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The Effects of the National Agricultural Input Voucher Scheme (NAIVS) on Sustainable Intensification of Maize Production in Tanzania

By

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ABSTRACT

We use nationally representative household panel survey data from Tanzania to estimate the effects of receipt of vouchers for inorganic fertilizer and/or maize seed from the country's input subsidy program (ISP) from 2008 to 2014, the National Agricultural Input Voucher Scheme (NAIVS), on maize-growing households' use of several soil fertility management (SFM) practices. We focus on three SFM practices that are important in the Tanzanian context: use of inorganic fertilizer, organic fertilizer (compost or manure), and maize-legume intercropping. Given poor returns to ISPs in many African countries driven in large part by low maize yield response to inorganic fertilizer, we are particularly interested in how receipt of NAIVS vouchers affects farmers' joint use of inorganic fertilizer with organic fertilizer and/or maize-legume intercropping, which can improve that yield response. Using a multinomial logit model combined with the control function approach, we find statistically significant positive effects of household receipt of a NAIVS voucher for inorganic fertilizer on maize-growing households' use of inorganic fertilizer only (without organic fertilizer or maize-legume intercropping); the probability of using inorganic fertilizer only is on average 10.0 percentage points higher than for households who do not receive a NAIVS fertilizer voucher. Importantly, the results further suggest that NAIVS inorganic fertilizer voucher receipt is also associated with a 9.6 percentage point increase in the probability of using inorganic fertilizer jointly with organic fertilizer and/or maize-legume intercropping. No such effects are found for use of organic fertilizer and maize-legume intercropping (either alone or in combination but without inorganic fertilizer). Receipt of a NAIVS voucher for maize seed has no statistically significant effect on farmers' use of the SFM practices considered. The positive effects of NAIVS on joint use of inorganic fertilizer with organic SFM practices is encouraging, as it suggests that the program may have helped promote not just short-run increases in maize yields but also longer-term improvements in soil health.

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ACRONYMS AND ABBREVIATIONS

AMIS	Agricultural Market Information System
APE	Average partial effect
CA	Conservation Agriculture
CF	Control function
CRE	Correlated random effects
IIA	Independence of irrelevant alternatives
ISFM	Integrated Soil Fertility Management
ISP	Input subsidy program
IV	Instrumental variable
LSMS-ISA	Living Standards Measurement Study-Integrated Surveys on Agriculture
MIT	Ministry of Industry and Trade
MNL	Multinomial logit
NAIVS	National Agricultural Input Voucher Scheme
SACCOS	Savings and Credits Cooperatives Societies
SFM	Soil fertility management
SI	Sustainable intensification
SOC	Soil organic carbon
SOM	Soil organic matter
SSA	Sub-Saharan Africa
TNPS	Tanzania National Panel Surveys
TZS	Tanzania Shillings

1. Introduction

Hunger and food insecurity continue to be major challenges in sub-Saharan Africa (SSA). Currently, SSA is the region with the largest gap between cereal consumption and production and about a quarter of the population suffered from chronic food deprivation in 2017 (van Ittersum et al., 2016; FAO, IFAD, UNICEF, WFP and WHO, 2018). These problems may become more serious in the future because by 2050 the population in SSA is projected to increase 2.5-fold and its cereal demand is projected to triple, while the region already imports substantial quantities of cereals to meet current demand (van Ittersum et al., 2016). In addition, there is an emerging consensus that conventional intensification of agricultural systems involving the use of inorganic fertilizer and high-yielding crop varieties may be insufficient to sustainably intensify agricultural production and that conventional intensification can have negative environmental externalities (Petersen and Snapp, 2015; Pingali, 2012). In this context, sustainable intensification (SI) has been identified as a potential means to feed an increasing global population and meet rising food demand (Godfray et al., 2010). The main goal of SI is to produce more agricultural output from the same area of land (or less land) on a sustainable basis without adverse environmental impact (Pretty et al., 2011; The Montpellier Panel, 2013). While SI does not refer to a specific set of agricultural inputs or management practices and there are likely to be many pathways to SI, Holden (2018) points to integrated soil fertility management (ISFM) and conservation agriculture (CA) as two potential approaches to SI. ISFM is defined as the combined use of inorganic fertilizer and locally available soil amendments and organic matter, whereas CA involves crop rotation/intercropping with legumes, permanent soil coverage, and minimum soil disturbance.

Nonetheless, many African governments' policies aimed at increasing agricultural productivity have primarily focused on conventional intensification – in particular, trying to raise smallholder farmers' use of inorganic fertilizer and improved maize and rice varieties through large scale input subsidy programs (ISPs). In recent years, 10 African countries spent approximately US$0.6-1 billion annually on ISPs. But despite the heavy spending on the programs, the effects of ISPs on crop production and productivity as well as incomes and poverty have generally been smaller than anticipated (Jayne et al., 2018). In a review paper on Africa's ISPs, Jayne et al. (2018) argue that low crop yield response to inorganic fertilizer consistently reduces the productivity effects of ISPs. In particular, poor soil quality (e.g., low soil organic matter (SOM) and high soil acidity on many smallholders' fields) is a leading cause of low crop yield response to inorganic fertilizer application (Marenya and Barrett, 2009; Burke et al., 2017). It is therefore important to address poor soil quality issues (e.g., through an application of complementary soil fertility management (SFM) practices) in order to improve the agronomic efficiency of inorganic fertilizer use as well as ISPs' effectiveness (Holden, 2018; Jayne et al., 2018).

In recognition of the importance of integrated agricultural practices that improve soil health and the efficiency of inorganic fertilizer use, contribute to SI of agricultural systems, and have implications for the effectiveness of ISPs, the main research question of this study is whether ISPs encourage or discourage farmers' joint use of inorganic fertilizer with other SFM practices; this joint use can be considered a form of SI. To our knowledge, there have been no previous studies on this relationship. Instead, there have been only a few empirical studies on the effects of ISPs on farmers' use of individual SFM practices other than inorganic fertilizer in Malawi (Holden and Lunduka, 2012; Kassie et al., 2015a; Koppmair et al., 2017) and Zambia (Morgan et al., 2019). This is in contrast to the larger literature on the effects of ISPs on inorganic fertilizer purchases or use, which does not consider the programs' effects on other SFM practices or joint use of inorganic fertilizer with practices. (See Jayne et al. (2013) and Jayne et al. (2018) for listings and syntheses of these studies.)

We focus here on the case of Tanzania and the ISP implemented by the Government of Tanzania from 2008/09 through 2013/14: the National Agricultural Input Voucher Scheme (NAIVS). NAIVS provided targeted beneficiaries with vouchers for inorganic fertilizer and seed for improved varieties of maize or rice – two major staple crops in Tanzania. NAIVS is a "second-generation" ISP and a key example of a "market-smart" subsidy program designed to overcome the shortcomings of past programs including their limited impacts on productivity, high costs (and low benefit-cost ratios), politicization, and sidelining of the private sector (Jayne et al., 2018; Dorward, 2009; Morris et al., 2007; Pan and Christiaensen, 2012).1 Tanzania's NAIVS is an important case study on this topic because it is widely considered to be the most private sector-friendly ISP in SSA to date (Wanzala et al., 2013). NAIVS was implemented through vouchers redeemable at private agro-dealers' shops whereas the above-mentioned studies on the effects of Malawi's and Zambia's ISPs on individual SFM practices cover periods when those countries' programs distributed subsidized fertilizer through government parastatals (Malawi) or farmer cooperatives (Zambia) and not through the private sector (Mason and Ricker-Gilbert, 2013). Thus, the effects of NAIVS on farmers' use of SFM practices may differ from the effects in Malawi and Zambia. Furthermore, the design and implementation of ISPs varies across countries and time, so insights from a new country (in this case, Tanzania) can also help deepen our understanding of how ISP effects on farmers' use of SFM practices may vary depending on differences in program design and implementation.

This study focuses on SFM practices for maize production because maize is both the main staple food cultivated by the majority of Tanzanian smallholders and the main crop promoted through NAIVS (World Bank, 2004). The SFM practices considered here include the use of inorganic fertilizer, organic fertilizer such as animal manure or compost, and maize-legume intercropping. We focus on these three because they are the main SFM practices used by maize growing households in rural Tanzania. We follow Kim et al. (in press) and group the eight possible combinations of use of these three SFM practices into four "SI categories": i) "Non-adoption", meaning none of the practices are used; ii) "Intensification" to denote inorganic fertilizer use only; iii) "Sustainable", meaning use of organic fertilizer, maize-legume intercropping, or both; and iv) "SI" meaning joint use of inorganic fertilizer with at least one of the practices in the "Sustainable" category. Using nationally representative household panel survey data from Tanzania (the Tanzania National Panel Survey (TNPS) of 2008/09 and 2012/13), we estimate the impacts of receipt of vouchers for inorganic fertilizer and/or maize seed through NAIVS on farmers' use of the four categories defined above. The models are estimated using a multinomial logit (MNL) model combined with correlated random effects (CRE) and the control function (CF) approach to control, respectively, for time-invariant and time-varying unobserved heterogeneity that could be correlated with farmers' SI category decisions and their receipt of NAIVS vouchers.

This study contributes to the literature in several ways beyond being the first analysis of an SSA ISP's effects on farmers' joint use of inorganic fertilizer and complementary SFM practices. First, unlike several of the previous studies in the ISP-SFM literature that did not use nationally representative data (Holden and Lunduka, 2012; Kassie et al., 2015a; Koppmair et al., 2017) or used

[1] Most first generation ISPs were phased out in the 1990s, and second generation ISPs began being introduced in the early-mid 2000s (Jayne et al., 2018). Morris et al. (2007) provide 10 guiding principles to be a 'market-smart' ISP and Pan and Christiaensen (2012) briefly define such ISPs as follows: ISPs "are 'market-smart' if they are part of a broader productivity enhancement program, if they have a clear exit strategy, and most importantly, if they are carefully targeted at helping agents overcome market failures" (p. 1619).

cross-sectional data (Kassie et al., 2015a), this study uses nationally representative household panel survey data. By using panel data methods, the internal validity of our results should be enhanced as we can control for time-invariant unobserved heterogeneity. Also, external validity should be improved by using the nationally-representative data. Second, we use the CF approach to address potential correlation of receipt of subsidized inputs with time-varying unobserved heterogeneity; in contrast, Kassie et al. (2015a) and Koppmair et al. (2017) do not directly address this issue, which may result in biased and inconsistent estimates.

We find statistically significant positive effects of household receipt of a NAIVS voucher for inorganic fertilizer on maize-growing households' use of inorganic fertilizer only (i.e., "Intensification"): the probability of using inorganic fertilizer only is on average 10.0 percentage points higher than for households who do not receive a NAIVS voucher. Our results further suggest that NAIVS voucher receipt encourages farmers to use inorganic fertilizer jointly with organic fertilizer and/or maize-legume intercropping. More specifically, NAIVS voucher receipt for inorganic fertilizer is associated with a 9.6 percentage point increase in a household's probability of using practices in the "SI" group. On the other hand, no such effects are found for the practices in the "Sustainable" group. In addition, receipt of a NAIVS voucher for maize seed has no statistically significant effect on farmers' SI category decisions.

The remainder of this study is organized as follows. First, we provide background information on the NAIVS program and SI of maize production in Tanzania. Next, we outline the conceptual framework and empirical strategies for estimating the effects of the NAIVS program on a maize-growing household's decision to use various SI categories, including joint use of inorganic fertilizer with other SFM practices. Then, we describe the data and variable specifications. Finally, we present our results and conclude by discussing policy implications.

