significantly reduces the efficiency of fertilizer use. Under financial constraints, credit constraints or limited access to agro-inputs, these farmers are often not able to adopt fertilizer application rates with full efficiency. It can be argued that partial asset constraints and partial market access lead to partial adoption.

Figure 1 presents the analytical framework as it has been discussed up until this section. The figure highlights the theory of this study and is therefore simplified. It does not include other factors that relate to adoption, such as factors rooted in local culture and religion. A household might have the incentive and assets/market access to involve in modernized agriculture, but still decide not to adopt for some reasons.

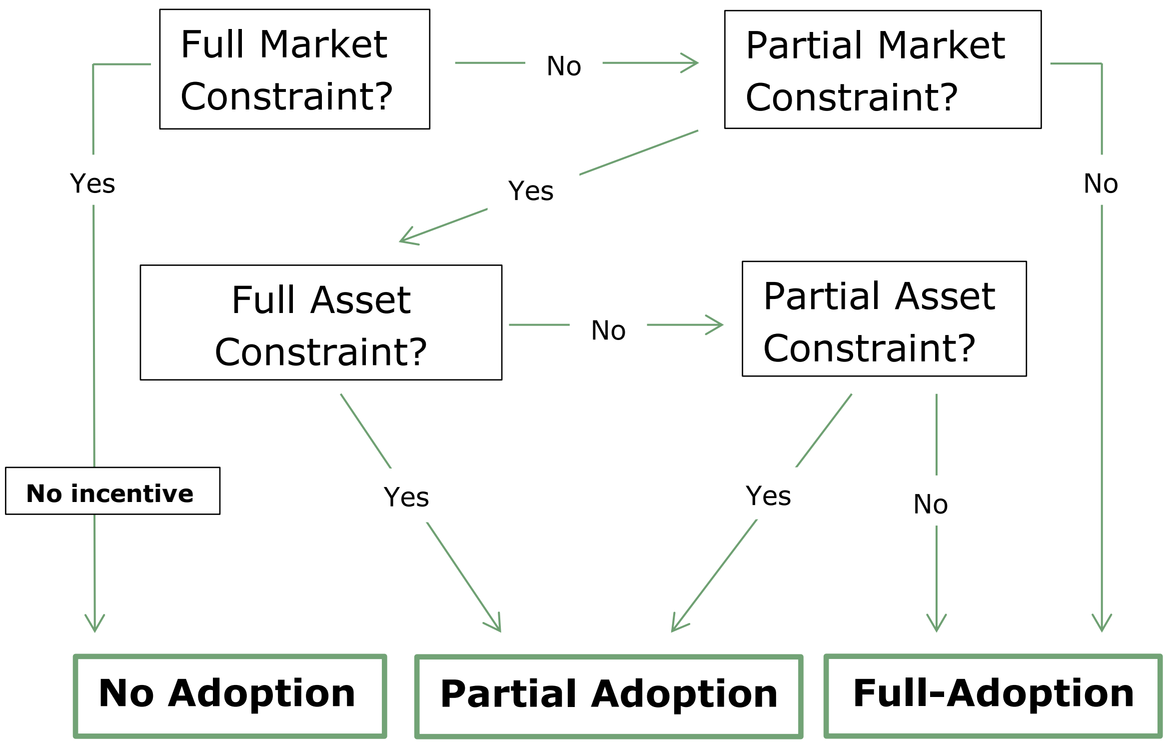

Figure 10 The role of market access and household assets on technology adoption

3.4 Hypothesis

This study is based on the hypothesis that both household assets and market access facilitate technology adoption. Households that are rich in household assets will be more likely to adopt ISFM as well as households that are better connected to markets. Therefore a negative relation between adoption and asset constraint and/or market constraints is expected.

4. Data and Methodology

4.1 Data

For the baseline of an independent impact evaluation of the integrated AGRA project entitled: "Increasing Agricultural Productivity in the Breadbasket Area of Southern Tanzania", 1648 households in the districts Mbeya Rural, Momba, Mbozi and Mbarali, in Mbeya Region have been surveyed over the period of December 2014 and January 2015. This survey will provide the needed information to study the relation between market access and adoption of ISFM. In this baseline survey, data has been collected on the adoption of the ISFM technologies. ISFM is not necessarily a fixed package of practises; the technologies that this study covers have been selected by the project implementers. Besides the data on ISFM adoption, the survey provides a wide range of household information that provides indicators for household assets and market access. The survey does not provide detailed information on plot level adoption of conservation practises and does not quantify the adoption of conservation practises, for example in terms of acreage covered. It does provide information on external input expenditures, which allows to measure adoption intensity of these components. The survey also lacks detailed information on access to agricultural extension.

Since the survey is part of a randomized control trial, the sample of this study is randomized over farmer groups and consequently randomized within these farmer groups. There are no structural influences on the selection, except for the fact that all households are farmer group members in Mbeya, Mbozi, Momba or Mbarali district. The sampling method requires the observations to be clustered in farmer groups; members of the same farmer group are likely to show similarities. Since the proportion of respondents per farmer group do not always match the proportions of farmer group size to the total population, the observations are weighed in order to make the sample representative to the targeted population.

The survey was split into two parts that were simultaneously conducted with two household members. One part was conducted with the household member that was primarily responsible for decision taking about agriculture, whereas the other part was conducted with the household member responsible for household chores. This study is largely based on the agricultural survey, although information about household members, assets and animals is based on the other survey.

4.2 Variables

Explanatory variables will be used that represent the household asset status and market access.

Financial capital is proxied by variables for total value of cattle and assets. Simply asking for amounts of money possessed will likely not lead to honest answers. Also, many rural households are financially excluded which means that they often cannot fully participate in financial services such as banking. It is therefore common for households to invest money in animals or assets, to save the money in a productive form. Indicators of motorcycle and car possession are separated, since these assets have also important implications for households to deal with remoteness. It is expected that households with more financial capital are more likely to adopt ISFM since they can use this capital to respond to market incentives to invest in intensification.

Human capital will be measured by the characteristics of the household and household head specifically. The household head is considered to be the main decision maker in most cases, especially when it comes to financial decisions such as those related to production. The oldest man in the household is usually the household head. Age, farm experience and education of the household head are the best indicators available for this study. It is a common idea that women a have different position in society in terms of power and preferences. Since this might influence their ability or willingness to adopt certain practises, the gender of the household head will also be used. The amount of household members will also be used to indicate human capital, in combination with the dependency ratio. This ratio indicates the amount of household members between 15 and 70 years old divided by those outside this range.

Physical capital is measured in a way that is relevant for agriculture. The more equipment and facilities the household uses, the more physical capital the household has to operate the farm. There is no information available on the possession of traction animals, but the possession of cattle has been separated because they can serve as traction animals and financial capital. The possession of a power tiller is also separated for the same reason since power tillers are often used as a means of transport as well. When disconnected from the plow and attached to a cart, they can be used to transport heavy loads.

Irrigation use is measured since it could make a difference in households' capacity to involve in intensification. Another form of natural capital is land. The total size of the plots per household is therefore used. A variable on land ownership is used since hired land, communal land or any other form of access in which the household is not the owner might have implications for decision making. There is a lower incentive to make long term adjustments to the soil while priority goes to short term maximization of production. In the end, not only quantity but also quality of the soil should play a role and the household's perception of soil quality could determine the decision to intervene using technology. Soil quality is an aspect of natural capital.

Social capital is difficult to measure since the value of a social network is not easily quantifiable. This study will use the total amount of members per FO as an indicator, since collective action could play a role in the social position of farmers and bigger FOs should have more social influence. Also, social capital is likely to play a role in markets access in terms of providing market information, bargaining power and creating economies of scale. A trader is more likely to visit a village if there is a cooperative collectively selling their produce instead of having to visit single farms for small harvest.

Earlier, this study showed how market access can be expressed in terms of transaction costs which are included in the market price. Therefore this study will use the median output price per village of the four major crops to indicate market access per village. Output prices should be higher in places that are more market constrained. The prices are calculated per tin, a common trading unit in Tanzania. It should not be confused with a can; it rather has the size of a bucket. The prices are calculated as the village median, to control for outliers and to establish consistent estimates of market access per village. Output prices do not provide information about access to extensions, agro-inputs and credit though. The distances and travel durations of farms to the nearest market place, agro-dealer and tarmac road will also be included. A household is credit constrained if it has ever applied for a credit but did not receive it, or if it did not apply because they knew that they would not succeed. A household is not credit constrained if it has ever received a loan. Even though there is data on the amount of government extension officers per district, which is often considered as the basic source of agricultural information, this information will not be used since the officers are known to be constraint by a lack of vehicles to reach the whole district. Also, farmers exchange information with each other which does not mean that direct contact with extension is required for diffusion of innovation.

The different districts covered by the survey have some considerably different characteristics in geographical and socio-economic spheres. Since you cannot identify and control for every factor, this study includes district dummies in the analyses.

4.3 Adoption of a 'package'

The adoption of individual technologies offers interesting insight, but this study is about the adoption of ISFM which requires the combined adoption of practises. The GR perspective is on combining modern intensification practises with sustainable conservation practises. From an agronomic perspective, ISFM is defined as: "A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm, combined with the knowledge of how to adapt these practices to local conditions, aimed at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles." (Vanlauwe et al. 2010b, p. 19). Not necessarily all the aspects that AGRA promotes in their development projects need to be adopted to meet this definition, the focus needs to be on fertilizer, improved seeds and organic inputs. This study does not aim to redefine ISFM, but to study the adoption of existing concepts of ISFM.

