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| Wageningen UR |  |
| Is promoting agricultural input use the way to improve nutrition? |  |
| A study on how farm-level adoption of improved maize seeds and fertiliser affects food security for households in rural Tanzania |  |

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| Verbeek, Anne  10/13/2016 |

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# 1. Introduction

The World Bank estimated that in 2013 roughly 946 million people where undernourished, of which 184 million people living in Sub-Sahara Africa. In Tanzania, 17.3 million people where undernourished in 2013. This represents 34.6 % of the total population, compared to the regional Sub-Saharan average of 19.5% (World Bank, 2016a, 2016b, and own calculations). The largest part of the poor population of Tanzania lives in rural areas and depend on income from agriculture (Tiberti & Tiberti, 2015). National agricultural production in Tanzania may be sufficient to meet per capita energy requirement in terms of calories, but access to food is still unequally distributed (Knueppel, Demment, & Kaiser, 2010). At the same time, meeting calorie requirements is not enough to meet dietary needs. In most developing countries and particularly in Africa, diets are not only low in energy but are also described as one-sided. They usually have a lack of animal products, fruits and vegetables (Leyna, Mmbaga, Mnyika, Hussain, & Klepp, 2010). Maize and rice are important food crops, but the farming system for these crops is characterised by low productivity (World Bank, 2014) due to low use of inputs amongst others. Maize is the main staple in Tanzania, but yields remain low and it is mostly produced by subsistence smallholders (Pauw & Thurlow, 2011). Less than 8 % of all smallholder farmers used improved seed, and less than 3 % used inorganic fertilizer at the time of the 2007/2008 Census Survey of Agriculture (World Bank, 2014). In comparison, average national fertiliser use in 2013 was 4.7 kg/ha of arable land for Tanzania compared to 52.5 kg/ha of arable land for Kenya (World Bank, 2016). Many smallholders are unable to try new agriculture related technologies and techniques due to constraints including lack of money, information, and access to natural resources or inputs (Silvestri et al., 2015).

Although the agricultural sector of Tanzania overall has grown rapidly between 2000-2007, this has had little impact on nutrition for the population as a whole. Large-scale farms producing export crops were the main drivers of this growth, whereas the performance of most major food crops remained poor (Tiberti & Tiberti, 2015). Several studies have examined the link between agricultural productivity, food security and/or nutrition (Dillon, McGee, & Oseni, 2015a; Keding, Schneider, & Jordan, 2013; Kriti, 2015a; Slavchevska, 2015). These studies suggest that a positive link exists, thus higher productivity leads to a better nutritional status of the population. Increased fertilizer use for example appears to have positive effects on household food security (Kriti, 2015a), whereas production diversity correlates positively with dietary diversity (Dillon et al., 2015a). Nevertheless, systematic- and empirical evidence on household level agricultural production related to household nutrition is still very limited (G. Carletto, Ruel, Winters, & Zezza, 2015). A farm-level link between agricultural production and nutrition has been theorised, but few scientific studies provide evidence (Slavchevska, 2015). At the same time, the pathways from agriculture to nutrition have proven to be complex and difficult to define (Kanter, Walls, Tak, Roberts, & Waage, 2015). This represents an important knowledge gap, especially because the role of agriculture in food security and nutrition improvement is increasingly recognised by policy makers (G. Carletto et al., 2015).

The aim of our research is to fill this knowledge gap for the case of Tanzania, by analysing how farm-level adoption of improved maize seeds and fertiliser use affects food security for maize farming households in Tanzania. We will combine three different research methods to investigate the link between farm-level adoption of improved maize seeds and fertiliser and food security. We use a literature review to show how the concepts of nutritional status, food security and health are defined and how these concepts are related. We then perform quantitative data analysis using three waves of the Tanzania National Panel Survey (NPS), conducted in 2008-2009, 2010-2011 and 2012-2013. This survey was conducted by the Tanzania National Bureau of Statistics (NBS) in collaboration with the World Bank Living Standard Measurement Study –Integrated Surveys on Agriculture (LSMS-ISA). This data analysis estimates the link between technology adoption on food- and nutrition security for farm households. In addition, we use expert interviews to verify our results and put them into a practical perspective.

In the first chapter, we will discuss the policy context to get an understanding of what is being done in an attempt to improve food security by promoting agricultural input use and to identify potential problems. The next chapter is a literature review focussing on all aspect of the food security concept, the definitions and the relation to nutrition and health. Also, this chapter contains an overview of food security and nutrition indicators and an assessment of the relevance and feasibility for our study. The fourth chapter is a theoretical framework, designed to better understand the theoretical relationship between agricultural input use and food security, and to structure the way in which we will formalise our model. The following chapter will focus on our empirical strategy. We will elaborate on the nature of our data and the variables we use. It contains a descriptive analysis of hybrid seed- and fertiliser use and food security, and an econometric estimation strategy. In the sixth chapter we present our results from the data analysis part. The seventh chapter will focus on the relation between our data analysis and our field interviews, and in addition it will provide an overview of possible policy implications. Lastly we will give a discussion on our research and a conclusion.

# 2. Policy context: National Input Voucher Scheme

In Tanzania the Ministry of Agriculture, Food Security and Cooperatives (MAFC) aims at improving national food security. Since 2008 the MAFC administers The National Agricultural Input Voucher Scheme (NAIVS). NAIVS was set up in response to the food crisis of the late 2000s. It promotes agricultural input use as a way to improve food security in response to the high international food prices (Baltzer et al., 2011). In Tanzania average agricultural input use is low, fertiliser use for example was at the start of the program only 9 kg/ha, compared to Africa average of 21 kg/ha and world average of 100 kg/ha (Aloyce, Gabagambi, & Hella, 2014) The NAIVS is meant to promote input use, increase food production, and thereby reducing the pressure on food staple prices and increase incomes to improve food security. The program works as follows. Vouchers with a 50 per cent subsidy on the purchase of chemical fertiliser and improved seeds are provided to maize- and rice farming households (Gine, Patel, Cuellar-Martinez, McCoy, & Ralph, 2015). It is specifically targeted towards smallholders: To be eligible for the program households must not cultivate more than one hectare of maize or rice. Eligibility also requires households to be able to afford the top-up amount of the input price, as the subsidy only covers 50 per cent of the costs. After three consecutive years of subsidy, the program requires farmers to graduate. After graduation farmers are expected to support themselves (Aloyce et al., 2014).

## 2.2 History of national policies

The voucher programme originates from a long history of agricultural input subsidies (World Bank, 2014). From 1967 until the early 1980s, all agricultural inputs where state-controlled. The state monitored the import and distribution of agricultural inputs and kept prices low with subsidies. The economic crisis in the 1980s was followed by a period of market liberalisation and reform of state monopolies. Ultimately this resulted in the removal of expensive price controls on inputs. All input subsidies decreased rapidly in the late 1980s and early 1990s. In the 2000s, new subsidies to promote input use were put in place, this time on fertiliser transports. Around 2007 this transport subsidy was revised and replaced with the National Agricultural Input Voucher Scheme (NAIVS) (World Bank, 2014). In 2007/08 the first pilot of the NAIVS scheme took place. In contrary to the nationwide input subsidies from the past, this new program is “market smart” (Pan & Christiaensen, 2012). Market smart means that a subsidy program is designed in such a way, that it is part of a larger productivity improvement program. Also, to be market smart it needs to have a defined exit strategy and beneficiaries need to be targeted with deliberation. It is argued that this way of designing a subsidy program will overcome the shortcomings of the programs of the past, like the limited effects on smallholder productivity and the high costs for the government.

## 2.2 Subsidy Targeting

In 2007/08 the NAIVS programme was piloted in two districts and expanded to 53 districts across 11 high potential regions in 2008/09: Iringa, Mbeya, Ruvuma and Rukwa, Kilimanjaro, Arusha, Manyara, Kigoma, Tabora, Mara and Morogoro (World Bank, 2014). The vouchers were distributed amongst these high potential maize and rice producing regions, and then allocated to districts where irrigation is available. The districts in turn distributed the vouches to villages, where Village Voucher Committees (VVC) selected the end beneficiaries. The pilot programme had very broad targeting criteria. The guidelines given to the VVCs were to select literate households, that were willing to use the vouchers for the intended crops, and able to meet the top-up payment of 50% of the price for the inputs (Baltzer et al., 2011). This decentralised way of targeting beneficiaries has the advantage of being less costly than a centralised system, due to the efficient use of local knowledge. However, an evaluation of this pilot programme of 2008 showed the downsides of decentralised targeting. The broadness of the criteria made that VVCs had a lot of power in allocating the vouches, whereas the criteria themselves (literacy, and being able to pay 50%) pointed towards the less poor households. Therefore, this form of decentralised targeting was susceptible to ‘elite capture’ (Baltzer et al., 2011; Pan & Christiaensen, 2012). In response to this experience, new targeting criteria were formulated to clarify the intended targeting for further rounds of the programme (Baltzer et al., 2011):

1. Full time farmers residing in the village
2. Farmers cultivate less than one hectare of maize or rice
3. Farmers use the subsidised input for maize or rice production
4. Farmers agree to serve as good examples in how to use good agricultural practices
5. Farmers are willing and able to cover the co-financing
6. Female-headed households are given priority
7. Farmers, who have not used inputs in the past five years, are given priority

Nevertheless, an evaluation of the round of 2010/2011 shows that inconsistencies still exist. Beneficiaries appear to be on average richer and more connected to the VVC than non-beneficiaries (World Bank, 2014). Overall, demand for input vouchers is greater than supply. This has led to inconsistent targeting, where vouchers were given to farmers alternatingly: the farmer that received a voucher in one year did not get one in the next year (Aloyce et al., 2014). Other challenges with regards to the program are that the top-up payment required to purchase the inputs is still too high to afford for many subsistence farmers, and that in many cases the inputs are not distributed on time (Aloyce et al., 2014). Despite these challenges, NAIVS is still running today (August 2016).

# 3. Literature review

We have provided some background on the policy context concerning agricultural input use in relation to food security. Now, a clear overview of the concepts of nutritional status, food security and health is necessary in order to further investigating the link between farm-level adoption of improved maize seeds and fertiliser and household food security. In the first section of this chapter we will discuss the concepts related to food security, nutrition and health, their definitions and how they overlap. The second section gives an overview of household food security and nutrition indicators. The third section consists of the systematic assessment of these indicators.

## 3.1 Food, nutrition and health: definitions and concepts

The first section of this chapter will provide some historical background on food security. It gives a chronological overview of how international policy makers thought about the topic in the past and how the way of thinking has evolved. Next, we will elaborate on the definition of food security that is now widely used and how it related to undernourishment, malnutrition, hunger an undernutrition.

### 3.1.1 History of food security perspectives

Food- and nutrition security are concepts that have been in use for a long time and the definitions have developed and changed across time. An insight in the historical evolution of food and nutrition related concepts is crucial for understanding what definitions are used today. In the 1943 Hot Spring Conference of Food and Agriculture, the concept of a “secure, adequate, and suitable supply of food for everyone” was accepted internationally. Later, the right to food as a core element of an adequate standard of living was recognised in the Universal Declaration of Human Rights in 1948. During the 1950s, donor countries started disposing their agricultural surplus overseas (Gross, Schoeneberger, Pfeifer, & Preuss, 2000). With the establishment of the World Food Program in 1963, the concept of food for development was introduced. With the rise of this program, food aid became more and more multilateral and the focus shifted slowly from disposal of agricultural surpluses to food self-sufficiency promotion through cash contributions (Barrett, 2002). The world food crisis of 1972-74 was followed by the green revolution of the 1980s (Gross et al., 2000). This lead to a change in the food security paradigm. In the 1970s, foreign aid donors and agencies like the FAO played a major role in generalising and analysing food security information, focussing on national and international data (Barrett, 2002; S. Maxwell & Smith, 1992). With the global increase in production during the 1980s, it was recognised that food insecurity was not as much caused by insufficient supply, but rather by inequality and low purchasing power of specific groups (Gross et al., 2000). During that time the focus shifted from the supply side to the demand side (Barrett, 2002): for nations towards individuals and households, with an emphasis on access and entitlement to food (S. Maxwell & Smith, 1992) in terms of caloric sufficiency. By the mid-1990s, a second shift took place in the food- and nutrition security paradigm. Nutrition research started focussing not only on access and availability of food, but also on overall diet quality and micronutrient deficiencies (Jones, Ngure, Pelto, & Young, 2013). This resulted in a revision of the international definition of food security, agreed upon at the World Food Summit, highlighting the importance of dietary quality and dietary needs both for the household and the individual.

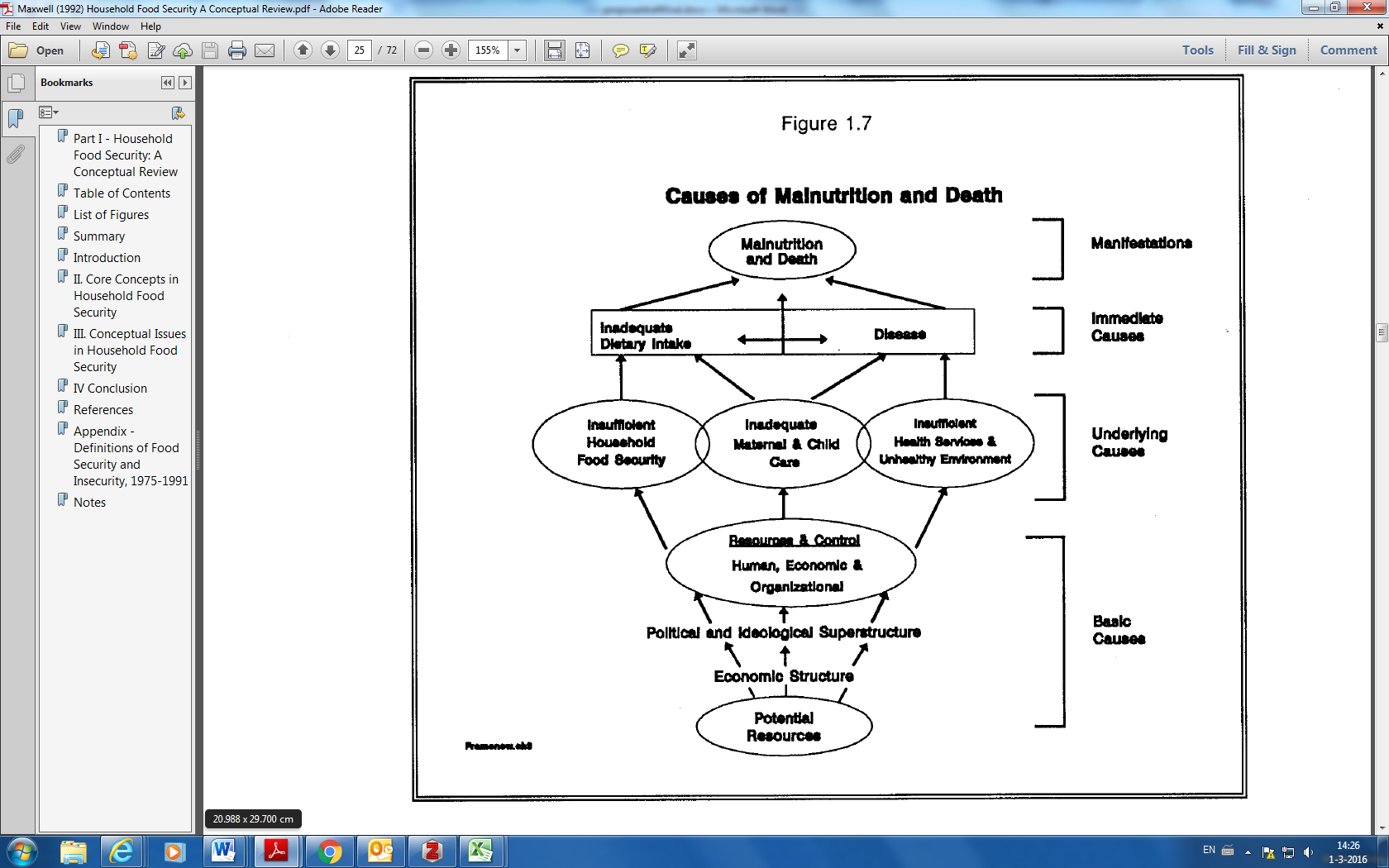
### 3.1.2 Definitions and overlapping concepts

At the 1996 World Food Summit, the following definition of food security was agreed upon: “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life’’ (C. Carletto, Zezza, & Banerjee, 2013). This definition is still widely accepted (de Haen, Klasen, & Qaim, 2011). It covers all previously mentioned concepts: sufficiency, availability, access and dietary quality. Nutrition security is sometimes used interchangeably with food security (Jones et al., 2013), but is a different and less commonly used term (Haddad, Kennedy, & Sullivan, 1994). The FAO definition of nutrition security is “A situation that exists when secure access to an appropriately nutritious diet is coupled with a sanitary environment, adequate health services and care, in order to ensure a healthy and active life for all household members” (Jones et al., 2013). The UNICEF (1990) ‘conceptual framework for the causes of malnutrition in society’ in figure 1 is and widely used depiction of the relation between food, nutrition and health (J. B. Mason, n.d.; S. Maxwell & Smith, 1992). It clearly shows the difference between food- and nutrition (in)security. Food insecurity relates to individual- and household food intake, whereas nutrition also depends on good health. Food security is an ex-ante condition with respect to nutrition and health (Barrett, 2002). It is a necessary, but not a sufficient condition (Jones et al., 2013). Both food security and health depend on human, economic and organisational resources.

If food security involves always having access to sufficient, safe and nutritious food, then ‘**food insecurity’** means that access to enough and appropriate food is uncertain (Barrett, 2002). Sometimes food insecurity is classified as chronic or transitory, but the time frames for these classifications have not been made explicit (Jones et al., 2013). **Undernourishment** is seen as an extreme form of food insecurity. It is a term used by the FAO to describe the situation when caloric intake is below the dietary energy requirement (Jones et al., 2013). **Malnutrition** is a similar term, that also takes into account micronutrient deficiencies (or excess) (Barrett, 2002; Jones et al., 2013). **Micronutrients** are vitamins, minerals and certain other substances that are required by the body in small amounts (Millennium Project Task Force on Hunger, 2004). Figure 2 shows how the different concepts overlap: **Hungry** means lacking the basic food intake needed to be fully productive, both in terms of energy or nutrients. This is an outcome of food insecurity: all hungry people are food insecure, but not all food insecure people are hungry. People that are at risk of losing access to food are food insecure, without necessarily being hungry. **Undernutrition** can be food related or non-food related (e.g. due to illnesses or sanitary issues). It can be caused by undernourishment but also by poor absorption or use of nutrients. If undernutrition is food related, it can either be direct hunger, or hidden hunger (e.g. malnutrition from micro-nutrient deficiency) (Millennium Project Task Force on Hunger, 2004). Note that undernutrition is not the same as undernourishment or malnutrition. In summary:

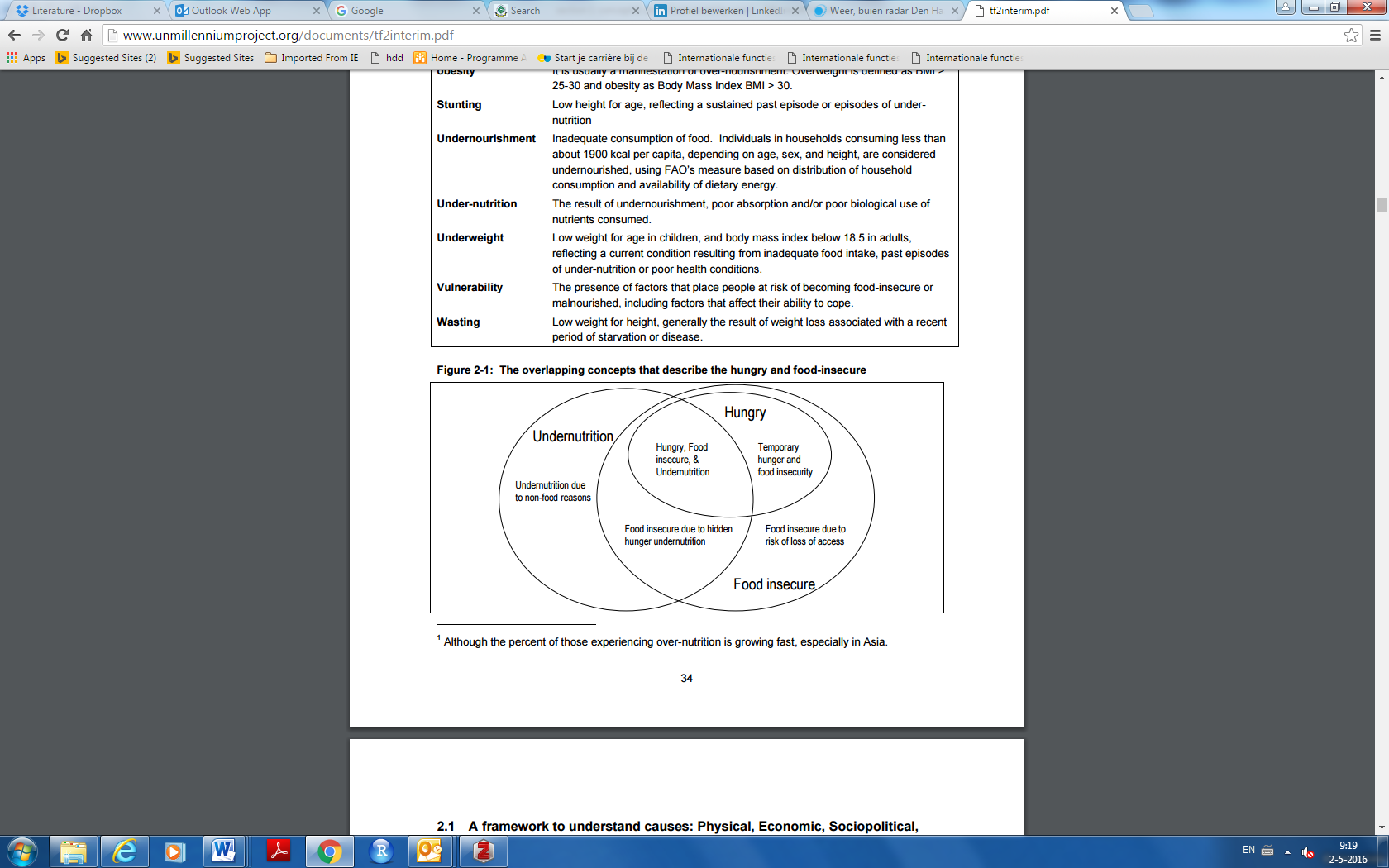
* **Undernourishment** is inadequate calorie intake, because intake is below the dietary energy requirement.
* **Malnutrition** is inadequate dietary intake, can be inadequate both due to deficiency of certain nutrients (calories, vitamins, minerals) and/or to excess of certain nutrients (saturated fats, added sugar).
* **Hunger:** lacking the basic food intake needed to be fully productive.
* **Undernutrition:** poor intake-, absorption- or use of nutrients.

**Figure 1** *Conceptual framework for the causes of malnutrition in society*



Source: Reprinted from Maxwell & Smith (1992) p. 23

**Figure 2** *Overlapping concepts within the context of food and nutrition insecurity.*



Source: Reprinted from Millennium Project Task Force on Hunger (2004), p. 34

Our research question is positioned mainly around food security, instead of nutrition. Farm-level adoption of improved maize seeds and fertiliser is expected to affect household food status via production. Production can affect access to food and food intake, but the relation between production and non-food related causes for undernutrition is not within the focus of our research. The dataset (NPS LSMS ISA) we work with contains elaborate information on food intake and individual nutritional status, but it does not contain all the necessary medical information needed to differentiate between food- and non-food reasons for undernutrition . Within the range of food security, we look at all aspects: access, sufficiency and quality. Nevertheless, individual nutritional status is an important component and definitely should be included in a follow-up study. For that reason, we do include nutrition in the literature study.

## 3.2 Food security and nutrition indicators

In the previous section we have covered food security and nutrition related concepts, their definitions and how they overlap. In this section we will discuss how they can be studied empirically, using different indicators. Food- and nutrition security are frequently used concepts in different research- and policy domains and the existence of multiple understandings of these concepts make them particularly hard to measure. There is no ‘standard measure’ for food security. Maxwell et al. (1999, p. 2) even argue that food security is probably too complex to ever be captured by a single, one dimensional indicator.

In this line of thinking we have developed an overview of the most frequently used indicators for (household) food and nutrition security. Our aim is to select a set of these indicators that together will give an adequate profile of the food and nutrition situation for the households in our sample. We have selected the most frequently mentioned indicators in scientific literature in the fields of food policy, health and nutrition, agricultural economics and development and poverty research. We have categorised the 22 indicators in our list into 6 different groups: food acquisition, dietary intake, subjective measurements, coping strategies, anthropometric measurements and biochemical measurements. Food acquisition, dietary intake, subjective measurements and coping skills are typical household level measurements, whereas anthropometric measurements and biochemical measurements measure at individual level.

### 3.2.1 Criteria for indicAtor assessment

For our research on the link between farm-level adoption of improved maize seeds and fertiliser and household nutrition, we need a limited set of dependent variables for household food security and/or nutrition. Table 1 below provides a clear overview that we will use when selecting the indicators we will use. We will discuss each criterion individually and give a systematical assessment of the list of indicators.

Tabel Criteria for indicator assessment[[1]](#footnote-1)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Not context specific** | **Can be measured at household level** | **Measures dietary quality** | **Measures nutritional status** | **Measures lived experiences** | **Not easy to manipulate** | **Available in NPS LSMS ISA TNZ** |
| **Food acquisition** | **Food expenditure** | X | V | X | X | X | V | X |
| **Acquired food quantity** | X | V | X | X | X | V | X |
| **Dietary intake** | **HDDS** | X | V | V | X | X | V | Adapted version: 7 day recall |
| **IDDS** | X | X | V | X | X | V | No individual data available |
| **FCS** | V | V | V | X | X | V | V |
| **FVS** | V | V | V | X | X | V | V |
| **Subjective measurements** | **SAFS** | X | V | X | X | V | X | Adapted version |
| **HFSSM** | X | V | X | X | V | X | No data available |
| **HFIAS** | X | V | X | X | V | X | No data available |
| **HHS** | X | V | X | X | V | X | No data available |
| **Coping strategies** | **CSI** | X | V | X | X | V | V | Reduced version |
| **Anthropometric measurements** | **Wasting** | X | X | X | V | X | V | V |
| **Stunting** | X | X | X | V | X | V | V |
| **Underweight** | X | X | X | V | X | V | V |
| **MUAC** | V | X | X | V | X | V | Not available for wave 1, overall relatively few observations |
| **Quetelet’s index** | X | X | X | X | X | V | V |
| **CED** | X | X | X | X | X | V | V |
| **Biochemical measurements** | **Skinfold measurements** | V | X | X | V | X | V | X |
| **Vitamin A deficiency** | V | X | X | V | X | V | X |
| **Iron deficiency** | V | X | X | V | X | V | X |
| **Iodine deficiency** | V | X | X | V | X | V | X |

**Not context specific**: comparativeness of an indicator can be very important. Not only whether one indicator can be compared to another, but also whether two studies using the same indicator in different contexts can be compared to each other. The absence of a ‘standard measure’ against which we can measure the performance of other indicators, makes that it difficult to identify the reliability of indicators (D. Maxwell, Vaitla, & Coates, 2014). This raises the demand for comparative and therefore not context specific indicators. For us, it is important that an indicator is operational without the need for extensive contextualisation.