2 Background: SI of maize production & the NAIVS program in Tanzania

2.1 SI of maize production in Tanzania

Per Kim et al. (in press), the main rationale for the categorization of inorganic fertilizer use only as "Intensification" but not "SI" is that although use of inorganic fertilizer has substantially contributed to raising agricultural productivity over the last several decades (Godfray et al., 2010; Pingali, 2012), its sole use can have adverse consequences including over-reliance on fossil fuels; decreases in biodiversity; ground and water pollution; and reductions in soil pH, soil organic carbon (SOC), soil aggregation, and microbial communities (Matson et al., 1997; Pingali, 2012; Petersen and Snapp, 2015; Bronick and Lal, 2005). Organic fertilizer use and maize-legume intercropping are considered "Sustainable" practices but not "SI" because they are local and renewable ways to raise soil fertility but their use without inorganic fertilizer is unlikely to significantly raise maize yields. Finally, the combined use of inorganic fertilizer with either organic fertilizer and/or maize-legume intercropping is considered "SI" because it is expected to result in sustainable increases in maize yields from the same area of the land while preserving or improving soil health due to the synergistic effects of joint use of the practices. See Kim et al. (in press) for a much more detailed discussion of the rationale for these categorizations, including extensive references to the agronomy and other related literatures.

Table 1 shows the prevalence of the various SFM practices and SI categories on maize plots in Tanzania. Out of 2,559 maize plots in the sample (TNPS 2008/09 and 2012/13, described below), 41.4% of them are cultivated with only one of the three SFM practices. The maize plots with inorganic fertilizer only and organic fertilizer only account for 8.8% (case 2) and 6.5% (case 3) of all maize plots, respectively; and the maize plots intercropped with legumes but without use of the other two practices account for 26.1% (case 4). On the other hand, the proportion of maize plots cultivated with two or more SFM practices is relatively low, accounting for 13.3% of total maize plots (i.e., cases 5, 6, 7, and 8). Table 1 also shows the plot-level SI categories used for the empirical analysis: out of 2,559 maize plots, the "Sustainable" group accounts for 37% , while the "Intensification" and "SI" categories account for much lower proportions at approximately 9% of maize plots each. In particular, among the maize plots included in the "SI" group, the combined use of inorganic fertilizer and at least maize-legume intercropping accounts for 6.9%, while joint use of inorganic fertilizer and at least organic fertilizer is less prevalent. The remaining 45% of maize plots fall in the "Non-adoption" category. Among the three SFM practices, maize-legume intercropping is the most common among maize-growing households in rural Tanzania as it is used on 38% of all maize plots in the sample (alone or in combination with other practices). Inorganic fertilizer use and organic fertilizer use are much lower at 18% and 14% of maize plots, respectively (Table 1).

Table 1: SI of maize production categories and prevalence on maize plots in the sample

Case	Inorganic fertilizer	Organic fertilizer	Maize-legume intercropping	No. of maize plots (%)	SI category	No. of maize plots (%)
1				1,159 (45.3)	Non-adoption	1,159 (45.3)
2	√			224 (8.8)	Intensification	224 (8.8)
3		√		166 (6.5)	Sustainable	948 (37.0)
4			√	669 (26.1)		
5		√	√	113 (4.4)		
6	√	√		50 (2.0)	SI	228 (8.9)
7	√		√	147 (5.7)		
8	√	√	√	31 (1.2)		
Total number of maize plots				2,559 (100.0)		2,559 (100.0)
Use of inorganic fertilizer				452 (17.7)		
Use of organic fertilizer				360 (14.1)		
Use of maize-legume intercropping				960 (37.5)		

Note: Figures in the table are based on maize plots (*n*=2,559) cultivated by the balanced panel of rural maize-growing households across two waves of the TNPS (2008/09, and 2012/13). The eight cases and SI categories are each mutually exclusive, while the number of maize plots for the practices listed at the bottom of the table include maize plots for which the practice was applied alone or in combination with other practices. The legume crops reported as being intercropped with maize in the survey are beans, soybeans, groundnuts, cowpeas, pigeon peas, chickpeas, field peas, green grams, bambara nuts, and fiwi.

Source: Authors' calculations.

2.2 The National Agricultural Input Voucher Scheme

In Tanzania, there were large-scale, universal subsidy programs between the 1960s and the 1980s, where the government controlled importation and distribution of agricultural inputs and heavily subsidized input prices (World Bank, 2014). With the economic crisis in the mid-1980s that resulted in an economic reform program, the Tanzanian government greatly reduced subsidy rates on fertilizer from 80% in 1990 to 55% in early 1992, and to no more than 20% by mid-1992 (Putterman, 1995). These subsidies were ultimately phased out altogether after liberalization of agricultural markets between 1991 and 1994. In 2003, after a decade with no subsidized agricultural inputs, the Government of Tanzania resumed a transport subsidy for companies that were involved in the distribution of fertilizers. However, the transport subsidy was not successful since the distributors and agro-dealers who directly received the subsidy did not pass on the cost savings to smallholder farmers (Mather et al., 2016). Also, there were some constraints frequently reported under this system: delayed input delivery, inputs not being effective due to quality deterioration, and smuggling to neighboring countries (Aloyce et al., 2014). Eventually, due to concerns regarding the cost effectiveness of the program, targeting, and the distribution of subsidy benefits, the program was phased out and redesigned in 2007.

Following the 2007/2008 food price crisis, the Government of Tanzania decided to launch a voucher-based input subsidy program that was piloted in two districts within the Mbeya and Rukwa regions in 2007/08. The Tanzanian government with financial support from the World Bank in 2008/09 rapidly scaled up the existing input voucher pilot program with the goal of enhancing short and longer-term food security in the country (Mather et al., 2016; Pan and Christiaensen, 2012). The scaled-up program was called the NAIVS and it operated in 58 districts across 11 regions in 2008/09; the goal was to eventually reach 2.5 million households for three consecutive years each.[2] The NAIVS was initially geographically targeted to areas favorable to maize and rice production in Tanzania. However, the NAIVS program was expanded nationwide by 2011/12 due to political pressure, which allowed other rural regions to receive at least small quantities of vouchers while a substantial share of the vouchers was still concentrated in the originally designated regions (World Bank, 2014). Table 2 shows the number of household beneficiaries of the NAIVS program between 2008/09 and 2013/14, where the 730,667 households in the 2008/09 crop season were expected to receive vouchers for three consecutive years. The number of household beneficiaries reached its peak in 2010/11 and then declined as beneficiaries completed their three years of assistance. NAIVS officially ended during the 2013/14 cropping season.[3]

[2] The targeted regions were intially Iringa, Mbeya, Ruvuma, Rukwa, Kilimanjaro, Arusha, Manyara, Kigoma, Tabora, Mara, and Morogoro, with Pwani added in 2009/10 (World Bank, 2014).

[3] External funding through the World Bank was finally terminated in 2014, which was the official closure of NAIVS. However, in subsequent years the government of Tanzania continued providing input subsidies to farmers through different approaches including: (i) credit-based subsidies in 2014/15 through which the government provided loans and credit to farmer groups and cooperatives to access inputs; (ii) the government's return to using a voucher-based system in 2015/16; and (iii) subsidized fertilizer by entering into contracts with seed and fertilizer companies to supply inputs in 2016/17 (Masinjila and Lewis, 2018).

Table 2: Household beneficiaries for the NAIVS

	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Planned	740,000	1,500,000	2,040,000	1,800,000	1,000,000	500,000
Actual	730,667	1,511,900	2,011,000	1,779,867	940,783	932,100

Source: World Bank (2014)

The major goals of NAIVS were to: (i) increase the production of maize and rice, the two major staple crops in Tanzania; (ii) improve farmers' access to inorganic fertilizer and seed for improved maize and rice varieties; and (iii) strengthen private sector improved seed and inorganic fertilizer value chains and increase agro-dealer activity at village level (World Bank, 2014; Mather et al., 2016).

Unlike Malawi's and Zambia's ISPs, which historically relied mainly on government distribution systems for subsidized inputs and have only recently started engaging the private sector in major ways, from its start, NAIVS used a much more private sector-oriented approach whereby the private sector handled importation, distribution, and retailing of the subsidized fertilizer while the government's role was limited to distributing vouchers (Mather et al., 2016).[4] In addition, NAIVS primarily targeted households with limited experience using modern inputs but that had the farming resources required to use these inputs well (World Bank, 2014). More specifically, to be eligible for the program, beneficiaries had to: (i) have the ability and willingness to co-finance the input purchase (i.e., upon redeeming the vouchers for each subsidized input which had a face value of half of the market price, the recipient needed to pay the remaining 50% of the price); and ii) be full time farmers with one hectare or less of maize or rice under cultivation, where female-headed households and farmers that had not used modern inputs on maize or rice within the past five years were to be prioritized.[5] Given these targeting criteria, NAIVS was not intended to help the most vulnerable households among the poor because farmers who cannot co-finance the inputs purchased with the voucher are less likely to be able to purchase the inputs at market prices once subsidies are phased out. In addition, the second criterion was designed to prevent the vouchers from reaching households who were already capable of self-financing purchase of the inputs (Mather et al., 2016).

Each voucher recipient was to obtain three vouchers for three consecutive years and approximately 80% of the vouchers were assigned to maize-growing households.[6] The vouchers were for: i) one 50 kg bag of urea, ii) one 50 kg bag of Di-Ammonium Phosphates (DAP) or two 50 kg bags of Minjingu Rock Phosphate (MRP) with nitrogen supplement, and iii) 10 kg of hybrid or open-pollinated maize seed or 16 kg of rice seed, which is suitable for planting approximately one acre of

[4] In Malawi, the government parastatal distributed fertilizers from the port to parastatal depots (Mather et al., 2016) and until recently, fertilizer vouchers for the ISP could only be redeemed at government depots (and not at private agro-dealers' shops) (Lunduka et al., 2013). In Zambia, an electronic-voucher pilot program was launched in 2015/16, but until this point Zambia's program did not use vouchers; rather, subsidized fertilizers and seeds were distributed through a dedicated system that operated separately from private agro-dealers instead of through them.

[5] Mather and Minde (2016) provide descriptive evidence based on data from the TNPS and a World Bank household survey that the majority of NAIVS recipients met the major targeting criteria such as voucher distribution to the most suitable regions for maize and rice production and targeted farmers who have one hectare or less of maize or rice area and who had previously not been using modern inputs within the last five years. However, out of 2.5 million voucher recipients between 2008 and 2013, only 14.7% of them were women although female-headed households were supposed to be given preference (Masinjila and Lewis, 2018).

[6] There may be lagged or enduring effects of the vouchers received for three consecutive years, but this study cannot directly control for this due to lack of data on NAIVS participation in years prior to the years captured in the surveys.

land (World Bank, 2014; Pan and Christiaensen, 2012). The voucher recipients were to redeem their vouchers at local agro-dealerships participating in the program and pay the 50% top-up fee for the subsidized inputs at that time.[7]

In general, the NAIVS vouchers were geographically allocated each year through a multi-stage targeting process. As the first step, a national voucher committee which consisted of central and regional government officials and representatives from private sector input supply chains would meet to determine how vouchers should be allocated among regions. Then, a similar voucher committee at the district level set the number of vouchers to assign to each district (ward/village). At each level of government, the vouchers were allocated based on the estimated numbers of farmers that could 'make best use of these inputs' instead of allocating proportionally to population size (Mather et al., 2016). At the last stage of the distribution, a village voucher committee which consisted of elected village leaders, several resident farmers, and extension agents generated a list of beneficiary farmers which was then submitted to the village assembly for approval. Finally, the input vouchers were distributed to farmers that were approved by the village assembly and met the eligibility criteria.