First the adoption of different combinations of ISFM components was studied using multivariate probit regressions based on the basic principle that practises should be adopted in combination with fertilizer and improved seeds. In the first combination these inputs are adopted in combination with the leaving of crop residues in the field, since the application of organic matter to the soil increases the responsiveness of fertilizer and improved seeds. The second combination involves no-tillage and herbicides, since an important purpose of tillage is the killing of weeds and therefore no-tillage needs to be combined with the use of herbicides. The third combination involves the use of mulches and/or cover crops and the fourth combination involves the use of intercropping and/or rotation. These are practises that roughly serve the same purpose. For the output tables, see the appendix. The outcomes show a low robustness of the models. Every combinations results in different significant variables, with a high differentiation in positive and negative relations per variable. The 'atrho' outcomes, indicate the coefficient of correlation between the residuals of the probits. They are often significant indicating that the probabilities of adopting specific pairs are predicted more accurately than in the case of two individual probits. Pairs of technologies that show significant 'atrho' values are: fertilizer and improved seeds, fertilizer and herbicides, fertilizer and mulching and/or cover crops, improved seeds and rotation and/or intercropping, improved seeds and herbicides, improved seeds and mulching and/or cover crops, and herbicides and no-tillage. This means that there are common determinants of these technology pairs that therefore not technology specific. The outcomes of the multivariate probits show a high diversity in significant variables though, which is not a useful outcome to identify the relation between market access and ISFM. Combining all the available technology choices in on multivariate probit model would solve this problem, but a model of that size cannot be calculated using available means. Also, the marginal values of the coefficient of a multivariate probit regression cannot be calculated using a multivariate probit model which would be useful to identify the size of probability changes when a variable changes in value.

Since multivariate probit models, only prove to be useful to identify the correlations between technology pairs, a different approach will be used to study the relation between ISFM adoption and market access. This is an approach that defines ISFM more accurately as a package by using double hurdle models, which are based on a probit regressions follow by a truncated regressions. This allows for the calculations of marginal values of the probit outcomes and for identification of factors related to the intensity of adoption. The methodology will be explained below.

4.4 Adoption intensity of chemical fertilizer, improved seeds and additional ISFM components

Since ISFM is a package that does not necessarily require the adoption of all relevant components but is based on the use of fertilizer and improved seeds, the analysis of adoption intensity is not straightforward. An approach such as by Noltze et al. (2012), using a variable that measures the amount of package components adopted would not be sufficient, since the combined adoption of fertilizer and improved seeds is required. An analysis of the acreage covered with each practise is not possible due to data constraints. This study will use data on chemical fertilizer and improved seed expenditures and data on the amount of additional ISFM practises adopted to analyse adoption intensity. Total acreage will be used as one of the explanatory variables; therefore the adoption intensity does not have to be recalculated per acre. An Ordinary Least Squares (OLS) regression would not be sufficient for this analysis, since it would assume the dependent variable to be fully continuous. Expenditure, however, cannot be negative which means that it is censored at zero. The amount of practises adopted cannot be higher than 7, the amount of practises recorded, so this variable is censored below 0 and above 7. A standard censored tobit model could be used to account for this, but this model would combine the effects on probability and intensity of adoption. A double hurdle model separates these effects by first using a probit to estimate the probability of adoption and consequently using a truncated regression to analyse the intensity of adoption.

In the first analysis, the combined adoption and intensity of chemical fertilizer and improved seed will be analysed. A standard probit model, referred to as the 'first hurdle', will be used to analyse a binary variable that represents the adoption of both chemical fertilizer and improved seeds. A value of 1 stands for 'farm household uses both improved seed and chemical fertilizer' whereas a value of 0 stands for all other outcomes. A truncated regression, referred to as the 'second hurdle', will be used to analyse the combined expenditure on these inputs, which is a continuous variable that is censored below 0.

In the second analysis, a probit model, referred to as the 'first hurdle', will serve to analyse a binary variable that represents the adoption of any ISFM components used additionally to chemical fertilizer and improved seeds. A value of 1 stands for 'farm household uses improved seeds and chemical fertilizer and at least one of the other ISFM practises' whereas a 0 stands for 'farm household uses improved seeds and chemical fertilizer but no additional ISFM practises'. Consequently a truncated regressions , referred to as the 'second hurdle', will be used to analyse the quantity of ISFM components adopted additionally to these inputs, which is a continuous variable that is censored below 0 and above 7, only observations are used in which improved seed and chemical fertilizer are adopted.

Below, the probit and truncated regression will be explained as the first hurdle and second hurdle respectively which will serve in both the first and second analysis.

First Hurdle (probit model)
The household's decision whether to adopt the technology combination is a binary variable (d_h) such that:

3) $d^*_h = X'_h\beta + \varepsilon_h$

and

4) $d_h = \begin{cases} 1 \; if \; d^*_h > 0 \\ 0 \; if \; d^*_h \leq 0 \end{cases}$

Equation 3) assumes that the h[th] farm household has an unobserved preference denoted by d^*_h. This preference is influenced by both observed (X_h) and unobserved factors (ε_h). The relation between the observed parameters and d^*_h can be estimated through vectors denoted by β. The explanatory variables denoted by X_h represent household assets and market access.

Second Hurdle (truncated regression model)
The household's decision on adoption intensity is a continuous variable (Y_h) such that:

5) $Y^*_h = X'_h\beta + \varepsilon_h$

and

6) $Y_h = \begin{cases} Y^*_h \; if \; Y^*_h > 0 \; and \; d_h = 1 \\ 0 \; if \; Y^*_h \leq 0 \; and \; d_h \leq 1 \end{cases}$

Equation 5) assumes that the h[th] farm household has an unobserved preference denoted by Y^*_h. This preference is influenced by both observed (X_h) and unobserved factors (ε_h). The relation between the observed parameters and Y^*_h can be estimated through vectors denoted by β. The explanatory variables denoted by X_h represent household assets and market access.

5. Descriptive Statistics

5.1 Crops

The sample of this study covers four districts of Mbeya region: Mbeya rural, Momba, Mbozi and Mbarali. 1648 Agricultural households have been interviewed that are all member of a farmers group. The survey took place during the start of a new cropping season, but referred to the last cropping season which is the cropping season of the year 2014. Figure 11 shows the eleven most cultivated crops in these districts. A diversity of crops is cultivated in these regions, but maize is by far the most cultivated crop, followed by beans, groundnuts, rice and coffee. This pattern is roughly the same when comparing cultivation per district.

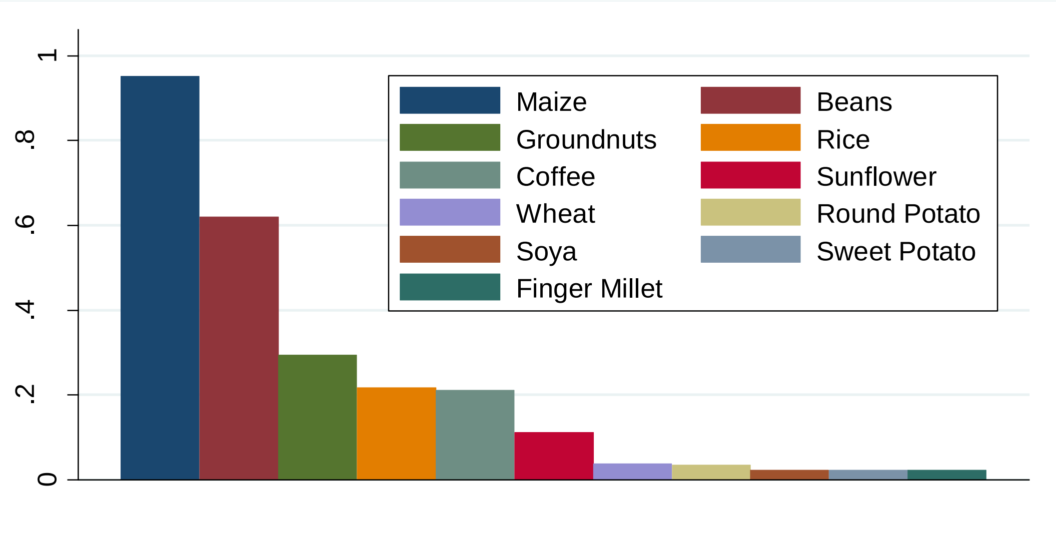

Figure 11 Proportion of households in sample cultivating each crop

5.2 Technology Knowledge and Adoption

Respondents indicated if they knew about each technology. Almost every household was familiar with chemical fertilizer, followed by improved seeds, herbicides, intercropping and rotation. At least 85% of the households knew about these technologies. Approximately 40 to 50 % of the households were aware of no tillage, mulching, crop residues and cover crops (see table 1). From this can be concluded that the awareness of conservation agriculture is clearly lower than that of external inputs. This matches findings about farm household's concerns about the erosion and nutrient depletion of their plots. While many farmers see the decreasing fertility of their soils as an average to high threat, many see soil erosion as a very low threat (see table 6).

To get a clearer picture of the proportions of adopters, table 1 shows the proportions of the total sample with knowledge of each technology and consequently the proportions of adopters within these knowledge groups. The adoption rate is highest for chemical fertilizer, crop-rotation, leaving crop residuals, improved seeds and herbicides. Other practises show a rough adoption rate of 50% except for no-tillage, which was only adopted by an approximate of 35%. It is important to consider knowledge of a technology before making conclusions about adoption behaviour, since knowledge of technologies determines adoption in the first place.

Table 1: Proportions of households with knowledge of a technology and the adopters among them.

Technology	Proportion with knowledge of technology	Proportion adopters, if having knowledge of technology
Chemical Fertilizer	0.987	0.857
Improved Seeds	0.922	0.662
Herbicides	0.883	0.626
No-Tillage	0.390	0.360
Mulching	0.360	0.519
Leaving Crop Residues	0.534	0.696
Cover Crops	0.436	0.525
Intercropping	0.913	0.435
Rotation	0.854	0.739
Organic Fertilizer	0.940	0.541

Notes:
Post Stratification weight used to make farmer group sizes in the sample representative of the population.

Figure 13 shows the expenditure per acre on chemical fertilizer and improved seeds, variables that will be used to analyse the intensity of adoption. Households spend an average of 325,900 Tsh, approximately 175 USD, on chemical fertilizer with a standard deviation of 673,300 Tsh (360 USD) and 111,000 Tsh, approximately 60 USD, on improved seeds with a standard deviation of 297,200 Tsh (160 USD). Households spend more on chemical fertilizer than on improved seeds. The variation between households is also big, in the analysis land size will be controlled for since this is likely a high contributor to this variability. Figure 11 shows that a majority of households spends under 500 thousand Tsh on chemical fertilizer while a small minority spends more than 2,000,000 Tsh. Improved seeds show a similar distribution, but at approximately 1/3 of the fertilizer expenses.