* **Can be measured at household level:** All analyses will be done at household level, because we are looking into the link between farm-level adoption of improved maize seeds and fertiliser and household nutrition. For that reason, we have a preference for indicators that provide information on the household rather than the individual. Most of the indicators we selected are household indicators, except for the anthropometric- and biochemical measurements. These measurements specifically indicate nutritional status, a characteristic of the individual and not of the household as a whole. We must note that this preference is not in line with the theory of Barrett (2002), that stresses that a useful model for food security should include information on within household food allocation, which would require information on the individual.
* **Dietary quality, nutritional status and/or health, or lived experiences:** For our research we are interested in these three concepts: Dietary quality, nutritional status and/or health, or lived experiences. We are looking for an indicator or a set of indicators that gives information on these three characteristics. The dietary diversity measures: HDDS, IDDS and FCS, measure dietary quality. All anthropometric and biochemical indicators measure nutritional status and/or health. All subjective measurements and the coping strategy index measure lived experiences. The food acquisition measures are not particularly suited to measure either of these characteristics. For our research, we want to have at least one indicator for dietary quality, and for lived experiences. From the dataset we will use, it is possible to construct an adapted HDDS, a FCS and a FVS to indicate dietary quality. To indicate lived experiences of hunger and food insecurity we can construct a reduced version of the CSI and possibly a version of the SAFS. As we explained earlier, the nutritional status and/or health indicators can only be measured for an individual. For follow-up research, it would be interesting to look at nutritional indicators in comparison to household level indicators to adequately include and compare all three concepts.
* **Not easy to manipulate:** Self-assessed measures, SAFS, HFSSM, HFIAS and HHS, can be easy to manipulate in programmatic contexts. If a program is targeting the poorest or least food secure households, households could exaggerate their situation when answering self-assessment questions, in order to meet the eligibility criteria. We use a national dataset, that might as well be used for targeting for various programs. When we would use a SAFS, it is important to check for a significant correlation with objective measurements.

### 3.2.2 Food acquisition

One way of measuring household food security in terms access to food is measuring the amount of food that enters the household. We call this household food acquisition. This is not necessarily an expenditure; this food can be purchased, but it can also be received as a gift or produced for own consumption. To assess household food acquisition, data on household food consumption and expenditures from national household budget surveys can be used. We distinguish two kinds of food acquisition indicators: ‘food expenditures’ and ‘acquired food quantity’. To avoid confusion, both indicators include purchased as well as received and produced food. The difference is that ‘food expenditures’ measures food acquisition in monetary value, whereas ‘acquired food quantities’ measures in actual quantities. These indicators work under the assumption that food acquisition equals food consumption. This assumption only holds for population level analysis. At household level, these estimates are not accurate enough to make comparisons between households or for the same households over time. Some households can rely on food stocks acquired before the reference period, others can buy new food, or food can be wasted or lost, which causes household level differences to become random errors (Jones et al., 2013).

### 3.2.3. Dietary intake

Dietary intake is a proxy for actual consumption. Many nutritional problems are not directly due to a lack of calories in the diet, but to a lack of nutrient diversity (C. Carletto et al., 2013). A dietary diversity score is being advocated as a good way to measure dietary quality. The household dietary diversity score (HDDS) was developed by the FANTA project (Food and Nutrition Technical Assistance) and is constructed by summing a total of 12 food groups over a reference period of 24 hours (C. Carletto et al., 2013; Jones et al., 2013) The score includes two groups for staples and separates fish, meat and eggs into different groups. Furthermore, it includes several groups for miscellaneous food items, which can differ per study or region (C. Carletto et al., 2013). The IDDS, the same score but measured individually, has the advantage over the HDDS that it can measure nutrient adequacy of the diet. Special IDDS measures are available for infants and young children (Steyn, Nel, Nantel, Kennedy, & Labadarios, 2006) The main difficulty with dietary diversity scores is the comparison across studies. Different recall periods and different measurement tools make it difficult to interpret differences in results (C. Carletto et al., 2013).

Another dietary intake measure is the food consumption score FCS (sometimes referred to as food frequency score FFS). This indicator is used by the WFP (World Food Program) to identify the prevalence of food insecurity in countries and regions and to monitor changes over time (Jones et al., 2013). The FCS is similar to the HDDS, but it generally uses a 7 day recall period and only 8 food groups. Moreover, the FCS takes into account the food frequency and it uses weights for the 8 different groups. Food frequency, the number of days in which one or more items from a certain group is consumed, is multiplied by the corresponding group weight. The standard format of this indicator and the universal cut-off points make it possible to compare results across different studies. However, in some specific cases the FCS misclassifies households with a poor diet as food secure, which shows a lack of conformity of the FCS and other universal benchmarks (D. Maxwell et al., 2014).

Another option for measuring dietary intake is taking a food variety score (FVS). This is a simple count of all different food items consumed over a 24h period (Steyn et al., 2006). The advantage is that this indicator provides a variable that contains all dietary information. In contrast to the dietary diversity score, food items are counted individually and not classified into fixed groups. This means the variable has a larger spread and differences between households can be measured more precisely. However, there is no common consensus on what a food item is. This makes it difficult to compare scores between different studies.

### 3.2.4. Subjective measurements

Subjective measurements attempt to measure food security directly by asking households how they experience their own food security, instead of looking at consumption level. A self-assessed food security score (SAFS) is constructed of a respondents’ perception of their own household food security status (Shiferaw, Kassie, Jaleta, & Yirga, 2014). Households are asked to score themselves, the scale on which this is done can differ per study. Maxwell et al. (2014) let families score themselves on a scale from 1-5, one being food secure, five being extremely food insecure (D. Maxwell et al., 2014). Shiferaw, Kassie, Jaleta, & Yirga (2014) have households score their food security status on a four level scale: chronic food insecurity, transitory food insecurity, breakeven or food surplus.

Other subjective indicators for food security make use of a standard question list about the households’ perception of their own food security status, so that the household can be scored on different elements. We distinguish four of the most frequently used questionnaire based subjective indicators: the Radimer/Cornell hunger and food insecurity scale, the Household Food Security Survey Module (HFSSM), the Household Food Insecurity Access Scale (HFIAS) and the Household Hunger Scale (HHS). The Radimer/Cornell hunger and food insecurity scale classifies households as either hungry or not hungry. Households answer 30 questions or statements on how they perceive the following: their food depletion, food anxiety, diet inadequacy, intake insufficiency, disrupted eating patterns, children’s diet inadequacy, children’s intake insufficiency and children’s disrupted eating patterns. A household that answers ‘yes’ to four or more of these questions is classified as hungry (Radimer, Olson, Greene, Campbell, & Habicht, 1992). The HFSSM is the United States Department of Agriculture’s measure for food security. This measure is also sometimes used to asses food security in developing countries (Hadley, Mulder, & Fitzherbert, 2007). The question list is similar to the Radimer/Cornell hunger and food insecurity scale. The score is based on anxiety about household food supplies, perceptions that the quality or quantity of accessible food is not adequate, reduced adult food intake and reduced food intake by children. Based on their answers households are classified in three different categories: food secure, low food security or very low food security (Jones et al., 2013). The recall period is 12 months. Based on the HFSSM, the HFIAS was developed. This measure uses a question list of only 9 questions on the same topics, and a recall period of 4 weeks. HFIAS was developed by The Food and Nutrition Technical Assistance Project (FANTA) (Ballard, Coates, Swindale, & Deitchler, 2011) and USAID uses it as an indicator for program evaluations (Jones et al., 2013). The HHS is an adapted version of the HFSSM and the HFIAS, that is best suited for areas where food insecurity is substantial. It is based on a survey module of six questions on the experience of hunger, with a recall period of four weeks.

Subjective measurements are particularly well suited for measuring lived experiences of food insecurity. While intake- or acquisition indicators make an approximation of food security by using different kinds of information, subjective measurements look at food security directly. When using a subjective indicator, however, it can be difficult to compare between different cultural context. Households with different cultural backgrounds might approach and experience food insecurity differently. Also, getting used to having little access to food can change someone standards. This can lead to biased answers. Lastly, subjective measurements could be vulnerable to manipulation especially in project context.

### 3.2.5 Coping strategies

The Coping Strategy Index (CSI) is a behavioural measure for food security. It was developed under the assumption that the food security status of households can be derived by looking at the frequency and severity of their coping behaviour. Maxwell et al. (1999) argue that the most common indicators for food security revolve around food consumption and not around actual vulnerability. A coping strategy index can be a way to measure exactly this (D. Maxwell et al., 1999). The index was developed by the WFP and the organisation CARE (Jones et al., 2013). A focus group generates a region specific question list with the most common coping behaviours. Then households are interviewed about their coping behaviour of the past 30 days, and afterwards the focus group meets again and assigns severity weights to each coping strategy. The frequency in which a household reports using a specific coping strategy is multiplied by its assigned weight and the total is summed to construct a score for each household. This score in itself does not provide any information, it can only be used to compare between households of a certain country or region and identify the most vulnerable ones (Jones et al., 2013). A reduced version of the CSI was developed, which can be used in different contexts and is therefore better comparable across studies. This reduced measure is not as good in identifying vulnerable households as the original CSI, but it correlates just as well with other measures such as household assets and expenditures (Jones et al., 2013)

### 3.2.6 Anthropometric measures

Anthropometric measurements are indicators for individual nutritional status, instead of household food security. They provide nutritional information derived from a person’s measurements, weight, height, circumference, etcetera. Distribution of food within the household can be unequal, resulting in a difference in nutritional status between household members that cannot be identified when measuring food security at household level. We distinguish between seven different anthropometric measures: wasting, stunting, underweight, Quetelet’s index, chronic energy deficiency (CED), middle-upper arm circumference (MUAC) and skinfold measurements.

Wasting, stunting and underweight are three different child anthropometric indicators that are usually combined to give a good sense of both chronic and acute undernutrition (de Haen et al., 2011). Wasting means that a child has a low weight for its height, stunting means low height for age and underweight means that a child has low weight for its for age. These measures show the direct effect of undernutrition on children’s health and correlate well with morbidity and mortality (de Haen et al., 2011). The Quetelet’s index is the most commonly used Body Mass Index (BMI) indicator. This measure is used for adults and it is calculated by the formula weight over height squared. Different cut-off points for undernutrition exist for age and gender, but usually a BMI of 18.5 or below indicates undernutrition (de Haen et al., 2011). CED is a related measure that categorises different stages of undernutrition between the BMI score of 16 and 18.5. The problem with wasting, underweight and BMI related measurements is that they can be biased by oedema. Also, the worldwide trend towards sugary, fatty or starchy foods can create problems in identifying nutrient deficiency in the diet when simply looking at a person’s weight in combination with height.

Another anthropometric measure to indicate nutritional status is an estimation of muscle mass based on middle-upper arm circumference (MUAC). As this is a direct measure for muscle mass, it is a useful measure for a combination of protein- and energy deficiency. This measure can be used for both children and adults. Because the MUAC varies little in children between 6 months and 5 years, this can be a good measure in developing countries in case the exact age of the children is uncertain (Gibson, 2002). Another anthropometric measurement that is not biased by oedema is the measurement of skinfolds. But instead of muscle mass, this is a measurement for subcutaneous fat (Gibson, 2002).

### 3.2.7 Biochemical measurements

Biochemical measures can be taken from serum (fluid from the blood) or urine samples. We distinguish between three biochemical measures for nutritional status: Vitamin A deficiency, iron deficiency and iodine deficiency. These are the three most common and most severe micronutrient deficiencies in developing countries (Gross et al., 2000). Vitamin A deficiency is most problematic in children, as they are most vulnerable to a lack of this micronutrient (WHO, 2011). It can be measured by taking children’s serum retinol. For iron deficiency, many different indicators exist. As a lack of iron can have various manifestations, it can be necessary to use a range of different indicators to give a good diagnosis. Especially when assessing something as complex as a person’s food and nutritional status, it is usually not enough to only look at a single indicator (Morón & Viteri, 2009). Iodine deficiency can be diagnosed by measuring the urinary iodine concentration. A deficiency of iodine can also lead to an enlargement of the thyroid. Measuring the size of the thyroid can be an indicator for iodine deficiency as well (WHO, 2001).

Biochemical indicators show the direct impact an insufficient diet has on a person’s health. On the other hand, urine and blood values are also highly influenced by all kind of health conditions, blood loss, infections, helminths and so on.

### 3.2.8 Examples of studies using food security indicators in tanzania

When selecting an appropriate indicator for household food security, it is important to know if this indicator is regularly used in the region of interest. Firstly, it helps making sure that the indicator is relevant to the region and that information on the specific indicator is available and reliable. Secondly, it can give insight in what kind of studies make use of a certain indicator and with what purpose. This can show in which scientific field the indicator is relevant and where our research would fit in. We have found studies for each category of indicators: food acquisition, dietary intake, subjective measurements, coping strategies, anthropometric measurements and biochemical measurements. A summary of these studies can be found in table 2 below. All indicators below have proven to be relevant to the case of Tanzania. The studies that are most closely linked to our research, are the ones that relate food security to agriculture and food production. Ngongi & Urassa (2014) use the CSI in their case study on Farm Households Food Production and Households’ Food Security Status: A Case of Kahama District, Tanzania. The HDDS is used by Dillon, McGee, & Oseni (2015b) in relation to agricultural production and climate variability. Thirdly, Keding, Msuya, Maass, & Krawinkel (2012) use both a HDDS and a FVS to relate to vegetable production and socio-economic status of women.

Tabel Examples of studies using food security indicators in tanzania

|  |  |  |
| --- | --- | --- |
| **Metric** | **Studies in Tanzania** | **Author(s) (year)** |
| **CSI** | Alternative food-security indicators: revisiting the frequency and severity of `coping strategies’ | Maxwell et al. (1999) |
|  | Farm Households Food Production and Households’ Food Security Status: A Case of Kahama District, Tanzania | Ngongi (2014) |
|  | Experience-based Measures of Food and Water Security: Biocultural Approaches to Grounded Measures of Insecurity | Hadley & Wutich (2009) |
| **Food expenditures**  **(HES, HCES, HBS)** | Measuring Food Security Using Household Expenditure Surveys | Smith & Subandoro, (2007) |
| **Acquired food quantities** | Agricultural growth, poverty, and nutrition in Tanzania | Pauw & Thurlow, (2011) |
| **HDDS** | Price Shocks, Vulnerability and Food and Nutrition Security among Rural and Urban Households in Tanzania. | Romano & Carraro, (2015) |
| Dietary Patterns and Household Food Insecurity in Rural Populations of Kilosa District, Tanzania | Ntwenya, Kinabo, Msuya, Mamiro, & Majili (2015) |
| Agricultural Production, Dietary Diversity and Climate Variability | Dillon, McGee, & Oseni ( 2015) |
| **FFS/FCS** | Price Shocks, Vulnerability and Food and Nutrition Security among Rural and Urban Households in Tanzania. | Romano & Carraro, (2015) |
| **FVS** | Relating dietary diversity and food variety scores to vegetable production and socio-economic status of women in rural Tanzania. | Keding, Msuya, Maass, & Krawinkel, (2012) |
| **Radimer/Cornell**  **hunger and food insecurity scale** | Validation of the Radimer/Cornell food insecurity measure in rural Kilimanjaro, Tanzania. | Leyna, Mmbaga, Mnyika, & Klepp, (2008) |
| **HFSSM** | Experience-based Measures of Food and Water Security: Biocultural Approaches to Grounded Measures of Insecurity. | Hadley & Wutich, (2009) |
| **HFIAS** | Dietary Patterns and Household Food Insecurity in Rural Populations of Kilosa District, Tanzania. | Ntwenya et al., (2015) |
| **Wasting, stunting, underweight** | Indicators and Causal Factors of Nutrition—Application of Correlation Analysis. | Babu, Gajanan, & Sanyal, (2014) |
| Agricultural Production and the Nutritional Status of Family Members in Tanzania. | Slavchevska (2015) |
| Five-year follow-up of a food-based vitamin A intervention in Tanzania. | Kidala, Greiner, & Gebre-Medhin (2000) |
| **Vitamin A deficiency** | Five-year follow-up of a food-based vitamin A intervention in Tanzania. | Kidala, Greiner, & Gebre-Medhin (2000) |
| Randomized efficacy trial of a micronutrient-fortified beverage in primary school children in Tanzania. | Ash, Tatala, Frongillo, Ndossi, & Latham, (2003) |
| **Iodine deficiency** | Randomized efficacy trial of a micronutrient-fortified beverage in primary school children in Tanzania. | Ash, Tatala, Frongillo, Ndossi, & Latham, (2003) |

Based on the table 1, the following assessment and the relevance to Tanzania and our field of interest, we will use a HDDS, a FCS, the CSI for our analysis.

# 4. Theoretical framework

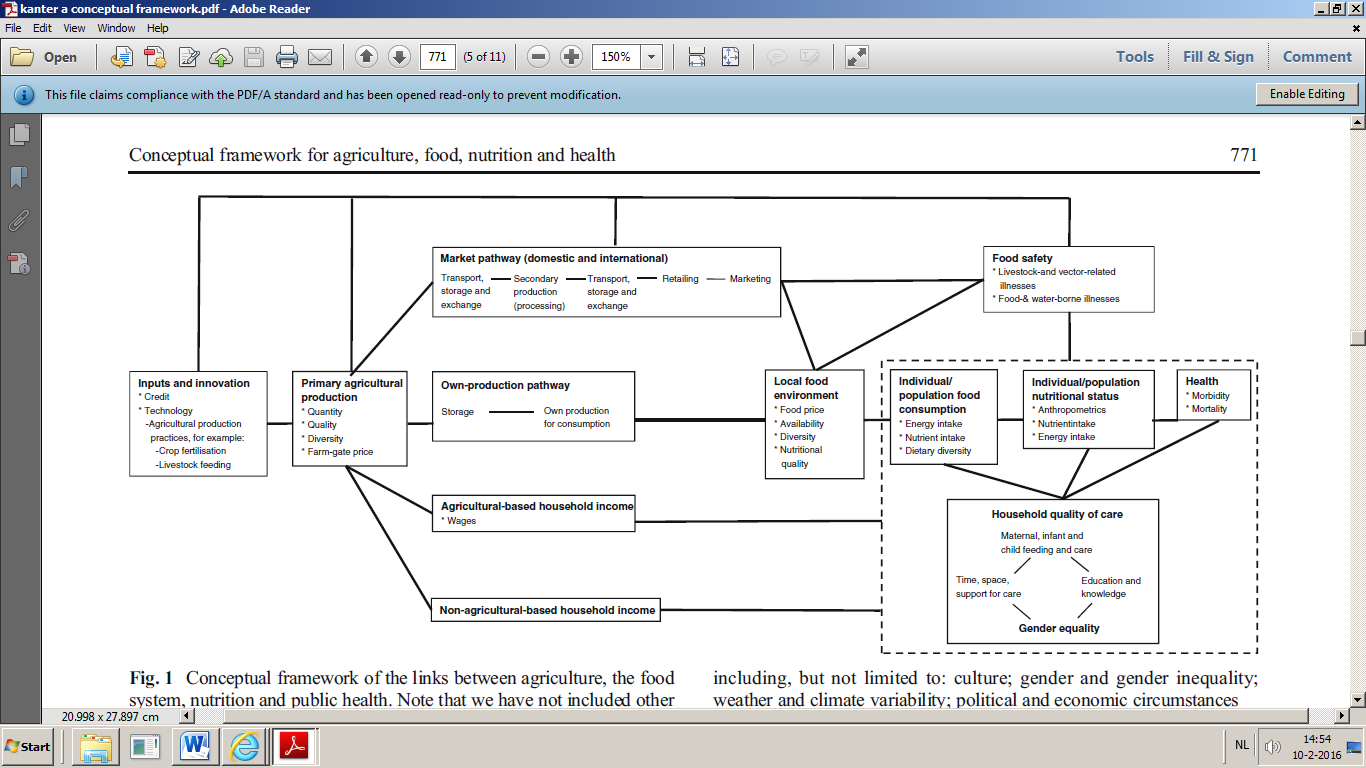
This chapter will focus primarily on the theoretical relation between the use of hybrid seeds and fertiliser and household food security. The first theory we will discuss is the conceptual framework introduced by Kanter et al. (2015). We will discuss this theory and adapt it into our own version. Our adapted framework will be the foundation for our hypotheses on the relation between the use of hybrid seeds and fertiliser and household food security. The second theory is the Agricultural Household Model, which provides insightful concepts when it comes to modelling the relation between technology adoption and food- and nutrition security and testing our hypotheses.

## 4.1 The Conceptual Framework

Figure 3 shows the conceptual framework introduced by Kanter et al. (2015). It explains how the relation between agriculture, food, nutrition and health has different pathways and can go in different directions. It is a comprehensive framework that takes elements from different existing scientific domains and combines them into this overview. In the framework in figure 3, three different pathways are incorporated: the market pathway, the own production pathway and the income pathway. The last one is split out into agricultural income and non-agricultural income. The framework does not include arrows that indicate direction of influence. It was designed as a visual tool to better understand how policies affect agriculture, food and nutrition and to identify new potential policy strategies (Kanter et al., 2015). The framework provides useful insight for our research. In our case, the box ‘inputs and innovation’ is the starting point. The use of fertiliser and improved seeds is expected to directly relate to production and to the inputs available on the market. This is also shown by the lines that go from the ‘inputs and innovation’ box in the figure. The rest of the boxes are indirectly affected. Food consumption, nutrition and health are expected to be related to input use via income, own production and the market. Higher production can lead to higher income, which can lead to more wealth, more consumption and better nutritional status and health. Higher production may also lead to more consumption from own-produced products, or to higher availability of food on the local market, which can lead to lower prices, more consumption and then to better nutritional status and health.

**Figure 3** *Conceptual framework of the links between agriculture, the food*

*system, nutrition and public health.*



Source: Reprinted from Kanter et al (2015 p. 771).

When applying the framework by Kanter et al. (2015) to a farm-level analysis of subsistence smallholders in Tanzania however, it is unclear at two points. First, agricultural-based household income is described as wages earned from agricultural labour. It does therefore not include direct income from market sales of agricultural products. This income would be earned via the market pathway: products are sold on the market, revenue is generated and households earn income. The market pathway in the figure however does not show any household income from sales: the ‘market-pathway’ box does not show a direct connection to the ‘consumption, nutrition and health’ box. Second, the effect of income, savings and household assets on access to the market and production possibilities is not mentioned in the framework. In short, households with higher incomes are expected to have more saving possibilities. Therefore, they are more likely to be able to invest in capital, for example education, agricultural technology, information technology, storage or transport. This can affect their local food environment: it can improve their access to markets and their access to food.

We have adapted the framework in these respects so that it can be applied to our research. The adapted framework is shown in figure 4. Three sources of income are specified, income from agricultural sales, income from wage labour and income from other sources. All income lines are connected to the large dashed box in which consumption- and saving decisions are made. Wages include both agricultural and non-agricultural wage and are connected via a ‘time endowment’ to primary agricultural production; as wages partly influence the decision on how much time is spend on own-farm labour and vice-versa. The income from sales from agricultural products is linked to the market pathway. Some of the household’s income is spend on consumption (of both food- and non-food items), what is left is savings. Part of these savings can be used for investment in capital, that and can affect both production and the local food environment, or in inputs. In de adapted framework, the box ‘food safety’ is not included, as it is beyond the scope of our research. The adapted framework also does not include arrows that indicate causality of effects.

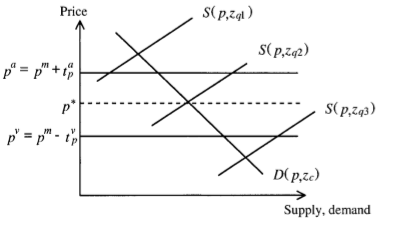
**Figure 4** Conceptual framework of the links between agriculture, the food system, nutrition and public health.

Figure 4. Our conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health.

## 4.2 The Agricultural Household Model

The Agricultural Household Model provides insightful concepts when it comes to modelling the relation between technology adoption and food- and nutrition security. As the framework by Kanter et al. shows, inputs and innovation are related through a complex network of interconnected pathways that follow more than one direction. We expect input use to affect production, thereby affect farm income and the availability of own-produced food products, and increase household food security. Most of the households in our sample do not operate in a context of perfect functioning markets. In this context, the Agricultural Household Model is appropriate. It offers insight in farm household behaviour in the context of market failures.

A market fails when transaction causes greater disutility than the utility gain it will generate (de Janvry, Fafchamps, & Sadoulet, 1991). In extreme cases this will result in the market being non-existent. Generally speaking, the specific market does exist, but some farm households will not participate in it because their gains are below the costs. The costs associated with a certain transaction are household specific, depending on for example location, access to information etcetera. Typically, when smallholder farmers can buy or sell food their sales price is a fraction of their purchase price causing household to rely (partly) on their own food supply (de Janvry et al., 1991).



Figuur 1 Reprinted from de Janvry & Sadoulet (2006) Chapter 6, p.157

This difference between sales- and purchase price results in a price band. Figure .. shows three supply curves of household 1, 2 and 3. Zq indicates the households’ productive resources and zc the households’ consumer characteristics. Ta are the household specific transaction costs involved when purchasing food, tz are transaction costs when selling food. Pa is the acquisition price of food, pv is the effective sales price. P\* is the unobservable shadow price. This simply figure shows how the decision to participate in the market depends on the relative position of the households supply- and demand curves, and therefore on the respective productive resources and consumer characteristics zq and za. Household 1 and 3 will participate on the market. Household1 has an equilibrium price that is above the effective acquisition price and will be a net buyer of food. Household 3 has an equilibrium price below effective sale price and is a net seller. For household 2, the equilibrium price is within the price band. Therefore, this household will not participate on the market: the equilibrium price is above the effective sales price but below the effective acquisition price. For this household the optimum choice is to remain self-sufficient. Within the price band, production and consumption decisions are of the non-separable type: the second households’ decisions regarding production and consumption are adjusted to each other. Their equilibrium price p\*(zq, zc) is specific to productive resources and consumer characteristics (Thorbecke, De Janvry, & Kanbur, 2006).

# 5. Empirical Strategy

Now that we have explained the theory behind the relation between agricultural input use and food security, we can continue with our empirical analysis. First, we explain our estimation strategy based on the theory of the Agricultural Household Model. Afterwards, we will elaborate on the nature of our data and the variables we use. Then, we present a descriptive analysis of hybrid seed- and fertiliser use and food security, to get more insight in the data and identify possible irregularities.

## 5.1 Estimation strategy

Our regression model will relate improved seed- and fertiliser use to the DDS, FVS, FCS and CSI. We explain food security variables by the variables for input use and exogenous explanatory variables, which include various household, farm, and region characteristics as described earlier. Our method will be analogue to the empirical strategy described by Smale et al. (2015) in their article on hybrid maize adoption and dietary diversity on family farms in Zambia.