Among the 1,624 maize growing households in our sample (which is drawn from the 2008/09 and 2012/13 TNPSs), 6.7% (108 households) of them received vouchers for inorganic fertilizers and/or maize seed through the NAIVS program (Table 3). Unlike the planned input subsidy package that three vouchers be allocated to each targeted farmer, Table 3 shows that 65.7% of recipient households (pooled across both waves of the TNPS) obtained vouchers only for inorganic fertilizer while 11.1% of them received only a voucher for improved maize seed; just 23.1% of recipient farmers received vouchers for both inorganic fertilizer and improved maize seed.[8] Given the geographic targeting and eligibility criteria for NAIVS, most of these voucher recipients reside in high potential maize production regions – e.g., approximately 73.1% of them live in the Southern Highlands (i.e., Ruvuma, Iringa, Mbeya, and Rukwa regions); and 21.3% of them live in the northern part of the country (i.e., Arusha, Kilimanjaro, Tanga, Mara, and Manyara regions). Table 3 further shows that 87% of the sample farmers that received vouchers actually redeemed them at local agro-dealerships. According to Mather and Minde (2016), some voucher recipients did not redeem their vouchers because they could not afford the top-up fee; other recipients may have redeemed their vouchers with payment of the top-up fee and then sold one or more of their inputs to another farmer or back to the agro-dealer for cash. We cannot observe resale of inputs acquired with NAIVS vouchers in the TNPS data.

[7] Although vouchers were intended to cover 50% of the input costs, increasing fertilizer prices in some years meant that they only covered 40-45% of the input cost (World Bank, 2014).

[8] In the TNPS, the reasons why farmers may not have received the full set of vouchers are not reported, but Masinjila and Lewis (2018) provide several potential explanations for this. For example, some farmers with limited financial resources may want to take a voucher for a specific input type instead of the entire package of the vouchers. In other cases, farmers were asked to sign for all the vouchers but did not receive all their inputs when inputs were delayed or local agro-dealers had run out of that input.

Table 3: Number and percentage of rural maize-growing households that received versus redeemed a NAIVS voucher by input voucher type received

	TNPS 2008/09 (%)	TNPS 2012/13 (%)	Total (%)
Voucher receipt			
Inorganic fertilizer only	14 (50.0)	57 (71.3)	71 (65.7)
Improved maize seed only	3 (10.7)	9 (11.3)	12 (11.1)
Both	11 (39.3)	14 (17.5)	25 (23.1)
Total number of households	28 (100.0)	80 (100.0)	108 (100.0)
Voucher receipt and redemption			
Inorganic fertilizer only	13 (92.9)	50 (87.7)	63 (88.7)
Improved maize seed only	2 (66.7)	8 (88.9)	10 (83.3)
Both	8 (72.7)	13 (92.9)	21 (84.0)
Total number of households	23 (82.1)	71 (88.8)	94 (87.0)

Source: Authors' calculations.

Table 4 shows the number and percentage of sample maize plots in each SI category owned by recipients of a NAIVS voucher (for inorganic fertilizer and/or improved maize seed) versus NAIVS non-recipients. Out of 2,559 maize plots, 8.4% (215 maize plots) are owned by households who received a NAIVS voucher while 91.6% (2,344 maize plots) are owned by non-recipients. Among the 215 maize plots owned by NAIVS voucher recipients, approximately 36% and 31% fall in the "Intensification" and "SI" categories, respectively. Considering the input voucher types, recipients who received a voucher for inorganic fertilizer only or vouchers for both fertilizer and maize seed are more likely to fall in the "Intensification" and "SI" groups compared to those who received improved maize seed only. On the other hand, approximately 14% and 19% of maize plots owned by NAIVS voucher recipients fall in the "Non-adoption" and "Sustainable" categories, respectively.[9] Unlike the case of the NAIVS voucher recipients, most of the maize plots owned by non-recipients fall in the "Non-adoption" and "Sustainable" categories, accounting for 48% and 39% of them, respectively. The "Intensification" and "SI" categories are much less prevalent among NAIVS non-beneficiaries, at approximately 6% and 7% of maize plots each. This may indicate that maize-producing households have difficulty affording inorganic fertilizers at unsubsidized prices.

[9] Note that even if a farmer received an inorganic fertilizer voucher, they could fall in the "Non-adoption" or "Sustainable" categories if they used the inorganic fertilizer acquired on a crop other than maize and/or if they did not redeem their voucher for inorganic fertilizer.

Table 4: Number and percentage of maize plots owned by NAIVS voucher recipients vs. non-recipients under SI category

	Non-adoption (row %)	Intensification (row %)	Sustainable (row %)	SI (row %)	Total (row %)
Voucher recipients	**31 (14.4)**	**77 (35.8)**	**41 (19.1)**	**66 (30.7)**	**215 (100.0)**
Input voucher type					
Inorganic fertilizer only	16 (11.2)	57 (39.9)	21 (14.7)	49 (34.3)	143 (100.0)
Improved maize seed only	10 (45.5)	1 (4.5)	9 (40.9)	2 (9.1)	22 (100.0)
Both	5 (10.0)	19 (38.0)	11 (22.0)	15 (30.0)	50 (100.0)
Non-recipients	**1,128 (48.1)**	**147 (6.3)**	**907 (38.7)**	**162 (6.9)**	**2,344 (100.0)**
Total maize plots	1,159 (45.3)	224 (8.8)	948 (37.0)	228 (8.9)	2,559 (100.0)

Source: Authors' calculations.

3 Methodology

3.1 Conceptual framework

Following previous studies (e.g., Marenya and Barrett, 2007; Di Falco and Veronesi, 2013; Teklewold et al., 2013), we use a random utility framework to conceptualize the effects of NAIVS voucher receipt on a household's use of SFM practices on a given maize plot. Let I_{imj}^{*} denote a latent variable that represents farmer i's expected utility from choosing SI category j on maize plot m, $j = 0, 1, 2, \dots, J$. ($J = 3$ in this study given that there are four SI categories). This study specifies the latent variable as:

$$I_{imjt}^{*} = \boldsymbol{X_{it}}\boldsymbol{\gamma_j} + \beta_j NAIVS_{it} + c_{ij} + \eta_{imjt}, \qquad (1)$$

where *t* indexes the agricultural year; $\boldsymbol{X_{it}}$ and $\boldsymbol{\gamma_j}$, respectively, capture the observed household, plot, and community characteristics and their corresponding parameters (discussed in Section 3.4.2 below); $NAIVS_{it}$ with associated parameter β_j is a dummy variable equal to one if the household received a NAIVS voucher for inorganic fertilizer, improved maize seed, or both, and equal to zero otherwise; c_{ij} is household-level time-invariant unobserved heterogeneity; and η_{imjt} is the time-varying error term.[10]

However, we do not directly observe the expected utility from choosing alternative j, only the choice ultimately made by the farmer. It is assumed that farmer i will choose alternative j if using j provides greater expected utility than any other alternative $h \neq j$. This can be expressed as:

[10] The TNPS is a household-level panel dataset, not a plot-level one; thus we are only able to control for household-level (not plot-level) time-invariant unobserved heterogeneity.

$$I_{imt} = \begin{cases} 1 \; if \; I^*_{im1t} > \max_{h \neq 1}(I^*_{imht}) \\ \vdots \\ J \; if \; I^*_{imJt} > \max_{h \neq J}(I^*_{imht}) \end{cases} \qquad \text{for all } h \neq j \tag{2}$$

3.2 Estimation strategy

For the empirical analysis, we apply an MNL model, which is widely used in economic applications such as studies on adoption of multiple agricultural technologies and their impacts (Grabowski et al., 2016; Teklewold et al., 2013; Kassie et al., 2015a; Khonje et al., 2018). The main advantage of using an MNL model (compared to a multivariate probit model, discussed below) is its computational simplicity in calculating choice probabilities without any requirement of multivariate integration (Tse, 1987; Hassan and Nhemachena, 2008). In addition, the log-likelihood function for the MNL specification is globally concave, which makes the maximization problem straightforward (Hausman and McFadden, 1984). The main drawback of the MNL model is the assumption of independence of irrelevant alternatives (IIA), which implies that the relative odds between any two alternatives are independent of the characteristics of the other alternatives in the choice set (Wooldridge, 2010; Hausman and McFadden, 1984).

An alternative approach to the MNL model is the multinomial probit model, which relaxes the IIA property by assuming that the residuals in a farmer's utility function (call them a_{ij} from choosing alternative j for $j = 1, 2, \ldots, J$) has a multivariate normal distribution with arbitrary correlations between a_{ij} and a_{ih} for all $j \neq h$. The multinomial probit model is theoretically attractive but it also has some practical challenges: (i) the choice probabilities are very complicated, which makes it difficult to obtain partial effects on the choice probabilities; (ii) it requires that multivariate normal integrals be evaluated to estimate the unknown parameters; and (iii) it is not feasible for more than five alternatives, although this latter issue is not a constraint in the current application (Hausman and McFadden, 1984; Wooldridge, 2010). For these reasons, we use an MNL model instead of a multinomial probit model here.

Assuming that the η in equation (1) are identically and independently Gumbel distributed, the probability that farmer i characterized by $\boldsymbol{X},$ $NAIVS_{it}$, and c_{ij} in equation (1) will choose alternative j can be specified by the MNL model (McFadden, 1973) as:

$$\mathrm{P}\left(I_{imt} = j \middle| \boldsymbol{X_{it}}, NAIVS_{it}, c_{ij}\right) = \frac{\exp\,(\boldsymbol{X_{it}\gamma_j} + \beta_j NAIVS_{it} + c_{ij})}{\sum_{h=0}^{3} \exp\,(\boldsymbol{X_{it}\gamma_h} + \beta_h NAIVS_{it} + c_{ih})} \tag{3}$$

As noted above, relatively few NAIVS beneficiaries received vouchers for both inorganic fertilizer and maize seed, while approximately 66% of the recipients pooling across both waves received only vouchers for inorganic fertilizer. The effects of NAIVS voucher receipt on households' SI category decisions may differ by the type of input voucher(s) received. We therefore generate two alternative *NAIVS* variables based on input types: i) $NAIVS_{fert\_it}$ equals one if the household received a voucher for inorganic fertilizer, and ii) $NAIVS_{seed\_it}$ equals one if the household received a voucher for improved maize seed. In addition, when farmers received the vouchers but did not redeem them, the actual effects of the NAIVS program on each adoption strategy may be under- or over-estimated. We thus also estimate a set of models using another set of alternative *NAIVS* variables based on households' voucher redemption.

To control for time-constant unobserved household-level heterogeneity (c_{ij}) that may be correlated with the observed explanatory variables, a CRE/Mundlak-Chamberlain device approach is applied. This entails including the household-level time averages of the explanatory variables that change across i and t as additional regressors in equation (3) (Mundlak, 1978; Chamberlain, 1984; Wooldridge, 2010). This approach requires the assumptions of strict exogeneity of the explanatory variables conditional on the unobserved heterogeneity, and that the unobserved effects are linearly correlated with the household-level time averages of the observed explanatory variables.

Even though our model controls for time-invariant unobserved heterogeneity via CRE, we still have concerns about potential endogeneity related to time-varying unobserved heterogeneity, particularly since NAIVS beneficiaries are not randomly selected. The NAIVS voucher receipt variables (i.e., $NAIVS_{it}$, $NAIVS_{fert\_it}$, and $NAIVS_{seed\_it}$) may be systematically related to time-varying unobserved factors that influence the household's SI category decisions (η_{imjt}).