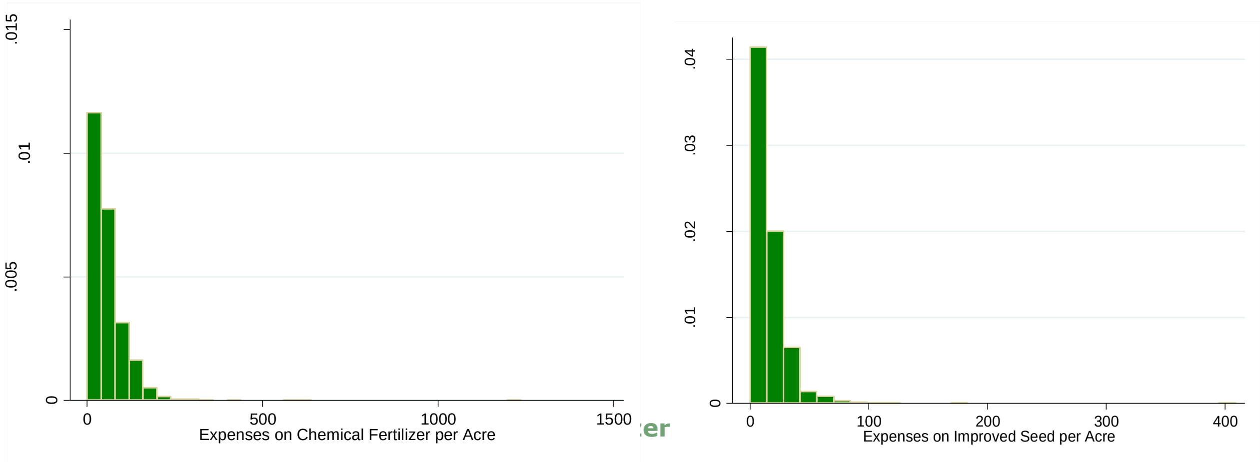

Figure 13: Expenses on Chemical Fertilizer and Improved Seed in 1000 Tsh per Acre

ISFM is based on the use of fertilizer and improved seeds. A range of technologies can be combined with these technologies to meet existing ideas of what ISFM entails. Table 2 shows the number of adopters, within the whole sample, who adopt fertilizer and improved seeds and the combinations that will be analysed. It shows that combinations with organic matter application and with intercropping or rotation are most common. Combinations with mulches/cover crops or no-tillage systems are less common.

Table 2: Frequencies of adopted combinations within sample

Technology Combination	***N (total = 1648)***
Basis: Chem. Fertilizer and/or Org. Fertilizer and Impr. Seeds	969
Comb. 1: Chem. Fertilizer and/or Org. Fertilizer, Improved Seeds and Crop Residues and/or Organic Fertilizer	728
Comb. 2: Chem. Fertilizer and/or Org. Fertilizer, Improved Seeds, No-Tillage and Herbicides	138
*Comb. 3:*Chem. Fertilizer and/or Org. Fertilizer, Impr. Seeds and Intercropping and/or Crop Rotation.	787
*Comb. 4:*Chem. Fertilizer and/or Organic Fertilizer, Impr. Seeds and Mulching and/or Cover Crops	400

While fertilizer combined with improved seeds has an adoption rate of 61.93%, 96.34% of this proportion combines these technologies with any other technology from the whole package. On average, these households adopt 2.8 additional practises besides fertilizer and improved seeds.

Reported adoption Constraints

Non-adopters have also been asked for a reason why they did not use each practise over the last season. The results are displayed in table 3. Available answers where 'a lack of money', 'a lack of labour', 'too risky', 'no understanding of the technology', 'no positive expectation of the technology', 'no trust in the information source', 'the technology has no added value', 'we are not interested in increasing productivity', 'the technology is not applicable to my farm' or a reason that is not among the available answers. Respondents were allowed to give multiple answers. The dominant constraint for input adoption is a lack of money, the second most mentioned reasons are 'risk', 'understanding', 'expectation/value' and 'labour' for chemical fertilizer, herbicides, improved seeds and organic fertilizer respectively. The times that a lack of money is mentioned, however, is an approximate 10 times higher than the second values. The most mentioned reason for the other 6 practises is a negative expectation of the technology. This indicates that households are generally not convinced of the benefits of conservation agriculture.

The relative frequency that 'expectation' was mentioned is not as high as 'money' for input adoption. Also 'risk', 'understanding', 'source' and 'production' are mentioned more than the others. Interestingly, a lack of money is also mentioned quite some times for practises such as zero tillage, crop residues, rotation and intercropping that do not require any financial investment even though the invested labour and other capital can eventually be considered opportunity costs.

Table 3: Reported reasons for non-adoption, proportions.

Technology	Total Non-Adopters	Money	Labour	Risk	Understanding	Expectation	Source	Value	Production	Applicable	Other
Chemical Fertilizer	213	0.80	0.02	0.08	0.02	0.04	0.04	0.02	0.06	0.04	0.07
Herbicides	539	0.70	0.01	0.05	0.06	0.05	0.05	0.04	0.04	0.04	0.09
Improved Seed	511	0.64	0.01	0.02	0.05	0.07	0.05	0.07	0.04	0.01	0.17
Organic Fertilizer	707	0.56	0.18	0.00	0.09	0.10	0.09	0.01	0.02	0.05	0.18
No-Tillage	405	0.13	0.03	0.08	0.12	0.30	0.21	0.03	0.13	0.05	0.15
Mulching	278	0.06	0.06	0.05	0.15	0.23	0.16	0.14	0.08	0.12	0.22
Leaving Crop Residuals	264	0.03	0.05	0.10	0.21	0.22	0.15	0.02	0.05	0.08	0.35
Cover Crops	332	0.14	0.23	0.02	0.20	0.26	0.23	0.08	0.02	0.07	0.11
Rotation	363	0.11	0.09	0.06	0.22	0.29	0.26	0.02	0.06	0.11	0.24
Intercropping	843	0.04	0.03	0.10	0.14	0.39	0.14	0.07	0.27	0.04	0.16

'Money' = Not enough money
'Labour' = Not enough labour
'Risk' = Too risky
'Understanding' = Difficulty to understand the practise
'Expectation' = A negative expectation of the outcomes
'Source' = No trust in the source of information
'Value' = The technology has no added value to our farm
'Production' = I am not interested in increasing productivity
'Applicable' = The technology is not applicable to my farm
'Other' = Other reason namely: …

Two respondents mentioned as another reason that herbicides are difficult to combine with mixed cropping systems. A problem with improved seeds is that farmers do not trust the legitimacy of seeds since there is also a trade in fake seeds, seeds that are claimed to be improved but are of very low quality. This explains why some farmers rather stick to their own seeds, which have likely provided consistent yields for generations. A common remark on no-tillage, is that it is not applicable to rice cultivation even though Rice et al. (1986) shows that no-tillage systems can be beneficial for this crop. Mulches and crop residuals are reported to be stolen or eaten by animals, households also use them to feed their own cattle or as fuel for cooking. One farmer reports that crop residues are stolen from his field by ants. Additional reasons for not adopting rotation systems are a lack of land and inconsistency with rice cultivation. Rice requires a specific soil with a high water supply; therefore plots cannot easily be rotated. The same constraints are encountered when using intercropping systems in rice cultivation.

5.3 Household Assets and Market Access

Table 6 presents summary statistics of explanatory variables that will be used in the analysis.

The average household head is 48 years old, 12.3% of the households are headed by a female and 8.34% of the household head received no education at all and only 13% of the household reached a higher education level than the primary level, although 69.5% of the household heads did finish primary school (and no further). As table 4 shows, female household heads are generally less educated than male household heads. An approximate 13% of male household heads received no education while 35% of female household head is fully uneducated. For primary education these proportions are an approximate 74% against 60% respectively and for secondary or higher education this is an approximate 12% against 5%.

Table 4: Education level proportions by gender

Education	Gender	Proportion
None	Male	.1341612
	Female	.3550983
Primary	Male	.7473271
	Female	.5991604
Secondary or higher	Male	.1185117
	Female	.0457413

Note: Post Stratification weight used to make farmer group sizes in the sample representative of the population.

The average amount of household members is 5.38. The dependency ratio is 0.854 on average which means that every household member outside of the age range of 15 to 70 depends on 0.854 household members within this range.

The amount of farm equipment/facilities used s based on a score that determines the household's amount of physical capital in agriculture. The more equipment/facilities the households uses, the more physical capital the household has to operate the farm. The average amount of equipment/facilities that households used of this score is 2.638. The average value of animals and assets in possession is USD604.8 and USD542.53 respectively. 14.3% of the households indicated to make use of irrigation, which is a minority. The average amount of land that households use is 7.3 acres of which an average of 90.5% is in the household's possession. 9.5% is hired land, communal land or any other form of access in which there is no ownership.

The amount of farmer organization members indicates the amount of members per farmer organization (FO) by December 2014. The average amount of FO members was 121.182.

Information on the distances and travelling duration of farms to the nearest market place, agro-dealer and tarmac road has also been collected. While the average distances to markets, agro-dealers and tarmac roads were 62.48 km, 15.53 km and 13.82 kilometres respectively, the travel durations were 67.5, 54.4 and 55.4 minutes. Market places are usually much further away than agro-dealers, but most time is spend on traveling to the nearest tarmac road. Travel time and distance to the nearest market and agro-dealer have been excluded from the analysis since they are too related to the time to the tarmac road. Including all of these variables results in inconsistent outcomes whereas distance to the tarmac road is considered a better indicator for remoteness which also works as an indicator of access to markets and inputs. The average village medians of prices per tin are USD2.33 for maize, USD9.97 for beans, USD3.77 for rice and USD5.65 for groundnuts. The output prices for maize, beans, rice and groundnuts give high Variance Inflation Factor (VIF) values. The fact that they are collinear shows that these variables can be reduced to one variable that shows per village trend of output prices. The majority of the respondents grow maize; this is therefore the best crop to be used in the analysis.