(1)

FS: Food security indicators in operational terms

V: Vector of household, farm and region characteristics

h: hybrid seed use

f: fertiliser use

Equation 1 represents a reduced form equations that explains food security variables by the variables for input use and exogenous explanatory variables. In equation 1, FS expresses our food security indicators in operational terms, V is a vector of household, farm, and region characteristics, h indicates the use of hybrid seeds and f the use of fertiliser. Before we can estimate equation 1 however, we need to test for possible interaction effects between our variables of interest, and for possible endogeneity of hybrid seed use and fertiliser use to our food security indicators.

Possible endogeneity of input use variables to food security can lead to biased estimates. Smale et al. (2015) address this problem by using instrumental variables for hybrid seed use in Zambia.

The instrumental variables they use are all related to the Farm Input Support Programme (FISP) in Zambia, indicating whether a farmer received subsidised seed or was more likely to receive subsidised seed. These variables are expected to be related to hybrid seed use but not to food security. They performed diagnostic tests for endogeneity with instrumental variables (Wu-Hausman, Pagan-Hall, Sargan statistic, Anderson statistic). Their results suggest that in their case endogeneity was not a problem. As a consequence they estimated all regressions using OLS. We will adopt a similar strategy. As explained in the theory of the Agricultural Household Model, we might deal with non-seperability in our model, where production decisions are not independent from consumption decisions. We cannot assume that decisions about hybrid seed use and fertiliser use are exogenous to our household food security indicators.

(2)

FS: Food security indicators in operational terms

V: Vector of household, farm and region characteristics

h: hybrid seed use

f: fertiliser use

Equation 3 is a system of equations, FS again expresses our food security indicators in operational terms, V is a vector of household, farm, and region characteristics, h indicates the use of hybrid seeds and f the use of fertiliser. Here and are dependent on FS and on the vector of independent variables. To check for endogeneity of hybrid seed- and fertiliser use, we use an instrumental variable approach. We will apply a two stage least squares (2SLS).

(3)

FS: Food security indicators in operational terms

V: Vector of household, farm and region characteristics

M: Vector of instrumental variables

h: hybrid seed use

f: fertiliser use

Equation 4 represents the first- and second stage of our 2SLS. As instruments we use two dummy variables, indicating whether the household has received a subsidy for seeds and/or whether the household has received a subsidy for fertiliser in the survey year. Furthermore, we include the lagged proportion of hybrid seeds and fertiliser use at district level as second set of instruments. In the first stage we explain hybrid seed- and fertiliser use by these instruments M and V, the vector for exogenous independent variables. In the second stage we use the estimated values for hybrid seed- and fertiliser use as explanatory variables in the original equation. By overidentifying our model we can test whether the instrument exogeneity conditions are valid with a Sargan test. If these conditions are met we perform a hausman test to indicate whether IV (instrumental variable) regression coefficients are significantly different from ordinary least squares (OLS). If this is not the case, we may assume exogeneity and continue all analysis with OLS.

(4)

FS: Food security indicators in operational terms

V: Vector of household, farm and region characteristics

h: hybrid seed use

f: fertiliser use

Equation 4 is a model including interaction effects between hybrid seed use and fertiliser use, and hybrid seed use and housing quality index. To be fully effective, hybrid seeds require the use of extra fertiliser. Therefore, we expect a positive interaction between the two dummy variables: the use of only hybrid seeds without fertiliser is expected to have a smaller effect compared to when both inputs are used. Secondly, we expect hybrid seeds to be interact negatively with our long term wealth indicator: the housing quality index. The higher a household scores on long term wealth, the less likely it would be that their food security is positively affected by hybrid seed use. When coefficients β4 and β5 are insignificant in equation 2, we can estimate the main effects of hybrid seed use as in equation 1.

## 5.2 Data and variable description

We use data of three waves of the Tanzania National Panel Survey (NPS), conducted in 2008-2009, 2010-2011 and 2012-2013. This survey was conducted by the Tanzania National Bureau of Statistics (NBS) in collaboration with the World Bank Living Standard Measurement Study –Integrated Surveys on Agriculture (LSMS-ISA). The survey is representative for the nation as a whole and covers a broad range of topics in one questionnaire. It was designed to meet three main objectives (National Bureau of Statistics, Tanzania, 2011). The first is to track implementation progress across the three clusters of the National Strategy for Growth and Reduction of Poverty, namely the following: Growth, reduction of poverty, improvement of quality of life and social wellbeing and governance and accountability. Secondly, it was designed to provide a better understanding of the determinants of poverty reduction. Thirdly, the survey is meant for assessment of the impact of public policy initiatives. The sample consists of respectively 3,280, 3,265 and 5,010 households for the first, second and third wave (National Bureau of Statistics, Tanzania, 2011, 2012, 2014). This increase over time is mainly due to household members marrying or migrating and therefore splitting up the original household and forming new households. These new households were tracked and interviewed as well. The attrition rate was 3% for the second wave and 4% for the third wave (National Bureau of Statistics, Tanzania, 2014). The NPS contains data on various agricultural input use as well as food security and nutrition indicators. Technology indicators are available at plot level and food- consumption and security measures at household level. The survey consists of four questionnaires on different topics: a household-, an agriculture-, a livestock and fisheries- and a community questionnaire. We combined data obtained from different questionnaires to construct indicators for improved maize seeds and fertiliser use and for household food security. Since we are interested in input use, we exclude all households that have no land under cultivation.

### 5.2.2. Nutrition variables

Household food security is the dependent aspect of our analysis. As dependent variables, we use a set of food security indicators: the DDS, the FVS, the FCS and the CSI. The DDS is a score based on sum of response data on the consumption of 12 (sometimes more/less) food groups on a 24h recall period. Unfortunately, the NPS LSMS ISA dataset does not include consumption data on 24h recall but only on 7 day recall. We have constructed a modified DDS based on our 7-day recall household consumption data as is done in the study by Jones, Shrinivas, & Bezner-Kerr (2014). The FVS is defined as the number of food items consumed over a 24 h period (Steyn, Nel, Nantel, Kennedy, & Labadarios, 2006). In the NPS LMSM ISA dataset, we do not have consumption data on 24h recall, but only on 7 day recall. Therefore we have constructed an adapted FVS with the number of food items consumed over 7 days by the household, out of a total of 59 different items. The FCS is an indicator based on the frequency in which items of 9 different food groups are consumed over a period of 7 days. The frequency of consumption is multiplied by the weight of each group to construct the total score. We have constructed this indicator based on guidelines by the World Food Programme (World Food Programme, 2008). The 8 food groups we used are main staples, pulses, vegetables, fruit, meat and fish, milk, sugar, oil and condiments. We have no data on consumption frequencies for 2008, so this indicator can only be used for 2010 and 2012. The CSI is a behavioural measure for food security. A number of regular behavioural responses to not having enough food can be identified and assessed. As earlier explained, this measure is usually very context specific. We use however a comparative, reduced version, that does not include region specific coping strategies. Our indicator is based on the coping strategy index field methods manual by Maxwell & Caldwell (2008), who claim that the reduced index correlates as well with other indicators of food security as the original version. Since we have no data on coping behaviour in the wave of 2008, the CSI can only be constructed for the waves of 2010 and 2012. More information on how the indicators are constructed can be found in annex 2.

### 5.2.3 Explanatory variables

The variables we are primarily interested in are hybrid seed use and fertiliser, defined as 1 if the corresponding input is used in survey year and 0 if otherwise. With the conceptual framework presented in figure 4 in mind, we control for several household- and farm characteristics. We position hybrid seed- and fertiliser use at the far left box (inputs and innovation). We expect them to have an effect on household food security through a system of pathways: the market-, income-, own production pathway.

Table 3 input use

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Description | Mean | St. Deviation | Min | Max | Skew | Valid N |
|  |  | | | | | | | |
| Hybrid seed use | | 1 if hybrid seed is used in survey year, 0 if not | 0.145 | 0.352 | 0 | 1 | 2.019 | 23,895 |
| Fertiliser use | | 1 if fertiliser is used, 0 if not | 0.105 | 0.306 | 0 | 1 | 2.585 | 23,895 |

However, as seen in the framework, household food consumption is also influenced by household quality of care, farm- and household capital and outside sources of income. To be able to clearly show the relation between hybrid seed- and fertiliser use and household food security, we need to control for these elements. Household quality of care can be influenced by several factors. First of all, we control for female headship, as evidence suggests that households with a female household head allocate more resources to the improvement of household food consumption. (R. Mason, Ndlovu, Parkins, & Luckert, 2015; Wagah, Hodge, & Lewis, 2015). We also expect education of the household head to be strongly related to better and more diverse household food supply (R. Mason et al., 2015). The best indicator for education that is available in our dataset is whether the household head has ever been to school yes or no. Migration of the household or household head can be associated with higher variability in food supply and more vulnerability of the household. Similarly, migration could also lead to better (income) opportunities. To control for this effect, we include a variable: ‘years in community’, defined as the number of years the household head has lived in the community of current residence. Next, we count to total household size defined as the number of household members. We include a household dependency ratio, defined as the percentage of household members that require care. We add up the number of children (below the age of 15) and the number of elderly (above the age of 65) and divide this by the total household size times 100. This ratio controls for potential labour constraints due to time used for caregiving. As indicator for living conditions and long term wealth we use a housing quality index. This index contains information on the tenure status of the house, the material of the walls and roof, the main source of drinking water, the sewage facilities, the main source of drinking water and the fuel used for lighting and cooking. This index is based on the list of items presented in Fiadzo, Houston, & Godwin (2001) Controlling for these factors enables us to distinguish between different kinds of housing and therefore different wealth statuses. Elaborate explanation on the way this index is constructed can be found in annex 3.

Table 4 household characteristics

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Description | Mean | St. Deviation | Min | Max | Skew | Valid N | |
|  |  | | | | | | | |
| Female headship | | 1 if household head is female, 0 if not | 0.226 | 0.418 | 0 | 1 | 1.308 | 23,895 | |
| Education head | | Yes if household head received any education, no if if not | 0.764 | 0.425 | 0 | 1 | -1.243 | 23,718 | |
| Years in community | | Years household head lived in community | 34.297 | 21.695 | 0 | 105 | 0.158 | 14,903 | |
| Household size | | Number of household members | 5.652 | 3.443 | 1 | 55 | 2.907 | 23,895 | |
| Dependency ratio | | Number of household member younger than 15 and older than 65, devided by household size times 100 | 44.131 | 24.013 | 0 | 100 | -0.204 | 23,895 | |
| Housing quality index | | Housing quality index | 3.764 | 0.682 | 1.869 | 6.500 | 0.807 | 21,572 | |

The framework by Kanter et al. includes two sources of income: farm income and off-farm income. We control for both. Since we have no data on off-farm income for 2008, we only include the data from the waves of 2010 and 2012. We do not have data on other sources of income.

Table 5 income

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Description | Mean | St. Deviation | Min | Max | Skew | Valid N |
|  |  |  |  |  |  |  |  |
| Farm income | Income from crop production, rented land and livestock sales over 12 months in Tsh divided by 100.000 | 43.207 | 281.494 | 0 | 14,522.000 | 26.510 | 11,310 |
| Off farm income | Off farm income from wage and self-employment in Tsh divided by 100.000 | 50.916 | 315.546 | 0 | 14,522.000 | 23.717 | 8,934 |

Farm characteristics are estimated using a second set of variables. Land is an important part of wealth and farm production potential. Total land holdings have been measured by GPS, but unfortunately, this indicator has many missing observations. Where possible, we have substituted missing GPS measured land size data with the farmers estimate. However, these farmer estimated data are fairly unreliable. To adequately control for primary agricultural production potential we have added and indicator for the total value of farm equipment and structures. Additionally, we account for livestock ownership in a Tropical Livestock Unit (TLU) variable. The TLU is a weighed total of all livestock owned by the household. The following units of livestock are taken into account: bulls, cows, calves, heifers, steers, goats, sheep, donkeys, chickens, ducks and rabbits. This list is based on available information in the LSMS ISA dataset. The weights are based on the ones published by HarvestChoice/International Food Policy Research Institute (IFPRI) in 2011 (HarvestChoice/IFPRI, 2011). In the framework by Kanter, credit is a part of (farm) inputs and innovation. We control for access to credit by including credit/saving group membership, which is called SACCO.

Tabel 6 Farm characteristics

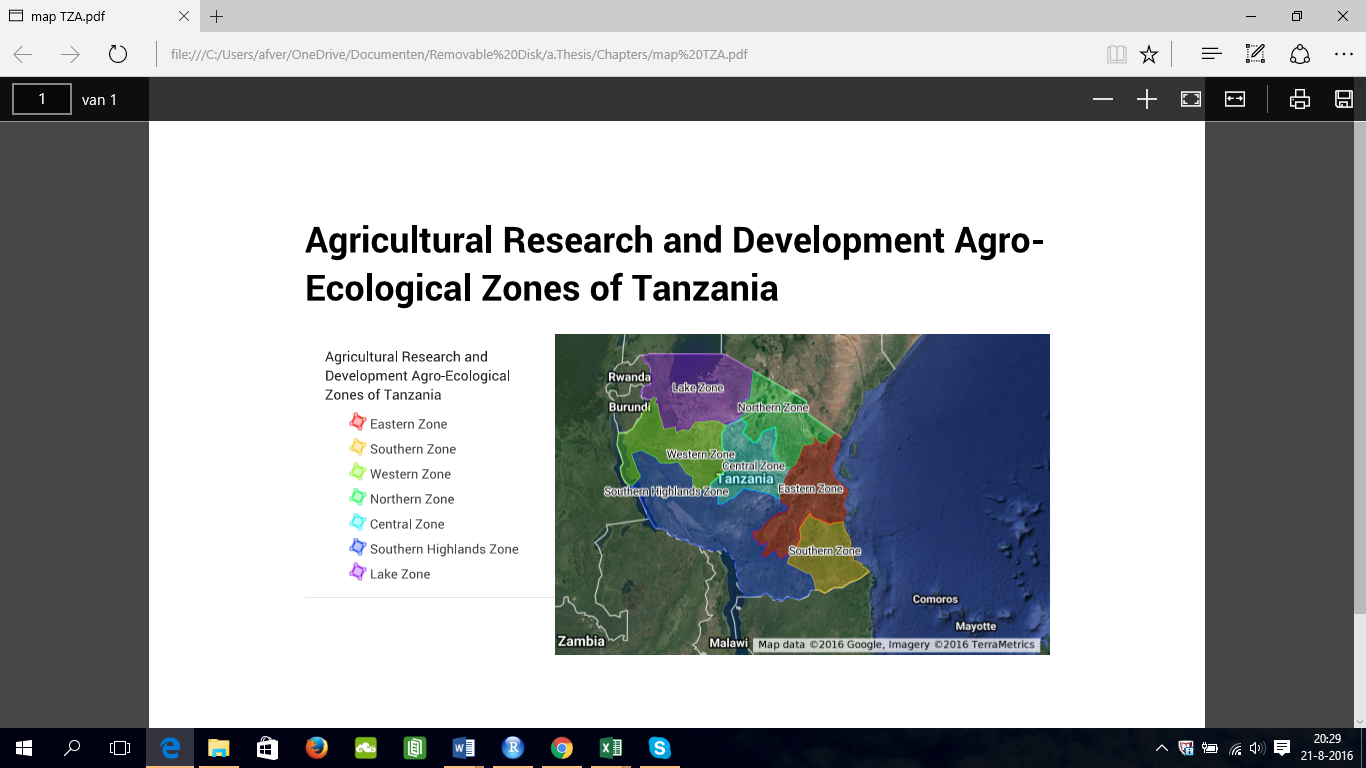
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Description | Mean | | St. Deviation | Min | Max | | Skew | | Valid N | |
|  |  | | | | | | | | | | |
|  | |  |  |  | |  |  |  | |  | |
| Total land size | | Household total land holdings in acres | 3.255 | 9.074 | | 0.004 | 625 | 44.691 | | 8,182 | |
| Farm assets | | Total value of farm equipment and structure in Tsh divided by 100.000 | 197.677 | 6,865.489 | | 0.00000 | 571,162.300 | 74.727 | | 8,013 | |
| Tropical livestock | | Tropical Livestock Unit | 3.179 | 12.625 | | 0 | 632.100 | 25.642 | | 5,878 | |
| Credit or saving group | | 1 if at least one household member is member of a credit association (SACCO), 0 if not | 0.058 | 0.234 | | 0 | 1 | 3.778 | | 12,199 | |

Then, we include different regional zones within Tanzania in our regressions, to control for regional differences that might influence the outcome variables. We divide Tanzania in nine zones: the northern zone, the eastern zone, the southern zone, the western zone, the central zone, the southern highlands, the lake zone and the island Zanzibar. We use the Central zone as the reference zone in our analyses. Figure 5 shows a map of the zones. Similarly, we control for average annual weather conditions, more specifically temperature and rainfall. Lastly, we have included the distance from the household to nearest town and to the nearest market in our analysis.

Tabel 7 geographical- and climate variables

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Description | Mean | St. Deviation | Min | Max | Skew | Valid N |
|  | | | | | | | | |
| Central Zone | 1 if the household lives in the central zone, 0 if not | 0.045 | 0.208 | 0 | 1 | 4.372 | 12,199 |
| Eastern Zone | 1 if the household lives in the eastern zone, 0 if not | 0.220 | 0.414 | 0 | 1 | 1.352 | 12,199 |
| Lake Zone | 1 if the household lives in the Lake Zone, o if not | 0.110 | 0.312 | 0 | 1 | 2.501 | 12,199 |
| Northern Zone | 1 if the household lives in the Northern Zone, 0 if not | 0.114 | 0.317 | 0 | 1 | 2.434 | 12,199 |
| Southern Zone | 1 of the household lives in the Southern Zone, 0 if not | 0.150 | 0.357 | 0 | 1 | 1.960 | 12,199 |
| Southern Highlands | 1 if the household lives in the Southern Highlands, 0 if not | 0.105 | 0.306 | 0 | 1 | 2.579 | 12,199 |
| Western Zone | 1 if the household lives in the Western Zone, 0 if not | 0.125 | 0.330 | 0 | 1 | 2.274 | 12,199 |
| Zanzibar | 1 if the household lives on Zanzibar, 0 if not | 0.132 | 0.338 | 0 | 1 | 2.176 | 12,199 |
| Total annual rainfall | Total annual precipitation, from monthly climatology in mm | 1,115.479 | 307.001 | 462 | 2,377 | 0.777 | 11,596 |
| Average annual temperature | Average annual temperature calculated from monthly climatology, multiplied by 10 in °C | 234.373 | 26.788 | 127 | 278 | -0.642 | 11,596 |
| Distance to nearest town | Distance to the population centre with +20,000 people in kilometres | 26.929 | 33.502 | 0 | 200 | 1.865 | 11,711 |
| Distance to nearest market | Distance to nearest market in kilometres | 52.238 | 49.439 | 0.300 | 257.100 | 1.099 | 11,711 |

**Figure 5** *Map of Agricultural Research and Development Agro-Ecological Zones of Tanzania*



Source: Reprinted from Google Maps (n.d.)

## 5.3 Descriptive analysis

Before we start our estimation, we will discuss the details concerning our sample. We select only maize farmers for our analysis. We select maize farming households based on whether they dedicated one or more plots to maize in the survey year. Table 8 shows how our maize farmers compare to the total sample. Our subsample appears to be consistent with the total sample, on most accounts. Fertiliser use is with 35% much higher amongst maize farmers compared to the average of 1.8%, which could be explained by the fact that not everyone in the total sample is farmer. With 40.3%, hybrid seed use is slightly higher for maize farmers than the total average of 2. Maize farmers consume on average items out of 7.9 different food groups out of the twelve groups of the dietary diversity score. This is somewhat lower than the average of 8.1. The food variety score and the food consumption score are also on average slightly lower for maize farmers. Surprisingly, this is not reflected in coping behaviour: the coping strategy index is even slightly lower.

Tabel 8 Maize farmers compared to other total sample

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Total sample – maize farmers N=7567 | | | Maize farmers N= 4632 (37,9%) | | |  |  |
|  |  | Mean | Std | N | Mean | Std | N | Χ2 | t |
| Input use | Hybrid seed use | 0,020 | 0,140 | 7567 | 0,208 | 0,403 | 4632 | 1192,197\*\*\* |  |
|  | Fertiliser use | 0,018 | 0,132 | 7567 | 0,144 | 0,351 | 4632 | 743,578\*\*\* |  |
| Household characteristics | Female headship | 0,256 | 0,436 | 7567 | 0,234 | 0,424 | 4632 | 6,885\*\*\* |  |
|  | Education head | 0,807 | 0,395 | 7511 | 0,743 | 0,437 | 4598 | 68,465\*\*\* |  |
|  | Years in community | 27,717 | 22,012 | 4723 | 35,849 | 20,595 | 2891 |  | -16,288\*\*\* |
|  | Household size | 4,851 | 2,946 | 7567 | 5,606 | 3,225 | 4632 |  | -12,967\*\*\* |
|  | Dependency ratio | 38,116 | 25,397 | 7567 | 46,551 | 23,513 | 4632 |  | -18,647\*\*\* |
|  | Housing quality index | 4,106 | 0,803 | 7227 | 3,582 | 0,561 | 4093 |  | 40,688\*\*\* |
| Income | Farm income | 59,838 | 351,941 | 6678 | 19,229 | 118,084 | 4632 |  | 8,746\*\*\* |
|  | Off farm income | 68,948 | 382,554 | 5612 | 20,455 | 138,161 | 3322 |  | 8,596\*\*\* |
| Farm characteristics | Land size | 2,406 | 4,177 | 3569 | 3,912 | 11,470 | 4613 |  | -8,241\*\*\* |
|  | Farm assets | 141,161 | 2137,389 | 3443 | 240,256 | 8899,887 | 4570 |  | -0,725 |
|  | TLU | 2,821 | 15,857 | 2532 | 3,450 | 9,467 | 3346 |  | -1,769\*\* |
|  | SACCO | 0,064 | 0,244 | 7567 | 0,049 | 0,216 | 4632 | 10,797\*\*\* |  |
| Geographical | Central Zone | 0,028 | 0,165 | 7567 | 0,074 | 0,261 | 4632 | 138,064\*\*\* |  |
|  | Eastern Zone | 0,304 | 0,460 | 7567 | 0,083 | 0,276 | 4632 | 817,339\*\*\* |  |
|  | Lake Zone | 0,130 | 0,336 | 7567 | 0,076 | 0,265 | 4632 | 86,055\*\*\* |  |
|  | Northern Zone | 0,084 | 0,278 | 7567 | 0,162 | 0,368 | 4632 | 172,296\*\*\* |  |
|  | Southern Zone | 0,099 | 0,299 | 7567 | 0,234 | 0,423 | 4632 | 408,120\*\*\* |  |
|  | Southern Highlands | 0,044 | 0,204 | 7567 | 0,205 | 0,404 | 4632 | 797,785\*\*\* |  |
|  | Western Zone | 0,104 | 0,305 | 7567 | 0,158 | 0,365 | 4632 | 77,504\*\*\* |  |
|  | Zanzibar | 0,207 | 0,405 | 7567 | 0,009 | 0,093 | 4632 | 990,862\*\*\* |  |
|  | Total annual rainfall | 1164,955 | 304,566 | 7050 | 1038,750 | 294,779 | 4546 |  | 22,216\*\*\* |
|  | Average annual temperature | 241,630 | 25,853 | 7050 | 223,118 | 24,202 | 4546 |  | 39,143\*\*\* |
|  | Distance to nearest town | 21,692 | 31,218 | 7162 | 35,174 | 35,272 | 4549 |  | -21,067\*\*\* |
|  | Distance to nearest market | 43,446 | 47,991 | 7162 | 66,080 | 48,513 | 4549 |  | -24,712\*\*\* |
| Instruments | Seed voucher | 0,014 | 0,116 | 7567 | 0,064 | 0,244 | 4632 | 228,280\*\*\* |  |
|  | Fertiliser voucher | 0,001 | 0,032 | 7567 | 0,012 | 0,107 | 4632 | 63,854\*\*\* |  |
| Food security | DDS | 8,134 | 2,661 | 7567 | 7,870 | 2,066 | 4632 |  | 6,132\*\*\* |
|  | FVS | 14,174 | 6,083 | 7567 | 12,828 | 4,939 | 4632 |  | 13,365\*\*\* |
|  | FCS | 54,471 | 21,501 | 5609 | 49,506 | 17,872 | 3321 |  | 11,748\*\*\* |
|  | CSI | 4,193 | 8,080 | 5609 | 3,473 | 7,123 | 3322 |  | 4,386\*\*\* |

In table 9, we compare summary statistics of maize farmers that do use hybrid maize and those that do not. 23% of hybrid seed users are also fertiliser users, compared to 12% of non-adopters. A remarkable difference between the two groups is that hybrid maize adopters appear to have significantly better scores on all food security indicators than non-adopters. The average dietary diversity score is 0.96 points higher, the food variety score is 2.20 points higher, the food consumption is 7.21 higher and the coping strategy index 1.03 lower. Whether this is due to the use of hybrid seeds is still to be seen, because we are clearly looking at two different groups of farmers. The group of adopters also owns more land and farm assets then the group of non-adopters. Only 17.8% of hybrid seed using households are female headed (compared to 24.9%). A higher percentage of them has been to school, 81.8% compared to 72.4%. On average, adopters have higher incomes, own more assets, more livestock, have higher quality housing and live closer to the town and the market than none-adopters. These factors could all contribute to this group having higher scores on food security. On average, hybrid seed users are wealthier in general than non-hybrid seed users.