To test and control for this potential endogeneity of the *NAIVS* variables, we use the CF approach. The CF approach in the context of the current study consists of two steps (Wooldridge 2015). In the first step, we estimate a reduced form model via CRE logit in which the relevant *NAIVS* variables are the covariates in equation (3) and at least as many instrumental variables (IVs) as there are potentially endogenous *NAIVS* variables (J.M. Wooldridge, personal communication, May 2017). The logit generalized residuals obtained from the reduced form serve as the control functions. In the second step, the reduced form logit residuals are included as additional regressors in the main MNL model. If the coefficient on a given logit generalized residual variable is statistically significant at the 10% level or lower, then the null hypothesis that that *NAIVS* variable is exogenous is rejected. However, including the logit residuals in the main MNL model corrects for endogeneity of that *NAIVS* variable (Rivers and Vuong 1988). Because the logit generalized residuals are generated in a first stage estimation, we use bootstrapping to obtain valid standard errors for the parameter estimates in the MNL model (Wooldridge, 2010).

To be valid IVs, there are two requirements: i) the IVs must be strongly partially correlated with the *NAIVS* variables, and ii) partially uncorrelated with η_{imjt}, where condition ii) is a maintained assumption that cannot be tested. This study considers two candidate IVs for the *NAIVS* variables. The first IV, $Voucher_{rt}$, is the number of vouchers for inorganic fertilizer (nitrogen) distributed to region *r*. This variable is expected to be positively correlated with fertilizer and maize seed voucher receipt by a maize-growing household because most of the fertilizer vouchers are geographically targeted to the most suitable areas for maize. The second IV is $ElectoralThreat_{dt}$, which was used by Mather and Minde (2016) as an IV for the quantity of subsidized fertilizer received by a household. It is defined as the district-level (*d*) ratio of the proportion of votes for the runner-up in the most recent presidential election (Ibrahim Lipumba in 2005 and Willibrod Peter Slaa in 2010) over the proportion of votes for the winner (Jakaya Mrisho Kikwete in both 2005 and 2010).[11] According to previous studies (e.g., Banful, 2011; Mason et al., 2017; Mather and Minde, 2016), past election results and voting patterns in a given area (district, constituency, etc.) have been found to affect the targeting of subsidized fertilizer in Ghana, Malawi, Zambia, and Tanzania. In Tanzania in

[11] Both IVs, $Voucher_{rt}$ and $ElectoralThreat_{dt}$, used in this study are time-varying in addition to varying across regions and districts, respectively.To construct $ElectoralThreat_{dt}$, we used constituency-level data on electoral results from the 2005 and 2010 presidential elections and then aggregated them to the district level because the TNPS does not provide village names, which prevents us from being able to match households with their constituency. The electoral results in 2005 and 2010 were used to construct the IV for household receipt of NAIVS vouchers in TNPS 2008/09 and 2012/13, respectively.

particular, Mather and Minde (2016) found that electoral threat significantly affects the quantity of subsidized fertilizer received by the household. The reduced form CRE logit results indicate that these IVs are indeed very strongly partially correlated with the potentially endogenous *NAIVS* variables; the IVs are jointly significant for all *NAIVS* variables at the 1% level (see Table A1 and Table A2 in the Appendix).

Regarding requirement (ii) for the validity of the two IVs, $Voucher_{rt}$ and $ElectoralThreat_{dt}$, we argue that after controlling for the rich set of observed covariates described below and time invariant household-level unobserved heterogeneity via CRE, these variables should only affect a household's SI category decisions through their effects on the household's receipt of NAIVS vouchers. Moreover, these IVs are exogenous to an individual household because district-level election results reflect the decisions of thousands of voters and the regional allocation of NAIVS vouchers is decided by the central government.

4 Data and description of variables

4.1 Data

Our primary data source is the TNPS, which is a three-wave nationally representative household panel survey conducted in 2008/09, 2010/11, and 2012/13.[12] The TNPS was implemented by the Tanzania National Bureau of Statistics with technical assistance from the World Bank through the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) program. The survey captures information on agricultural production and input use, off-farm income sources, household consumption, socio-economic characteristics, and other topics. A stratified random sampling procedure was employed to select the households in four analytical strata: Dar es Salaam, other urban areas in mainland Tanzania, rural areas in mainland Tanzania, and Zanzibar. Within each stratum, clusters were randomly chosen as the primary sampling units and eight households from each cluster were randomly selected in the last stage.[13] The 2008/09 TNPS consisted of 3,265 households that were clustered in 409 enumeration areas. This original sample of 3,265 households and individual members in these households were tracked and re-interviewed in the second (2010/11 TNPS) and third rounds (2012/13 TNPS). The second round tracked 97% of the first round households and the third round tracked 96% of the second round households; thus attrition between rounds was very low (Tanzania National Bureau of Statistics, 2014).

For the empirical analysis, we exclude the second (2010/11) wave of the TNPS because the questions on NAIVS participation are not comparable to those on the first and third waves. Specifically, the survey instrument in 2010/11 recorded input voucher receipt at the plot level (only if a given input was used) and has no information on whether recipients indeed redeemed the vouchers, while the voucher receipt and redemption information in the other two rounds (2008/09 and 2012/13 TNPS) was directly collected at the household level (and so it captured all voucher receipt regardless of whether a given input was used); the latter data are used to generate the *NAIVS* variables described above. Our analytical sample involves the balanced panel of maize-

[12] Data from the fourth wave of the survey (TNPS 2014/15) are now publicly available. However, only 860 households corresponding to 68 clusters were selected from the TNPS 2012/13 sample as part of the 2014/15 "Extended Panel" while a new sample was entirely refreshed for all future rounds. Therefore, we consider only the first three rounds of the survey in this study.

[13] In urban areas, the clusters are census enumeration areas based on the 2002 Population and Housing Census; in rural areas, the clusters are villages.

growing households interviewed in both TNPS 2008/09 and 2012/13, and their associated maize plots: 1,624 total household observations (812 observations in each round) and 2,559 total maize plots cultivated by these households (1,225 maize plots in 2008/09 and 1,334 maize plots in 2012/13).

In addition, the TNPS data provided by the World Bank include a range of secondary geospatial variables from other sources. Among these, we use in the empirical analysis the rainfall data from the National Oceanic & Atmospheric Administration-Climate Prediction Center (NOAA-CPC) and the soil nutrient availability data from the Harmonized World Soil Database.

Other data used in the analysis are: (i) monthly wholesale price data for maize and rice from the Agricultural Market Information System (AMIS) of the Ministry of Industry and Trade (MIT);[14] and (ii) constituency-level data from the 2005 and 2010 presidential elections from the national election commission of Tanzania.[15]

4.2 Explanatory variables

Table 5 provides descriptive statistics for the explanatory variables used in the analysis. These variables were selected based on a careful review of the technology adoption literature and the literature on the impacts of ISPs on SFM in other SSA countries (e.g., Pender and Gebremedhin, 2007; Ndiritu et al., 2014; Doss and Morris, 2001; de Janvry et al., 1991; Kassie et al., 2013; Kassie et al., 2015a and 2015b; Amsalu and Graaff, 2007; Morgan et al., 2019; Koppmair et al., 2017).

The key explanatory variables of interest in this study are the *NAIVS* variables. Out of 1,624 household observations during TNPS 2008/09 and 2012/13, 7% of the sample (3% and 10% of the sample households in 2008/09 and 2012/13, respectively) received a NAIVS fertilizer and/or maize seed voucher $(NAIVS_{it})$. By input type of the voucher received, 6% and 2% of the sample households received a NAIVS fertilizer voucher $(NAIVS_{fert\_it})$ and a NAIVS seed voucher $(NAIVS_{seed\_it})$, respectively.

[14] These prices were collected on a weekly basis from 20 wholesale markets that are matched to regions in Tanzania. Out of 26 regions in the TNPS, there are six regions that are not covered by AMIS. For the wholesale prices in these regions, we use an average price calculated from wholesale markets in adjacent regions.

[15] We thank Dr. David Mather for sharing these data.

Table 5: Summary statistics for the variables used in the analysis

Variables	Variable description	Mean	Std. dev.
Household characteristics			
$NAIVS_{it}$	1=yes if the household received a NAIVS voucher for inorganic fertilizer and/or maize seed	0.07	0.25
$NAIVS_{fert\_it}$	1=yes if the household received a NAIVS voucher for inorganic fertilizer	0.06	0.24
$NAIVS_{seed\_it}$	1=yes if the household received a NAIVS voucher for maize seed	0.02	0.15
Male-Headed HH	1=yes if the household head is male	0.79	0.41
Age of HH head	Age of the household head (years)	48.96	15.15
Education of HH head	Highest grade completed by the household head (years)	4.74	3.38
Household endowments of physical, human, and social capital			
Family labor	Number of adults (15-64 years old) per acre of cultivated land	0.97	1.33
Total cultivated land	Total land area cultivated (acres)	6.23	10.41
Off-farm income	1 = yes if the HH earned off-income in the past 12 months	0.43	0.49
Farm assets	Total value of farm implements and machinery (1,000 TZS) owned in the past 12 months	1,131.23	5,761.07
Livestock ownership	1 = yes if the HH has livestock (cattle, goats, sheep, pigs, or donkeys)	0.46	0.50
Access to credit	1 = yes if the HH borrowed cash, goods, or services in the past 12 months	0.07	0.25
Membership (SACCOS)	1 = yes if the HH has a member of SACCOS	0.04	0.19
Agricultural extension and access to information and input suppliers			
Extension from gov't/NGO	1 = yes if the HH received agricultural advice from government/NGO in the past 12 months	0.12	0.32
Extension from cooperative	1 = yes if the HH received agricultural advice from cooperative/large scale farmer in the past 12 months	0.04	0.19
Cooperatives	1 = yes if farmers' cooperative present within the village	0.46	0.50
Input supplier	1 = yes if improved maize seed supplier present within the village	0.39	0.49
Shocks and other constraints			
Drought/Flood	1 = yes if the HH was negatively affected by drought or flood in the past two years	0.11	0.31
Crop disease/Pests	1 = yes if the HH was negatively affected by crop diseases or pests in the past two years	0.08	0.28
Rainfall	12-month total rainfall (mm) in July-June	766.64	270.51
Soil nutrient constraint	1 = yes if soil nutrient availability constraint is moderate or severe	0.62	0.49

Table 5 (cont'd)

Variables	Variable description	Mean	Std. dev.
Input and expected output prices			
Inorganic fertilizer price	Inorganic fertilizer price at district level (TZS/kg)	1,141.35	371.39
Real price of maize	Average price of maize from Jul. to Sep. in prior year (TZS/100kg bag)	29,941.11	7879.33
Real price of rice	Average price of rice from Jul. to Sep. in prior year (TZS/100kg bag)	91,313.88	17,695.48
Bean price	Bean market price at region level (TZS/kg)	1281.17	274.05
Groundnut price	Groundnut market price at region level (TZS/kg)	1541.44	499.50
Plot characteristics			
Plot size	Plot size (acres)	2.94	5.68
Plot tenure	1 = yes if the HH has title deed for the plot	0.09	0.28
Distance from home	Distance from plot to home (km)	3.66	20.16
Distance from main road	Distance from plot to main road (km)	2.05	5.11
Distance from market	Distance from plot to major market (km)	10.84	14.18
Good soil quality	1 = yes if farmer's perception of soil quality on the plot is good	0.50	0.50
Poor soil quality	1 = yes if farmer's perception of soil quality on the plot is poor	0.05	0.22
Flat plot slope	1 = yes if farmer's perception of the slope on the plot is flat	0.64	0.48
Moderate plot slope	1 = yes if farmer's perception of the slope on the plot is slightly sloped	0.32	0.47
Instrumental variables			
$ElectoralThreat_{d\_it}$	Proportion of votes for the presidential runner-up divided by the proportion of votes for the winner	0.24	0.47
$Voucher_{r\_it}$	Number of inorganic fertilizer (nitrogen) vouchers distributed to region	52,373.05	42,070.34

Note: The means and standard deviations for plot characteristics are calculated based on the plot level data (n=2,559), whereas the means and standard deviations for the other control variables are calculated based on the balanced household-level data (n=1,624).