83.8% of the households indicate to be credit constrained, based on the fact that they have applied for a loan but did not succeed or do not even apply because they know that they will not succeed. The other 16.2% received a loan, and is therefore not credit constrained. As table 5 shows, approximately 10% of female headed households versus 20% of the male headed households access credit.

Table 5: Credit access proportions by gender

Credit Access	Gender	Proportion
Yes	Male	.1928139
	Female	.1059263
No	Male	.8071861
	Female	.8940737

Note: Post Stratification weight used to make farmer group sizes in the sample representative of the population.

The indicators for perception of soil erosion and decreasing fertility, as presented in tables 1 and 2, will also be used in the analysis. In the end, the household's perception of soil quality should play a role in the decision to intervene using technology. Soil quality is an aspect of natural capital, low quality soils can be a constraint to adoption of intensification strategies.

Table 6: Summary statistics of explanatory variables

Variable	Obs	Mean	Std. Dev.	Min	Max
District dummies:					
Mbozi[b]	1641	.3315052	.4708977	0	1
Momba[b]	1641	.2065814	.4049759	0	1
Mbarali[b]	1641	.190128	.3925216	0	1
Mbeya Rural[b]	1641	.269348	.4437563	0	1
Human Capital					
hh_head_ge~r[b]	1627	.1395206	.3465955	0	1
hh_head_age	1627	48.44192	12.8973	20	100
Some years primary education.[b]	1625	.0910769	.287807	0	1
Primary completed.[b]	1625	.6935385	.4611656	0	1
Some years secondary ordinary.[b]	1625	.0289231	.167642	0	1
Secondary ordinary completed[b]	1625	.0652308	.2470086	0	1
Some years secondary advanced[b]	1625	.0006154	.0248069	0	1
Secondary advanced completed[b]	1625	.0055385	.0742373	0	1
Some years higher education[b]	1625	.0024615	.049568	0	1
Higher education completed[b]	1625	.0116923	.1075301	0	1
Professional Education[b]	1625	.0166154	.1278647	0	1
Amount of Household Members	1633	5.382731	2.222296	1	20
Years of Own Farm Experience	1636	19.80379	13.37687	0	70
Dependency Ratio	1625	.8540673	.7051992	0	5
Physical Capital					
Amount of Farm Tools/Facilities Used	1637	2.641417	1.140098	1	8
Motorcycle Owner[b]	1637	.0232132	.150626	0	1
Power Tiller Owner[b]	1637	.0281002	.1653096	0	1
Car Owner[b]	1632	.0349265	.1836499	0	1
Financial Capital					
Total Value of Cattle / 1000 Tsh	1636	1001.924	2127.992	0	28308
Total Value of Assets / 1000 Tsh	1636	1117.083	2627.568	0	62500
Natural Capital					
Total Plot Acreage	1637	7.283335	13.37863	0	249
Plot Ownership Ratio (ratio of owned land to used land)	1635	.9049171	.2483896	0	1
Irrigation User[b]	1637	.1313378	.3378727	0	1
Threat Perception of Decreasing Soil Fertility:					
Low[b]	1625	.1076923	.3100868	0	1
Average[b]	1625	.5790769	.4938592	0	1
High[b]	1625	.2190769	.4137482	0	1
Very high[b]	1625	.0486154	.2151288	0	1
Threat Perception of Soil Erosion:					
Low[b]	1586	.2868852	.4524502	0	1
Average[b]	1586	.2156368	.4113931	0	1
High[b]	1586	.0794451	.2705176	0	1
Very high[b]	1586	.0094578	.0968205	0	1
Social Capital					
Total Amount of Farmer Group Members	1522	121.182	110.6282	14	451
Market Access					

Credit Constrained[b]	1395	.8587814	.3483718	0	1
Time Needed to Travel to the Nearest Tarmac Road	1635	54.80061	56.8634	0	300
Village Median of Sales Price of Maize per Tin in 1000 Tsh	1509	4.42765	1.126437	2.7	10

Notes: [b] binary variable
Post Stratification weight used to make farmer group sizes in the sample representative of the population.

6. Analysis

There is less knowledge on the use of mulching, crop residues, cover-crops and no-tillage. Also the adoption rates of these practises are lower than those of the other technologies. This means that these four practises are used much less in the study area compared to external inputs, rotation, intercropping and organic fertilizers. Respondents bring non-adoption of external inputs into relation with financial constraints whereas the adoption of conservation practises is not expected to be beneficial and/or the source of information is not trusted. To add up, the concern for soil erosion is much lower than for decreasing soil fertility. The fact that households generally do not consider soil erosion as a threat matches the findings of lower awareness and adoption of conservation practises. Giller et al. (2009) show that the time horizon of farmers is an important factor in their decision-making on agricultural practise. Since soil erosion is a process that decreases agricultural productivity over the long term and conservation agriculture practises shows their benefits over the long-term, it is not surprising that farmers are more concerned with technologies such as external inputs which manifest on a short-term.

Female household heads are generally less educated; also they have a lower access to credit. This could mean that there is a female empowerment issue that decreases the ability of women and men to participate in society under equal terms. This could also have consequences for their ability to use ISFM.

Tables 7 Shows the results of a double hurdle model on the use of chemical fertilizer and improved seeds. The first hurdle shows a probit regression on the combined adoption of chemical fertilizer and improved seed, the second hurdle shows a truncated regression on the combined expenditure on these inputs.

Table 7: Double Hurdle Model of Combined use and Expenditure on Chemical Fertilizer and Improved Seed

Double Hurdle Model	**First Hurdle**		**Second Hurdle**	
Variables	Combined Use of Chemical Fertilizer and Improved Seed		Combined Expenditure on Chemical Fertilizer and Improved Seed	
	dy/dx	z-value	Coefficient	z-value
District dummy 2	-0.224	(3.96)***	5,079.448	(0.87)
District dummy 3	-0.378	(4.60)***	-25,194.723	(1.48)
District dummy 4	0.006	(0.08)	-21,060.001	(1.31)
Human Capital				
Female Household Head	-0.098	(1.88)*	1,822.199	(0.41)
Household Head Age	0.001	(0.44)	-199.702	(0.97)
Primary education completed	0.114	(2.20)**	2,134.910	(0.59)
Secondary or higher education completed	0.178	(2.36)**	1,882.297	(0.38)
Amount of Household Members	-0.000	(0.01)	695.686	(1.81)*
Years of Own Farm Experience	-0.002	(1.11)	210.618	(1.49)
Dependency Ratio	-0.014	(0.73)	-706.983	(0.41)
Physical Capital				
Amount of Farm Tools/Facilities Used	0.052	(2.52)**	1,673.386	(1.36)
Motorcycle Owner	-0.126	(1.18)	7,683.214	(1.26)
Power Tiller Owner	-0.089	(1.03)	8,289.423	(0.56)
Car Owner	-0.236	(1.11)	970.648	(0.24)
Financial Capital				
Total Value of Cattle (/Std. dev)	-0.043	(3.58)***	-536.472	(1.03)
Total Value of Assets (/Std. dev)	0.116	(2.93)***	678.011	(0.79)
Natural Capital				
Total Plot Acreage	-0.003	(1.60)	266.357	(2.47)**
Plot Ownership Ratio (ratio of owned land to used land)	-0.166	(2.55)**	2,556.482	(0.41)
Irrigation User	-0.041	(0.89)	-3,354.492	(0.47)
Concern for Decreasing Soil Fertility	-0.002	(0.05)	4,350.867	(0.97)
Concern for Soil Erosion	-0.021	(0.65)	2,463.017	(1.06)
Social Capital				
Total Amount of Members in Farmer Group	-0.000	(1.45)	-33.154	(0.89)
Market Access				
Credit Constrained	-0.076	(2.11)**	184.608	(0.08)
Time in Minutes from Plot to Nearest Tarmac	-0.000	(1.48)	-64.538	(1.03)

Road				
Median of Village Sales Price of Maize per Tin in 1000 Tsh	0.008	(0.47)	-573.966	(0.90)
Constant			-25,180.111	(1.45)
Sigma Constant			3,112.835	(2.86)***
N	1051		673	

Notes: * *p*<0.1; ** *p*<0.05; *** *p*<0.01
Post Stratification weight used to make farmer group sizes in the sample represent the population

Probit regression:
Wald chi2(36) = 320.18
Prob > chi2 = 0.0000
Log pseudolikelihood = -12.596385
Pseudo R2 = 0.1399
(Std. Err. Adjusted for 42 clusters in Farmer Group)
dy/dx for factor levels is the discrete change from the base level.

Truncated regression:
Limit: lower = 0 upper = +inf
Wald chi2(36) = 257.82
Log pseudolikelihood = -94.616681
Prob > chi2 = 0.0000
(Std. Err. adjusted for 41 clusters in Farmer Group)

The marginal values (dy/dx) in the probit model indicate the change in likelihood of adoption if the concerning explanatory variable increases by on unit while keeping all other variables unchanged. The coefficient in the truncated regression shows the increase of the dependant variable if the explanatory variable increases by one unit while keeping all other variables unchanged.

A household that is credit constrained is 0.071 less likely to be a combined user of chemical fertilizer and improved seeds. Even though wealthier households are more likely to use these inputs, these results show that access to credit can make a difference in the financial constraint that prevent households from adoption. This result conforms to the outcomes of previous studies into the role of credit access in the use of external inputs (Abebe et al. 2013; Bullock et al. 2014; Jara-Rojas et al. 2013; Katungi et al. 2011; Tambo and Abdoulaye 2012; Teklewold et al. 2013; Tiwari et al. 2008; Tura et al. 2010). The size of the effect is moderate; many other factors contribute to the likelihood of the use of these inputs.