Table 9 adopters of hybrid seeds versus non adopters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Non-adopters hybrid N=3686 | | | Adopters hybrid N=946 (20,8%) | | |  |  |
|  |  | Mean | Std | N | Mean | Std | N | Χ2 | t |
| Input use | Hybrid seed use | 0,000 | 0,000 | 3686 | 1,000 | 0,000 | 946 |  |  |
|  | Fertiliser use | 0,121 | 0,326 | 3686 | 0,232 | 0,422 | 946 | 196,894\*\*\* |  |
| Household characteristics | Female headship | 0,249 | 0,433 | 3686 | 0,178 | 0,382 | 946 | 56,407\*\*\* |  |
|  | Education head | 0,724 | 0,447 | 3656 | 0,818 | 0,386 | 942 | 93,424\*\*\* |  |
|  | Years in community | 36,939 | 20,340 | 2422 | 30,220 | 21,003 | 469 |  | 6,374\*\*\* |
|  | Household size | 5,414 | 3,068 | 3686 | 6,355 | 3,680 | 946 |  | -7,248\*\*\* |
|  | Dependency ratio | 46,995 | 23,863 | 3686 | 44,819 | 22,021 | 946 |  | 2,664\*\* |
|  | Housing quality index | 3,528 | 0,521 | 3278 | 3,800 | 0,654 | 815 |  | -11,043\*\*\* |
| Income | Farm income | 15,888 | 60,225 | 3686 | 32,245 | 232,326 | 946 |  | -2,147\* |
|  | Off farm income | 17,009 | 69,518 | 2644 | 33,893 | 273,026 | 678 |  | -1,597 |
| Farm characteristics | Land size | 3,695 | 7,103 | 3670 | 4,759 | 21,136 | 943 |  | -1,524 |
|  | Farm assets | 234,908 | 9487,122 | 3637 | 261,104 | 6096,583 | 933 |  | -0,103 |
|  | TLU | 3,106 | 8,771 | 2602 | 4,650 | 11,503 | 744 |  | -3,389\*\*\* |
|  | SACCO | 0,042 | 0,201 | 3686 | 0,076 | 0,265 | 946 | 48,362\*\*\* |  |
| Geographical | Central Zone | 0,077 | 0,266 | 3686 | 0,062 | 0,242 | 946 | 5,811\*\* |  |
|  | Eastern Zone | 0,081 | 0,273 | 3686 | 0,089 | 0,285 | 946 | 1,430 |  |
|  | Lake Zone | 0,069 | 0,253 | 3686 | 0,104 | 0,305 | 946 | 33,967\*\*\* |  |
|  | Northern Zone | 0,137 | 0,344 | 3686 | 0,258 | 0,438 | 946 | 212,678\*\*\* |  |
|  | Southern Zone | 0,269 | 0,444 | 3686 | 0,095 | 0,294 | 946 | 335,242\*\*\* |  |
|  | Southern Highlands | 0,211 | 0,408 | 3686 | 0,181 | 0,385 | 946 | 11,371\*\*\* |  |
|  | Western Zone | 0,146 | 0,353 | 3686 | 0,207 | 0,406 | 946 | 56,297\*\*\* |  |
|  | Zanzibar | 0,010 | 0,098 | 3686 | 0,004 | 0,065 | 946 | 7,103\*\*\* |  |
|  | Total annual rainfall | 1047,091 | 299,139 | 3622 | 1006,053 | 274,749 | 924 |  | 3,978\*\*\* |
|  | Average annual temperature | 223,903 | 24,266 | 3622 | 220,041 | 23,715 | 924 |  | 4,398\*\*\* |
|  | Distance to nearest town | 35,244 | 35,298 | 3625 | 34,902 | 35,187 |  |  | 0,263 |
|  | Distance to nearest market | 67,294 | 47,896 | 3625 | 61,318 | 50,607 |  |  | 3,239\*\*\* |
| Instruments | Seed voucher | 0,038 | 0,191 | 3686 | 0,164 | 0,370 | 946 | 526,717\*\*\* |  |
|  | Fertiliser voucher | 0,009 | 0,097 | 3686 | 0,020 | 0,140 | 946 | 19,294\*\*\* |  |
| Food security | DDS | 7,674 | 2,038 | 3686 | 8,634 | 1,998 | 946 |  | -13,133\*\*\* |
|  | FVS | 12,379 | 4,698 | 3686 | 14,575 | 5,445 | 946 |  | -11,366\*\*\* |
|  | FCS | 48,037 | 17,260 | 2644 | 55,246 | 19,037 | 677 |  | -8,956\*\*\* |
|  | CSI | 3,684 | 7,373 | 2644 | 2,650 | 5,984 | 678 |  | 3,816\*\*\* |

Table 10 compares summary statistics of maize farming fertiliser users and non-fertiliser users. As for hybrid seeds, fertiliser adopters score higher on all food security indicators. Their dietary diversity score is on average 0.945 higher, their food variety score is 2.10 higher, their food consumption score is 2.69 higher and their coping strategy index is 1.79 lower. 21,7% of fertiliser using households are female headed, and as many as 88.5% of them have a household head that has been to school. Their average land size is slightly lower than the average for non-adopters (3.87 ha compared to 3.918), which is surprising, and they also own on average fewer pieces of livestock. However, they have higher incomes, own on average much more farm assets, they have higher quality housing, and they live closer to the town and the market.

Table 10 adopters of fertiliser versus non adopters

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  | Non-adopters fertiliser | | | Adopters fertiliser | | |  |  |
|  |  | Mean | Std | N | Mean | Std | N | Χ2 | T |
| Input use | Hybrid seed use | 0,183 | 0,387 | 3967 | 0,329 | 0,470 | 665 | 196,894\*\*\* |  |
|  | Fertiliser use | 0,000 | 0,000 | 3967 | 1,000 | 0,000 | 665 |  |  |
| Household characteristics | Female headship | 0,237 | 0,426 | 3967 | 0,217 | 0,412 | 665 | 3,657\* |  |
|  | Education head | 0,719 | 0,449 | 3937 | 0,885 | 0,319 | 661 | 215,976\*\*\* |  |
|  | Years in community | 35,880 | 20,747 | 2468 | 35,669 | 19,705 | 423 |  | 0,202 |
|  | Household size | 5,638 | 3,294 | 3967 | 5,415 | 2,771 | 665 |  | 1,866\*\* |
|  | Dependency ratio | 46,971 | 23,568 | 3967 | 44,043 | 23,043 | 665 |  | 3,022\*\*\* |
|  | Housing quality index | 3,527 | 0,537 | 3485 | 3,897 | 0,589 | 608 |  | -14,478\*\*\* |
| Income | Farm income | 16,331 | 68,639 | 3967 | 36,515 | 262,220 | 665 |  | -1,974\*\* |
|  | Off farm income | 17,506 | 79,979 | 2815 | 36,824 | 298,985 | 507 |  | -1,446\* |
| Farm characteristics | Land size | 3,918 | 12,203 | 3953 | 3,877 | 5,276 | 660 |  | 0,147 |
|  | Farm assets | 123,044 | 3024,756 | 3912 | 937,115 | 22266,742 | 658 |  | -0,936 |
|  | TLU | 3,805 | 10,182 | 2814 | 1,568 | 3,336 | 532 |  | 9,311\*\*\* |
|  | SACCO | 0,042 | 0,200 | 3967 | 0,095 | 0,293 | 665 | 90,517\*\*\* |  |
| Geographical | Central Zone | 0,081 | 0,273 | 3967 | 0,029 | 0,167 | 665 | 60,847\*\*\* |  |
|  | Eastern Zone | 0,094 | 0,292 | 3967 | 0,017 | 0,128 | 665 | 118,446\*\*\* |  |
|  | Lake Zone | 0,086 | 0,281 | 3967 | 0,014 | 0,116 | 665 | 113,613\*\*\* |  |
|  | Northern Zone | 0,166 | 0,372 | 3967 | 0,137 | 0,344 | 665 | 9,475\*\*\* |  |
|  | Southern Zone | 0,226 | 0,418 | 3967 | 0,281 | 0,450 | 665 | 25,892\*\*\* |  |
|  | Southern Highlands | 0,167 | 0,373 | 3967 | 0,435 | 0,496 | 665 | 660,612\*\*\* |  |
|  | Western Zone | 0,170 | 0,376 | 3967 | 0,089 | 0,285 | 665 | 74,207\*\*\* |  |
|  | Zanzibar | 0,010 | 0,100 | 3967 | 0,000 | 0,000 | 665 | 17,813\*\*\* |  |
|  | Total annual rainfall | 1020,877 | 295,416 | 3884 | 1143,613 | 268,191 | 662 |  | -10,719\*\*\* |
|  | Average annual temperature | 225,811 | 23,208 | 3884 | 207,320 | 23,895 | 662 |  | 18,480\*\*\* |
|  | Distance to nearest town | 36,402 | 35,635 | 3887 | 27,966 | 32,153 | 662 |  | 6,139\*\*\* |
|  | Distance to nearest market | 67,374 | 48,037 | 3887 | 58,484 | 50,591 | 662 |  | 4,209\*\*\* |
| Instruments | Seed voucher | 0,059 | 0,237 | 3967 | 0,089 | 0,285 | 665 | 21,492\*\*\* |  |
|  | Fertiliser voucher | 0,002 | 0,045 | 3967 | 0,069 | 0,254 | 665 | 587,100\*\*\* |  |
| Food security | DDS | 7,734 | 2,071 | 3967 | 8,680 | 1,839 | 665 |  | -12,040\*\*\* |
|  | FVS | 12,527 | 4,878 | 3967 | 14,623 | 4,926 | 665 |  | -10,168\*\*\* |
|  | FCS | 49,096 | 17,817 | 2814 | 51,786 | 18,022 | 507 |  | -3,099\*\*\* |
|  | CSI | 3,746 | 7,441 | 2815 | 1,959 | 4,728 | 507 |  | 7,079\*\*\* |

Table 11 shows the summary statistics for hybrid maize and fertiliser and all food security indicators per zone. The majority of maize farmers in our sample live in the Northern, Southern, Western and Southern Highland Zone. These regions also score higher on hybrid seed- and fertiliser use than the other regions. The Northern zone has the highest scores on dietary diversity and food variety, and the second best scores on food consumption and coping strategy index. Zanzibar has on average the highest food consumption score, and the Southern Highlands have the lowest coping strategy index. The Central and Southern zone score relatively low on all food security indicators.

Table 11 summary statistics per zone

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Central | Eastern | Lake | Northern | Southern | Southern Highlands | Western | Zanzibar |
| N | 341 | 384 | 352 | 750 | 1082 | 950 | 733 | 40 |
| hybrd1 | 0,173 | 0,219 | 0,278 | 0,325 | 0,083 | 0,180 | 0,267 | 0,100 |
| fert1 | 0,056 | 0,029 | 0,026 | 0,121 | 0,173 | 0,304 | 0,080 | 0,000 |
| DDS | 7,088 | 8,701 | 8,003 | 8,615 | 7,367 | 7,836 | 7,809 | 6,975 |
| FVS | 11,578 | 15,336 | 12,659 | 14,772 | 11,775 | 12,527 | 12,198 | 11,550 |
| FCS | 46,398 | 51,998 | 51,674 | 58,563 | 43,261 | 47,284 | 50,640 | 59,981 |
| CSI | 3,732 | 2,979 | 4,869 | 2,786 | 4,296 | 2,474 | 3,629 | 3,593 |

Table 12 below shows the pearson correlation coefficients between the food security indicators in our only maize farmers subsample for the years 2010 and 2012 (since we do not have a FCS or CSI for 2008). It clearly shows that all indicators are positively and significantly correlated with each other, except of course the CSI which shows the behavioural response of the household to food insecurity and index increases as food security decreases. This index is negatively correlated with the other indicators for food security, which is in line with our expectations.

Table 12 Correlation food security indicators

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
|  | DDS | FVS | FCS | CSI |  |  |
| DDS |  |  |  |  |  |  |
| cor | 1 | 0.8617 | 0.5455 | -0.1691 |  |  |
| N | 3322 | 3322 | 3321 | 3322 |  |  |
| CI\* |  | (0.8526,0.8702) | (0.5212,0.569) | (-0.2019,-0.1359) | |  |
| stat\*\* |  | 97.83 (3320) | 37.5 (3319) | -9.885 (3320) | |  |
| p-value |  | 0.0000 | 0.0000 | 0.0000 |  |  |
| FVS |  |  |  |  |  |  |
| cor | 0.8617 | 1 | 0.5678 | -0.1694 |  |  |
| N | 3322 | 3322 | 3321 | 3322 |  |  |
| CI\* | (0.8526,0.8702) |  | (0.5443,0.5904) | (-0.2023,-0.1362) | |  |
| stat\*\* | 97.83 (3320) |  | 39.74 (3319) | -9.906 (3320) | |  |
| p-value | 0.0000 |  | 0.0000 | 0.0000 |  |  |
| FCS |  |  |  |  |  |  |
| cor | 0.5455 | 0.5678 | 1 | -0.158 |  |  |
| N | 3321 | 3321 | 3321 | 3321 |  |  |
| CI\* | (0.5212,0.569) | (0.5443,0.5904) | | (-0.191,-0.1247) | |  |
| stat\*\* | 37.5 (3319) | 39.74 (3319) | | -9.219 (3319) | |  |
| p-value | 0.0000 | 0.0000 |  | 0.0000 |  |  |
| CSI |  |  |  |  |  |  |
| cor | -0.1691 | -0.1694 | -0.158 | 1 |  |  |
| N | 3322 | 3322 | 3321 | 3322 |  |  |
| CI\* | (-0.2019,-0.1359) | (-0.2023,-0.1362) | (-0.191,-0.1247) | |  |  |
| stat\*\* | -9.885 (3320) | -9.906 (3320) | -9.219 (3319) | |  |  |
| p-value | 0.0000 | 0.0000 | 0.0000 |  |  |  |

|  |
| --- |
| \*\* t (df) |
| \* 95% pe |
|  |
| HA: two.s |

# 6. Results

## 6.1 Endogeneity tests

To test for possible endogeneity of hybrid seed use and fertiliser use to our food security indicators, we performed an two stage least square regression. The outputs can be found in annex.. As instrumental variables, we used two dummy variables, indicating whether the household has received a subsidy for seeds and/or whether the household has received a subsidy for fertiliser in the survey year. Furthermore, we include the lagged proportion of hybrid seeds and fertiliser use at district level as second set of instruments. The Sargan test, with the null hypothesis that the instruments are valid (uncorrelated with the error term) turned out insignificant for all four regressions (DDS, FVS, FCS and CSI). The null hypothesis that the instrument has a low correlation with the endogenous explanatory variable, was rejected for all instruments by the F-statistic for weak instruments. We therefore assume the 2SLS procedure is consistent. The null hypothesis of exogeneity of the Wu-Hausman test was not rejected in any of the four cases. Since we have not proven that OLS indicators are inconsistent, we continue to use OLS for our analyses.

## 6.2 Results OLS procedure

We estimated equation 4 using OLS. The results are shown in table 13.

Table 13 Regression results DDS, FVS, FCS and CSI

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | | | | |
|  |  | Dependent variable: | | | |
|  |  |  | | | |
|  |  | DDS | FVS | FCS | CSI |
|  |  | (1) | (2) | (3) | (4) |
|  |  | | | | |
| Input use | Hybrid seed use | 0.311\*\*\* | 0.530\* | 0.649 | -0.499 |
|  |  | (0.120) | (0.300) | (1.115) | (0.463) |
|  |  |  |  |  |  |
|  | Fertiliser use | 0.494\*\*\* | 0.885\*\*\* | 0.740 | -0.954\* |
|  |  | (0.133) | (0.333) | (1.236) | (0.514) |
|  |  |  |  |  |  |
| Household characteristics | Female headship | -0.042 | -0.017 | -0.040 | 1.247\*\*\* |
|  |  | (0.101) | (0.253) | (0.939) | (0.390) |
|  |  |  |  |  |  |
|  | Education head | 0.664\*\*\* | 1.625\*\*\* | 3.360\*\*\* | -1.035\*\*\* |
|  |  | (0.097) | (0.242) | (0.899) | (0.374) |
|  |  |  |  |  |  |
|  | Household size | -0.016 | -0.049 | -0.001 | 0.103\* |
|  |  | (0.015) | (0.038) | (0.141) | (0.059) |
|  |  |  |  |  |  |
|  | Dependency ratio | -0.003 | -0.005 | -0.009 | 0.017\*\* |
|  |  | (0.002) | (0.005) | (0.017) | (0.007) |
|  |  |  |  |  |  |
|  | Housing quality index | 0.630\*\*\* | 2.232\*\*\* | 6.412\*\*\* | -1.175\*\*\* |
|  |  | (0.083) | (0.209) | (0.777) | (0.323) |
|  |  |  |  |  |  |
| Income | Ln (Farm income +1) | 0.069\*\*\* | 0.146\*\*\* | 0.225\* | -0.104\*\* |
|  |  | (0.013) | (0.033) | (0.123) | (0.051) |
|  |  |  |  |  |  |
|  | Ln (off farm income +1) | 0.014\*\* | 0.064\*\*\* | 0.127\* | 0.036 |
|  |  | (0.007) | (0.018) | (0.065) | (0.027) |
|  |  |  |  |  |  |
| Farm characteristics | Ln(land size) | 0.089\* | 0.318\*\*\* | 1.153\*\*\* | -0.491\*\*\* |
|  |  | (0.047) | (0.117) | (0.435) | (0.181) |
|  |  |  |  |  |  |
|  | Ln(farm assets) | 0.057\*\* | 0.205\*\*\* | 0.571\*\* | -0.161 |
|  |  | (0.028) | (0.071) | (0.262) | (0.109) |
|  |  |  |  |  |  |
|  | Ln(TLU+1) | -0.125\*\* | -0.350\*\* | 4.321\*\*\* | -0.435\* |
|  |  | (0.059) | (0.147) | (0.545) | (0.226) |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  | SACCO | 0.342\*\* | 1.463\*\*\* | 5.194\*\*\* | -0.405 |
|  |  | (0.164) | (0.413) | (1.530) | (0.636) |
|  |  |  |  |  |  |
| Geographical | Eastern zone | 0.874\*\*\* | 1.679\*\*\* | 4.657\*\* | 0.398 |
|  |  | (0.242) | (0.607) | (2.253) | (0.936) |
|  |  |  |  |  |  |
|  | Lake zone | 0.373\* | -0.001 | 3.623\* | 1.326 |
|  |  | (0.217) | (0.545) | (2.022) | (0.840) |
|  |  |  |  |  |  |
|  | Northern zone | 0.800\*\*\* | 1.675\*\*\* | 9.545\*\*\* | -0.018 |
|  |  | (0.187) | (0.469) | (1.740) | (0.723) |
|  |  |  |  |  |  |
|  | Southern zone | -0.172 | -1.290\*\* | -2.773 | 1.072 |
|  |  | (0.202) | (0.507) | (1.881) | (0.782) |
|  |  |  |  |  |  |
|  | Southern highlands | -0.098 | -0.996\*\* | -0.828 | 0.241 |
|  |  | (0.196) | (0.492) | (1.825) | (0.758) |
|  |  |  |  |  |  |
|  | Western zone | 0.174 | -0.667 | -1.828 | 1.305\* |
|  |  | (0.197) | (0.493) | (1.829) | (0.760) |
|  |  |  |  |  |  |
|  | Zanzibar | 1.152 | 1.841 | 17.863\* | -1.858 |
|  |  | (1.006) | (2.524) | (9.361) | (3.891) |
|  |  |  |  |  |  |
|  | Total annual rainfall | 0.001\*\*\* | 0.002\*\*\* | 0.003\* | -0.001 |
|  |  | (0.0002) | (0.0004) | (0.001) | (0.001) |
|  |  |  |  |  |  |
|  | Average annual temperature | 0.004\* | 0.019\*\*\* | 0.064\*\*\* | 0.004 |
|  |  | (0.002) | (0.005) | (0.018) | (0.008) |
|  |  |  |  |  |  |
|  | Distance to nearest town | -0.005\*\*\* | -0.008\*\* | 0.002 | 0.005 |
|  |  | (0.002) | (0.004) | (0.014) | (0.006) |
|  |  |  |  |  |  |
|  | Distance to nearest market | 0.002 | 0.003 | 0.010 | -0.015\*\*\* |
|  |  | (0.001) | (0.003) | (0.010) | (0.004) |
|  |  |  |  |  |  |
| Surveyyear | Survey year 2012 | 1.028\*\*\* | 1.636\*\*\* | 4.920\*\*\* | -0.206 |
|  |  | (0.162) | (0.407) | (1.508) | (0.627) |
|  |  |  |  |  |  |
| Interaction term | hybid:fert | -0.479\*\* | -1.008\* | -0.716 | 1.101 |
|  |  | (0.224) | (0.563) | (2.089) | (0.868) |
|  |  |  |  |  |  |
|  | Constant | 1.618\*\* | -6.856\*\*\* | -10.841 | 10.524\*\*\* |
|  |  | (0.724) | (1.816) | (6.736) | (2.800) |
|  |  |  |  |  |  |
|  |  | | | | |
|  | Observations | 1,901 | 1,901 | 1,900 | 1,901 |
|  | R2 | 0.245 | 0.270 | 0.253 | 0.076 |
|  | Adjusted R2 | 0.235 | 0.260 | 0.243 | 0.063 |
|  | Residual Std. Error | 1.673 (df = 1874) | 4.198 (df = 1874) | 15.573 (df = 1873) | 6.473 (df = 1874) |
|  | F Statistic | 23.445\*\*\* (df = 26; 1874) | 26.628\*\*\* (df = 26; 1874) | 24.423\*\*\* (df = 26; 1873) | 5.930\*\*\* (df = 26; 1874) |

### 6.2.1 Input use

We find significant negative interaction effects of -0.479 of hybrid seed use and fertiliser use on the DDS. Main effects are significant and positive. The DDS in expected to be 0.311 points higher for households that use hybrid seeds but no fertiliser, if everything else is constant. Using just fertiliser and no hybrid seeds increases the DDS by 0.494 points. Using both hybrid seeds and fertiliser relates to an increase of 0.326 (=0.311 + 0.494 – 0.479) in DDS, compared to using neither. This difference is considerable; a point 1 increase in DDS means that one of twelve food groups more is consumed. The interaction of hybrid seeds and fertiliser is also significant and negative for the FVS: -1.008. Main effects are again significant and positive. Using just hybrid seeds leads to an increase in 0.530 and just fertiliser to an increase of 0.885, if everything else is constant. Using both relates to an increase of 0.407 (=0.530 + 0.885 – 1.0080). A 1 point increase of FVS means that one extra food item of any food group is consumed. We find no interaction effects of hybrid seeds and fertiliser on the FCS or CSI, so we continue to analyse the main effects. Hybrid seed use has no significant effect on the FCS and CSI. Fertiliser use relates to a decrease in coping strategy index of 0.954 if everything else is constant. Overall, fertiliser use seems to have more effect on food security than hybrid seed use. This effect can be considered strong: it is almost as high as the effect of education of the household head compared to no education. Using just fertiliser and no hybrid seeds, appears to be the best strategy to increase food security.

### 6.2.2 Household characteristics

Of all household characteristics, education of the household head and housing quality have the strongest significant relation to food security. The effect of education is positive and significant on DDS, FVS and FCS and negative and significant on CSI. Households with an educated head, consume more than one food item more (1.625) during a 7 day period. Their food consumption score is considerably higher, meaning that also the nutritional quality or frequency of food consumption is higher. Housing quality also has a strong and significant effect, positive for DDS, FVS and FCS an negative for CSI. Housing quality is expected to be strongly related to household wealth, which might explain this difference. Female headship is positively related to the CSI. This might be because households with a female household head are more likely to be single parent households. Being a single parent could possibly lead to more coping behaviour. The same could be true for the dependency ratio: a higher dependency ratio leads to more coping behaviour. It is expected that households with more children and elderly need to take more action in case of lack of access to food, and for that reason have a higher coping strategy index.

### 6.2.3 Income

The coefficients of the natural logarithm of farm income are between 0 and 1 and significantly positive for DDS, FVS and FCS and negative for CSI. This means that the relative change in DDS, FVS and CSI with an increase in farm income is positive and the relative change in CSI is negative. This is in line with our expectations. We find the same relative effects for off farm income for DDS, FVS and FCS. The relative change in CSI with an increase in off farm income is not significant.

### 6.2.4 Farm characteristics

Most of the included farm characteristics are significantly related to food security. An increase in land size leads to a positive relative change in DDS, FVS and FCS and a negative relative change in CSI. Farm assets have a similar effect, except that they are not significantly related to coping behaviour. An increase in livestock however, leads to a negative relative change in DDS and FVS, which is not in line with our expectations. However, livestock contributes positively to FCS and relates to a relative decrease in coping behaviour. Being member of a credit/saving group (SACCO) has high, positive effects on DDS, FVS and FCS.

### 6.2.5 Geographical characteristics

We compare the difference between all zones by comparing them to the Central zone of Tanzania. The Eastern zone and the Northern zone score significantly better than the Central zone on most food security indicators, if everything else is the same. The Lake zone score higher on DDS and FCS. In the Southern zone and Southern Highlands, the FVS is significantly lower than in the Central zone. The Western zone has a higher CSI. Surprisingly Zanzibar scores 17.863 points higher on FCS, which is a big difference. Since we have only 40 maize farming households in Zanzibar in our sample, this could be due to selection. Rainfall and temperature have small but positive and significant effects on DDS, FVS and FCS, but no significant effect on CSI. The distance to the nearest town has a small but significant and negative effect on DDS and FVS. Distance to the nearest market leads to a slight decrease in CSI, which is surprising.

### 6.2.6 Surveyyear

Our analysis also shows that DDS, FVS and FCS are significantly higher in 2012 compared to 2010, keeping everything else constant. The difference is considerable: 1.028 point on DDS, 1.636 points on FVS and 4.920 points on FCS. The CSI is not significantly different between 2010 and 2012.

## 7. Verification and Practical Implications

To verify our results and to find out what the practical implications are, we have done fieldwork in Tanzania. This part of our research consists of seven interviews, with NGOs and government representatives involved in agricultural input use and or food security. We have done semi-structured interviews, with a focus on the following topics:

* What do you think about the relation between agricultural input use and food security? Specifically hybrid seed- and fertiliser use in maize production.
* What are the main problems in your view?
* What needs to be improved and how?
* What projects are you/is your organisation currently working on?
* What do our results mean for policies/practices/projects in the future?

Other discussed topics differ per interviewee. A complete overview of all questions and corresponding answers can be found in annex 5.

First we will elaborate on the overall impression we had of Tanzania and the maize sector. Then we will give a summary of the different views our local expert had on the relation between agricultural input use and food security. Thirdly, we will explain how our results relate to the policy environment and what could be possible future implications.

## 7.1 General impression

Our research took place in Mbeya region and in Dar Es Salaam. Mbeya is one of the larger maize growing areas, located in the Southern Highlands. Before we give an analysis of our interviews, we will provide an overall impression of the situation in the case of Mbeya. Notice that statements we make about the situation in this region are not necessarily true for the rest of the country.

The city of Mbeya is surrounded by farming villages, connected to each other by unpaved roads. Maize, which is used to make the local dish Ugali, is a very important food crop (Interview 1, Interview 2, Interview 3). Most of the maize is produced by smallholders and used for own- or for village consumption (Interview 2, Interview 3). It is processed within the village, farmers take their maize yield to the village mill to take the outer layer off (Interview 2). A different type of mill can process the maize into flower. Not each village has both types of mills, some farmers have to walk to another village for processing. After the maize is processed into flower, farmers take it back home. Other crops we have seen include for example tomatoes, onions, avocados, bananas, leafy green vegetables (Mchicha, Chinisi), sunflowers, pumpkin leaves and oranges. Although we have come across farmers that supplement their food supply by maintaining a home garden, this is not very common. Only a small part of the village population owns livestock, mainly chickens and goats, sometimes pigs or cattle. Productivity and use of agricultural technology is still low, although agriculture is a prominent source of income in the area and Mbeya is considered to be a high potential maize growing region. Most of the farm labour is done in a traditional way: water is transported by hand from the river to the farm, and ploughing, watering and weeding is also done by hand. For farmers living on subsistence level, it proves to be difficult to save money to invest back in the farm.

## 7.2 The relation between agricultural input use and food security: our experts’ views

Our experts had different views on the relation between agricultural input use and food security. Most of them agreed that the use of inputs can be considered low (Interview 1, Interview, 2, Interview 3, Interview 5) and that access to inputs is a problem for small-scale farmers (Interview 1, Interview 2, Interview 4). However, views differ on whether input use is a good way to address food security and nutrition.