This study controls for household-level heterogeneity by including characteristics of the household head – such as his/her age, gender, and education level – which are relevant variables that may influence decision-making processes within the household. That is, use of modern inputs and management practices may differ across households depending on the characteristics of the household head as a main decision-maker. For example, more educated farmers may be more aware of the benefits from the use of each SFM practice (or combined use thereof), and thus they may be more likely to purchase inputs or adopt agricultural practices that could have the potential to improve crop yields (Pender and Gebremedhin, 2007). Moreover, there may exist gender differences in adoption strategies for the SFM practices since female farmers often have less access to things like land, labor, credit, education, and information (Ndiritu et al., 2014; Doss and Morris, 2001).

In the context of imperfect or missing markets for land and labor, a household's capital endowments (physical, human, and social), represented by total cultivated land, off-farm income, farm assets, livestock ownership, family labor, access to credit, and membership in Savings and Credits Cooperatives Societies (SACCOS) in this study, may significantly affect a farmer's decision to use external inputs and SFM practices (de Janvry et al., 1991; Pender and Gebremedhin, 2007). Households with greater physical assets and social capital generally have more savings and better access to credit which would help them to finance the purchase of inputs such as inorganic fertilizer and improved seeds (Kassie et al., 2013). Livestock ownership could also facilitate use of organic fertilizer because animal manure is one of the major sources of organic fertilizer and it can rarely be purchased from the market. In addition, family labor availability, defined here as the number of adults aged 15 to 64 within the household per acre of total cultivated land, could be an important determinant of household use choices among the SFM practices. For example, particularly in the context of missing or imperfect labor markets, greater availability of family labor could enable households to choose relatively labor-intensive practices (e.g., maize-legume intercropping or organic fertilizer, or both) rather than investing in inorganic fertilizer only.

Agricultural extension services are a key channel to promote the use of modern inputs and improved management practices (Pender and Gebremedhin, 2007; Kassie et al., 2015a). We thus include two dummy variables associated with agricultural extension services depending on the organizations: i) one is a variable equal to one if the household received agricultural extension advice from government or an NGO in the past 12 months; and ii) the other equals one if the household received agricultural extension advice from a farmers' cooperative or large-scale farmer in the past 12 months. In addition, the presence of a farmers' cooperative or input supplier within the community could provide farmers with better access to information about or better physical access to farm inputs. Thus, this study includes dummy variables for the existence of a farmers' cooperative and improved maize seed supplier within the household's village as proxies for access to information and agricultural inputs.

Given that African farmers are often vulnerable to weather shocks and crop pest/disease outbreaks, which could affect their use of SFM practices in subsequent seasons, we also control for the following two binary variables (following Kassie et al., 2015b): i) drought/flood which equals one if the household was negatively affected by a drought or flood during the past two years; and ii) crop diseases/pests which equals one if the household was negatively affected by crop diseases or pests in the past two years. We also control for two geospatial variables: i) 12-month total rainfall (mm) in the household's area from July to June; and ii) soil nutrient availability constraint which equals one if soil nutrient availability in the household's area is moderate, severe, or very severe (with the base category being no or slight constraint).[16]

Input and expected output prices could also be key factors when the household makes decisions to use inputs and agricultural management practices on their maize plots. In particular, there is a

[16] According to the Harmonized World Soil Database, soil nutrient availability is one of the key soil qualities for crop production (where maize is used as the reference crop). It is measured based on important characteristics (i.e., soil texture, soil organic carbon, soil pH, total exchangeable bases) of the top soil (0-30 cm) and the subsoil (30-100 cm). Moderate, severe, and very severe constraints are generally rated between 60% and 80%, between 40% and 60%, and less than 40% of the growth potential, respectively.

significant gap between the prices of leguminous crops and maize in Tanzania, and thus use of SFM practices may vary depending on the (expected) prices of these crops. (Output prices at harvest are not known at planting time.) For the price of maize, we assume naïve price expectations – i.e., that the expected harvest price of the crop equals the observed market price in the previous year. Given that the MIT collects wholesale prices throughout the year for maize, we calculate the average real wholesale price per 100 kg bag from the nearest wholesale market during the post-harvest period (i.e., from July through September) of the previous year's main season harvest; this is then included in the model as a proxy for the household's expected maize price. The data available on legume prices are more limited. Due to these data limitations, we utilize the price information available in the TNPS and include the average prices of beans and groundnuts per kilogram at region level as a proxy for the expected prices of legume crops (i.e., we assume perfect foresight). We also control for the average price of inorganic fertilizer per kilogram at district level as the major relevant input price in this study.[17]

Plot-specific attributes such as plot size, plot tenure status, distance from the plot to home/main road/market, and farmer's perception of the soil quality and slope of the plot are also included in our model. Per previous studies (Amsalu and Graaff, 2007; Kassie et al., 2013; Kassie et al., 2015a), these plot characteristics are often important determinants of the use of soil conservation and SFM practices in eastern and southern Africa including Tanzania.

5 Results

5.1 Test for endogeneity of household receipt of NAIVS voucher

The parameter estimates from the CRE-MNL regression models with CF approach are reported in Appendix Table A3. Two sets of estimated coefficients are presented based on different *NAIVS* variables: i) *NAIVS* variable for receipt of any input voucher ($NAIVS_{it}$, column 1); and ii) two *NAIVS* variables by input types ($NAIVS_{fert\_it}$ and $NAIVS_{seed\_it}$, column 2). We find that the generalized residuals from the CF first-stage CRE logit models in both model specifications are not statistically significant, implying we fail to reject the exogeneity of the *NAIVS* variables considered in this study.[18] Similar results hold if *NAIVS* variables and residuals based on households' voucher *redemption* (instead of receipt) are used. Thus, in the remainder of this study, we focus on the results of CRE-MNL models that exclude the CF residuals. Parameter estimates for these models are reported in Table A4 in the Appendix. These coefficients are the log-odds of each respective SI category ("Intensification", "Sustainable", and "SI") for each control variable relative to the reference SI category ("Non-adoption"), holding the other variables constant. To reach conclusions based on actual probabilities, we need to calculate average partial effects (APEs). We report and discuss these APEs below.

[17] No data are available on maize seed prices at district level.

[18] The p-values on the generalized residuals for $NAIVS_{it}$, $NAIVS_{fert\_it}$, and $NAIVS_{seed\_it}$ are 0.449, 0.498, and 0.430, respectively. Mather and Minde (2016), who used the electoral threat IV for household quantity of NAIVS fertilizer, also fail to reject exogeneity of NAIVS fertilizer quantity received.

5.2 APEs of NAIVS voucher receipt on household use of practices in the various SI categories

Table 6 shows the APEs of household receipt of NAIVS vouchers on household's use of practices in various SI categories by input voucher type received (Panels A and B, column 1). As noted in Section 3.3.2, because some farmers did not redeem their vouchers, we also report the APEs of households' voucher redemption (Panels A and B, column 2).

Table 6: APEs of NAIVS voucher receipt and redemption on household use of practices in the various SI categories

	NAIVS voucher receipt				NAIVS voucher redemption			
Variables	N	I	S	SI	N	I	S	SI
Panel A								
NAIVS for any input	-0.214***	0.096***	0.027	0.091***	-0.212***	0.100***	0.008	0.104***
	(0.048)	(0.015)	(0.048)	(0.016)	(0.056)	(0.016)	(0.052)	(0.015)
Panel B								
NAIVS for inorganic fertilizer	-0.251***	0.100***	0.055	0.096***	-0.219***	0.099***	0.020	0.101***
	(0.059)	(0.017)	(0.056)	(0.016)	(0.065)	(0.018)	(0.060)	(0.016)
NAIVS for maize seed	-0.034	0.011	0.023	-0.001	-0.102	0.039	0.025	0.038
	(0.074)	(0.026)	(0.074)	(0.032)	(0.097)	(0.025)	(0.089)	(0.030)

Notes: I, S, and SI denote "Intensification", "Sustainable", and "SI", respectively. *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.

There are three main empirical findings drawn from Table 6. First, based on the results from Panel A in column 1, we find that receipt of a NAIVS voucher for any input (i.e., inorganic fertilizer or maize seed or both) has a significant positive effect on both the household's probability of adopting inorganic fertilizer use only ("Intensification") and joint use of inorganic fertilizer with other SFM practices ("SI") on a given maize plot. More specifically, household receipt of a NAIVS voucher is associated with a 9.6 percentage point average increase in the probability of "Intensification" on a given maize plot and a 9.1 percentage point average increase in "SI" on a given maize plot. Given high inorganic fertilizer prices and lack of liquidity and credit considered as major constraints that farmers in SSA face, this significant positive effect on household inorganic fertilizer use is entirely reasonable. This is consistent with findings in Mather and Minde (2016) that household receipt of one NAIVS fertilizer voucher (50kg of subsidized fertilizer) increases the household's probability of purchasing commercial fertilizer by 4.0 percentage points, on average. Two potential explanations of the positive effect on the "SI" group are as follows. First, for households who originally considered using inorganic fertilizer only on their maize plot, the subsidized NAIVS voucher for inorganic fertilizer and/or maize seed could free up their resources to invest in other inputs (e.g., legume seeds or organic fertilizers in our study) that facilitate joint use of these practices with inorganic fertilizer. Second, for households who initially planned use of organic fertilizer and/or maize-legume intercropping but not inorganic fertilizer, a NAIVS voucher, especially a voucher for inorganic fertilizer, could be a great incentive to or make it possible for the household to jointly use these SFM practices. The positive effect of receipt of a NAIVS voucher on the use of practices in the "SI" category on maize plots is an encouraging result, as it could suggest that NAIVS stimulated ISFM and could improve soil health of the associated maize plots as well as maize yields and yield response to inorganic fertilizer in the long term. On the other hand, we find no statistically significant effects of NAIVS voucher receipt on the use of practices in the "Sustainable" category.

The second main finding based on Table 6 is that the statistically significant positive effects of NAIVS on farmers' use of the practices in the "Intensification" and "SI" categories appear to be mainly driven (as expected) by receipt of a voucher for inorganic fertilizer as opposed to receipt of a voucher for maize seed. In particular, note that based on the results in Panel B, the APEs of the NAIVS inorganic fertilizer voucher are positive and statistically significant at the 1% level for the "Intensification" and "SI" categories, whereas the APE for the NAIVS maize seed voucher is not statistically different from zero. However, no significant effects of the NAIVS maize seed voucher may be explained by the very small proportion of sample households that received it. That is, there may indeed be an impact of maize seed voucher receipt, but such an impact may not be detected unless it is very large due to low statistical power.

The third main finding based on Table 6 is that the estimated effects of NAIVS on the use of practices in various SI categories are very similar in sign, significance, and magnitude in the results with voucher receipt (column 1) versus voucher redemption (column 2). This finding is perhaps not that surprising given that overall 87% of household beneficiaries who received at least one NAIVS voucher indeed redeemed it (Table 3). Nevertheless, it shows that our results are robust to alternative definitions of "participation" in NAIVS.