Remoteness from the nearest tarmac road and the maize output price do not show significant relations to the adoption or adoption intensity of improved seed and chemical fertilizer. Since the effect of output prizes on technology adoption is not widely studied, this outcome cannot be brought into comparison to previous studies. However, since the factor is based on a village median, household specific transaction costs are not accounted for while they could provide more accurate results. Remoteness from the nearest tarmac road is not widely used as a factor either, though factors such as distance to the nearest urban centre, input supplier or market place often show a negative relation to the adoption of external inputs (Staal et al. 2002; Zeller et al. 1998; Katungi et al. 2011; Teklewold et al. 2013). Indeed the relation of this variable to adoption and adoption intensity is negative, but not significant. Therefore it cannot be used for conclusions.

The probability that a household is a combined user of improved seeds and chemical fertilizer decreases by 0.097 when the household head is female. Mikalitsa (2010) shows from a case in Kenya how women are constraint from adopting improved inputs by a lack of access to land, extension services, credit, income and education. Doss and Morris (2001) show that gender related differences in adoption of agricultural innovation is caused by differences in access to complementary inputs such as land, labour and extension services. Since education, credit, land and income are already incorporated in the model, these factors are controlled for. Still there is a significant difference between male and female household heads that could explain the difference in the use of chemical fertilizer and improved seed. Since women appear to have less access to these inputs, it takes them more efforts to achieve adoption. This could mean that women are generally less empowered in taking action compared to men, which means that social exclusion explains their increased difficulties in achieving agricultural intensification. Extension officers could not be considering them as a potential partner, just as traders or farmer groups. Women are also expected to do other sort of work, such as household chores, which take time and create opportunity costs. The extra efforts that it takes women to take action could be translated into transaction costs which mean that women have lower access to markets which constraints them from improved input use. This shows how market access can also be dependent of institutions that are not affected by interventions such as stimulating microfinance or agro-dealers.

The probability of using chemical fertilizer and improved seed increases by 0.114 when the household head completed primary education and by 0.178 when he/she completed secondary education or higher. These are the largest effects in the model. It could simply be a matter of increased knowledge and/or intelligence which results in increased ability or willingness to use these inputs. As Knight et al. (2010) show, knowledge and/or intelligence also increase the capability of estimating risks, which decreases risk adversity in the adoption of agricultural innovation. From a transactions costs point of view, a higher education could have many beneficial effects that reduce the efforts that are needed to access to the factors that enable the use of these inputs. From this point of view, educated household heads are better able to take action and contribute to a better household specific access to markets. As Mariano et al. (2012) state, governments should keep on making efforts to improve the educational status of farming households. Not only quality of roads and institutions determine the ability of households to participate in intensive market-oriented production.

Households that use more farm tools/facilities are more likely to use these inputs combined, with an effect of 0.052 per tool/facility. It is not a surprising outcome that households who use more different tools or facilities are more likely to use chemical fertilizer and improved seeds since both can be part of a strategy to increase the efficiency of agricultural practises. On the one hand this is a matter of financial well-being, which is required to invest in agricultural intensification (Knowler and Bradshaw 2007). To invest in tools and inputs, though, also requires a willingness to spend money on- and/or make efforts for improved agricultural practises. Both variables can therefore be depending on an omitted variable, although the access to certain tools can also be of direct influence on input adoption since the use of these inputs requires certain tools to be implemented and certain facilities like irrigation or storage increase the efficiency in which the inputs can be used. It therefore decreases the household specific transaction costs of production using chemical fertilizer and improved seed.

The probability that chemical fertilizer and improved seeds are used decreases by 0.043 if the total value of cattle increases by one standard deviation while it increases by 0.116 if total value of assets increases by one standard deviation, these deviations are 2127,992 Tsh and 2627,568 Tsh respectively. Since the total amount of assets is a proxy for wealth, this shows that there is a financial constraint to input adoption. Households with a higher value of assets are more likely to be richer which decreases the financial constraint. This finding is in accordance with many other studies that find a positive correlation between financial well-being and technology adoption (Knowler and Bradshaw 2007). The total value of cattle can be considered a proxy for wealth as well. However, having more cattle will likely result in more access to manure which can be a substitute for chemical fertilizer. Also, household who focus more on livestock might be less interested in improved cropping techniques. There could therefore be several effects at work within this variable. The outcome of a positive relation between wealth and the likelihood of chemical fertilizer and improved seed adoption matches with the results of reported adoption constraints in table 3, which shows that many household consider a lack of money the main constraint to adoption of these inputs.

Someone who does not own any of his plots is 0.166 more likely to use to use these combined practises to someone who owns all of his used plots. The dominant view on the role of tenure in adoption behaviour is that land owners are more concerned with maintenance of their farms (Knowler and Bradshaw 2007). The results of this study show that farmers without land ownership are generally more likely to use these inputs. However, it can be debated whether the use of external inputs can be considered maintenance or mere intensification behaviour. Land renters might be more interested in short term solutions such as fertilisers and improved seeds, whereas land owners are more interested in long-term solutions to safeguard the sustainability of their production. Another explanation would be that land owners build upon more familiarity with the land and site-specific knowledge on practises that have proven to be useful to mitigate risk over the past. Land renters, who are less familiar with the land that they are working, base their practise more on general knowledge such as provided by extension officers. However, the causality might be the other way around. Farmers who use fertilizer and improved seed could be more likely to rent extra plots if they have profit and are maximizing their profits. This would mean that there is a relation between access to land markets and the use of these inputs. More detailed information on the access to land markets, instead of the use of land markets, could provide interesting outcomes in future research since it prevents endogeneity and it could also be that the access to land markets goes parallel with the access to other markets that facilitate the adoption of ISFM.

There are fewer significant determinants for adoption intensity, which is expressed in expenses. Households spend 266,357 Tsh, an approximate 145 USD, more on chemical fertilizer and improved seeds per additional acre of used land. Land size does not say anything about adoption intensity though, since it is a matter of fact that more land needs more input expenditures.

Households spend 695,686 Tsh, an approximate 330 USD, more on chemical fertilizer and improved seeds per additional household member. There are two views on the relation of off-farm family labour to agricultural adoption behaviour. One is that this off-farm labour provides extra money which enables technology adoption, the other is that off-farm work diminishes the priority of agriculture and thereby reduces interest in agricultural innovation. Results of previous studies are therefore mixed, although they are often focussed on conservation agriculture practises (Knowler and Bradshaw 2007). The findings of this study match with the first explanation, although the value of assets, a proxy for wealth, does not show a significant relation while it should provide financial capital as well. Perhaps it is the liquidity of off-farm income that contributes to the ability to invest more in inputs as compared to wealth which is often invested in property. In the end, wealth is not the same thing as income.

Table 8 shows the results of a double hurdle model on the use of additional ISFM components besides chemical fertilizer and improved seed. The first hurdle shows a probit regression on the use of any additional ISFM components, the second hurdle shows a truncated regression on the amount of additional components used. Some variables are omitted in the first hurdle due to perfect prediction. This occurs, for example, when the amount of observations for a certain explanatory variable is low and nearly all observations show adoption, which does not enable the comparison of the explanatory variable outcomes to cases of non-adoption.

Table 8: Double Hurdle Model of ISFM Components Used Additional to Chemical Fertilizer and Improved Seed

Double Hurdle Model	**First Hurdle**		**Second Hurdle**	
Variables	Use of Any Additional ISFM Components Besides Chemical Fertilizer and Improved Seed: Marginal Effects		Amount of Additional ISFM Components Used Besides Chemical Fertilizer and Improved Seed	
	dy/dx	z	Coefficient	z
District dummy 2	-0.065	(2.60)***	-0.989	(6.32)***
District dummy 3	-0.141	(1.50)	-1.854	(9.21)***
District dummy 4	-0.035	(1.76)*	-0.943	(5.26)***
Human Capital				
Female Household Head	0.016	(0.82)	0.046	(0.22)
Household Head Age	-0.000	(0.04)	0.007	(1.00)
Primary education completed	-0.012	(0.45)	0.179	(1.39)
Secondary or higher education completed	O.		0.186	(1.16)
Amount of Household Members	-0.003	(0.80)	-0.009	(0.31)
Years of Own Farm Experience	0.001	(1.35)	0.001	(0.12)
Dependency Ratio	-0.003	(0.32)	0.118	(1.35)
Physical Capital				
Amount of Farm Tools/Facilities Used	0.031	(3.72)***	0.300	(4.07)***
Motorcycle Owner	O.		-0.466	(1.44)
Power Tiller Owner	O.		-0.052	(0.29)
Car Owner	O.		-0.680	(1.17)
Financial Capital				
Total Value of Cattle (/Std. dev)	0.000	(0.04)	0.093	(1.35)
Total Value of Assets (/Std. dev)	0.001	(0.05)	0.270	(2.43)**
Natural Capital				
Total Plot Acreage	0.000	(0.34)	0.001	(0.15)
Plot Ownership Ratio (ratio of owned land to used land)	-0.028	(0.74)	0.027	(0.13)
Irrigation User	O.		0.225	(1.06)
Concern for Decreasing Soil Fertility	0.011	(0.72)	-0.179	(1.24)
Concern for Soil Erosion	0.022	(0.95)	-0.127	(1.14)
Social Capital				
Total Amount of Members in Farmer Group	0.000	(1.14)	0.002	(2.53)**
Market Access				
Credit Constrained	-0.059	(1.89)*	-0.155	(0.89)
Time in Minutes from Plot to Nearest Tarmac Road	0.000	(0.06)	0.000	(0.01)
Median of Village Sales Price of Maize per Tin in 1000 Tsh	-0.004	(0.64)	-0.097	(3.63)***
Constant			2.519	(4.72)***
Sigma Constant			1.167	(46.38)***
N	515		644	

Notes: * $p<0.1$; ** $p<0.05$; *** $p<0.01$
Post Stratification weight used to make farmer group sizes in the sample represent the population
O. = Omitted due to perfect prediction

Probit regression:	Truncated regression:
Wald chi2(26) = 130.76	Limit: lower = 0 upper = 7
Prob > chi2 = 0.0000	Wald chi2(36) = 884.87

Log pseudolikelihood = -1.4933495	Log pseudolikelihood = -20.039719
Pseudo R2 = 0.2098	Prob > chi2 = 0.0000
(Std. Err. adjusted for 39 clusters in Farmer Group)	(Std. Err. adjusted for 40 clusters in Farmer Group)
dy/dx for factor levels is the discrete change from the base level	

The probability of using any ISFM components additional to chemical fertilizer and improved seeds increases by 0.031 if the amount of farm tools/facilities increases by 1 keeping all other variables unchanged. From the second hurdle can be concluded that households adopt 0.300 additional ISFM components per tool/facility used. As Knowler and Bradshaw (2007) show, two other studies into the role of availability of agricultural machinery on the use of conservation agriculture show a significantly positive relation as well. Both variables can be depending on an omitted variable which determines the willingness to invest in improved agricultural practises, although the access to certain tools can also be of direct influence on input adoption since the use of these inputs requires certain tools to be implemented and certain facilities like irrigation or storage increase the efficiency in which the inputs can be used. It therefore decreases the household specific transaction costs of production using chemical fertilizer and improved seed.