According to the Monitoring and Evaluation Officer at the Ministry of Agriculture, the relation between input use and food security is obvious. He has evaluated the changes in yields before and after the adoption of improved seeds and fertiliser. All farmers had positive responses and their yields increased significantly. This lead him to the conclusion that the use of inputs has increased their chances and therefore their income and food security. Our interviewee from the organisation the One Acre Fund had the same line of reasoning. Increasing the use of inputs will increase productivity. This in turn will lead to extra income that can be used for other things, for example food. This would confirm the positive relation between input use and food security that we have found in our data analysis.

Although the relation might seem obvious to some, it is not clear whether increasing input use is the most efficient way to improve food security. We refer back to the framework by Kanter, Walls, Tak, Roberts, & Waage (2015) in figure 3 and 4, that shows the actual theoretical pathways in which input use can affect food security. We have interviewed a peace corps volunteer who lives in one of the villages in Mbeya region. She has recently done interviews with farmers in her village, asking five short agriculture and health related question. According to her, farmers themselves generally believe that the use of fertiliser would help for better crop production and higher yields. However, she is not convinced of the supposedly positive effect of higher maize yields on food security. First of all, when we look back on the framework, the own production pathway does not work in this case according to her. She told us the problem is the maize based diet, people need more variety in their diet, not more maize. At the same time, higher yields do not necessarily lead to higher incomes as we would expect from the market pathway. Maize is not the best income generating crop. Within the villages, yields and prices coincide, when yields are high prices are low. This effect can be discouraging (Interview 6). Transporting surplus maize to other regions can be challenging, leading to high transportation costs and loss of product. Storing surplus yield can also be problematic (Interview 1, Interview 2, Interview 5). Smallholder maize farmers often have no access to good storage facilities. Poor storage therefore leads to higher post-harvest losses. In summary, although maize yields might increase due to higher use of inputs, the effect on food security is not so obvious, because higher maize consumption is not contributing to a diverse diet and selling or storing more maize can be challenging, costly and wasteful.

Secondly, the use of inputs like hybrid seeds and fertiliser requires a long-term commitment that subsistence smallholders may not be able to make. According to our interviewee from TOAM, if a farmers decides to use fertiliser one year, he will need to use it the next year. Inorganic fertiliser decreases the natural fertility of the soil (Interview 7). The same goes for hybrid seeds. It is not possible to reuse hybrid seeds for more than one season, which means that new seeds need to be bought each year. Medium scale and/or commercial farmers may be able to make this commitment, but for subsistence farmers this is most likely not the case (Interview 7). They do not have the means to go to town and buy seeds every year, nor to buy and transport enough bags of fertiliser (Interview 7). Availability of and access to inputs can be a struggle, especially in remote and rural areas. When aiming at improving food security, we need to look at the poorest population group. Starting the use of hybrid seeds and/or fertiliser without the security of being able to get access to these inputs the next season, could potentially harm future production and income.

In short, although we have verified the positive effect of input use on maize production, the relation to food security is more complex:

* The own production pathway does not work: People need more variety in their diets, maize offers little extra nutritional value.
* The market pathway does not work as we would expect: Higher maize yields do not necessarily lead to higher incomes, because
  + Prices within the village coincide: higher yields lead to lower prices
  + Transport and storage of maize surplus can be difficult, expensive and wasteful
* Hybrid maize and fertiliser use requires a long term commitment, that is probably not in the best interest of the poorest population group.

## 7.3 Practical implications

We have found positive effects of the use of fertiliser on food security, but not of hybrid seeds. This is not only interesting from a scientific perspective, but it may also be important for future policies. The Tanzanian government is currently still subsidising improved seeds and fertiliser (NAIVS) and is working hard to increase the use of agricultural inputs. However, is this the most effective way to address food security? We asked our experts. We first discuss the current policy context and the outlook on future policies. Secondly, we discuss what needs to be improved in order for the market- and own production pathway as presented in figure 4 to work.

### 7.3.1. Current policy context

NAIVS, the national agricultural input voucher scheme, is being phased out. It has proven to be a very expensive program, not only in terms of subsidy, but also regulation and enforcements. The program was partially funded by the World Bank, and topped up by the government. It was meant to be a temporary policy. The goal was to show farmers, with the voucher scheme, how effective the use of fertiliser and improved seeds was. The first few years they could get their input for 50% of the price. After they have had the chance to experience the positive effects it had on their yield, the expectation was that they would continue to use these inputs at their own costs after the program had ended (Interview 5). However it turned out to become a political tool, for politicians to win the hart of farmers and secure their votes (Interview 5). Now, the World Bank has ended their funding (Interview 6). The Tanzanian Government is still continuing with the scheme, but with a lower budget (this year only 20 billion shillings) which is hardly anything (Interview 6). The future of the scheme is unsure. One of our interviewees from the government expected it to continue for no longer than 3 more years (Interview 5), the other one told us it would probably end after this year (Interview 6). We asked whether they thought it has been effective. In terms of creation of demand for inputs, it has been according to our interviewees at the Ministry of Agriculture. The program introduced new technologies to farmers and it provided the infrastructure for input delivery. Many of them have expressed their positive view on the use of inputs, and they expect that these farmers will buy them at their own costs in the future (Interview 5).

### 7.3.2 Future policies

What will happen after NAIVS ends, is still unsure. The problem remains that prices of fertiliser are too high for small-scale subsistence farmers. There are several options. One is to subsidise inputs on credit. Farmers would get the inputs on credit, and the government would subsidise the interest rate from the bank. The farmers would then repay their loans after harvest (Interview 5, Interview 6). The NAIVS scheme as it is now, is a smart program, which means that it is specifically targeted at the farmers that need it most. This reduces the amount of subsidy that has to be played in total, but it also comes with costs of regulation and enforcement. The idea of the credit system is that it is non-exclusive, everyone can buy their inputs on credit. This system has been proposed, but it was rejected: the Bank asked for subsidies upfront, and the government was not able to agree on those terms (Interview 6). However, the government is still looking for a way to make this work. Another option is to find a way to reduce the costs of fertiliser. In recent years, fertiliser policies have been revised in an attempt to attract new investments (Interview 5). The Fertiliser Act and the Fertiliser Regulations of 2011 relax the existing rules

### 7.3.3 Effectiveness of the pathways from input use to food security

As we explained, the increase in own production of maize does not necessarily mean that diets improve. Maize is already a large part of the diet, the consumption of more maize does not offer extra diversity or micro nutritional value. In the case of Santilya, more knowledge on production and consumption diversity is needed. People generally know that they need more variety in their diets, but not how to achieve this: What to buy, what to grow and so on (Interview 1, Interview 2). For policies that stimulate production to be effective in improving food security, more investments in education are needed. The same goes for the effectiveness of increasing incomes after the stimulation of production: farmers need to know the proper techniques of after harvest crop handling, storage and of course market access. Increasing agricultural- and nutritional education can be done by NGOs or the government. In Santilya, Uyole research institute’s agriculture extension and Kyumbe are active in educating people about agriculture, nutrition and HIV for example (Interview 2). The NAIVS program involves several types of education. Farmer field schools are organised to teach correct agricultural techniques (Interview 5, Interview 6). The One Acre Fund and TOAM are also involved in training programs for agricultural techniques (Interview 4, Interview 7).

Apart from education, the issues market access and transport need to be addressed for the market pathway to be effective. It is discouraging if production is increased, but the excess supply cannot be sold for a good price. Some areas of Tanzania go without food, whereas others have extra’s. The Tanzanian government is a large buyer of maize. They keep food reserves throughout the year; excess supply of maize from certain areas is bought in and distributed to areas that are prone to hunger (Interview 5). The government are looking at options to expand the maize market internationally, to supply to neighbouring countries. However, they are facing the problem of food safety standards. The quality of maize is not good enough for exporting standards; product, grains, storage and packaging standards are not met. National regulations will need to be put in place that comply with international food safety standards, to fully benefit from the international market options. Lastly, the issue of transport needs to be addressed. In our experience, the roads leading to remote rural villages where many subsistence farmers live are very bad. When interviewing our representative from the One Acre Fund, she asked about the road to Santilya, because they were thinking of expanding there, but could not get their trucks there because of the bad roads. This speaks volumes. The transport of bulky product is definitely constraint due to bad infrastructure, which keeps farmers from selling their product outside of their village. Effective investment in infrastructure would make a big difference. Tanzania has no railway system. Rails are cheaper for transport of bulky product than roads, investments in a railway system would reduce transport costs immensely (Interview 6).

In summary, this is the practical context of our research and results:

* The expensive and ineffective NAIVS program is being phased out
* The laws and regulations around fertiliser are being relaxed, in an attempt to remove barriers to attract investments and reduce fertiliser costs
* To make the own production- and the market pathway more effective, more investments in agricultural and nutritional education are needed, from NGOs and/or the government
* For the market pathway to work effectively, markets need to be expanded, nationally and internationally and infrastructure needs to be improved.

# 8. Discussion and conclusion

In this study we have analysed how farm-level adoption of improved maize seeds and fertiliser use affects food security for households in rural Tanzania. We have developed a theoretical framework based on scientific literature that relates input use to household food consumption via three different pathways: the market pathway, the own production pathway and the income pathway. We expected the use of inputs in maize production to stimulate production, which could either increase income from market sales or increase the amount of food available to the household from own production, or both. Using literature review we have analysed the most commonly used indicators for food security and nutrition. An assessment based on the following characteristics: not context specific, can measure at household level, measures dietary quality, measures nutritional status, measures lived experiences, not easy to manipulate and available in the LSMS ISA TNZ dataset, has lead us to select the DDS, FVS, FCS and CSI as most suitable criteria for food security. Unfortunately in this study we were not able to look further into individual nutritional status. Although this is a very relevant aspect to food security, the fact that a nutrition indicator cannot be aggregated to household level has kept us from using a nutrition indicator in our analysis. Nevertheless, the DDS, FVS, FCS and CSI very well capture the elements of dietary quality and lived experiences of food security. Based on the theory of the Agricultural Household Model, we had to deal with the issue of non-seperability of production and consumption decisions. To address this, we applied a 2SLS estimation to control for possible endogeneity of hybrid seed- and fertiliser use to household food security, using subsidies received for improved seeds or fertiliser as instruments.

The results of our empirical analyses do not show that hybrid seed has an effect on the DDS, FVS or FCS. The effect on the CSI however is positive, which means that hybrid seed use contributes to food insecurity rather than food security. Also, we have found that fertiliser use however contributes positively to the DDS and the FVS. This supports the conclusion from the study by Kriti (2015) that fertilizer in particular, is positively correlated with household food security. The interaction effects are different than we expected: the interaction effect between hybrid seed use and fertiliser use is only significant for the DDS and the FVS, and negative. This could be due to the fact that to use both inputs, the household needs to make a double investment at once. This could possibly lead to a short-term shortage of means to use to secure household food supply. Education is a predominant positive influence on food security. Living for a shorter period of time in the community of residence relates to better overall food security outcomes, possibly because the ability to migrate indicates a higher wealth status and better ability to secure access to food. Furthermore, we have found that wealth indicators such as total value of farm assets, total land size, a housing quality index and being member of a credit- and/or saving group relate positively to food security. When comparing the geographical zones of Tanzania, we found that the Northern zone scores consistently better, and the Southern- and Western zone score consistently worse on food security. More rainfall and higher temperatures contribute predominantly positive to food security. In contrary to our expectation that households that live in more remote areas would struggle more with securing their access to food, we see no such effect in our results.

Using semi-structured expert interviews with NGO and government representatives in Tanzania, we were able to relate our results back to the pathways in our framework. The relation between hybrid seed use and food security has proven to be very complex. We have found evidence that the own production pathway does not work when adopting hybrid seeds and fertiliser in maize production, since extra maize in a maize based diet offers no extra diversity or variety. The market pathway does not work as we would expect either, as higher maize yields do not necessarily lead to higher incomes. This is due to the fact that on the one hand prices within the village coincide and higher yield lead to lower prices. On the second hand, transport and storage facilities are often lacking, making it difficult, expensive and wasteful to sell surplus maize outside of the village. Our field interviews have pointed out that, in order to make the own production- and the market pathway more effective, more investments in agricultural and nutritional education are needed, from NGOs and/or the government. For the market pathway to work effectively, markets need to be expanded, nationally and internationally and infrastructure needs to be improved.

In short, our study adds an important element to what we know from the research done by Keding, Schneider, & Jordan (2013) and Slavchevska (2015). Our research supports the conclusion from (Keding, Schneider, & Jordan (2013) that investing in improving agricultural systems is not enough to improve food security. Effective storage and food processing technologies are required, as is education of households to create and understanding of what constitutes a healthy diet. Slavchevska (2015) too concluded that although agricultural interventions do affect agricultural production, this does not necessarily lead to better nutrition, because of failure to invest in complementary interventions such as health focussed programs. To effectively impact food security and nutrition via agricultural input use promotion, a trans-disciplinary approach is required. Many elements need to be taken into account from education to storage, transport and market access. More, integrated research is required to effectively assess all elements that link agricultural input use to food security in order to fully understand how to make promotion of agricultural input use effective in improving household food security.

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# ANNEX 1 Food security indicators from literature

Table 20 Food security and nutrition indicators: literature study

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Categories of indicators | Indicator | Description | Method of measurement | Advantage(s) | Disadvantage(s) |
| Food acquisition | **Food expenditures**  **From**  **HES/HCES/HBS**  **surveys** | Monetary value of food acquired by household (purchased, received and produced for own consumption)vii | Reference period differs per survey:  HBS in Tanzania has a recall period of one calendar month[[2]](#endnote-1) | * Measures physical and economical access to food * Survey data available for many countriesvii | * Acquisition does not equal consumptionvii |
| **Acquired food quantities** | Quantity of food acquired by household (purchased, received and produced for own consumption)vii |
| Dietary intake | **HDDS** | Sum of household data on the consumption of 12 (sometimes more/less) food groups. Score ranging from 1-12 | Score based on sum of response data on the consumption of 12 (sometimes more/less) food groups on a 24h recall periodvii | * Measure for dietary qualityx * food group   consumption data are easy to collectvii | * no unique definition of dietary diversity for all settingsvii |
| **IDDS** | Same as HDDS but based on individual- instead of household data[[3]](#endnote-2) | Same as HDDSii | * specific categories available for infants and   young childrenii   * can estimate nutrient adequacy of   the diet | * no unique definition of dietary diversity for all settings |
| **FFS/FCS** | Household food security is scored as “poor” or “acceptable” frequency of consumption  of different food groupvii | Score based on household reported consumption of 8 food groups. Frequency of consumption is multiplied by the weight of each group. vii | * data are easy to collect and the indicator is simple   to calculate   * standard cut-off points allow for comparison between different settingsvii | * the universal standard cut-off points can in specific cases lead to bad misclassificationsv |
| **FVS** | Score based on count of different food items consumed. Score can range between 0 and the total amount of items per study | Sum of food items consumed over a 24h period, all items have the same weightiii | * can estimate nutrient adequacy of   the diet[[4]](#endnote-3) | * no universal definition of what a food item isiii |
| Subjective measurements | **SAFS** | Different categorisations exist, based on different assessment scales. Household assess their own food security status on a scale ranging from food secure to extremely food insecure, with different options in between [[5]](#endnote-4),v | Perception  of the respondents’ own food security statusv | * distinguishes medical   definitions of hunger from poverty-related hungervii   * Captures lived experiences of hunger and food insecurityvii | * Variation across countries how households approach and report food insecurity: difficult to formulate cut-off points for classificationvii * changing internal standards   or values could result in changed perceptions of one’s food security  statusvii   * easy to   manipulate in programmatic contexts[[6]](#endnote-5) |
| **Radimer/Cornell**  **hunger and food insecurity scale** | Households are classified as hungry or not-hungry based on whether or not they answered positive to four or more questions or statements[[7]](#endnote-6) | Household scores are based on a 30 questions questionnaire on their perceived:   * Food depletion * Food anxiety * Diet inadequacy * Intake insufficiency * Disrupted eating patterns * Children’s diet inadequacy * Children’s intake insufficiency * Children’s disrupted eating patterns |
| **HFSSM** | Households are classified as either   * food secure * having low food security * having very low food security[[8]](#endnote-7) | Score based on household annually reported experience on:   * anxiety about household food supplies * perceptions that   the quality or quantity of accessible food is not adequate   * reduced adult food intake * reduced food intake * by childrenvii |
| **HFIAS** | Households are categorised in a 4-level variable reflecting prevalence of food insecurityvii | Same as HFSSM, except:   * recall period is 4 weeks (instead of 1 year) * frequency response   questions are incorporatedvii |
| **HHS** | Based on their answers to the HHS questionnaire, households are classified as either:   * Little to no hunger in the household * Moderate hunger in the household * Severe hunger in the household[[9]](#endnote-8) | The scale was derived from the HFIAS. The HHS module is based on a 6 questions related to how often household members experience hunger, go to sleep without food or go day and night without eating because there was not enough food. The recall period is 4 weeks.viii |
| Coping strategies | **CSI** | Level of food insecurity is measured by the severity and frequency of coping strategies[[10]](#endnote-9) | Most common (regional) coping behaviour is identified during focus group discussions. List of behaviours is ranked and weighted for severity. Households level frequencies of each strategy are multiplied by the weight and summed to make up the indices ix,vii | * Can be used to identify vulnerable householdsvii | * Not comparable across contextvii |
| Anthropometric measurements | **Wasting** | low weight for  height | Z-score that measures standard deviations between the anthropometric performance of a particular children and  the median of the reference population[[11]](#endnote-10) | * measures directly   how undernutrition affects  health and well-being   * three different indicators together give a   good sense of both chronic and acute undernutritionx | * poor anthropometric status can be result of things   unrelated to food security, such as presence of diseases.   * focus on children, neglects food insecurity   among adolescents and adults   * can generate   problems in identifying undernourishment, with the worldwide trend towards food with a high content in  starch, fats, and sugar   * height and weight potential is influenced by genetic differences: makes a worldwide reference standard questionablex |
| **Stunting** | low height for age |
| **Underweight** | low  weight for age |
| **Quetelet’s index** | weight over height2 | Score for body mass index (BMI). Score below 20 is considered underweight[[12]](#endnote-11) | * reliable BMI measure for adults * easily calculated   of all BMI scores, least biased by heightxi | * cut-off points vary among populations   does not account for muscularity or weight related health conditions such as oedema xi |
| **CED** | Quetelet’s index (weight/height2) | Three stages of chronic energy deficiency scored between 16 and 18.5 of the Quetelet’s indexxi | * reliable BMI measure for adults * easily calculated * of all BMI scores, least biased by heightxi | * cut-off points vary among populations * does not account for muscularity or weight related health conditions such as oedema xi |
| **Skinfold measurements** | Estimate for subcutaneous fat which is an estimate for total body fat, based on triceps skinfold, biceps skinfold, subscapular skinfold or suprailiac skinfold | Measurements are taken with specific precision skinfold thickness calipers. The optimum combination of skinfold measurements sites  varies with age, race, sex |  |  |
| **MUAC** | Muscle mass estimate based on middle-upper arm circumference | Circumference measurement taken at the nearest millimetre at the midpoint of the upper  left arm.xi Adolescents, adults, the elderly, and pregnant women are classified according to group specific cut-off points[[13]](#endnote-12) | * quicker to measure than weight and heightxi * can be used for adults and children * in developing countries where changes in MUAC directly reflect changes in muscle mass, it is a very useful way to diagnose specifically protein-energy malnutrition or starvationxi * varies little between ages of six months and five years and can therefore be used in areas where the ages of children are uncertainxi | * somewhat biased, tends to selecting younger children as malnourished and miss older childrenxi |
| Biochemical measurements | **Vitamin A deficiency** | Deficiency of vitamine A is measured using serum retinol values. [[14]](#endnote-13) | Prevalence of serum retinol values of 0.70 µmol/l or  lower among children younger than six years of age, is used to define a deficient population. xiii | * Direct measure for health impact | * Usually only measured in children (a group that is more vulnerable to vitamin A deficiency)xiii   Influenced by health conditions not directly related to food intake, such as helminths. |
| **Iron deficiency** | Many different indicators for iron status available (serum iron, transferrin, plasma ferritin, TfR, blood Hb, free erythrocyte protoporphyrins and RBC characteristics)[[15]](#endnote-14) | Universal cut-off points available for all indicators | * Universally comparable and applicable to adult populations, can be adjusted for sex, age, physiological   status, and for populations living at different  altitudes above sea level.   * Direct measure for health impact | * Influenced by health conditions not directly related to food intake such as blood loss, infections etc.xiv |
| **Iodine deficiency** | Urinary iodine concentration |  | * Universally comparable and applicable to adult populations, can be adjusted for sex, age, physiological   status, and for populations living at different  altitudes above sea level.   * Direct measure for health impact |  |

I ILO Microdata Repository. (2015). Tanzania - National Household Budget Survey, Study Description. Retrieved February 5, 2016, from http://www.ilo.org/surveydata/index.php/catalog/508/study-description

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# ANNEX 2 Food security indicator construction

#### Dietary Diversity Score and Food Variety Score

All three waves of the NPS LSMS ISA survey include the following question:

* Within the past 7 days, did the members of this household eat/drink any [. . .] within the household?

A list with 59 food items is presented, and each households answers for each item yes or no. We have arranged all these items into a total of 12 food groups: Cereals, roots and tubers, vegetables, pulses and nuts, fruits, meat, eggs, fish and seafood, oils and fats, sugar and condiments. Which item belongs to which group is shown in table 22 below. If a household consumes in one week anything that belongs to a food group, the score for that group is 1, if not the score is 0. The dietary diversity score ranges from 1 (all items consumed belong to the same group) to 12 (household consumes at least one item from each food group). The food variety score is based on the same question, but not the score is summarised into groups. The food variety score is simply a count of all food items consumed, and ranges from 0 to 59.

Table 22 Dietary diversity score

|  |  |
| --- | --- |
| Food Group | Food Item |
| 1. Cereals | Rice (paddy) |
| Rice (husked) |
| Maize (green, cob) |
| Maize (grain) |
| Maize(flour) |
| Millet and Sorghum (grain) |
| Millet and Sorghum (flour) |
| Wheat, barley and other cereals |
| Bread |
| Buns, cakes and biscuits |
| Macaroni and spaghetti |
| Other cereal products |
| 1. Roots and Tubers | Cassava fresh |
| Sweet potatoes |
| Yams/cocoyams |
| Irish potatoes |
| Cooking bananas, plantains |
| Other starches |
| 1. Vegetables | Onions, tomatoes, carrots and green pepper, other viungo |
| Spinach, cabbage and other green vegetables |
| Canned, dried and wild vegetables |
| 1. Pulses and Nuts | Peas, beans, lentils and other pulses |
| Groundnuts in shell/shelled |
| Cashew, almonds and other nuts |
| Seeds and products from nuts/seeds (excl. cooking oil) |
| 1. Fruits | Citrus fruits (oranges, lemon, tangarines, etc.) |
| Coconuts (mature/immature) |
| Mangoes, avocadoes and other fruits |
| 1. Meat | Beef including minced sausage |
| Pork including sauages and bacon |
| Chicken and other poultry |
| Wild birds and insects |
| Goat meat |
| Other domestic/wild meat products |
| 1. Eggs | Eggs |
| 1. Fish and Seafood | Fresh fish and seafood (including dagaa) |
| Dried/salted/canned fish and seafood (incl. dagaa) |
| Package fish |
| 1. Milk and milk products | Fresh milk |
| Milk products (like cream, cheese, yoghurt etc) |
| Canned milk/milk powder |
| 1. Oils and Fats | Cooking oil |
| Butter, margarine, ghee and other fat products |
| 1. Sugar | Sugar |
| Sugarcane |
| Sweets |
| Honey, syrups, jams, marmalade, jellies, canned fruits |
| 1. Condiments | Tea dry |
| Coffee and cocoa |
| Other raw materals for drinks |
| Bottled/canned soft drinks (soda, juice, water) |
| Prepared tea, coffee |
| Salt |
| Other spices |

#### Food consumption score

The NPS LSMS ISA survey wave 2 and 3 contains the following question:

• Over the past one week (7 days), how many days did you or others in your household consume any [...]?

1. **Cereals, Grains and Cereal Products** (Maize Grain/Flour; Green Maize; Rice; Finger Millet ; Pearl Millet; Sorghum; Wheat Flour; Bread; Pasta; Other Cereal)
2. **Roots, Tubers, and Plantains** (Cassava Tuber/Flour; Sweet Potato; Irish Potato; Other Tuber/Plantain)
3. **Nuts and Pulses** (Bean; Pigeon Pea; Macadamia Nut; Groundnut; Green Bean; Cow Pea; Other Nut/Pulse)
4. **Vegetables** (Onion; Cabbage; Wild Green Leaves; Tomato; Cucumber; Other Vegetables/Leaves)
5. **Meat, Fish and Animal Products** (Egg; Dried/Fresh/Smoked Fish (Excluding Fish Sauce/Powder); Beef; Goat Meat; Pork; Poultry; Other Meat)
6. **Fruits** (Mango; Banana; Citrus; Pineapple; Papaya; Guava; Avocado; Apple; Other Fruit)
7. **Milk/Milk Products** (Fresh/Powdered/Soured Milk; Yogurt; Cheese; Other Milk Product - Excluding Margarine/Butter or Small Amounts of Milk for Tea/Coffee)
8. **Fats/Oil** (Cooking Oil; Butter; Margarine; Other Fat/Oil)
9. **Sugar/ Sugar Products/ Honey** (Sugar; Sugar Cane; Honey; Jam; Jelly; Sweets/Candy/Chocolate; Other Sugar Product)
10. **Spices/Condiments** (Tea; Coffee/Cocoa/Milo; Salt; Spices; Yeast/Baking Powder; Tomato/Hot Sauce; Fish Powder/Sauce; Other Condiment - Including Small Amounts of Milk for Tea/Coffee)

The food group ‘main staples’ consists of ‘cereals and grains’ and ‘roots and tubers together’. We have added up the number of days of consumption for both products and rounded off every number over 7 to 7. Next, we have multiplied the number of days of consumption for each food group with a corresponding weight. The weights we used are shown in table 23 below and are based on World Food Programme, (2008).

Table 23

|  |  |
| --- | --- |
| Food group | Weight |
| Main staples | 2 |
| Pulses | 3 |
| Vegetables | 1 |
| Fruits | 1 |
| Meat and fish | 4 |
| Milk | 4 |
| Sugar | 0.5 |
| Oil | 0.5 |
| Condiments | 0 |

#### Coping strategy index

The NPS LSMS ISA survey wave 2 and 3 contains the following question:

• In the past 7 days, how many days have you or someone in your household had to:

1. Rely on less preferred foods?
2. Limit the variety of foods eaten?
3. Limit portion size at meal-times?
4. Reduce number of meals eaten in a day?
5. Restrict consumption by adults for small children to eat?
6. Borrow food, or rely on help from a friend or relative?
7. Have no food of any kind in your household?
8. Go a whole day and night without eating anything?