To further explore the above findings, we conduct additional analyses to unpack how NAIVS voucher receipt affects the use of different packages of the practices included in the "SI" group. To do this, we consider two sets of categorizations focusing on the use of at inorganic fertilizer and at least one of the Sustainable practices on a given maize plot, respectively: i) four categories based on the combinations of inorganic fertilizer and maize-legume intercropping irrespective of the use of organic fertilizer (Table 7), and ii) four categories based on the combinations of inorganic fertilizer and organic fertilizer irrespective of the use of maize-legume intercropping (Table 8). The APEs of these categorizations in CRE-MNL models are reported in Tables 7 and 8, respectively. The results suggest that household receipt of a NAIVS voucher has a positive impact on the household's probability of using each of the inorganic fertilizer plus Sustainable practice combinations included in the "SI" group, although the effect on the probability of joint use of inorganic fertilizer and at least maize-legume intercropping is larger in magnitude. More specifically, household receipt of a NAIVS voucher for any input is associated with an 7.5 percentage point average increase in the probability of joint use of inorganic fertilizer and at least maize-legume intercropping on a given maize plot and a 2.9 percentage point average increase in the probability of joint use of inorganic fertilizer and at least organic fertilizer. Tables 7 and 8 also show that the three main findings drawn in Table 6 are largely upheld.[19]

[19] In addition to these main findings, APEs of other factors influencing the use of practices in various SI categories are presented in Appendix Table A5.

Table 7: APEs of NAIVS voucher receipt and redemption on household sole or joint use of inorganic fertilizer and maize-legume intercropping

Variables	NAIVS voucher receipt: None	NAIVS voucher receipt: Inorganic fertilizer only	NAIVS voucher receipt: Maize-legume IC only	NAIVS voucher receipt: Both	NAIVS voucher redemption: None	NAIVS voucher redemption: Inorganic fertilizer only	NAIVS voucher redemption: Maize-legume IC only	NAIVS voucher redemption: Both
Panel A								
NAIVS for any	-0.180***	0.113***	-0.009	0.075***	-0.208***	0.122***	0.001	0.084***
input	(0.049)	(0.016)	(0.048)	(0.014)	(0.058)	(0.017)	(0.055)	(0.014)
Panel B								
NAIVS for	-0.188***	0.120***	-0.007	0.075***	-0.196***	0.123***	-0.005	0.078***
inorganic fertilizer	(0.060)	(0.018)	(0.057)	(0.015)	(0.066)	(0.018)	(0.063)	(0.015)
NAIVS for maize	-0.016	0.001	0.006	0.009	-0.065	0.036	-0.012	0.040
seed	(0.077)	(0.030)	(0.075)	(0.028)	(0.105)	(0.028)	(0.099)	(0.027)

Notes: *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.

Table 8: APEs of NAIVS voucher receipt and redemption on household sole or joint use of inorganic fertilizer and organic fertilizer

Variables	NAIVS voucher receipt: None	NAIVS voucher receipt: Inorganic fertilizer only	NAIVS voucher receipt: Organic fertilizer only	NAIVS voucher receipt: Both	NAIVS voucher redemption: None	NAIVS voucher redemption: Inorganic fertilizer only	NAIVS voucher redemption: Organic fertilizer only	NAIVS voucher redemption: Both
Panel A								
NAIVS for any	-0.196***	0.157***	0.009	0.029***	-0.201***	0.169***	-0.002	0.034***
input	(0.035)	(0.021)	(0.028)	(0.010)	(0.039)	(0.022)	(0.030)	(0.009)
Panel B								
NAIVS for	-0.225***	0.160***	0.032	0.033***	-0.212***	0.162***	0.015	0.035***
inorganic fertilizer	(0.041)	(0.023)	(0.033)	(0.011)	(0.043)	(0.024)	(0.033)	(0.011)
NAIVS for maize	-0.014	0.018	-0.004	-0.000	-0.101	0.073*	0.012	0.015
seed	(0.063)	(0.040)	(0.042)	(0.018)	(0.105)	(0.028)	(0.099)	(0.027)

Notes: *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.

These findings are new and important considering that previous studies (Holden and Lunduka, 2012; Koppmair et al., 2017; Morgan et al., 2019; Kassie et al., 2015a) have typically found evidence of no significant effects or negative effects of fertilizer subsidies in Malawi and Zambia on the use of SFM practices – specifically organic manure, intercropping maize with other crops, ridges, terraces and stone bunds, and fallowing – when considered individually. This may be similar with our findings of no significant effects of NAIVS voucher receipt on use of practices in the "Sustainable" group but the weight of the evidence in our study suggests significant positive subsidy program effects on inorganic fertilizer use only as well as *joint use* of inorganic fertilizer with other SFM practices – something that is not explicitly investigated in previous studies.

Although we find fairly consistent and robust evidence on the effects of Tanzania's ISP on farmers' use of SFM practices, a key limitation of the study is that although NAIVS beneficiaries were to receive input vouchers for three consecutive years, our data only capture one year of participation in the NAIVS program. Hence, our findings should be considered as the immediate or short-run effects of the NAIVS program on households' use of SFM practices rather than the long-run effects of their full participation in the program. Future research using alternative data sources (if available) could seek to address this limitation.

6 Conclusions and policy implications

In many African countries, government policies through large-scale ISPs have primarily focused on conventional intensification of agricultural systems involving the use of inorganic fertilizer and high-yielding crop varieties. Yet there is an emerging consensus that these conventional means are unlikely to be sufficient to sustainably intensify agricultural production. Despite heavy spending on ISPs in SSA, the productivity and welfare effects of these programs have, in many cases, been considerably smaller than expected (Jayne et al., 2018). One of the major reasons for this is low crop yield response to inorganic fertilizer on many smallholders' fields due to poor soil quality (Ibid.). Given this limited effect of ISPs, it is increasingly apparent that use of complementary SFM practices along with inorganic fertilizer is needed to improve the agronomic efficiency of inorganic fertilizer use as well as the effectiveness of ISPs (Holden, 2018; Jayne et al., 2018). However, no previous studies have investigated the effects of an African ISP on joint use of inorganic fertilizer with other SFM practices.

Using nationally representative household panel survey data from Tanzania, this study estimates the effects of household receipt of vouchers for inorganic fertilizer and/or maize seed through the NAIVS program on farmers' use of various SFM practices. Our results from CRE-MNL models suggest that receipt of a NAIVS voucher for any input (i.e., inorganic fertilizer, improved maize seed, or both) is associated with increases in maize-growing households' probability of using inorganic fertilizer only (referred to as "Intensification") as well as joint use of inorganic fertilizer with organic fertilizer and/or maize-legume intercropping (referred to as "SI") on a given maize plot. In addition, we find that these effects are mainly driven by receipt of a voucher for inorganic fertilizer as opposed to receipt of a voucher for improved maize seed. No statistically significant NAIVS effects are found for the practices in the "Sustainable" group (i.e., organic fertilizer use only, maize-legume intercropping use only, or both). These findings are also robust to a household's voucher redemption status. Furthermore, we find that household receipt of a NAIVS fertilizer voucher has a positive effect on the household's probability of adopting joint use of both combinations in the "SI" group: inorganic fertilizer with organic fertilizer and inorganic fertilizer with maize-legume intercropping, with the latter effect found to be larger in magnitude. Overall, the results suggest that Tanzania's NAIVS program encouraged farmers' sole use of inorganic fertilizer, but more importantly, that the program also incentivized households' combined use of inorganic fertilizer with other complementary SFM practices, which could raise inorganic fertilizer use efficiency as well as contribute to SI goals.

The results have several policy implications, both for Tanzania and other SSA countries' ISPs.[20] First, our main findings demonstrate that NAIVS increased households' use of inorganic fertilizer only as well as joint use of inorganic fertilizer with organic fertilizer and/or maize-legume intercropping as sustainable forms of agricultural intensification. Although further research is needed, these positive effects could be explained by its more private sector-friendly design and more effective targeting criteria and implementation. Compared to other SSA countries' ISPs, the NAIVS program was designed to target relatively resource poor households who have limited experience in using modern inputs and the majority of voucher recipients met these criteria (Mather and Minde, 2016).[21] In addition, our data also show that most of voucher recipients redeemed their voucher(s) at local agro-dealerships. NAIVS' positive effects on the sole use of inorganic fertilizer and joint use of it with other SFM practices may imply that developing ISPs closer to 'smart subsidy' criteria in both design and implementation is crucial to achieving the goals of ISPs and stimulating SI. In addition, because most NAIVS beneficiaries prior to NAIVS had very limited experience with using inorganic fertilizer (unlike many subsidized fertilizer recipients in Malawi and Zambia – see Ricker-Gilbert et al. (2011) and Jayne et al. (2013)) and relied mainly on organic sources of soil fertility, they may consider inorganic fertilizer to be a complement to rather than a substitute for practices like use of organic fertilizer and maize-legume intercropping. Therefore, the receipt of a NAIVS voucher for inorganic fertilizer may have encouraged households' combined use of inorganic fertilizer with these other practices. The second policy implication is related to the fact that approximately 38% of the maize plots in rural Tanzania involved maize-legume intercropping (Table 1) but this use rate is still far from universal and much lower relative to other countries in the region such as Kenya (Kassie et al., 2015a). Given this, promoting wider adoption of legume intercropping with maize through including a legume seed subsidy in the ISP may be a country-specific strategy to incentivize joint use of inorganic fertilizer with maize-legume intercropping as an SI strategy. However, further research is needed to identify if this policy shift would be a cost-effective means of promoting SI of maize production in Tanzania.

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[20] Although the NAIVS program officially ended in 2014, a similar ISPs was implemented in 2015/16 and it is possible that a similar program will be re-introduced in Tanzania in the future.

[21] In contrast, in Malawi and Zambia, households with greater land and asset wealth received more subsidized fertilizer through ISPs (Jayne et al., 2013). Kenya's ISPs was targeted to areas where most of rural households were already using commercially-priced inorganic fertilizer on maize a few years before the programs started (Mather and Minde, 2016).