There is a significant financial constraint to the adoption intensity of ISFM components additional to chemical fertilizer and improved seed. This matches with other studies that find that there is a significant relation between financial well-being and the adoption of conservational agriculture practises (Knowler and Bradshaw 2007). When a household is credit constrained, the likelihood of the use of any ISFM practises additional to chemical fertilizer and improved seed decreases by 0.059. Therefore credit can make a difference in overcoming the financial constraint both for chemical fertilizer and improved seeds and for the adoption of conservational agriculture practises.

When the farmer group, of which a household is a member, increases by one member, the household uses 0.002 more ISFM components. This shows that there is a very small relation between social capital and ISFM adoption. Studies in diffusion of innovations show the significant role of social capital in gaining information on new practises, the size of this role increases whenever the complexity of the technology increases. Also the role of membership in producer organizations has more often been found to be positive to adoption (Knowler and Bradshaw 2007). However, when the effect is due to a farmer group with a specific function such as production or input supply, the effect is not caused directly through social capital. It shows how the clustering of farmers can be useful though, to achieve economies of scale for example which can increase market access by decreasing transaction costs.

When the median village output price of maize increases by 1000 Tsh, households use 0.097 fewer ISFM components additional to chemical fertilizer and improved seeds. This outcome is counter intuitive if you follow the reasoning that an increased output price increases the incentive to improve agricultural practise. Three other studies into the relation between output prices in general and adoption of conservation agriculture have been conducted before, only one of them revealed a significant relation which was negative as well. Crop specific output prices have not led to the identification of significant relations yet (Knowler and Bradshaw 2007). The meaning of this negative relation is a point of discussion, also because the results of surveying on prices are questionable. Money is a sensitive topic which is shows by the amount of refusals to answer. When outcomes are questionable, it is better to take them with a pinch of salt. The suspected quality of the data used to generate the variable on maize prices does not disturb the other effect in the model, as leaving this variable out does not change the initial outcomes.

7. Conclusion and Discussion

7.1 Conclusion

Sub-Saharan African agricultural productivity has increasingly been lacking behind on the rest of the world. The Alliance for a Green Revolution in Africa stimulates market access and Integrated Soil Fertility Management (the combined use of fertilizer, improved seed and conservation practises) in order to achieve a uniquely African Green Revolution. This thesis fills the gap between general economic- and context specific studies by studying the relation between market access and ISFM adoption in Mbeya region, which is identified by AGRA as a 'breadbasket region' since it shows potential to produce a surplus that could feed food scarce parts of the country.

Credit access is a direct determinant of adoption. Households, who can mobilize more financial capital, are also more likely to use chemical fertilizer and improved seed. There is a financial constraint to the adoption of ISFM in which credit access can make a difference. Credit constrained households are likely to be non-adopters and an increase in credit access is expected to result in an increased adoption of ISFM. Adoption intensity does not relate to credit access although the amount of additional ISFM components used besides fertilizer and improved seed does positively relate to the total value of assets. Financial capital therefore plays a role, although less explicit in the adoption intensity of ISFM.

There is no significant relation between ISFM adoption and the distance to the nearest tarmac road. Remoteness, if measured in this way, is therefore not a constraint to adoption.

Households that own a larger proportion of the land that they use are less likely to use fertilizer and improved seed. This shows that there is a positive relation between other forms of land access, such as rental, and the use of these inputs. Since the variable 'access to land markets' could not be used in this study this does not provide definite conclusions about its relation to adoption, but it shows that further study into this topic could reveal interesting insights.

Households that have more members spend more on fertilizer and improved seed. This could be caused by the fact that extra household members can realize extra on-farm work but also that they provide the possibility of generating off-farm income which in turn can be used to overcome financial constraints. This shows how the access to labour markets can be beneficial to allocate extra money through labour.

Female headed households are less likely to use fertilizer and improved seed, even after controlling for access to credit, education and other indicators of the household asset status. An explanation can be found in the position of women in Tanzanian society. Social exclusion could play a role, just as the extra burden that women bear in the work that they are expected to do in their daily live. It is therefore not only a lack of the right facilities that can constrain increased production for markets, also local culture and institutions have their effect on the ability of households to take action.

Similar conclusions can be taken when examining the fact that the education of household heads plays a big role in the likelihood in the use of fertilizer and improved seed. This could be a consequence of knowledge and intelligence, but also shows that the quality of education has an impact on technology adoption and possibly on the ability to access markets as well.

This study started from the hypothesis that markets both incentivize ISFM adoption and provide a means to achieve ISFM adoption. This is partly true, as is shown by the outcome that access to credit increases the likelihood of ISFM adoption and outcomes that indicate the potentially beneficial role of land and labour markets. However, outcomes on the role of gender and education also show that the empowerment to adopt ISFM is dependent of local culture and institutions. This empowerment issue likely has a broader impact than just the adoption of agricultural technology; it could also affect market access. Stimulating market production through the stimulation of facilities such as credit suppliers and dealers is therefore not sufficient to achieve equal access to markets for all layers of society. Poverty and market access are not separable. More focus on female empowerment and quality of education could help to achieve a broader access to markets and will result in higher adoption of ISFM.

7.2 Limitations

This study covers the adoption of ISFM and factors that could explain this adoption. This is not a study into the agronomic- or productivity effects of adoption and can therefore not be used to say anything about the desirability of the spread of ISFM. It is important to assess the impact of ISFM adoption though; future research should address this topic. Neither does this research shine light on the diffusion of information on ISFM, which is another important topic that could provide interesting insights. Since ISFM, however, is already under promotion in several regions of sub-Saharan Africa, this study is valuable since it provides insight into the drivers and constraints of farm adoption.

The adoption of different combinations of fertilizer, improved seed and conservation practises shows that there are significant relations between the adoptions of different pairs of technologies. The combined adoption of these technologies does not provide common determinants though, it rather relates to different factors in different ways. This shows that the adoption of a package of technologies cannot be predicted using common determinants. This study only focusses on the role of market access on adoption of ISFM, it is also important to consider technology specific and context specific constraints to adoption. These are beyond the scope of this study though. Qualitative research methods in particular have potential to provide more specific insights into these topics.

Market access proves to be a challenging phenomenon to measure. This study used access to credit, travel time to the nearest tarmac road and the output price of crops as indicators of market access. Only access to credit shows a significant relation to the adoption of ISFM. However, from the measured relations between household head gender and education can be concluded that these factors matter in the likelihood of chemical fertilizer and improved seed use. These effects are due to household specific transaction costs which are an important aspect of market access. A more detailed identification of household specific transaction costs is likely to yield more interesting results. Household specific transaction costs influence the effective sales price per household which could provide interesting data to measure market access in a more extensive way. Future studies could use data that allow for a more precise identification of transaction costs to get a more specific look into the relation of market access to technology adoption.

This study looks into the role of market access on ISFM adoption while controlling for the household level characteristics. If market access and ISFM adoption really are beneficial to the overall asset status of a household, this will eventually mean that the two of these cannot be separated. It could therefore be that the effects of market access are much stronger than this study suggests but an exact identification of the relationship between market access, ISFM adoption and household asset status would different analysis. Similarly, defining adoption by a binary variable is a limited approach. Important insight could be gained by observing long term dynamics and to explain dis-adoption. Longitudinal data could therefore provide more interesting insights. The end-line survey of the impact evaluation that provided data for this study will therefore be an interesting opportunity for future studies.

7.3 Discussion

Dar Es Salaam, which is the most populated city of Tanzania and home to one of the most important ports of the continent, is food scarce. This means that food prices are relatively high, which allows food commodities to be sold for high prices but also means that life is expensive. Mbeya is food abundant, which means that life is cheap but also that food commodities can only be sold for low prices. This study uses the medians of sales prices per village to represent market access, under the hypothesis that better market access means les transaction cost which results in higher sales prices and therefore a higher incentive to adopt ISFM. Since the sales price is only used on a village level, villages that are closer to markets, in terms of transaction costs, should show higher values. Life closer to the market, however, is also more expensive. But whether it is the narrow approach to transaction costs, the quality of the data, or a wrong hypothesis, this variable did not provide significant outcomes. In a simplified world, the distance to Dar Es Salaam could be used as a measure for market access. It would be possible to relate this distance to prices because every additional effort that it takes to reach this market would be expressed in a higher supply price. However, markets are everywhere and not just in the major cities. Places where the population is denser are considered less remote, also because it means that demand is clustered. A spatial approach, such as used by Staal et al. (2002) with geographic information systems could therefore certainly reveal interesting outcomes into the proportional transaction costs determined by remoteness. Such an analysis would need a broad focus; factors such as quality of infrastructure, climate and policy would have to be taken into account. Still, such an approach would not be sufficient since proportional transaction costs can also be influenced by non-spatial factors. Ownership of vehicles or the achievement of economies of scale through production groups can give farmers in remote areas an advantage to those closer to markets. Also, such an approach would ignore the fixed and proportional transaction costs that are related to farm specific market access.