The response is a number ranging from 1-7, indicating the number of days in which each specific coping behaviour occurred within the household. To construct the CSI score, we multiplied each day with a corresponding weight for the severity per coping strategy. The weights we used are shown in table 24 below and are based on Caldwell (2008). Question 7: “Have no food of any kind in your household?” was not included in the score, as it does not concern coping behaviour.

Table 24 Coping strategy index

|  |  |
| --- | --- |
| Coping strategy | Weight |
| Rely on less preferred foods? | 1 |
| Limit the variety of foods eaten? | 1 |
| Limit portion size at mealtimes? | 1 |
| Reduce number of meals eaten in a day? | 1 |
| Restrict consumption by adults for small children to eat? | 3 |
| Borrow food, or rely on help from a friend or relative? | 2 |
| Have no food of any kind in your household? | 0 |
| Go a whole day and night without eating anything? | 4 |

# ANNEX 3 Housing quality index

This housing quality index contains information on the tenure status of the house, the material of the walls and roof, the main source of drinking water, the sewage facilities, and the fuel used for lighting and cooking. We have constructed a list of dummy variables for each of these seven housing quality categories. Details can be found in table 25 below. We have ranked each option according to quality, based on the list of Fiadzo et al. (2001) p. 146-147 and according to our own insight. Because not every group has the same number of options, we have divided the rank by the number of options in each categories, to get weights between 0 and 1. The construct the housing quality index, we have summed each variable times its weight.

Table 25 Housing quality index

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Group | Variable | Construction | Rank | Weight |
| Roof | (roof) grass\_, leaves, bamboo | 1 of roof is made of grass, leaves and or bamboo, 0 if else | 1 | 0,25 |
|  | (roof)mud, grass | 1 of roof is made of mud and grass, 0 if else | 2 | 0,5 |
|  | (roof)concrete | 1 of roof is made concrete, 0 if else | 4 | 1 |
|  | (roof) Corrugated galvanised iron | 1 of roof is made of corrugated galvanised iron (CGI), 0 if else | 2 | 0,5 |
|  | (roof)asbestos | 1 of roof is made of asbestos, 0 if else | 3 | 0,75 |
|  | (roof)tiles | 1 of roof is made of tiles, 0 if else | 4 | 1 |
|  | (roof)other | 1 of roof is made of none of the above, 0 if else | 2 | 0,5 |
| Wall | (wall) poles, branches, grass | 1 if wall is made of poles, branches and grass, 0 if else | 1 | 0,167 |
|  | (wall)poles, mud, stone | 1 if wall is made of poles, mud and stone, 0 if else | 2 | 0,333 |
|  | (wall)mud | 1 if wall is made of mud, 0 if else | 3 | 0,500 |
|  | (wall)mud, brick | 1 if wall is made of mud and brick, 0 if else | 4 | 0,667 |
|  | (wall)brick | 1 if wall is made of brick, 0 if else | 5 | 0,833 |
|  | (wall)concrete | 1 if wall is made of concrete, 0 if else | 6 | 1,000 |
|  | (wall)other | 1 if wall is made of mud of none of the above, 0 if else | 3 | 0,500 |
| Sewage facilities | (sew) no toilet | 1 the house has no toilet, 0 if else | 1 | 0,250 |
|  | (sew)flush toilet | 1 if house has a flush toilet, 0 if else | 4 | 1,000 |
|  | (sew)pit latrine | 1 if house has a pit latrine, 0 if else | 2 | 0,500 |
|  | (sew) ventilated improved pit latrine | 1 if house has a ventilated improved pit latrine (VIP), 0 if else | 3 | 0,750 |
|  | (sew)other | 1 if the house has another kind of toilet, 0 if else | 2 | 0,500 |
| Tenure status | (tenure)owner occupied | 1 if the house is owner occupied, 0 if else | 3 | 1,000 |
|  | (tenure)employer provided subsidised | 1 if the house is employer provided-subsidised, 0 if else | 2 | 0,667 |
|  | (tenure)employer provided free | 1 if the house is employer provided-free, 0 if else | 2 | 0,667 |
|  | (tenure)rent | 1 if the house is rented, 0 if else | 2 | 0,667 |
|  | (tenure)free | 1 if the house is free, 0 if else | 1 | 0,333 |
| Source of drinking water | (drink1)pipe inside | 1 if the main source of drinking water in the long rainy season is provided by a pipe inside the house, 0 if else | 7 | 1,000 |
|  | (drink1)pipe outside | 1 if the main source of drinking water in the long rainy season is provided by a pipe outside the house, 0 if else | 6 | 0,857 |
|  | (drink1)tap public | 1 if the main source of drinking water in the long rainy season is provided by a public standpipe or tap, 0 if else | 5 | 0,714 |
|  | (drink1)neighbour | 1 if the main source of drinking water in the long rainy season comes from a neighbouring household, 0 if else | 2 | 0,286 |
|  | (drink1)vendor | 1 if the main source of drinking water in the long rainy season is provided by a water vendor, 0 if else | 1 | 0,143 |
|  | (drink1)water truck/tanker service | 1 if the main source of drinking water in the long rainy season is provided by a water vendor, 0 if else | 1 | 0,143 |
|  | (drink1)well with pump | 1 if the main source of drinking water in the long rainy season is a well with a pump, 0 if else | 4 | 0,571 |
|  | (drink1)well without pump | 1 if the main source of drinking water in the long rainy season is a well witout pump, 0 if else | 3 | 0,429 |
|  | (drink1)river, lake, spring or pond | 1 if the main source of drinking water in the long rainy season is a river, lake, spring or pond, 0 if else | 2 | 0,286 |
|  | (drink1)rain | 1 if the main source of drinking water in the long rainy season is rainwater, 0 if else | 2 | 0,286 |
|  | (drink1)other | 1 if the main source of drinking water in the long rainy season is none of the above, 0 if else | 4 | 0,571 |
| Fuel for cooking | (cook) firewood | 1 if the main cooking fuel used is firewood, 0 if else | 4 | 0,667 |
|  | (cook)paraffin | 1 if the main cooking fuel used is paraffin, 0 if else | 6 | 1,000 |
|  | (cook)electricity | 1 if the main cooking fuel used is electricity, 0 if else | 5 | 0,833 |
|  | (cook)gas | 1 if the main cooking fuel used is gas, 0 if else | 3 | 0,500 |
|  | (cook)charcoal | 1 if the main cooking fuel used is charcoal, 0 if else | 2 | 0,333 |
|  | (cook)animal residue | 1 if the main cooking fuel used is animal residue, 0 if else | 4 | 0,667 |
|  | (cook)other | 1 if the main cooking fuel used is none of the above, 0 if else | 3 | 0,500 |
| Fuel for lighting | (light) electricity | 1 if the main lighting fuel is electricity, 0 if else | 4 | 1,000 |
|  | (light)solar | 1 if the main lighting fuel is solar energy, 0 if else | 3 | 0,750 |
|  | (light)biogas | 1 if the main lighting fuel is biogas, 0 if else | 3 | 0,750 |
|  | (light)gas | 1 if the main lighting fuel is gas, 0 if else | 3 | 0,750 |
|  | (light)lamp oil | 1 if the main lighting fuel is lamp oil, 0 if else | 2 | 0,500 |
|  | (light)candle | 1 if the main lighting fuel is a candle 0 if else | 1 | 0,250 |
|  | (light)firewood | 1 if the main lighting fuel is firewook, 0 if else | 1 | 0,250 |
|  | (light)private generator | 1 if the main lighting fuel is a private generator, 0 if else | 4 | 1,000 |
|  | (light)other | 1 if the main lighting fuel is none of the above, 0 if else | 2 | 0,500 |

# ANNEX 4 Endogeneity test

## Dietary diversity score

First stage: Hybrid seed use

#First Stage  
DDS1 <- lm(hybrd1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
  
  
summary(DDS1)

##   
## Call:  
## lm(formula = hybrd1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.92475 -0.23709 -0.05521 0.10945 1.06765   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -7.443e-01 1.489e-01 -4.998 6.35e-07 \*\*\*  
## subseed1 4.253e-01 2.756e-02 15.432 < 2e-16 \*\*\*  
## dishybrd1 2.700e-01 4.708e-02 5.734 1.14e-08 \*\*\*  
## subfert1 9.144e-02 8.509e-02 1.075 0.2827   
## disfert1 1.740e-02 3.901e-02 0.446 0.6556   
## fem\_head 4.326e-03 2.073e-02 0.209 0.8347   
## ed\_any 2.958e-02 1.982e-02 1.492 0.1359   
## hhsize 2.569e-03 3.103e-03 0.828 0.4079   
## dependency 2.620e-04 3.816e-04 0.686 0.4925   
## log(income + 1) 4.396e-03 2.714e-03 1.619 0.1055   
## log(off\_farm\_income\_hh + 1) -1.572e-03 1.433e-03 -1.097 0.2727   
## log(area\_tot) 1.709e-03 9.523e-03 0.179 0.8576   
## log(asset) 2.043e-02 5.760e-03 3.547 0.0004 \*\*\*  
## log(TLU + 1) -8.070e-05 1.201e-02 -0.007 0.9946   
## hqi 1.024e-01 1.699e-02 6.027 2.01e-09 \*\*\*  
## SACCO 3.732e-02 3.365e-02 1.109 0.2676   
## factor(ZONE)EASTERN 9.161e-02 4.958e-02 1.847 0.0648 .   
## factor(ZONE)LAKE 9.635e-02 4.464e-02 2.159 0.0310 \*   
## factor(ZONE)NORTHERN 9.788e-02 3.853e-02 2.540 0.0112 \*   
## factor(ZONE)SOUTHERN 3.715e-02 4.211e-02 0.882 0.3778   
## factor(ZONE)SOUTHERN-HIGHLANDS 4.415e-02 4.129e-02 1.069 0.2851   
## factor(ZONE)WESTERN 9.020e-02 4.005e-02 2.252 0.0244 \*   
## avgpPrecip -4.136e-05 3.265e-05 -1.267 0.2054   
## avgTemp -3.541e-04 4.206e-04 -0.842 0.3999   
## dist2town -3.424e-04 3.114e-04 -1.100 0.2716   
## dist2market -1.596e-04 2.181e-04 -0.732 0.4644   
## factor(surveyyear)2012 4.049e-01 3.220e-02 12.575 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3415 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3042, Adjusted R-squared: 0.2945   
## F-statistic: 31.19 on 26 and 1855 DF, p-value: < 2.2e-16

Dietary diversity score First stage: fertiliser use

DDS2 <- lm(fert1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
summary(DDS2)

##   
## Call:  
## lm(formula = fert1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.84899 -0.15252 -0.04695 0.06643 1.01255   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.470e-01 1.354e-01 -1.086 0.277793   
## subseed1 2.626e-02 2.506e-02 1.048 0.294833   
## dishybrd1 -2.155e-02 4.280e-02 -0.504 0.614645   
## subfert1 4.198e-01 7.736e-02 5.427 6.50e-08 \*\*\*  
## disfert1 5.925e-01 3.547e-02 16.706 < 2e-16 \*\*\*  
## fem\_head 2.709e-02 1.884e-02 1.438 0.150718   
## ed\_any 3.978e-02 1.802e-02 2.207 0.027407 \*   
## hhsize -3.986e-03 2.821e-03 -1.413 0.157846   
## dependency 3.228e-04 3.470e-04 0.930 0.352286   
## log(income + 1) 9.011e-03 2.468e-03 3.652 0.000268 \*\*\*  
## log(off\_farm\_income\_hh + 1) -1.919e-03 1.303e-03 -1.474 0.140758   
## log(area\_tot) 4.621e-02 8.658e-03 5.338 1.06e-07 \*\*\*  
## log(asset) 1.030e-02 5.237e-03 1.966 0.049422 \*   
## log(TLU + 1) -3.155e-02 1.092e-02 -2.890 0.003900 \*\*   
## hqi 9.671e-02 1.544e-02 6.262 4.71e-10 \*\*\*  
## SACCO 7.663e-02 3.059e-02 2.505 0.012336 \*   
## factor(ZONE)EASTERN 2.430e-02 4.508e-02 0.539 0.589855   
## factor(ZONE)LAKE 2.624e-02 4.058e-02 0.647 0.517988   
## factor(ZONE)NORTHERN 1.284e-02 3.503e-02 0.366 0.714056   
## factor(ZONE)SOUTHERN 8.487e-02 3.829e-02 2.217 0.026762 \*   
## factor(ZONE)SOUTHERN-HIGHLANDS 1.339e-02 3.754e-02 0.357 0.721290   
## factor(ZONE)WESTERN 1.856e-02 3.641e-02 0.510 0.610383   
## avgpPrecip 4.412e-07 2.968e-05 0.015 0.988142   
## avgTemp -2.028e-03 3.824e-04 -5.304 1.27e-07 \*\*\*  
## dist2town -2.411e-04 2.831e-04 -0.852 0.394480   
## dist2market 5.842e-05 1.982e-04 0.295 0.768265   
## factor(surveyyear)2012 2.101e-02 2.928e-02 0.718 0.473105   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3105 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3639, Adjusted R-squared: 0.355   
## F-statistic: 40.81 on 26 and 1855 DF, p-value: < 2.2e-16

Dietary diversity score Second stage

# Second Stage  
DDSi <- ivreg(DDS ~ hybrd1 + fert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear)|  
 fem\_head + ed\_any+ hhsize + dependency + log(income+1)++ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+hqi +  
 SACCO + factor(ZONE) + avgpPrecip  
 + avgTemp + dist2town + dist2market+factor(surveyyear) +subseed1 + dishybrd1+ subfert1 + disfert1, data=Data2010\_2012maize)  
  
summary(DDSi, diagnostics=TRUE)

##   
## Call:  
## ivreg(formula = DDS ~ hybrd1 + fert1 + fem\_head + ed\_any + hhsize +   
## dependency + log(income + 1) + log(off\_farm\_income\_hh + 1) +   
## log(area\_tot) + log(asset) + log(TLU + 1) + hqi + SACCO +   
## factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market +   
## factor(surveyyear) | fem\_head + ed\_any + hhsize + dependency +   
## log(income + 1) + +log(off\_farm\_income\_hh + 1) + log(area\_tot) +   
## log(asset) + log(TLU + 1) + hqi + SACCO + factor(ZONE) +   
## avgpPrecip + avgTemp + dist2town + dist2market + factor(surveyyear) +   
## subseed1 + dishybrd1 + subfert1 + disfert1, data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -8.69519 -1.04204 0.08301 1.12612 4.44061   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 1.9346217 0.7644432 2.531 0.011464 \*   
## hybrd1 0.0993569 0.2933405 0.339 0.734868   
## fert1 0.3560570 0.2885500 1.234 0.217377   
## fem\_head -0.0498148 0.1015271 -0.491 0.623728   
## ed\_any 0.6414573 0.0982587 6.528 8.56e-11 \*\*\*  
## hhsize -0.0116072 0.0152742 -0.760 0.447397   
## dependency -0.0028065 0.0018695 -1.501 0.133476   
## log(income + 1) 0.0705985 0.0135357 5.216 2.04e-07 \*\*\*  
## log(off\_farm\_income\_hh + 1) 0.0135412 0.0070166 1.930 0.053775 .   
## log(area\_tot) 0.0795682 0.0483469 1.646 0.099979 .   
## log(asset) 0.0593595 0.0293511 2.022 0.043279 \*   
## log(TLU + 1) -0.1271896 0.0595757 -2.135 0.032898 \*   
## hqi 0.6370344 0.0953324 6.682 3.10e-11 \*\*\*  
## SACCO 0.3288681 0.1663137 1.977 0.048145 \*   
## factor(ZONE)EASTERN 0.9654858 0.2445650 3.948 8.18e-05 \*\*\*  
## factor(ZONE)LAKE 0.4081902 0.2204709 1.851 0.064264 .   
## factor(ZONE)NORTHERN 0.8837635 0.1923109 4.595 4.61e-06 \*\*\*  
## factor(ZONE)SOUTHERN -0.1015789 0.2095781 -0.485 0.627959   
## factor(ZONE)SOUTHERN-HIGHLANDS -0.0548156 0.2009937 -0.273 0.785096   
## factor(ZONE)WESTERN 0.2319462 0.1982204 1.170 0.242094   
## avgpPrecip 0.0005943 0.0001608 3.695 0.000226 \*\*\*  
## avgTemp 0.0024154 0.0023065 1.047 0.295131   
## dist2town -0.0054555 0.0015339 -3.557 0.000385 \*\*\*  
## dist2market 0.0017120 0.0010638 1.609 0.107706   
## factor(surveyyear)2012 1.0375170 0.1940150 5.348 1.00e-07 \*\*\*  
##   
## Diagnostic tests:  
## df1 df2 statistic p-value   
## Weak instruments (hybrd1) 4 1855 72.873 <2e-16 \*\*\*  
## Weak instruments (fert1) 4 1855 91.114 <2e-16 \*\*\*  
## Wu-Hausman 2 1855 0.069 0.933   
## Sargan 2 NA 1.195 0.550   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 1.67 on 1857 degrees of freedom  
## Multiple R-Squared: 0.2402, Adjusted R-squared: 0.2304   
## Wald test: 24.05 on 24 and 1857 DF, p-value: < 2.2e-16

Food Variety Score First stage: Hybrid seed use

#First Stage  
FVS1 <- lm(hybrd1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
  
  
summary(FVS1)

##   
## Call:  
## lm(formula = hybrd1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.92475 -0.23709 -0.05521 0.10945 1.06765   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -7.443e-01 1.489e-01 -4.998 6.35e-07 \*\*\*  
## subseed1 4.253e-01 2.756e-02 15.432 < 2e-16 \*\*\*  
## dishybrd1 2.700e-01 4.708e-02 5.734 1.14e-08 \*\*\*  
## subfert1 9.144e-02 8.509e-02 1.075 0.2827   
## disfert1 1.740e-02 3.901e-02 0.446 0.6556   
## fem\_head 4.326e-03 2.073e-02 0.209 0.8347   
## ed\_any 2.958e-02 1.982e-02 1.492 0.1359   
## hhsize 2.569e-03 3.103e-03 0.828 0.4079   
## dependency 2.620e-04 3.816e-04 0.686 0.4925   
## log(income + 1) 4.396e-03 2.714e-03 1.619 0.1055   
## log(off\_farm\_income\_hh + 1) -1.572e-03 1.433e-03 -1.097 0.2727   
## log(area\_tot) 1.709e-03 9.523e-03 0.179 0.8576   
## log(asset) 2.043e-02 5.760e-03 3.547 0.0004 \*\*\*  
## log(TLU + 1) -8.070e-05 1.201e-02 -0.007 0.9946   
## hqi 1.024e-01 1.699e-02 6.027 2.01e-09 \*\*\*  
## SACCO 3.732e-02 3.365e-02 1.109 0.2676   
## factor(ZONE)EASTERN 9.161e-02 4.958e-02 1.847 0.0648 .   
## factor(ZONE)LAKE 9.635e-02 4.464e-02 2.159 0.0310 \*   
## factor(ZONE)NORTHERN 9.788e-02 3.853e-02 2.540 0.0112 \*   
## factor(ZONE)SOUTHERN 3.715e-02 4.211e-02 0.882 0.3778   
## factor(ZONE)SOUTHERN-HIGHLANDS 4.415e-02 4.129e-02 1.069 0.2851   
## factor(ZONE)WESTERN 9.020e-02 4.005e-02 2.252 0.0244 \*   
## avgpPrecip -4.136e-05 3.265e-05 -1.267 0.2054   
## avgTemp -3.541e-04 4.206e-04 -0.842 0.3999   
## dist2town -3.424e-04 3.114e-04 -1.100 0.2716   
## dist2market -1.596e-04 2.181e-04 -0.732 0.4644   
## factor(surveyyear)2012 4.049e-01 3.220e-02 12.575 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3415 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3042, Adjusted R-squared: 0.2945   
## F-statistic: 31.19 on 26 and 1855 DF, p-value: < 2.2e-16

Food Variety Score First stage: fertiliser use

FVS2 <- lm(fert1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
summary(FVS2)

##   
## Call:  
## lm(formula = fert1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.84899 -0.15252 -0.04695 0.06643 1.01255   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.470e-01 1.354e-01 -1.086 0.277793   
## subseed1 2.626e-02 2.506e-02 1.048 0.294833   
## dishybrd1 -2.155e-02 4.280e-02 -0.504 0.614645   
## subfert1 4.198e-01 7.736e-02 5.427 6.50e-08 \*\*\*  
## disfert1 5.925e-01 3.547e-02 16.706 < 2e-16 \*\*\*  
## fem\_head 2.709e-02 1.884e-02 1.438 0.150718   
## ed\_any 3.978e-02 1.802e-02 2.207 0.027407 \*   
## hhsize -3.986e-03 2.821e-03 -1.413 0.157846   
## dependency 3.228e-04 3.470e-04 0.930 0.352286   
## log(income + 1) 9.011e-03 2.468e-03 3.652 0.000268 \*\*\*  
## log(off\_farm\_income\_hh + 1) -1.919e-03 1.303e-03 -1.474 0.140758   
## log(area\_tot) 4.621e-02 8.658e-03 5.338 1.06e-07 \*\*\*  
## log(asset) 1.030e-02 5.237e-03 1.966 0.049422 \*   
## log(TLU + 1) -3.155e-02 1.092e-02 -2.890 0.003900 \*\*   
## hqi 9.671e-02 1.544e-02 6.262 4.71e-10 \*\*\*  
## SACCO 7.663e-02 3.059e-02 2.505 0.012336 \*   
## factor(ZONE)EASTERN 2.430e-02 4.508e-02 0.539 0.589855   
## factor(ZONE)LAKE 2.624e-02 4.058e-02 0.647 0.517988   
## factor(ZONE)NORTHERN 1.284e-02 3.503e-02 0.366 0.714056   
## factor(ZONE)SOUTHERN 8.487e-02 3.829e-02 2.217 0.026762 \*   
## factor(ZONE)SOUTHERN-HIGHLANDS 1.339e-02 3.754e-02 0.357 0.721290   
## factor(ZONE)WESTERN 1.856e-02 3.641e-02 0.510 0.610383   
## avgpPrecip 4.412e-07 2.968e-05 0.015 0.988142   
## avgTemp -2.028e-03 3.824e-04 -5.304 1.27e-07 \*\*\*  
## dist2town -2.411e-04 2.831e-04 -0.852 0.394480   
## dist2market 5.842e-05 1.982e-04 0.295 0.768265   
## factor(surveyyear)2012 2.101e-02 2.928e-02 0.718 0.473105   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3105 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3639, Adjusted R-squared: 0.355   
## F-statistic: 40.81 on 26 and 1855 DF, p-value: < 2.2e-16

Food variety score Second stage

# Second Stage  
FVSi <- ivreg(FVS ~ hybrd1 + fert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear)|  
 fem\_head + ed\_any+ hhsize + dependency + log(income+1)++ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+hqi +  
 SACCO + factor(ZONE) + avgpPrecip  
 + avgTemp + dist2town + dist2market+factor(surveyyear) +subseed1 + dishybrd1+ subfert1 + disfert1, data=Data2010\_2012maize)  
  
summary(FVSi, diagnostics=TRUE)

##   
## Call:  
## ivreg(formula = FVS ~ hybrd1 + fert1 + fem\_head + ed\_any + hhsize +   
## dependency + log(income + 1) + log(off\_farm\_income\_hh + 1) +   
## log(area\_tot) + log(asset) + log(TLU + 1) + hqi + SACCO +   
## factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market +   
## factor(surveyyear) | fem\_head + ed\_any + hhsize + dependency +   
## log(income + 1) + +log(off\_farm\_income\_hh + 1) + log(area\_tot) +   
## log(asset) + log(TLU + 1) + hqi + SACCO + factor(ZONE) +   
## avgpPrecip + avgTemp + dist2town + dist2market + factor(surveyyear) +   
## subseed1 + dishybrd1 + subfert1 + disfert1, data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -14.6385 -2.7998 -0.3316 2.4811 18.7957   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -5.9066686 1.9230315 -3.072 0.002160 \*\*   
## hybrd1 0.5854508 0.7379266 0.793 0.427662   
## fert1 -0.0659786 0.7258758 -0.091 0.927586   
## fem\_head -0.0339649 0.2554013 -0.133 0.894219   
## ed\_any 1.6205197 0.2471793 6.556 7.14e-11 \*\*\*  
## hhsize -0.0497375 0.0384237 -1.294 0.195671   
## dependency -0.0046727 0.0047029 -0.994 0.320557   
## log(income + 1) 0.1542848 0.0340503 4.531 6.24e-06 \*\*\*  
## log(off\_farm\_income\_hh + 1) 0.0607093 0.0176510 3.439 0.000596 \*\*\*  
## log(area\_tot) 0.3291834 0.1216214 2.707 0.006859 \*\*   
## log(asset) 0.1993918 0.0738356 2.700 0.006987 \*\*   
## log(TLU + 1) -0.3712037 0.1498686 -2.477 0.013343 \*   
## hqi 2.3124323 0.2398180 9.642 < 2e-16 \*\*\*  
## SACCO 1.4578286 0.4183784 3.484 0.000505 \*\*\*  
## factor(ZONE)EASTERN 1.8394886 0.6152271 2.990 0.002827 \*\*   
## factor(ZONE)LAKE -0.0212150 0.5546160 -0.038 0.969491   
## factor(ZONE)NORTHERN 1.7935934 0.4837770 3.707 0.000215 \*\*\*  
## factor(ZONE)SOUTHERN -1.0436663 0.5272143 -1.980 0.047897 \*   
## factor(ZONE)SOUTHERN-HIGHLANDS -0.8059247 0.5056192 -1.594 0.111121   
## factor(ZONE)WESTERN -0.5513558 0.4986427 -1.106 0.268994   
## avgpPrecip 0.0015036 0.0004046 3.716 0.000208 \*\*\*  
## avgTemp 0.0143287 0.0058022 2.470 0.013618 \*   
## dist2town -0.0082043 0.0038586 -2.126 0.033614 \*   
## dist2market 0.0036541 0.0026761 1.365 0.172280   
## factor(surveyyear)2012 1.4912706 0.4880637 3.055 0.002279 \*\*   
##   
## Diagnostic tests:  
## df1 df2 statistic p-value   
## Weak instruments (hybrd1) 4 1855 72.873 <2e-16 \*\*\*  
## Weak instruments (fert1) 4 1855 91.114 <2e-16 \*\*\*  
## Wu-Hausman 2 1855 0.418 0.658   
## Sargan 2 NA 0.912 0.634   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 4.201 on 1857 degrees of freedom  
## Multiple R-Squared: 0.2661, Adjusted R-squared: 0.2566   
## Wald test: 28.05 on 24 and 1857 DF, p-value: < 2.2e-16

## Food consumption score

First stage: Hybrid seed use

#First Stage  
FCS1 <- lm(hybrd1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
  
  
summary(FCS1)