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APPENDIX

Table A1: Reduced form CRE logit regression estimates of factors affecting household NAIVS voucher receipt

Variables	CRE logit (1) =1 if the household received a NAIVS voucher for inorganic fertilizer and/or maize seed	CRE logit (2) =1 if the household received a NAIVS voucher for inorganic fertilizer	CRE logit (3) =1 if the household received a NAIVS voucher for maize seed
$ElectoralThreat_{d\_it}$	0.734***	0.357	1.042***
	(0.220)	(0.632)	(0.398)
$Voucher_{r\_it}$	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Male-Headed HH	0.422	0.380	-0.861
	(0.411)	(0.443)	(0.546)
Age of HH head	0.029	0.097**	-0.032
	(0.057)	(0.043)	(0.080)
Education of HH head	0.131**	0.160***	0.133*
	(0.052)	(0.053)	(0.074)
Family labor	0.482*	0.506*	-0.058
	(0.249)	(0.270)	(0.368)
Total cultivated land	0.382***	0.374***	0.277***
	(0.077)	(0.082)	(0.076)
Off-farm income	0.317	-0.011	1.223*
	(0.399)	(0.411)	(0.634)
Farm assets	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Livestock ownership	0.977***	1.137***	0.225
	(0.354)	(0.376)	(0.495)
Access to credit	-1.514*	-1.341	-1.596
	(0.831)	(0.895)	(1.056)
Extension from gov't/NGO	0.472	0.153	-0.317
	(0.519)	(0.531)	(0.737)
Extension from cooperative	0.349	0.218	0.302
	(0.751)	(0.806)	(1.107)
Cooperative	0.102	0.178	-1.257**
	(0.335)	(0.362)	(0.623)
Input supplier	0.890***	1.031***	1.636***
	(0.323)	(0.344)	(0.557)
Drought/Flood	-1.262*	-1.073	-1.223
	(0.665)	(0.793)	(0.951)
Crop disease/Pests	0.299	0.705	-0.508
	(0.802)	(0.974)	(1.330)
Rainfall	-0.003*	-0.004*	-0.001
	(0.002)	(0.002)	(0.003)
Soil nutrient constraint	3.973***	3.581**	1.881
	(1.508)	(1.762)	(1.381)

Table A1 (cont'd)

Variables	CRE logit (1) =1 if the household received a NAIVS voucher for inorganic fertilizer and/or maize seed	CRE logit (2) =1 if the household received a NAIVS voucher for inorganic fertilizer	CRE logit (3) =1 if the household received a NAIVS voucher for maize seed
Inorganic fertilizer price	-0.001*	-0.002*	-0.001
	(0.001)	(0.001)	(0.001)
Real price of maize	0.000**	0.000*	-0.000
	(0.000)	(0.000)	(0.000)
Real price of rice	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Bean price	0.001	0.001	0.002
	(0.001)	(0.001)	(0.004)
Groundnut price	0.001	0.001	0.002
	(0.001)	(0.001)	(0.003)
Plot size	-0.045	-0.036	-0.053
	(0.031)	(0.034)	(0.035)
Plot tenure	-0.209	-0.147	-1.370**
	(0.412)	(0.443)	(0.638)
Distance from home	0.009*	0.012**	-0.005***
	(0.005)	(0.005)	(0.002)
Distance from main road	-0.076	-0.072	-0.269
	(0.059)	(0.060)	(0.165)
Distance from market	-0.005	-0.010	0.011
	(0.009)	(0.010)	(0.011)
Good soil quality	0.215	0.328	-0.034
	(0.236)	(0.251)	(0.302)
Poor soil quality	0.025	0.235	-0.861
	(0.463)	(0.430)	(0.939)
Flat plot slope	0.120	-0.010	-0.483
	(0.432)	(0.444)	(0.599)
Moderate plot slope	0.046	-0.011	-0.743
	(0.440)	(0.456)	(0.676)
Constant	-21.132***	-17.583***	-32.942***
	(4.230)	(4.016)	(9.691)
Joint significance of IVs	41.52***	43.72***	16.20***
Pseudo R-squared	0.426	0.445	0.442
Observations	2,599	2,599	2,599

Notes: *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Time-averages of household characteristics to control for time invariant unobserved heterogeneity were included in the model but not reported in Table A1. Robust standard errors clustered at the household level are in parentheses.

Table A2: Reduced form CRE logit regression estimates of factors affecting household NAIVS voucher redemption

Variables	CRE logit (1) =1 if the household redeemed a NAIVS voucher for inorganic fertilizer and/or maize seed	CRE logit (2) =1 if the household redeemed a NAIVS voucher for inorganic fertilizer	CRE logit (3) =1 if the household redeemed a NAIVS voucher for maize seed
$ElectoralThreat_{d\_it}$	0.778***	0.210	1.125**
	(0.220)	(0.747)	(0.441)
$Voucher_{r\_it}$	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Male-Headed HH	0.572	0.600	-0.529
	(0.421)	(0.463)	(0.613)
Age of HH head	0.039	0.121***	0.018
	(0.063)	(0.040)	(0.077)
Education of HH head	0.133***	0.154***	0.162**
	(0.049)	(0.051)	(0.074)
Family labor	0.459**	0.477**	0.019
	(0.209)	(0.214)	(0.294)
Total cultivated land	0.336***	0.345***	0.191**
	(0.072)	(0.078)	(0.087)
Off-farm income	0.286	0.196	1.285*
	(0.409)	(0.435)	(0.718)
Farm assets	0.000	0.000	-0.000*
	(0.000)	(0.000)	(0.000)
Livestock ownership	1.144***	1.215***	0.398
	(0.389)	(0.414)	(0.611)
Access to credit	-1.987*	-1.916	-3.331***
	(1.076)	(1.254)	(1.287)
Extension from gov't/NGO	0.167	0.043	-1.003
	(0.552)	(0.572)	(0.741)
Extension from cooperative	0.363	0.265	0.814
	(0.751)	(0.824)	(0.939)
Cooperative	0.247	0.277	-0.809
	(0.340)	(0.371)	(0.688)
Input supplier	0.899***	1.048***	1.518***
	(0.328)	(0.358)	(0.580)
Drought/Flood	-0.474	-0.601	0.424
	(0.638)	(0.785)	(0.881)
Crop disease/Pests	0.593	1.148	0.149
	(0.826)	(1.040)	(1.311)
Rainfall	-0.003	-0.003	0.002
	(0.002)	(0.002)	(0.004)
Soil nutrient constraint	3.693**	3.626*	3.396*
	(1.575)	(1.964)	(1.760)

Table A2 (cont'd)

Variables	CRE logit (1) =1 if the household redeemed a NAIVS voucher for inorganic fertilizer and/or maize seed	CRE logit (2) =1 if the household redeemed a NAIVS voucher for inorganic fertilizer	CRE logit (3) =1 if the household redeemed a NAIVS voucher for maize seed
Inorganic fertilizer price	-0.001	-0.002	-0.001
	(0.001)	(0.001)	(0.002)
Real price of maize	0.000**	0.000*	0.000
	(0.000)	(0.000)	(0.000)
Real price of rice	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Bean price	0.001	0.001	0.004
	(0.002)	(0.002)	(0.005)
Groundnut price	0.001	0.000	0.003
	(0.001)	(0.001)	(0.004)
Plot size	-0.030	-0.031	-0.022
	(0.029)	(0.033)	(0.035)
Plot tenure	-0.295	-0.113	-2.482**
	(0.461)	(0.461)	(1.045)
Distance from home	0.010**	0.014***	-0.003
	(0.005)	(0.005)	(0.003)
Distance from main road	-0.124**	-0.136**	-0.176
	(0.060)	(0.061)	(0.150)
Distance from market	-0.013	-0.012	-0.020
	(0.012)	(0.012)	(0.014)
Good soil quality	0.033	0.162	-0.430
	(0.255)	(0.273)	(0.355)
Poor soil quality	0.136	0.338	-0.265
	(0.433)	(0.419)	(0.897)
Flat plot slope	0.334	0.239	-0.087
	(0.469)	(0.462)	(0.663)
Moderate plot slope	0.251	0.211	-0.628
	(0.487)	(0.491)	(0.698)
Constant	-21.672***	-18.865***	-35.252***
	(4.836)	(4.623)	(12.584)
Joint significance of IVs	38.74***	36.46***	10.19***
Pseudo R-squared	0.436	0.462	0.484
Observations	2,559	2,559	2,559

Notes: *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively. Time-averages of household characteristics to control for time invariant unobserved heterogeneity were included in the model but not reported in Table A2. Robust standard errors clustered at the household level are in parentheses.

Table A3: CRE-MNL with CF regression results (relative log odds)

	CRE-MNL with CF (1)			CRE-MNL with CF (2)		
Variables	I	S	SI	I	S	SI
Male-Headed HH	-0.208	-0.039	-0.480	-0.167	-0.040	-0.432
	(0.270)	(0.149)	(0.339)	(0.267)	(0.150)	(0.342)
Age of HH head	-0.028	-0.001	-0.014	-0.034	-0.003	-0.025
	(0.033)	(0.016)	(0.025)	(0.034)	(0.016)	(0.024)
Education of HH head	0.141***	0.019	0.112**	0.141***	0.017	0.109**
	(0.048)	(0.018)	(0.049)	(0.047)	(0.018)	(0.047)
Family labor	-0.163	0.117**	-0.011	-0.146	0.110**	-0.013
	(0.149)	(0.051)	(0.178)	(0.131)	(0.051)	(0.179)
Total cultivated land	-0.104**	-0.035**	-0.112*	-0.099**	-0.035**	-0.110*
	(0.048)	(0.017)	(0.060)	(0.049)	(0.017)	(0.059)
Off-farm income	-0.100	0.111	-0.533*	-0.086	0.133	-0.495
	(0.321)	(0.167)	(0.317)	(0.327)	(0.170)	(0.303)
Farm assets	-0.000	-0.000	0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock ownership	0.333	0.355***	0.802***	0.360	0.345***	0.791***
	(0.274)	(0.125)	(0.300)	(0.283)	(0.126)	(0.295)
Access to credit	0.670	0.042	1.130**	0.670	0.038	1.096**
	(0.457)	(0.214)	(0.452)	(0.435)	(0.209)	(0.445)
Extension from	0.585	-0.059	0.517	0.664	-0.054	0.574
gov't/NGO	(0.411)	(0.186)	(0.399)	(0.425)	(0.187)	(0.392)
Extension from	0.380	0.408	0.943**	0.422	0.432	0.994**
cooperative	(0.624)	(0.499)	(0.435)	(0.633)	(0.511)	(0.462)
Cooperative	0.408	0.038	0.200	0.432	0.030	0.208
	(0.420)	(0.149)	(0.403)	(0.427)	(0.146)	(0.405)
Input supplier	0.147	-0.042	0.300	0.136	-0.053	0.269
	(0.347)	(0.130)	(0.354)	(0.352)	(0.132)	(0.359)
Drought/Flood	0.762	-0.221	0.568	0.843	-0.238	0.540
	(0.682)	(0.210)	(0.443)	(0.731)	(0.213)	(0.463)
Crop disease/Pests	0.248	-0.071	0.167	0.237	-0.101	0.118
	(0.584)	(0.266)	(0.756)	(0.586)	(0.266)	(0.766)
Rainfall	-0.001	0.000	-0.001	-0.001	0.000	-0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Soil nutrient constraint	-0.925	-2.236**	-1.843	-0.937	-2.222**	-1.792
	(1.547)	(1.078)	(1.297)	(1.597)	(1.090)	(1.320)
Inorganic fertilizer price	0.002***	0.000	0.001*	0.002***	0.000	0.001*
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
Real price of maize	-0.000	-0.000**	-0.000	-0.000	-0.000**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Real price of rice	0.000	-0.000	0.000	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bean price	-0.000	-0.001	-0.001	0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
Groundnut price	-0.000	0.001**	0.000	-0.001	0.001**	0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)

Table A3 (cont'd)

	CRE-MNL with CF (1)			CRE-MNL with CF (2)		
Variables	I	S	SI	I	S	SI
Plot size	0.095**	0.043**	0.125**	0.095**	0.043**	0.124**
	(0.046)	(0.018)	(0.054)	(0.046)	(0.018)	(0.054)
Plot tenure	-0.067	0.188	0.524	-0.037	0.183	0.542
	(0.579)	(0.211)	(0.495)	(0.591)	(0.209)	(0.509)
Distance from home	-0.016	-0.046***	-0.007	-0.016	-0.047***	-0.007
	(0.012)	(0.015)	(0.016)	(0.012)	(0.015)	(0.015)
Distance from main road	-0.041	0.021	-0.048	-0.038	0.022	-0.048
	(0.035)	(0.018)	(0.044)	(0.035)	(0.018)	(0.044)
Distance from market	0.001	0.004	-0.010	-0.000	0.005	-0.010
	(0.010)	(0.005)	(0.011)	(0.010)	(0.006)	(0.011)
Good soil quality	0.048	-0.241**	-0.323	0.037	-0.242**	-0.346
	(0.228)	(0.120)	(0.216)	(0.233)	(0.121)	(0.214)
Poor soil quality	-0.685	-0.167	0.252	-0.678	-0.180	0.216
	(2.737)	(0.241)	(0.464)	(2.644)	(0.242)	(0.471)
Flat plot slope	1.797	0.065	0.189	1.844	0.074	0.241
	(4.815)	(0.310)	(0.688)	(4.816)	(0.311)	(0.676)
Moderate plot slope	1.714	0.241	0.286	1.755	0.246	0.341
	(4.727)	(0.313)	(0.623)	(4.728)	(0.314)	(0.617)
NAIVS for any input	2.912**	0.846	3.056***			
($NAIVS_{it}$)	(1.316)	(0.729)	(1.183)			
CRE logit residuals	-0.581	-0.324	-0.883			
(Any input)	(1.343)	(0.777)	(1.166)			
NAIVS for inorganic				2.595*	1.394	3.147***
fertilizer ($NAIVS_{fert\_it}$)				(1.405)	(0.860)	(1.165)
NAIVS for maize seed				2.103	-0.162	1.328
($NAIVS_{seed\_it}$)				(1.654)	(1.113)	(1.632)
CRE logit residuals				0.004	-0.760	-0.778
(Inorganic fertilizer)				(1.395)	(1.014)	(1.148)
CRE logit residuals				-2.248	0.351	-1.440
(Improved maize seed)				(1.747)	(1.116)	(1.826)

Notes: Bootstrapped standard are in parentheses. To control for time-invariant unobserved household heterogeneity, time-averages of household characteristics were included in the model but not reported in Table A3. I, S, and SI denote "Intensification", "Sustainable", and "SI", respectively, where base category is "Non-adoption". *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.