To achieve an accurate measure of market access, researchers need a methodology that enables a very detailed approach to transaction costs. In a thought experiment, in which anything is possible, every effort that is required for a farm household to access the market can be translated into costs. The total sum of these transaction costs is an exact variable that represents market access for every household. The next step would be to see in how far such an experiment can be realized in reality. An issue such as transportation would be fairly easy to calculate using the costs of renting/buying a vehicle, the costs of fuel, maintenance and degradation over time. Field experiments could play an interesting role in revealing a measure of fixed transaction costs. Bargaining power could, for example, be studied by using an experiment which measures the ability of people to negotiate prices. The difference between a male headed household and a female headed household could be expressed in similar ways. It gets more difficult to account for opportunity costs that affect women that are burdened with daily household chores, or people that suffer from health problems. These factors affect the ability to access markets and therefore need to be translated into transaction costs. In reality, this will always remain a matter of estimation since many factors are too difficult or impossible to measure. Opportunity costs could be dealt with using regional averages of labour wages, for example, and an estimate of how much productive time someone loses per day due to certain constraints. Such a study would require a summing up of transaction costs caused by the household asset status, policies, institutions, processes, shocks, trends and seasonality. Therefore, the SLF remains useful. The data provided could be used for adoption studies, but many other topics could show interesting relations the ability of households to access markets as well.

When conducting the survey that supplied the data for this research, we have put some thought into an experiment to test the hypothesis that an increase in income does not result in an increase in food security since men are in control of household finances and they are less considered with nutrition. A topic that would be of relevance for the main purpose of this survey: an impact evaluation. Our idea was to confront men and women separately with a choice between an amount of cash or a certain amount of maize which differs in value relative to the amount of cash. We expected that women would choose for food in many cases, to safeguard the household's food security, whereas men would only choose for food if the value was significantly higher than the amount of cash. We never got to implement this experiment on a large scale, since trials made us realize that both men and women, picked cash in every case. They even chose for cash if the value of the food product was 5 or 10 times higher. This indicated that the normative value of cash was much higher than you would expect based on purchasing power. People explained that farm households have their sheds full of maize, beans, rice and groundnuts, though few opportunities to sell it. Money gives you freedom; you can buy many things that you cannot produce yourself. Since the trials already showed that implementing the experiment on a large scale would be a waste of money, the experiment did not take place and this information is therefore not based on published data and cannot be used as evidence. However, it suggests that the value of cash in remote areas is extremely high which means that financial constraints play an extra important role. So even though a tin of maize can be sold to traders for a dollar, this dollar has a much higher value to people when it becomes cash instead of maize. Liquidity is therefore an issue due to financial exclusion. This study confirms this by showing the role that access to credit plays in the adoption of ISFM and external inputs in particular. One of the characteristics of ISFM is that it increases the efficiency of external inputs use and decreases dependency on labour and, perhaps most importantly, cash.

The philosophy of an African Green Revolution is simple: for farmers to increase production beyond their own consumption demands, they need market access. This does not only mean access in terms of agro-inputs, they need access to cash, knowledge and, to create an incentive for intensification, output markets (AGRA 2015). This study brought us a little closer to revealing in how far market access determines ISFM adoption although there could be many more reasons to adopt or not to adopt an agricultural technology. An important consideration is whether farmers are willing to replace their conventional habits by innovative ones or not. ISFM is presented as a package that leaves room for local adaptation by farmers, but it remains debatable whether ISFM really is a flexible package or not. GR-advocates state the importance of the combined application of chemical fertilizer and improved seeds, no-till advocates state the importance of the combination of no-tillage with chemical fertilizer and herbicides and conservational agriculture advocates state the importance of combining many practises such as rotational/intercropping systems, mulches and crop residual management. To put more pressure on the capacity of farmers, ISFM advocates state the importance of combined application of external inputs and conservational agriculture. In the end, the emphasis on combined application requires farmers to make a fundamental change in their practise, practise that is often based on a long history in which site-specific agricultural knowledge has been developed. Bellwood-Howard (2014) argues, based on a case in Ghana, that the underpinning emphasis on market production of ISFM does not leave room for the incorporation of local subsistence mechanisms developed in response to risk, even though it offers aspects that farmers find useful. The way in which farmers use market production, subsistence farming and reciprocity is precisely tuned to the requirements of the environment. It depends on markets risks and agro-ecological risks. A solution such as credit provision is therefore only useful at moments that it facilitates market access when farmers need it. Full market production is just as risky as no market production, he shows from the Ghanaian case. Soil water retention capacity is locally crucial for soil fertility. Therefore, farmers have developed an approach to agriculture that facilitates the water retention of soils in many ways including manure application. Farmers prefer to buy bullock carts rather than investing in chemical fertilizer, for example. Even though ISFM is claimed by advocates to be universally applicable, this case shows that it is not necessarily a better way to achieve sustainability than the agro-ecological practises that farmers have already developed in response to site-specific circumstances over the past. Sub-Saharan Africa is big and the site-specificity is therefore an important factor to account for. This makes the statement that a package such as ISFM is universally superior to current practises a courageous claim. The ability to adapt these practises to local conditions is highly important, but ideas on how this should be realized are not sufficiently developed.

Even if ISFM appears to be superior to initial practises, the next step is to convince farmers of this fact. This study paid a lot of attention to the economic factors that affect smallholder farm households. As Moore (2015) states, differences in soil perception and faith-based framings of agricultural knowledge have their share as well. He states the difference between the scientist's perspective of soil fertility, from which ISFM is developed, and the farmer's perspective which is presented in table 9.

Table 9: Perceptions of Soil Fertility (Moore 2015).

	Scientist's perspective:	Farmer's perspective:
Measured through:	Chemical analysis of nutrients.	Visual assessment of crop performance and yield.
Factors determining soil fertility:	Threshold levels of nitrogen, phosphorous and potassium.	Soil colour, crop yield and presence of indicator weeds.
Consequent prescription:	Maximize soil quality for improved production.	Optimize soil use for livelihood priorities.

It shows that not only the perception of soil fertility is different, but also that the desired outcomes are not necessarily in common, even though farmers are likely to see the benefit of increased production. A part of this can be explained based on a difference in world views, which provide meaning to choices that might not be understood by others. Religion is one of the world views that provide meaning to certain behaviour and define what is the 'right' way to live and to work as a farmer. Differences in perception such as these challenge the diffusion of innovation, even if there is sufficient evidence that ISFM does increase yields. Understanding of differences in perception can be useful to frame farmers' choices and to develop successful ways of achieving agricultural innovation. Involving farmers in the development of innovation can be a solution. Richards et al. (2009) discuss an alternative to conventional agricultural research based on unsupervised learning supported by functional genomic analysis. They suggest that to let farmers do the experimenting themselves and to base innovation on their finding has the potential to result in better innovation that combines knowledge on genetics with knowledge of farmers. Above all, innovation that represents what farmers themselves find useful is very likely to result in higher adoption rates.

Giller et al. (2009) argue that, if an innovation does not provide short term benefits, farmers will likely not easily be convinced of the adoption benefits even though the long term results are promising. Soil erosion is not only a threat to market production but to agriculture in general, therefore it can be assumed that those who want to continue farming in the future are incentivized to adopt ISFM anyway, even if they are subsistence farmers. The question rather is how far the time horizon of farmers stretches and if conservation agricultural is really a response to the day to day struggles that concern the African smallholder. No matter how far or nearby their time horizon exactly is, climate change and population growth threaten the sustainability of sub-Saharan agriculture and even though farmers deserve autonomy, they also deserve to be kept save from threats that they cannot foresee. Therefore the challenge to governments, NGOs and other stakeholders is to prevent this sector from future failure whilst granting the farmers autonomy in how to work their own fields. ISFM could play an important role in conserving agricultural production, but the challenge of achieving widespread adoption should not be underestimated.

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Appendix

Table 10: Multivariate probit including crop residues

Multivariate Probit Model: Combination 1	Use of Fertilizer	Use of Improved Seed	Leaving Crop Residuals in the Field
Human Capital			
Female Household Head	-0.256	-0.317	0.257
	(1.14)	(1.68)*	(1.16)
Household Head Age	0.011	-0.008	0.005
	(0.89)	(1.06)	(0.71)
Household Head Education Level	0.048	0.014	-0.063
	(0.46)	(0.28)	(1.32)
Amount of Household Members	0.106	-0.003	-0.022
	(2.46)**	(0.12)	(0.55)
Years of Own Farm Experience	-0.012	0.009	-0.016
	(1.03)	(1.78)*	(3.01)***
Dependency Ratio	-0.353	0.028	0.022
	(2.62)***	(0.36)	(0.25)
Physical Capital			
Amount of Farm Facilities Used	0.179	0.132	0.213
	(1.25)	(1.71)*	(3.42)***
Motorcycle Owner	3.807	0.347	-0.033
	(7.28)***	(0.75)	(0.09)
Power Tiller Owner	4.944	-0.630	0.877
	(2.83)***	(2.12)**	(1.70)*
Car Owner	2.989	-0.436	0.866
	(3.23)***	(0.46)	(1.51)
Financial Capital			
Total Value of Cattle	0.192	-0.141	0.307
	(0.79)	(2.40)**	(2.05)**
Total Value of Assets	0.472	0.303	-0.206
	(2.00)**	(1.69)*	(1.68)*
Natural Capital			
Total Plot Acreage	-0.025	-0.006	-0.003
	(2.04)**	(1.17)	(0.64)
Plot Ownership Ratio	1.410	-0.811	0.182
	(2.63)***	(2.08)**	(0.71)
Irrigation User	-0.563	-0.136	-0.570
	(2.13)**	(0.85)	(3.61)***
Concern of Decreasing Soil Fertility	0.051	0.013	0.079
	(0.23)	(0.14)	(1.11)
Concern of Soil Erosion	-0.043	0.034	0.029
	(0.44)	(0.45)	(0.41)
Social Capital			
Total Amount of Members in Farmer Group	-0.001	-0.002	0.001
	(0.64)	(2.06)**	(2.97)***
Market Access			
Credit Constraint	-0.793	-0.340	0.108
	(2.05)**	(2.44)**	(1.06)
Time in Minutes from Plot to Nearest Tarmac Road	-0.004	-0.002	-0.001
	(2.83)***	(1.82)*	(1.08)
Median of Village Maize Output Price	0.366	0.034	-0.106
	(1.61)	(0.42)	(2.20)**
_cons	-1.116	1.661	0.220
	(0.62)	(2.11)**	(0.47)
atrho21	_cons	0.265	
		(2.70)***	
atrho31	_cons	-0.054	
		(0.64)	
atrho32	_cons	-0.029	
		(0.43)	
N			620