##   
## Call:  
## lm(formula = hybrd1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.92475 -0.23709 -0.05521 0.10945 1.06765   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -7.443e-01 1.489e-01 -4.998 6.35e-07 \*\*\*  
## subseed1 4.253e-01 2.756e-02 15.432 < 2e-16 \*\*\*  
## dishybrd1 2.700e-01 4.708e-02 5.734 1.14e-08 \*\*\*  
## subfert1 9.144e-02 8.509e-02 1.075 0.2827   
## disfert1 1.740e-02 3.901e-02 0.446 0.6556   
## fem\_head 4.326e-03 2.073e-02 0.209 0.8347   
## ed\_any 2.958e-02 1.982e-02 1.492 0.1359   
## hhsize 2.569e-03 3.103e-03 0.828 0.4079   
## dependency 2.620e-04 3.816e-04 0.686 0.4925   
## log(income + 1) 4.396e-03 2.714e-03 1.619 0.1055   
## log(off\_farm\_income\_hh + 1) -1.572e-03 1.433e-03 -1.097 0.2727   
## log(area\_tot) 1.709e-03 9.523e-03 0.179 0.8576   
## log(asset) 2.043e-02 5.760e-03 3.547 0.0004 \*\*\*  
## log(TLU + 1) -8.070e-05 1.201e-02 -0.007 0.9946   
## hqi 1.024e-01 1.699e-02 6.027 2.01e-09 \*\*\*  
## SACCO 3.732e-02 3.365e-02 1.109 0.2676   
## factor(ZONE)EASTERN 9.161e-02 4.958e-02 1.847 0.0648 .   
## factor(ZONE)LAKE 9.635e-02 4.464e-02 2.159 0.0310 \*   
## factor(ZONE)NORTHERN 9.788e-02 3.853e-02 2.540 0.0112 \*   
## factor(ZONE)SOUTHERN 3.715e-02 4.211e-02 0.882 0.3778   
## factor(ZONE)SOUTHERN-HIGHLANDS 4.415e-02 4.129e-02 1.069 0.2851   
## factor(ZONE)WESTERN 9.020e-02 4.005e-02 2.252 0.0244 \*   
## avgpPrecip -4.136e-05 3.265e-05 -1.267 0.2054   
## avgTemp -3.541e-04 4.206e-04 -0.842 0.3999   
## dist2town -3.424e-04 3.114e-04 -1.100 0.2716   
## dist2market -1.596e-04 2.181e-04 -0.732 0.4644   
## factor(surveyyear)2012 4.049e-01 3.220e-02 12.575 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3415 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3042, Adjusted R-squared: 0.2945   
## F-statistic: 31.19 on 26 and 1855 DF, p-value: < 2.2e-16

Food consumption score First stage: fertiliser use

FCS2 <- lm(fert1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
summary(FCS2)

##   
## Call:  
## lm(formula = fert1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.84899 -0.15252 -0.04695 0.06643 1.01255   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.470e-01 1.354e-01 -1.086 0.277793   
## subseed1 2.626e-02 2.506e-02 1.048 0.294833   
## dishybrd1 -2.155e-02 4.280e-02 -0.504 0.614645   
## subfert1 4.198e-01 7.736e-02 5.427 6.50e-08 \*\*\*  
## disfert1 5.925e-01 3.547e-02 16.706 < 2e-16 \*\*\*  
## fem\_head 2.709e-02 1.884e-02 1.438 0.150718   
## ed\_any 3.978e-02 1.802e-02 2.207 0.027407 \*   
## hhsize -3.986e-03 2.821e-03 -1.413 0.157846   
## dependency 3.228e-04 3.470e-04 0.930 0.352286   
## log(income + 1) 9.011e-03 2.468e-03 3.652 0.000268 \*\*\*  
## log(off\_farm\_income\_hh + 1) -1.919e-03 1.303e-03 -1.474 0.140758   
## log(area\_tot) 4.621e-02 8.658e-03 5.338 1.06e-07 \*\*\*  
## log(asset) 1.030e-02 5.237e-03 1.966 0.049422 \*   
## log(TLU + 1) -3.155e-02 1.092e-02 -2.890 0.003900 \*\*   
## hqi 9.671e-02 1.544e-02 6.262 4.71e-10 \*\*\*  
## SACCO 7.663e-02 3.059e-02 2.505 0.012336 \*   
## factor(ZONE)EASTERN 2.430e-02 4.508e-02 0.539 0.589855   
## factor(ZONE)LAKE 2.624e-02 4.058e-02 0.647 0.517988   
## factor(ZONE)NORTHERN 1.284e-02 3.503e-02 0.366 0.714056   
## factor(ZONE)SOUTHERN 8.487e-02 3.829e-02 2.217 0.026762 \*   
## factor(ZONE)SOUTHERN-HIGHLANDS 1.339e-02 3.754e-02 0.357 0.721290   
## factor(ZONE)WESTERN 1.856e-02 3.641e-02 0.510 0.610383   
## avgpPrecip 4.412e-07 2.968e-05 0.015 0.988142   
## avgTemp -2.028e-03 3.824e-04 -5.304 1.27e-07 \*\*\*  
## dist2town -2.411e-04 2.831e-04 -0.852 0.394480   
## dist2market 5.842e-05 1.982e-04 0.295 0.768265   
## factor(surveyyear)2012 2.101e-02 2.928e-02 0.718 0.473105   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3105 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3639, Adjusted R-squared: 0.355   
## F-statistic: 40.81 on 26 and 1855 DF, p-value: < 2.2e-16

Food consumption score Second stage

# Second Stage  
FCSi <- ivreg(FCS ~ hybrd1 + fert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear)|  
 fem\_head + ed\_any+ hhsize + dependency + log(income+1)++ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+hqi +  
 SACCO + factor(ZONE) + avgpPrecip  
 + avgTemp + dist2town + dist2market+factor(surveyyear) +subseed1 + dishybrd1+ subfert1 + disfert1, data=Data2010\_2012maize)  
  
summary(FCSi, diagnostics=TRUE)

##   
## Call:  
## ivreg(formula = FCS ~ hybrd1 + fert1 + fem\_head + ed\_any + hhsize +   
## dependency + log(income + 1) + log(off\_farm\_income\_hh + 1) +   
## log(area\_tot) + log(asset) + log(TLU + 1) + hqi + SACCO +   
## factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market +   
## factor(surveyyear) | fem\_head + ed\_any + hhsize + dependency +   
## log(income + 1) + +log(off\_farm\_income\_hh + 1) + log(area\_tot) +   
## log(asset) + log(TLU + 1) + hqi + SACCO + factor(ZONE) +   
## avgpPrecip + avgTemp + dist2town + dist2market + factor(surveyyear) +   
## subseed1 + dishybrd1 + subfert1 + disfert1, data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -59.9729 -10.4874 -0.5898 9.5482 57.4815   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -9.025673 7.138594 -1.264 0.206264   
## hybrd1 1.608004 2.757258 0.583 0.559836   
## fert1 -0.860540 2.703863 -0.318 0.750321   
## fem\_head -0.066046 0.947840 -0.070 0.944455   
## ed\_any 3.337811 0.917445 3.638 0.000282 \*\*\*  
## hhsize 0.004416 0.142608 0.031 0.975299   
## dependency -0.009611 0.017458 -0.551 0.582011   
## log(income + 1) 0.230127 0.126369 1.821 0.068757 .   
## log(off\_farm\_income\_hh + 1) 0.122105 0.065522 1.864 0.062540 .   
## log(area\_tot) 1.195626 0.451608 2.647 0.008178 \*\*   
## log(asset) 0.524707 0.273929 1.915 0.055584 .   
## log(TLU + 1) 4.234969 0.556253 7.613 4.22e-14 \*\*\*  
## hqi 6.564173 0.889940 7.376 2.45e-13 \*\*\*  
## SACCO 5.240895 1.552611 3.376 0.000752 \*\*\*  
## factor(ZONE)EASTERN 4.671981 2.283029 2.046 0.040858 \*   
## factor(ZONE)LAKE 3.378337 2.058455 1.641 0.100925   
## factor(ZONE)NORTHERN 9.533174 1.795649 5.309 1.23e-07 \*\*\*  
## factor(ZONE)SOUTHERN -2.490781 1.957625 -1.272 0.203409   
## factor(ZONE)SOUTHERN-HIGHLANDS -0.544319 1.877952 -0.290 0.771966   
## factor(ZONE)WESTERN -1.794611 1.850464 -0.970 0.332264   
## avgpPrecip 0.002430 0.001501 1.619 0.105662   
## avgTemp 0.056922 0.021556 2.641 0.008344 \*\*   
## dist2town 0.001624 0.014319 0.113 0.909716   
## dist2market 0.010739 0.009931 1.081 0.279642   
## factor(surveyyear)2012 4.400288 1.813286 2.427 0.015332 \*   
##   
## Diagnostic tests:  
## df1 df2 statistic p-value   
## Weak instruments (hybrd1) 4 1854 72.196 <2e-16 \*\*\*  
## Weak instruments (fert1) 4 1854 90.735 <2e-16 \*\*\*  
## Wu-Hausman 2 1854 0.168 0.846   
## Sargan 2 NA 0.390 0.823   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 15.59 on 1856 degrees of freedom  
## Multiple R-Squared: 0.249, Adjusted R-squared: 0.2393   
## Wald test: 25.72 on 24 and 1856 DF, p-value: < 2.2e-16

## Coping strategy index

First stage: Hybrid seed use

#First Stage  
CSI1 <- lm(hybrd1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
  
  
summary(CSI1)

##   
## Call:  
## lm(formula = hybrd1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.92475 -0.23709 -0.05521 0.10945 1.06765   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -7.443e-01 1.489e-01 -4.998 6.35e-07 \*\*\*  
## subseed1 4.253e-01 2.756e-02 15.432 < 2e-16 \*\*\*  
## dishybrd1 2.700e-01 4.708e-02 5.734 1.14e-08 \*\*\*  
## subfert1 9.144e-02 8.509e-02 1.075 0.2827   
## disfert1 1.740e-02 3.901e-02 0.446 0.6556   
## fem\_head 4.326e-03 2.073e-02 0.209 0.8347   
## ed\_any 2.958e-02 1.982e-02 1.492 0.1359   
## hhsize 2.569e-03 3.103e-03 0.828 0.4079   
## dependency 2.620e-04 3.816e-04 0.686 0.4925   
## log(income + 1) 4.396e-03 2.714e-03 1.619 0.1055   
## log(off\_farm\_income\_hh + 1) -1.572e-03 1.433e-03 -1.097 0.2727   
## log(area\_tot) 1.709e-03 9.523e-03 0.179 0.8576   
## log(asset) 2.043e-02 5.760e-03 3.547 0.0004 \*\*\*  
## log(TLU + 1) -8.070e-05 1.201e-02 -0.007 0.9946   
## hqi 1.024e-01 1.699e-02 6.027 2.01e-09 \*\*\*  
## SACCO 3.732e-02 3.365e-02 1.109 0.2676   
## factor(ZONE)EASTERN 9.161e-02 4.958e-02 1.847 0.0648 .   
## factor(ZONE)LAKE 9.635e-02 4.464e-02 2.159 0.0310 \*   
## factor(ZONE)NORTHERN 9.788e-02 3.853e-02 2.540 0.0112 \*   
## factor(ZONE)SOUTHERN 3.715e-02 4.211e-02 0.882 0.3778   
## factor(ZONE)SOUTHERN-HIGHLANDS 4.415e-02 4.129e-02 1.069 0.2851   
## factor(ZONE)WESTERN 9.020e-02 4.005e-02 2.252 0.0244 \*   
## avgpPrecip -4.136e-05 3.265e-05 -1.267 0.2054   
## avgTemp -3.541e-04 4.206e-04 -0.842 0.3999   
## dist2town -3.424e-04 3.114e-04 -1.100 0.2716   
## dist2market -1.596e-04 2.181e-04 -0.732 0.4644   
## factor(surveyyear)2012 4.049e-01 3.220e-02 12.575 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3415 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3042, Adjusted R-squared: 0.2945   
## F-statistic: 31.19 on 26 and 1855 DF, p-value: < 2.2e-16

Coping strategy index First stage: fertiliser use

CSI2 <- lm(fert1 ~ subseed1 + dishybrd1+ subfert1 + disfert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear), data=Data2010\_2012maize)  
summary(CSI2)

##   
## Call:  
## lm(formula = fert1 ~ subseed1 + dishybrd1 + subfert1 + disfert1 +   
## fem\_head + ed\_any + hhsize + dependency + log(income + 1) +   
## log(off\_farm\_income\_hh + 1) + log(area\_tot) + log(asset) +   
## log(TLU + 1) + hqi + SACCO + factor(ZONE) + avgpPrecip +   
## avgTemp + dist2town + dist2market + factor(surveyyear), data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.84899 -0.15252 -0.04695 0.06643 1.01255   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.470e-01 1.354e-01 -1.086 0.277793   
## subseed1 2.626e-02 2.506e-02 1.048 0.294833   
## dishybrd1 -2.155e-02 4.280e-02 -0.504 0.614645   
## subfert1 4.198e-01 7.736e-02 5.427 6.50e-08 \*\*\*  
## disfert1 5.925e-01 3.547e-02 16.706 < 2e-16 \*\*\*  
## fem\_head 2.709e-02 1.884e-02 1.438 0.150718   
## ed\_any 3.978e-02 1.802e-02 2.207 0.027407 \*   
## hhsize -3.986e-03 2.821e-03 -1.413 0.157846   
## dependency 3.228e-04 3.470e-04 0.930 0.352286   
## log(income + 1) 9.011e-03 2.468e-03 3.652 0.000268 \*\*\*  
## log(off\_farm\_income\_hh + 1) -1.919e-03 1.303e-03 -1.474 0.140758   
## log(area\_tot) 4.621e-02 8.658e-03 5.338 1.06e-07 \*\*\*  
## log(asset) 1.030e-02 5.237e-03 1.966 0.049422 \*   
## log(TLU + 1) -3.155e-02 1.092e-02 -2.890 0.003900 \*\*   
## hqi 9.671e-02 1.544e-02 6.262 4.71e-10 \*\*\*  
## SACCO 7.663e-02 3.059e-02 2.505 0.012336 \*   
## factor(ZONE)EASTERN 2.430e-02 4.508e-02 0.539 0.589855   
## factor(ZONE)LAKE 2.624e-02 4.058e-02 0.647 0.517988   
## factor(ZONE)NORTHERN 1.284e-02 3.503e-02 0.366 0.714056   
## factor(ZONE)SOUTHERN 8.487e-02 3.829e-02 2.217 0.026762 \*   
## factor(ZONE)SOUTHERN-HIGHLANDS 1.339e-02 3.754e-02 0.357 0.721290   
## factor(ZONE)WESTERN 1.856e-02 3.641e-02 0.510 0.610383   
## avgpPrecip 4.412e-07 2.968e-05 0.015 0.988142   
## avgTemp -2.028e-03 3.824e-04 -5.304 1.27e-07 \*\*\*  
## dist2town -2.411e-04 2.831e-04 -0.852 0.394480   
## dist2market 5.842e-05 1.982e-04 0.295 0.768265   
## factor(surveyyear)2012 2.101e-02 2.928e-02 0.718 0.473105   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3105 on 1855 degrees of freedom  
## (1440 observations deleted due to missingness)  
## Multiple R-squared: 0.3639, Adjusted R-squared: 0.355   
## F-statistic: 40.81 on 26 and 1855 DF, p-value: < 2.2e-16

Coping strategy index Second stage

# Second Stage  
CSIi <- ivreg(CSI ~ hybrd1 + fert1 + fem\_head + ed\_any+ hhsize + dependency + log(income+1)+ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+ hqi +  
 SACCO + factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market+factor(surveyyear)|  
 fem\_head + ed\_any+ hhsize + dependency + log(income+1)++ log(off\_farm\_income\_hh+1)++ log(off\_farm\_income\_hh+1) +  
 log(area\_tot) + log(asset) + log(TLU+1)+hqi +  
 SACCO + factor(ZONE) + avgpPrecip  
 + avgTemp + dist2town + dist2market+factor(surveyyear) +subseed1 + dishybrd1+ subfert1 + disfert1, data=Data2010\_2012maize)  
  
summary(CSIi, diagnostics=TRUE)

##   
## Call:  
## ivreg(formula = CSI ~ hybrd1 + fert1 + fem\_head + ed\_any + hhsize +   
## dependency + log(income + 1) + log(off\_farm\_income\_hh + 1) +   
## log(area\_tot) + log(asset) + log(TLU + 1) + hqi + SACCO +   
## factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market +   
## factor(surveyyear) | fem\_head + ed\_any + hhsize + dependency +   
## log(income + 1) + +log(off\_farm\_income\_hh + 1) + +log(off\_farm\_income\_hh +   
## 1) + log(area\_tot) + log(asset) + log(TLU + 1) + hqi + SACCO +   
## factor(ZONE) + avgpPrecip + avgTemp + dist2town + dist2market +   
## factor(surveyyear) + subseed1 + dishybrd1 + subfert1 + disfert1,   
## data = Data2010\_2012maize)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -9.2399 -3.3468 -1.7073 0.7566 60.6821   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 12.0182557 2.9894793 4.020 6.05e-05 \*\*\*  
## hybrd1 1.6993469 1.1471555 1.481 0.138681   
## fert1 -1.4943547 1.1284218 -1.324 0.185571   
## fem\_head 1.2948106 0.3970381 3.261 0.001130 \*\*   
## ed\_any -1.0307613 0.3842565 -2.682 0.007373 \*\*   
## hhsize 0.0841976 0.0597321 1.410 0.158829   
## dependency 0.0169675 0.0073110 2.321 0.020405 \*   
## log(income + 1) -0.1114682 0.0529334 -2.106 0.035354 \*   
## log(off\_farm\_income\_hh + 1) 0.0397976 0.0274397 1.450 0.147125   
## log(area\_tot) -0.4427532 0.1890685 -2.342 0.019298 \*   
## log(asset) -0.2118835 0.1147823 -1.846 0.065057 .   
## log(TLU + 1) -0.4152890 0.2329806 -1.783 0.074830 .   
## hqi -1.2942971 0.3728129 -3.472 0.000529 \*\*\*  
## SACCO -0.4038742 0.6503969 -0.621 0.534698   
## factor(ZONE)EASTERN 0.1641242 0.9564111 0.172 0.863767   
## factor(ZONE)LAKE 1.0900760 0.8621871 1.264 0.206276   
## factor(ZONE)NORTHERN -0.3776728 0.7520632 -0.502 0.615599   
## factor(ZONE)SOUTHERN 1.1660920 0.8195894 1.423 0.154969   
## factor(ZONE)SOUTHERN-HIGHLANDS 0.2644765 0.7860185 0.336 0.736550   
## factor(ZONE)WESTERN 1.0857225 0.7751730 1.401 0.161495   
## avgpPrecip -0.0004871 0.0006290 -0.774 0.438773   
## avgTemp 0.0024542 0.0090198 0.272 0.785581   
## dist2town 0.0056101 0.0059984 0.935 0.349777   
## dist2market -0.0136566 0.0041602 -3.283 0.001047 \*\*   
## factor(surveyyear)2012 -0.9016151 0.7587273 -1.188 0.234857   
##   
## Diagnostic tests:  
## df1 df2 statistic p-value   
## Weak instruments (hybrd1) 4 1855 72.873 <2e-16 \*\*\*  
## Weak instruments (fert1) 4 1855 91.114 <2e-16 \*\*\*  
## Wu-Hausman 2 1855 1.754 0.173   
## Sargan 2 NA 3.852 0.146   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 6.531 on 1857 degrees of freedom  
## Multiple R-Squared: 0.0632, Adjusted R-squared: 0.05109   
## Wald test: 6.239 on 24 and 1857 DF, p-value: < 2.2e-16

# ANNEX 5 Interviews

## Interview 1: Health volunteer peacecorps Santilya

Q: What can you tell me about maize production in your village?

A: I recently did a needs assessment involving interviews with local villagers. I did ten to twelve interviews in subvillages, asking 5 very simple questions. A lot came up about agriculture. You can stay in Santilya for a few days. Mbeya is one of the largest food producing regions. Now (july) is the dry season. Water is the biggest health issue here. Also when it comes to agriculture. Women need to hike down to the river to carry water on their head to the plots. Most people maintain the home garden and the shambo (farm). They are mostly pastoralists or farmers. They rely or their shambo for both income and food subsistence, but some of them have a little store or other side activity. Food from the shambo is sometimes supplemented with a home garden.

Q: What are the biggest problems in your view?

A: People do not know which foods are healthy. They know that they have a nutrition problem, but they do not know how to solve it. The village (Santilya) is very isolated with no access to resources.

Q: How does this relate to agricultural input use in your opinion?

A: The government gives away two bags of fertiliser to each farm, which is almost nothing. This is not really helping, it is like putting a band aid on a gushing wound really. People need more fertiliser or need to make it from manure. But there is always the issue of transportation. People all think that fertiliser would help! For better crop production and higher yields, but they do not have any money. Then there is the gender problem. Women do all the work, but the men receive the money. They often do not know what to do with it.

Q: Did you interview the women as well?

A: Women do not talk. In our village there are very bad domestic abuse and alcohol abuse problems.

[…]

People know that they need more variety in their diet. In my view, they do not need more corn.

Q: What would you suggest?

A: More leafy greens, root vegetables and beans. Rice is like a luxury. Everyone consumes corn. Each seed needs input, without water and fertiliser these seeds do nothing. Any investment directed towards nutrition should not be with corn. Santilya is at 6.000 feet altitude, there is not much production of tropical fruits, only banana and avocado, and of course tomatoes and onions. […]

For nutrition it would be important to first invest in equipment to farm the land. People do ploughing by hand, watering by hand and weeding and sowing by hand.

Q: What else needs to be improved?

A: The understanding of how to use pesticides and what can be used. There are initiatives to improve farm practises and nutrition. PSI in Mbeya: technoserve in Mbeya. One of them has a website to connect buyers and sellers. This is really helpful, the problem is that many people have no internet. They could set up a village group with one internet account and share it to use this service.

Iado also has an office in Santilya. This is the isangati agriculture development organisation. They sound good in theory. But I have not been able to talk to them, they are never there. When it comes to development projects, villages have to raise a certain amount of money, before the government gets involved; they need to put in an initial investment. Iado plans on developing a water pipe to the village. Decentralising water supply would help with the farmers.

Q: What do you know about food security and nutrition?

A: There are some real problems. In the first place with breastfeeding. This is great, if it wasn’t for HIV. You need to do either 6 months breastfeeding with no other food, or no breastmilk at all. Normal food make micro tears in the intestines, but if you give breastmilk at the same time HIV is transmitted more easily from mother to child. There are problems with stunting and wasting, because baby’s are fed Uyi, which is watered down Ugali. Ugali is made from corn flower and water. The issue with eating corn is that it should not be taken away (people are very used to it) but other food consumption needs to increase. Even if more nutritious food is available, it is not accessible to everyone. Most people live on subsistence and do not have any money to spare.

## Interview 2: Village extension officer

Q: What can you tell me about maize production in the area?

A: there is problems with storage. If production goes up, it goes wasted because of bad storage. There is no warehouse people store yield on the roof.

Q: What kinds of crops would people want to grow here?

A: Irish potatoes, carrots. In short more variety.

Q: More variety, what does that mean? What kind of crops are they thinking of?

A: Chinesi, spinache, chiche for example. But there is no knowledge that is why it is not grown. Because of the cold there is not much avocado. […] people from other villages go to the market in Santilya and buy them in the morning and sell them at smaller markets.

Q: What do you know about fertiliser use?

A: It is not much. People use manure. Not many people know how to make manure, organic fertiliser. Some do but there is no information. Few families get a little amount of subsidised fertiliser, but it is not enough. Fertiliser is very expensive to buy here.

Q: What are the most common grown crops here?

A: Corn, used only for eating. Beans are for selling and eating. Pyrethrum, is a natural pesticide made from chrysantium. This is for export only, for the US. Few sunflower seeds, for oil.

Q: How many people here would you say are food insecure?

A: there is not many people who eat only once a day. We have welfare, Tasaf for the poorest.

Q: You have a very beautiful vegetable garden. Is that common around here?

A: No not common, not more than five families have one and only here.

Q: You also have two cows and one goat. Do many families have livestock?

A: I try to make good for the family. I had some chickens but I had to remove them to make place for the tomatoes. Not many people have livestock here.

Q: What is the biggest problem in your view?

A: Education, knowledge in the community. How to grow and keep food.

Q: What is being done about this?

A: We get knowledge from Micaela [health volunteer peacecorps], about how and why. We sometimes go to see information from others [other villages] if it is good we learn and take it home. We work together with NGOs, Uyole agriculture extention on agriculture, Kyumbe for HIV education. We want more education on crop rotation, there is no knowledge.

Q: Is there anything else that I need to know?

A: You should do a trial run in Santilya with your seeds! With the corn based diet, it would be more useful to improve nutritional content than to improve yield. Tell them to do a trial run here.

## Interview 3: Health volunteer peacecorps Iwowo village

Q: What do you know about agricultural production in your area?

A: This area consists of small villages around Santilya. Crops that are produced are mostly corn, greens, sunflowers, wheat, potatoes and beans.

Q: Sunflowers?

A: The sunflowers are for oil, sold on the market. You can buy sunflower oil in the village, you have to bring your own bottle and it is scooped out of a large bucket into your bottle.

Q: Is everything produced on the shamba? Or do people supplement with their own garden?

A: No, home gardens are very rare. People do not use it as supplement for food. It would be a good idea though, we are trying to set something up to get this started around here.

Q: What are you thinking of? What are your ideas for crops to grow?

A: Maybe Chicha, chinesi, leafy vegetables. Also maybe pumpkin leafs, for consumption or for pig feed.

Q: Are pigs or other kinds of livestock common here?

A: Not really, it is mostly goats here. Some people have cows or pigs. Chickens are more common for the eggs.

Q: I heard the goats are used for meat, but not for milk. Is this true? Do you know why?

A: Yes, because they breed with them a lot. This does not work if you want to milk them. Maybe we can do something about this, goat milk would work well here; it is very nutritious. I do not know, maybe it is also in the culture somehow that people do not use goat milk.

Q: What do you know about agricultural input use? Meaning fertiliser and improved seeds?

A: Farmers do use fertiliser around here, mostly manure. I think they also buy in artificial maize seeds. Some farmers also use pesticide spray. It is a mixture of homemade stuff and bought in pesticides. It is available here, but not everyone can buy it.

Q: How does this relate to food security?

A: People here eat mostly Ugali and beans, or some kind of green. Sometimes they eat dagaa, cassava, sweet potatoes or oranges. I do not know much about nutritional problems here.

Q: Is there anything else that I need to know?

A: yes, there is some cash crop production here for example coffee or tea. This is for the export, it is very cheap. Dried green beans are exported and processed somewhere else, because there is no infrastructure to process them here.

Q: Is this done by big scale farmers or also by smallholders?

A: O smallholders do cash crops as well.

Q: Does this compete at all with food production?

A: No I do not think so. People just produce what gives them most income.

Q: Going back to maize production, what is maize mostly used for?

A: Maize is for village consumption and home consumption. A small amount is maybe sold on the market.

Q: Do you know how the maize is processed?

A: People take the corn to the mill, this mill takes the outer layer out and then they take it back home with them. There also is another kind of mill to make it into flower. Not every village has both mills, it may take a walk to another village to process the stuff.

## Interview 4: One Acre Fund

Q: What can you tell me about maize production in this region? What do you know about input use in terms of kinds of seeds and fertiliser?

A: With One Acre Fund, we recommend specific seeds types for specific regions

Q: How many farmers in total are you working with?

A: In total around 17.000 farmers. We are expanding in Mbeya with I think an extra 5.000 farmers. Currently we have 7 villages and in the coming season we will add 24.

Q: What do farmers need to do to apply?

A: Basically they need to sign up on a contract. We have different packages. One is say, for one acre they would get 10 kg of seeds that they can choose of our recommended seeds list, 50 kg of DAP, 50 kg of CAN. The package also includes insurance, like crop insurance, funeral insurance and also training. Like agricultural techniques, how to get most yields out of the farm. So the whole package is for example 250.000 shillings, for one year. Farmers know exactly what the price is for their package, it does not increase over time. […]

I have worked in Iringa with the farmers in the field. Usually farmers will not use good techniques, they will have low yields. On our program you can learn the right technique and crop spacing and you can increase the yield by three times.

Q: Wow that is quite a difference. How does this relate to food security?

A: The increase in yield means that farmers have extra income for other things. Some of the yield is used for own consumption and some is sold.

Q: Is the fund only directed towards maize or also other crops?

A: In Iringa we also do beans and also maize. In Mbeya in the upcoming season we are trying to do also coffee, because coffee is a cash crop. This is new, 2016 is going to be our first year that we do coffee.

Q: How is the processing organised?

A: We are not involved in processing. They do drying at home, they do storage at home. What we at One Acre Fund do, most of the times they use chemical sprays to keep the bugs of and keep the maize pest free I guess, but we offer storage bags. This is also part of the package as pest protection. That way you do not have to put chemicals on the maize.

Q: So the processing is all done at home, do you know how?

A: No, all I know is they dry it at home like on the ground. They put a mat on it and dry the maize. They shell it and then they take it to a kind of mill and they pay per kilo. But we are not involved in that process. We do not buy anything; all we do is provide the inputs and training. We do try to connect buyers and sellers sometimes. Storage is also done in the village not in our warehouses. We have some warehouses for coffee I think.

Q: Do you know anything about crop prices?

A: Last year… no I do not know crop prices for maize, I know for coffee.

Q: Do you know anything about the impact your program has on food security?

A: Well, my colleague Emma from Iringa she measures impact. We have done studies to compare one acre fund farmers to non-one acre fund farmers. The reason for us existing is also that many farmers do not have the means to purchase all inputs at once. With many agro dealers you have to pay upfront in cash. If you buy everything in one go it is around 250.000 Tsh. Most of the farmers do not have that money at once and they need to save until they have enough. And by that time, it is too late the rain season is halfway through and they missed the good rains. Other times, they can only pay the price of half an acre. Where we come in, we provide financial assistance in the form of inputs instead of money, because if we give money they can spend it all on other things. With these inputs, we know it is used for the farm and when it is ready it can be harvested and we pay the loan. It is basically financial access, and more security. I will link you up with Emma, she will know more about the impact.

Q: So you provide financial assistance, how is the payment for the package organised?

A: We encourage farmers to pay every week, if they can afford to pay. We encourage them not to wait until the last minute to pay off, because that means one they are burdened with a huge debt of the inputs at the end of the season and two it means that they have to use all the harvest to repay the loan. That is why we encourage them to pay like 2000 or 5000 a week. Any amount they can contribute, they can pay weekly.

Q: Has food security improved since you started with the One Acre Fund in Mbeya?

A: I would not have first-hand experience, but my colleagues do evaluation studies on the one year to the next. We do know that yield has increased. This is mainly due to using the quality product and the right tools and techniques like spacing. The farmers are checked on regularly to make sure they use the right techniques, that they are not draining the seeds with too much fertiliser etcetera. Plus, our field officers live in the villages that we operate in. so they are always in contact with the farmers.

Q: One of the thing I came across was, well I have been to Santilya…

A:… So far! How was the road?

Q: It was not good

A: Alright yes because we were thinking of expanding there, but we could not get our trucks there because of the bad roads.

Q: I have been there and was told that one of the main problems was education. Is education a part of your program?

A: We have monthly training on how to store your maize, how to harvest, not to burn your field, etcetera. Training is a big part of our program. And not just training, but also the following up in the field. Because most farmers, their habits take over, they tend to go back to their own ways and we need to prevent that.

Q: Storage is also a problem that I have come across.

A: That is why we offer the picsbags for yield, it takes 100 kilos a bag.

Q: Are you also involved in water use related issues?

A: No, we don’t do irrigation.

Q: What project are you currently working on?

A: Currently my main goal is to meet the expansion targets for this year. Other compartments are working on technical innovation, they are always looking for extra products they can provide. But for me on the field side, I am working on making sure that we have a high repayment rate from all the farmers, and secondly expanding in Mbeya. Because in Iringa we have expanded, we have nearly reached saturation.

Q: Where in Mbeya would you like to expand?

A: In Mbozi, we want to look at Rungwe, but the problem with Rungwe is that the rainseasons are very different from the rest of Mbeya and Mbozi. I would really like to go into Rungwe, but we need to see how this rainfall affects input delivery and repayment cycles. Mbozi has big potential though, we are already working there. We have four sited and will increase to sixteen this year.

Q: How does approaching new villages work?

A: We start in November. We use a tool that is developed by our internal consultants. What they do, is they do a mapping of basically whole Tanzania. They look at population, acrage, what is grown, we try to find the areas that we want to do a deep dive in. I drive out there and do a survey and interview for example ten random farmers and ask them a set of questions, and then we decide if it is a place we can operate in. There is a lot of factors involved in de decision if a site is a good place that we can make an impact in. We analyse the data, see if the farmers can use our help and if we can make an impact on their lives. The next step is to hire some expansion managers. They are managers that oversee the whole process. They interview in all villages all the field officers. It is probably a six months long process.

Q: For one village?

A: No, for the whole process from start to finish. We need to see if it is viable and if we can get the staffing, the managers and the field officers. The job interview process takes some time and afterwards we have a month long training.

Q: How far in the process are you now?

A: Nearly done, because we are signing the contracts with farmers next week. All staff is in place, we have had farmer meetings, everything is prepared.

Q: What do you do if it does not work out? Happens if a farmer cannot repay?

A: Then they are out of the program. We do not take any of their belongings, there is no collateral. They just cannot re-enrol. The whole group gets excluded?

Q: Group?

A: Yes you have to get onto the program as a group. You cannot enrol as an individual farmer. It is actually group pressure that keeps them paying.

Q: How many farmers are in one group?

A: We like to have groups of 10-15 farmers. If one farmer defaults, the entire group is out next year.

Q: The farmers you work with, are they mostly male or also female?

A: It is around 50-50 men and women. We find that female farmers are more responsible, have higher repayment rates. We encourage women to enrol.

## Interview 5 Ministry of Agriculture: Monitoring and Evaluation Officer

15-07-2016

Q: What do you think about the relation between agricultural input use and food security?

A: On average the use of input in Tanzania is low. Do you know the national average? It is around 3kg of fertiliser per hectare. The use of improved seed is very low. You should know that it is not the same everywhere. There are examples of regions where it is higher. The food basket areas is where most food is produced, think of Mbeya, Rukwa, Iringa, Morogoro. The maize growing regions are mostly Tange, Arusha, Kilimanjaro, Shinanga, Southern Highlands.

Q: What projects are currently being implemented? I have heard about the NAIVS?

A: Yes, this is the voucher scheme, for subsidised inputs for rice and maize.

Q: A voucher gives you 50% off the input price?

A: Yes, 50% off. The reason for this was not to increase income. It was actually to demonstrate the results of input use. It was to show the farmers the benefits of using inputs.

Q: Do you think this has worked?

A: We have done evaluations of the scheme. Minds are changing, the farmers have really understood the benefits.

A: The government has been working hard to invest in agriculture. Fertiliser investments are very welcome now. Policies have changed. The fertiliser industry has been revamped.

Q: What has been done in terms of policy changes?

A: The recent policy changes have been the ‘Fertiliser Act’ and new fertiliser regulations. We want to make investment in fertiliser more attractive and remove barriers. Before the fertiliser act, new fertiliser had to be tested for three consecutive seasons. So that would take three years. It was bureaucratically difficult to invest. Now it can be done much faster.

Q: Since when have these changed been put in place?

A: The fertiliser act was in 2011.

Q: Any successes in attracting new investments?

A: OCP is interested (Moroccan phosphate based fertiliser company group). Sooner or later, they want to invest here. They have subsidiaries in France, US, Middle East, India and Brazil. OCP Afri is dedicated to African agriculture.

Q: Will these new investors benefit from the NAIVS?

A: There are more than 81 companies involved in NAIVS and very many agrodealers. NAIVS is meant to be short term, it will not continue in the coming years. NAIVS is designed to change farmers minds. First they receive subsidised inputs and if they see how it works they can buy it at their own costs the next year.

Q: And? Are they buying it at their own costs now?

A: Farmers growing high value crops like cashewnuts, have started already using fertiliser at their own costs. But NAIVS is a smart subsidy: it is not for everyone. Even in the Southern Highlands, the subsidy is not enough for big farms. They buy additional inputs, because the subsidies are only for one acre. NAIVS is directed to smallholders, and the village committee distributes. It only targets food crops maize and rice. So it is only for maize growing or paddy growing areas. After understanding these areas, the government plans how many vouchers to send to the regional secretariat. They take it to the local authorities at district level. Then it goes to the villages, and the village committee allocates it to the farmers. Once the farmer gets the voucher, the farmer goes to the agrodealer. The government organises the agrodealers, they need a permit to collect vouchers. Each agrodealer needs to be approved, the number of farmers they can serve and the amount of vouchers. They are under very strict scrutiny.

Q: NAIVS was meant to be short term, but it is still running? How long will it continue?

A: How long it continues is a political thing. Politicians use it to win the hart of farmers. Although it is not generating revenue, it is still continuing.

Q: What do you expect for the future?

A: I think that it will not be extended to more than three years. It is very expensive. It is not recommended, this system.

Q: What would you recommend?

A: There are other options. Giving inputs on credit, for example. Farmers get the input on credit and repay after harvest. OCP is coming with that idea in mind.

Q: I have talked to someone from the one acre fund. They work with a financial assistance system in which they provide inputs on credit.

A: I have heard. Maybe we can link OCP with One Acre Fund to see a better way of doing this. We want to collaborate with local NGOs to find the most effective way. Also a better way would be not to do subsistence agriculture. I should not even call them farmers. One acre is not enough to make a real difference. We should focus on commercial and medium scale farmers. This works in Japan. They have very large farms (20-60 ha) 6 farmers supply all product. We should think in this way. We have a comparative advantage in rice, maize and sugar cane. East-Africa is a huge market. There is so much potential for Tanzania to supply neighbouring countries with enough food. Think about the Big Results Now program, that started five years ago. It focussed on these three crops: maize, rice and sugarcane. Two food crops and one cash crop. Maize has increased tremendously. We have seen good results in the annual reports.

Q: What do you think about the relation between input use and food security?

A: The relation with food security is obvious. I asked farmers. Before the adoption of inputs, one acre of farmland for example yields three bags of maize. After adoption, he yields 25-27 bags of maize per acre. So the use of inputs has increased their chances. I have asked many farmers and I always get good responses.

Q: Farmers have reported higher yields as a result, but have they also reported a change in the crops they produce?

A: No, do you mean a difference in cultivation patterns? No. Some areas do intercropping, but not with maize. Maize areas normally they do allocate a big amount of land just to maize.

Q: During my research I have come across the problem with education. Many smallholders are not aware of good agricultural practices, especially with input use. Is the government involved in education for farmers?

A: NAIVS involves several ways of education. The government has village extensions. Extension officers main job is going around farms and teach and correct agricultural techniques. Through NAIVS the village voucher committee members are trained to train the farmers in how to use the inputs. We also have farmer field schools, used to educate the farmers. These schools are organised by the government via the extension officers. In Tanzania, the use of inputs has just started. In Kenya, Uganda, Rwanda for example the use is much more. But now, the government is open to changes in the agricultural sector. We are removing some blockages that existed before.

Q: Can you give an example?

A: Formally, before the fertiliser act, registration of a new product or company even was a problem. It took a lot of time to get a licence. Now, if you comply with the rules, it can be done in a week. The government has set a maximum cost for demonstration and trials. Now, it cannot be more than USD 10.000. Before, this testing of a new product was very very expensive.

Q: Will this new policy have an effect on the market price of fertiliser?

A: Prices have slightly changed. With involving OCP, we are hoping to see a major change in prices. Investment policies have changed, the policy environment is now more friendly for investors. We want to attract manufacturing and processing firms. The law has been relaxed and the time to get a certificate has been reduced. The government has also reserved some land for agricultural investments. Have you heard about the Southern Agricultural Growth Corridors program? It is called SAGCOT a program that works to see more investment in Tanzania. Investments are directed towards the high potential regions which are Morogoro, Iringa, Songea, Mbeya, Rukwa.

Q: Is SAGCOT for foreign investors or for domestic investors?

A: Tanzanian investors mainly. Any serious investment actually, domestic and international. We are encouraging locals to pull up investments.

Q: Is there anything I need to know, but did not ask about?

A: Your findings are probably true. About the market; farmers are discouraged if they do not sell. The most important thing is to extend the market, increase the export especially maize. Most yields go wasted, because of no storage or transport. Also, some areas go without food whereas others have extras. Actually, the main buyer is the government. The government buys food and distributes it back. In case of a breakout of hunger, they have food reserves throughout the year.

The market and the prices coincide, this can also be a discouragement if yields are high but prices are low. We need to find a better way to find the advantage we have within the region (East-Africa). But there is the problem of standards aswel. We cannot export to the international market, because food safety standards are not looked at. We need to address that very seriously.

Q: What do you mean?

A: The quality is not good enough, the quality of the product, the grains, the storage, the packaging. Most product goes wasted because of mishandling of post-harvest; this is 15-20%. Formally, we cannot trade with neighbours, however we have porous borders and illegal trade takes place a lot. This is not regulated and also not standardized.

## Interview 6: Assistant Director for Agricultural Policies

Q: What do you think about the relation between agricultural input use and food security?

A: This is directly related. We recognise the difficulty you have, it is difficult to separate impact of input use from rain for example, or extension. The attribution of results is difficult. We know exactly that improved seeds lead to higher productivity. The evaluation of the first phase of implementation has shown an average productivity growth. We know exactly that the use of inputs improves productivity.

Q: Are you talking about NAIVS

A: NAIVS has had a direct impact. I am glad that you talked about education. Education is a big part of the NAIVS program. It is not only about supply, but more about creating the demand for inputs for the farmers. The creation of demand from farmers has had a positive effect. In the evaluation of the program it was shown that there was in increase in demand. The program introduced a new technology to the farmers, and it worked.

Q: I heard that NAIVS will likely not continue in the future?

A: It is being phased out, because of lack of budget. This year only 20 billion Tsh was available for NAIVS, which is very little. Because the program is so expensive, we can choose either to continue or to save the money and repay the debt. I do not think we are going to continue it next year. NAIVS was funded by the World Bank and topped up by the government. Now the World Bank has retreated from it, we do not have enough money.

Q: What policies will come in its place? Will the government continue to promote input use in a different way?

A: We tried to introduce a credit system. Farmers would get the inputs on credit, and the government would subsidise the interest rate from the bank. NAIVS as it is now, is a smart program, which means it is exclusive. Only a small part of the farmers is eligible. This include/exclude system is wrong. It is a political problem. The credit system would not be smart, everyone can get it. We were not able to make it work. The bank wants the subsidy upfront, this did not work. The government is now back to NAIVS, it stopped for a period of time and started again. This year it might not be implemented again. It is very expensive, not just the subsidies itself no: also the monitoring and the follow-up, the agricultural trainings, the extension officers.

Q: What would you recommend for the future?

A: Farmers have to be supported, because they need better access to inputs. There has to be some kind of government support. Studies on fertiliser have shown that it is very expensive to transport; sometimes the transport costs are half the price of the product. What we need to do is find a way to reduce transaction costs.

Q: Would it help to produce fertiliser domestically, instead of importing it?

A: Well, manufacturing falls into another Ministry; the Ministry of Industry, Trade and Investment. I know they are working with manufacturers to look into the possibility to work with locally available materials for fertiliser. Most of our focus is on the costs. Fertilisers are bulky products. There is no railway system in Tanzania, rails are cheaper for transport of bulky product than roads. A vamp in the railway system would reduce transport costs immensely.

Q: And on the demand side? What can be done, in terms of education for example?

A: Through the government extension packages, farmers are being told what to do at so called field schools. There are demonstration plots for rice intensification for example. Farmers are shown how new technologies work.

Q: What would you recommend for the future?

A: Like libraries, to organise libraries in the villages that have some literature on a specific field. Farmers would come to the libraries to learn on for example cashew production. The extension officer is available to help if they cannot read. We also have noted it is good to have a curriculum in secondary school and university specifically for agriculture, to engage younger people in agricultural activities.

And.. this is my own position not that of the government: this is very expensive (NAIVS) we cannot handle it. The credit system is better. Last time we proposed it we did not have enough preparation, but we need to try it again. Some people are proposing to digitalise NAIVS. This is not a good idea. The same problems will still exists, high expenses for the government, side selling of vouchers. Farmers have understood the importance of input, the problem is the price. How to reduce input prices? We need to make investing in fertiliser easier. Quite a lot has been done already in attracting more investments.

Q: Some NGOs already work with a credit system, is it an idea to work together with them?

A: Yes. For example to implement the system in a pilot region. If the results are good, we can scale up to other regions. We have overall seen good results, almost every farmer reported an increase in yield after the use of hybrid seeds and fertiliser. The costs are the main problem. A lot of initiatives are already being taken. The fertiliser and seed laws have been reformed. Almost all of them were very outdated, they are now being reviewed. The testing fees for fertiliser used to be 50.000USD, they are now around 10.000USD.

Q: Is there anything else I need to know, but did not ask?

We used to have problems with fake fertiliser on the market. The fine used to be small, the penalties and fines are now increased. Other changes are that we want to get the private sector involved in the seed trade as well. We have reviewed the access to government protected varieties. The access is now more business friendly and more accessible. We are also incentivising seed companies by reducing packaging costs. Local government law is different from the new seed act. It needs to be made streamlined, so that local laws do not contradict central law. The government was working with fertiliser company YARA, we will probably work with them in the future.

Importing fertiliser is difficult, sometimes you need to visit around eight government institutions for registering and licencing. We want to centralise this process, to have a sole regulator. The very bureaucratic nature makes it slow and difficult to do. We need to harmonise all these acts for importing fertiliser.

You should also look up the ‘big results now’ program. Storage is a part of it, warehouses are built to prevent post-harvest losses. This is being implemented later this year.

## Interview 7: TOAM

18-7-2016

Q: I have read the report you send me about farmer managed seed systems.

A: Yes. This research is commissioned by the Rosa Luxembourg Foundation, linked to Die Linke, the left wing party (*Democratic-socialistic political party in Germany)*. We have made a 30 minute film, the central character is a QDS (*Quality Declared Seeds)* seed producer. QDS is halfway between commercial seeds, and farmer saved seeds. It is an FAO endorsed concept, that started 10-15 years ago. It is generally recognised that the quality of seeds in Tanzania needs to be improved. The big idea is for commercial companies to do that. However, this takes a long time ánd it is usually only maize that they do. QDS was invented to fill that gap, by creating a simple certification system for open pollinated varieties of standard varieties. QDS is developed by small farmers under controlled conditions. An inspector from the government checks up during the growing and at the end of the season and they take the seeds to the laboratory. They need to make a certain seed quality threshold and then they can get a certificate to sell the seeds in their own ward. The advantage is that QDS can provide farmers in villages to get locally adapted, reliable, not fake like some commercial seeds, and affordable seeds. The majority of maize seeds are still commercial seeds in Tanzania. Paddy is for almost 100% FMSS. Farmers do not like most commercial maize seeds, because they are expensive, hybrid (which means they are not reusable) and unreliable (there is a lot of fake product on the market).

Q: Say I am a farmer and I want to sell QDS, what do I need to do to apply?

A: Farmers that want to sell QDS need to register with TOSCI or one of their local authorities. District councils have a seed inspector that does inspections on behalf of TOSCI. And you have to get basic seed from ASSA. QDS started 20 years ago.

Q: Can QDS seeds be reused?

A: Yes for 2 or 3 seasons. Usually the saved seeds are enough to share with the neighbours. Not every individual farmers saves his seeds, this can be due to various reasons: poor harvest, or he has eaten them all, or run out, or he did not grow maize in the previous season. So it is culture to share within the village. Sometimes they do for example exchange seeds for grains. QDS can only be sold within the ward. This makes the business unsustainable, because a QDS seller cannot use the same clients for three years, because if a farmer has bought your seeds once he can reuse and share it for at least two more seasons. To have enough clients, you will need economies of scale.

Q: What do you think about the relation between seeds and food security?

A: If you really want to address food and nutrition issues by improved seeds, get it in the FMSS where it spreads like wildfire. That is how to get things started. There was a three years trial in Dodoma starting with 200 farmers and in three years it got to 1000 farmers. For food security you need to reach the poorest of the poor. They cannot go to towns to buy seeds that is just not going to happen.

Q: How does the quality of QDS compare to commercial seeds?

A: They are reusable. After reusing the seeds, the quality goes down and in 2 or 3 years you need new seeds. Seed breeders have the knowledge based technology, they select the right seeds and make sure there is no cross pollination or what so ever. The problem with quality control will be minimal if you know how to select the best seeds and how to process and store them correctly.

The quality of seeds at the moment is generally low, because there is a total lack of investment in farmers’ capacity to select and store seeds. The government has made the decision to hand over the seed sector to the private sector. This is problematic. Hybrid seeds and inorganic fertiliser require investments every year. And the price is a big problem. Availability is another problem: sometimes farmers get seeds to late when the planting season has already started or they receive fake seeds. QDS is a solution, it is low in costs, available in the village on time, and if it is fake you know exactly who to come after because the seller lives in your community.

Q: Why is this not publicly funded do you think?

A: Tax. It is very difficult to tax QDS producers. Big companies pay far more in taxes. See this is the ‘agriculture first strategy’ implemented by the government. There is no mention of QDS in here. It goes even further. The government extension service advises farmer to use improved seeds, via agricultural advisors and farmer field trainings etcetera. We have asked farmers what advice they get: most of them got the advice to buy seeds from commercial stockists. If you are a subsistence farmer, how do you get the money to buy seeds? If you have cash crops, you can invest in new inputs but not if you only produce for subsistence.

Then there is the loss of biodiversity. Commercial seeds focus of few varieties. QDS, also makes use of seeds from ASSA to start breeding (these are breeder seeds). Traditional seeds are passed down through generations, this is a different thing. Do you know what Bio Piracy is? If you take traditional seeds and breed them for one generation, you can get plant breeders rights as a company. This is because of UPOV developed in 1991 by developed countries for use in developed countries. The new law says that if someone owns the right to a seed and you sell them, the buyer is not allowed to share them anymore. They have to be used on your own land only, for non-commercial use. You can only sell the grains, but not the seeds.

Q: I thought that there were regulations protecting traditional farmers from this bio piracy?

A: The international treaty on farmers rights for protection of genetic resources: ITFRPGR. Tanzania has signed this, but not implemented it to legal regulation. It was supposed to protect the right of farmers to their own traditional seeds. It says that if a breeder makes money of the traditional seed, than the community it comes from has the right to part of the benefits. Tanzania has not put this in place yet.

Q: The Tanzanian government tries to make the environment more business friendly by reforming policies to attract investments in the agricultural sector. What are your thoughts on that?

A: Yes. The governments of the richest countries in the world have aligned with the richest companies in the world in the G8 alliance, to invest in food and nutrition in the poorest countries. They have set up a framework that is full of “if we do this, then you do that’s”. We invest in better seeds, but our companies get the rights. The poor countries that sign, have to lift taxes, reduce the time required to release new varieties, and the time required for testing of fertiliser inputs and other agrochemicals.

Q: And what do you think of the subsidy scheme? (NAIVS)

A: The first point is that it is exclusive, which means it is only available to regions of high potential. This means that out of 31 regions, only 5 or 6 of them get the subsidy. And in the marginal areas, well no-one is giving out vouchers there! The idea is this: there is not enough money so let’s focus on the most impact areas. Even though the high potential areas need the support least. Secondly, these vouchers are for hybrid seeds and inorganic fertiliser. We are an organic agriculture movement. The use of inorganic fertiliser destroys the soil. It will burn the soil and kill all the nutrients. The hybrid seeds are designed to work with fertiliser and not without, the same goes for other chemicals. There is a social divide going on there. NAIVS was the product of considerable corruption. Sometimes this scheme was used to gain political backup.

Q: What is your alternative to the use of fertiliser?

A: The basis of ecological and organic agriculture is to give farmers and understanding of their responsibility to maintain the fertility of their soil. Fertiliser is like a drug; if you use it this year you will have to use it next year. Fertiliser feeds the plants, but it does not feed the soil. It kills the organisms that are naturally present in the soil. Actually a one percent increase in soil organic matter gives ten percent increase in soil fertility. It is all about dependence versus self-reliance. If you get hooked on hybrid seeds, you need to buy them every year. This dependence on input supplies is a problem. The sector is in very few hands, with very few investors. It is a massive monopoly. 70 percent of input supplies worldwide are in the hands of very few companies. Meanwhile farmers are being persuaded to convert to the industrial farming system, although this system is responsible for 30 percent of all greenhouse gas emissions. There is nothing sustainable about this process.

Q: Is TOAM also involved in farmer education?

A: Yes we have a training program on teaching farmers organic agriculture practises.

Q: How many farmers are you working with?

A: Around 5000 in this region and another 5000 in Dodoma. We also help with access to markets and policy advocacy. We tend not to work in areas of high productivity, but more in the poor and drought prone regions that need the help most. We want to expand when we get more donor support, but donors tend to through their money at big companies.

Q: What kind of policy advocacy are you working on?

A: First of all we are trying to find out what is going on. We do research so that we have new data to show the government. This can be a stakeholder analysis, reports, policy briefs, a film, or a multi stakeholder platform. This stakeholder platform has two purposes. Firstly to bring together farmers and friends to discuss the report and formulate farmers’ key messages to give the government and to train them in policy advocacy. Secondly to get opposition on board; committed policy makers that support seed companies and seed companies themselves. We need to develop a certain edge: a focus on marginalised farmers and female headed households so that they cannot dismiss us. At the moment there is no recognition of the rights of farmers in any government laws. Afronet is the network behind organic agriculture to create space for organic agriculture in the African Union. AFSA is the alliance for food sovereignty Africa, challenging the regional agendas of the industrial food system. They are for agroecology and against laws that support corporate agribusiness. The industry is targeting regional trading blocks, where international laws are put in place in a rush.

Q: Is there anything else that I need to know, but did not ask?

A: Correctly answering the following question will doubles one’s yield: What variety of which crop should I plant when? That information is free, there is no input required, it is complete knowledge based.

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