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Table 11: Multivariate probit including no-tillage and herbicides

Multivariate Probit Model: Combination 2	Use of Fertilizer	Use of Improved Seed	No-Tillage	Use of Herbicides
Human Capital				
Female Household Head	1.365	-0.457	0.216	-0.119
	(3.08)***	(1.90)*	(1.07)	(0.55)
Household Head Age	0.057	-0.013	-0.006	0.008
	(2.78)***	(1.66)*	(0.93)	(0.88)
Household Head Education Level	0.552	0.036	-0.065	0.140
	(3.04)***	(0.51)	(1.49)	(1.43)
Amount of Household Members	0.242	-0.022	0.028	-0.081
	(2.44)**	(0.62)	(0.89)	(2.01)**
Years of Own Farm Experience	-0.035	0.002	0.015	-0.011
	(2.73)***	(0.22)	(2.82)***	(1.21)
Dependency Ratio	-0.520	0.018	0.047	-0.104
	(2.31)**	(0.19)	(0.45)	(0.86)
Physical Capital				
Amount of Farm Facilities Used	0.071	0.022	0.127	0.181
	(0.46)	(0.16)	(1.57)	(1.88)*
Motorcycle Owner	3.340	0.102	-0.158	0.570
	(7.05)***	(0.23)	(0.30)	(0.95)
Power Tiller Owner	2.607	-0.082	-0.357	0.247
	(3.72)***	(0.17)	(0.70)	(0.44)
Car Owner	**Omitted**	-0.545	0.367	2.508
		(0.53)	(0.64)	(2.48)**
Financial Capital				
Total Value of Cattle	1.165	0.016	0.151	0.626
	(2.04)**	(0.19)	(2.44)**	(3.21)***
Total Value of Assets	3.638	0.251	0.066	0.555
	(2.52)**	(1.10)	(0.60)	(2.03)**
Natural Capital				
Total Plot Acreage	-0.014	-0.010	-0.004	-0.008
	(2.34)**	(2.46)**	(1.04)	(1.86)*
Plot Ownership Ratio	1.160	-1.029	-0.303	-0.314
	(3.79)***	(4.18)***	(1.22)	(1.21)
Irrigation User	-1.176	-0.327	-0.470	-0.223
	(3.85)***	(1.18)	(1.32)	(0.85)
Concern of Decreasing Soil Fertility	-0.142	-0.214	0.064	0.058
	(0.63)	(2.77)***	(0.70)	(0.63)
Concern of Soil Erosion	-0.295	0.136	-0.019	-0.160
	(1.95)*	(1.86)*	(0.34)	(2.05)**
Social Capital				
Total Amount of Members in Farmer Group	0.007	-0.002	-0.002	0.001
	(3.39)***	(1.84)*	(2.09)**	(0.45)
Market Access				
Credit Constraint	0.582	-0.221	0.078	-0.235
	(1.60)	(1.48)	(0.59)	(1.07)
Time in Minutes from Plot to Nearest Tarmac Road	-0.009	-0.002	-0.004	-0.003
	(4.38)***	(2.29)**	(1.85)*	(1.59)
Median of Village Maize Output Price	0.137	-0.001	-0.012	0.129
	(0.71)	(0.02)	(0.29)	(1.77)*
_cons	-4.170	3.234	-0.282	-0.149
	(2.38)**	(4.20)***	(0.57)	(0.15)
atrho21	_cons	0.419 (3.15)***		
atrho31	_cons	-0.008 (0.09)		
atrho41	_cons	0.364 (2.52)**		
atrho32	_cons	-0.066 (0.86)		
atrho42	_cons	0.282 (2.43)**		
atrho43	_cons	0.251 (2.92)***		
N				464

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Table 12: Multivariate probit including rotation and/or intercropping

Multivariate Probit Model: Combination 3	Use of Fertilizer	Use of Improved Seed	Rotation and/or Intercropping
Human Capital			
Female Household Head	-0.028	-0.374	0.240
	(0.29)	(2.51)**	(2.00)**
Household Head Age	0.001	-0.007	-0.010
	(0.17)	(1.19)	(1.82)*
Household Head Education Level	0.039	0.053	0.009
	(0.77)	(1.14)	(0.36)
Amount of Household Members	-0.004	-0.010	0.000
	(0.14)	(0.47)	(0.00)
Years of Own Farm Experience	0.002	0.007	0.025
	(0.27)	(2.02)**	(4.35)***
Dependency Ratio	-0.252	-0.043	0.039
	(3.57)***	(0.78)	(0.50)
Physical Capital			
Amount of Farm Facilities Used	0.176	0.072	0.036
	(1.44)	(1.01)	(0.40)
Motorcycle Owner	3.277	-0.039	-0.127
	(9.31)***	(0.10)	(0.41)
Power Tiller Owner	-0.328	-0.410	-0.204
	(1.12)	(1.71)*	(0.51)
Car Owner	2.840	-0.377	-0.293
	(2.59)***	(0.51)	(0.42)
Financial Capital			
Total Value of Cattle	0.343	-0.111	-0.097
	(2.77)***	(2.87)***	(2.14)**
Total Value of Assets	0.327	0.289	0.049
	(1.04)	(2.15)**	(0.53)
Natural Capital			
Total Plot Acreage	-0.011	-0.009	-0.002
	(2.07)**	(2.06)**	(0.42)
Plot Ownership Ratio	0.432	-0.547	0.255
	(1.85)*	(2.45)**	(0.93)
Irrigation User	-0.032	-0.002	-0.194
	(0.14)	(0.01)	(1.10)
Concern of Decreasing Soil Fertility	0.166	-0.077	0.054
	(1.27)	(1.04)	(1.13)
Concern of Soil Erosion	-0.088	0.054	0.028
	(1.17)	(0.78)	(0.50)
Social Capital			
Total Amount of Members in Farmer Group	-0.001	-0.002	-0.001
	(0.67)	(2.07)**	(0.79)
Credit Constraint	-0.607	-0.394	-0.058
	(2.06)**	(3.02)***	(0.32)
Time in Minutes from Plot to Nearest Tarmac Road	-0.002	-0.001	0.000
	(2.32)**	(2.06)**	(0.29)
Median of Village Maize Output Price	0.027	0.010	-0.072
	(0.28)	(0.16)	(0.89)
_cons	0.943	1.742	0.646
	(0.98)	(2.77)***	(0.92)
atrho21	_cons	0.325	
		(3.81)***	
atrho31	_cons	-0.012	
		(0.13)	
atrho32	_cons	0.244	
		(3.99)***	
N			1057

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Table 13: Multivariate probit including mulching and/or cover crops

Multivariate Probit Model: Combination 4	**Use of Fertilizer**	**Use of Improved Seed**	**Mulching and/or Cover Cropping**
Human Capital			
Female Household Head	-0.037	-0.372	-0.228
	(0.38)	(2.55)**	(1.76)*
Household Head Age	0.002	-0.007	0.005
	(0.20)	(1.12)	(0.63)
Household Head Education Level	0.041	0.049	-0.010
	(0.77)	(1.09)	(0.33)
Amount of Household Members	-0.004	-0.008	0.018
	(0.13)	(0.38)	(1.05)
Years of Own Farm Experience	0.002	0.007	0.010
	(0.29)	(1.83)*	(1.48)
Dependency Ratio	-0.239	-0.043	0.070
	(3.42)***	(0.78)	(0.89)
Physical Capital			
Amount of Farm Facilities Used	0.180	0.070	0.019
	(1.48)	(0.98)	(0.35)
Motorcycle Owner	3.313	-0.031	-0.095
	(9.33)***	(0.08)	(0.28)
Power Tiller Owner	-0.327	-0.406	-0.469
	(1.11)	(1.77)*	(2.45)**
Car Owner	2.873	-0.395	-0.461
	(2.66)***	(0.54)	(0.84)
Financial Capital			
Total Value of Cattle	0.324	-0.109	-0.104
	(2.62)***	(2.86)***	(2.73)***
Total Value of Assets	0.337	0.287	0.242
	(1.06)	(2.11)**	(2.05)**
Natural Capital			
Total Plot Acreage	-0.011	-0.009	-0.008
	(2.06)**	(1.98)**	(1.80)*
Plot Ownership Ratio	0.439	-0.528	0.301
	(1.94)*	(2.36)**	(1.30)
Irrigation User	-0.066	0.005	0.246
	(0.29)	(0.03)	(1.11)
Concern of Decreasing Soil Fertility	0.165	-0.077	-0.040
	(1.27)	(1.06)	(0.70)
Concern of Soil Erosion	-0.092	0.053	-0.101
	(1.24)	(0.76)	(1.65)*
Social Capital			
Total Amount of Members in Farmer Group	-0.001	-0.002	-0.000
	(0.65)	(2.04)**	(0.03)
Market Access			
Credit Constraint	-0.622	-0.385	-0.708
	(2.18)**	(3.03)***	(5.08)***
Time in Minutes from Plot to Nearest Tarmac Road	-0.002	-0.001	0.002
	(2.38)**	(2.06)**	(1.75)*
Median of Village Maize Output Price	0.028	0.010	-0.100
	(0.29)	(0.15)	(1.14)
_cons	0.922	1.719	0.071
	(0.94)	(2.74)***	(0.12)
atrho21	_cons	0.329	
		(3.71)***	
atrho31	_cons	0.174	
		(2.23)**	
atrho32	_cons	0.173	
		(2.67)***	
N			1057

* *p*<0.1; ** *p*<0.05; *** *p*<0.01