Table A4: CRE-MNL without CF regression results (relative log odds)

	Voucher receipt (1)			Voucher receipt (2)			Voucher redemption (1)			Voucher redemption (2)		
Variables	I	S	SI	I	S	SI	I	S	SI	I	S	SI
Male-Headed HH	-0.164	0.048	-0.407	-0.158	0.051	-0.399	-0.191	0.047	-0.444	-0.190	0.044	-0.435
	(0.335)	(0.143)	(0.300)	(0.338)	(0.143)	(0.302)	(0.336)	(0.143)	(0.297)	(0.338)	(0.143)	(0.299)
Age of HH head	-0.037	0.004	-0.017	-0.048*	0.003	-0.027	-0.037	0.003	-0.018	-0.047	0.004	-0.028
	(0.032)	(0.015)	(0.030)	(0.029)	(0.015)	(0.027)	(0.033)	(0.015)	(0.031)	(0.031)	(0.015)	(0.028)
Education of HH head	0.126***	0.002	0.099**	0.121***	0.001	0.098**	0.129***	0.002	0.103**	0.124***	0.001	0.102**
	(0.040)	(0.019)	(0.041)	(0.040)	(0.019)	(0.041)	(0.039)	(0.019)	(0.040)	(0.040)	(0.019)	(0.040)
Family labor	-0.123	0.147***	0.024	-0.134	0.146***	0.017	-0.138	0.146***	0.000	-0.145	0.146***	-0.000
	(0.146)	(0.055)	(0.131)	(0.146)	(0.055)	(0.132)	(0.150)	(0.054)	(0.134)	(0.149)	(0.055)	(0.133)
Total cultivated land	-0.101**	-0.028*	-0.124***	-0.098**	-0.028*	-0.121***	-0.104***	-0.027*	-0.130***	-0.107***	-0.027*	-0.131***
	(0.040)	(0.015)	(0.045)	(0.040)	(0.015)	(0.045)	(0.040)	(0.014)	(0.045)	(0.041)	(0.014)	(0.044)
Off-farm income	-0.071	0.100	-0.466*	-0.029	0.112	-0.428	-0.099	0.105	-0.493*	-0.074	0.107	-0.465*
	(0.291)	(0.143)	(0.263)	(0.294)	(0.142)	(0.261)	(0.291)	(0.142)	(0.265)	(0.291)	(0.142)	(0.262)
Farm assets	-0.000	-0.000*	0.000	-0.000	-0.000*	0.000	-0.000	-0.000*	0.000	-0.000	-0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock ownership	0.429*	0.462***	0.925***	0.423*	0.461***	0.927***	0.432*	0.462***	0.910***	0.430*	0.463***	0.908***
	(0.255)	(0.123)	(0.234)	(0.254)	(0.123)	(0.233)	(0.252)	(0.123)	(0.233)	(0.249)	(0.123)	(0.232)
Access to credit	0.740*	0.007	1.142***	0.713*	0.004	1.097***	0.761*	-0.003	1.203***	0.783**	-0.001	1.201***
	(0.411)	(0.234)	(0.423)	(0.413)	(0.234)	(0.421)	(0.398)	(0.233)	(0.392)	(0.395)	(0.233)	(0.390)
Extension from gov't/NGO	0.657*	-0.091	0.653*	0.697**	-0.084	0.679**	0.695**	-0.070	0.673**	0.749**	-0.073	0.719**
	(0.336)	(0.196)	(0.337)	(0.342)	(0.197)	(0.343)	(0.334)	(0.194)	(0.337)	(0.335)	(0.194)	(0.342)
Extension from cooperative	0.508	0.561	0.999**	0.551	0.572	1.040**	0.515	0.561	1.009**	0.539	0.559	1.042**
	(0.534)	(0.422)	(0.417)	(0.546)	(0.425)	(0.419)	(0.546)	(0.422)	(0.425)	(0.555)	(0.423)	(0.436)
Cooperative	0.467*	0.144	0.324	0.465*	0.144	0.315	0.467*	0.142	0.331	0.465*	0.143	0.331
	(0.253)	(0.114)	(0.216)	(0.251)	(0.115)	(0.218)	(0.254)	(0.114)	(0.219)	(0.249)	(0.114)	(0.220)
Input supplier	0.189	-0.051	0.336	0.163	-0.057	0.321	0.190	-0.046	0.321	0.156	-0.048	0.300
	(0.223)	(0.107)	(0.226)	(0.227)	(0.107)	(0.226)	(0.223)	(0.107)	(0.225)	(0.227)	(0.107)	(0.226)
Drought/Flood	0.643	-0.234	0.473	0.628	-0.239	0.439	0.543	-0.260	0.396	0.526	-0.261	0.360
	(0.458)	(0.207)	(0.413)	(0.466)	(0.208)	(0.418)	(0.450)	(0.205)	(0.396)	(0.455)	(0.205)	(0.396)
Crop disease/Pests	0.204	-0.166	0.235	0.105	-0.180	0.163	0.165	-0.161	0.177	0.058	-0.167	0.076
	(0.510)	(0.261)	(0.511)	(0.502)	(0.261)	(0.504)	(0.509)	(0.261)	(0.515)	(0.505)	(0.261)	(0.504)
Rainfall	-0.001	0.000	-0.001	-0.001	0.000	-0.001	-0.001	0.000	-0.001	-0.001	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

Table A4 (cont'd)

	Voucher receipt (1)			Voucher receipt (2)			Voucher redemption (1)			Voucher redemption (2)		
Variables	I	S	SI	I	S	SI	I	S	SI	I	S	SI
Soil nutrient constraint	-1.081	-2.258***	-1.733**	-1.095	-2.256***	-1.729**	-1.096	-2.264***	-1.734**	-1.080	-2.266***	-1.713**
	(0.926)	(0.708)	(0.791)	(0.918)	(0.711)	(0.788)	(0.928)	(0.707)	(0.786)	(0.918)	(0.708)	(0.782)
Inorganic fertilizer price	0.002***	0.000	0.001**	0.002***	0.000	0.001**	0.002***	0.000	0.001**	0.002***	0.000	0.001**
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Real price of maize	-0.000	-0.000**	-0.000	-0.000	-0.000**	-0.000	-0.000	-0.000**	-0.000	-0.000	-0.000**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Real price of rice	0.000**	-0.000	0.000	0.000**	-0.000	0.000	0.000**	-0.000	0.000	0.000**	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bean price	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Groundnut price	-0.000	0.001**	0.000	-0.000	0.001**	0.000	-0.000	0.001**	0.000	-0.000	0.001**	0.000
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Plot size	0.101***	0.036**	0.139***	0.100***	0.037**	0.137***	0.104***	0.036**	0.143***	0.107***	0.036**	0.145***
	(0.034)	(0.016)	(0.038)	(0.034)	(0.016)	(0.038)	(0.034)	(0.015)	(0.038)	(0.034)	(0.015)	(0.038)
Plot tenure	0.047	0.237	0.468	0.038	0.241	0.442	0.087	0.244	0.494	0.097	0.246	0.494
	(0.400)	(0.188)	(0.393)	(0.396)	(0.188)	(0.393)	(0.403)	(0.188)	(0.400)	(0.396)	(0.188)	(0.400)
Distance from home	-0.014*	-0.053***	-0.007**	-0.015*	-0.053***	-0.007**	-0.015*	-0.052***	-0.007***	-0.016*	-0.052***	-0.007***
	(0.007)	(0.014)	(0.003)	(0.008)	(0.014)	(0.003)	(0.008)	(0.014)	(0.003)	(0.009)	(0.014)	(0.003)
Distance from main road	-0.029	0.023	-0.042	-0.027	0.023	-0.041	-0.022	0.023	-0.038	-0.019	0.023	-0.035
	(0.031)	(0.015)	(0.035)	(0.031)	(0.015)	(0.035)	(0.031)	(0.015)	(0.036)	(0.031)	(0.015)	(0.035)
Distance from market	-0.004	0.002	-0.012	-0.004	0.002	-0.011	-0.004	0.002	-0.011	-0.004	0.002	-0.011
	(0.006)	(0.005)	(0.008)	(0.006)	(0.005)	(0.008)	(0.006)	(0.005)	(0.008)	(0.006)	(0.005)	(0.008)
Good soil quality	0.022	-0.248**	-0.271	0.007	-0.249**	-0.287	0.056	-0.242**	-0.248	0.046	-0.242**	-0.260
	(0.214)	(0.109)	(0.211)	(0.214)	(0.109)	(0.211)	(0.214)	(0.109)	(0.210)	(0.214)	(0.109)	(0.211)
Poor soil quality	-0.556	-0.155	0.398	-0.583	-0.162	0.357	-0.576	-0.159	0.367	-0.597	-0.162	0.322
	(0.518)	(0.249)	(0.405)	(0.520)	(0.249)	(0.409)	(0.518)	(0.249)	(0.411)	(0.523)	(0.249)	(0.414)
Flat plot slope	1.653**	0.011	0.150	1.674**	0.016	0.179	1.587**	0.012	0.078	1.598**	0.013	0.115
	(0.813)	(0.257)	(0.502)	(0.819)	(0.258)	(0.498)	(0.794)	(0.257)	(0.478)	(0.793)	(0.257)	(0.470)
Moderate plot slope	1.486*	0.160	0.117	1.512*	0.162	0.151	1.413*	0.161	0.038	1.439*	0.163	0.086
	(0.795)	(0.260)	(0.513)	(0.800)	(0.261)	(0.509)	(0.771)	(0.260)	(0.488)	(0.771)	(0.261)	(0.481)

Table A4 (cont'd)

	Voucher receipt (1)			Voucher receipt (2)			Voucher redemption (1)			Voucher redemption (2)		
Variables	I	S	SI	I	S	SI	I	S	SI	I	S	SI
NAIVS for any input	2.382***	0.610**	2.229***				2.507***	0.552*	2.449***			
($NAIVS_{it}$)	(0.323)	(0.249)	(0.321)				(0.356)	(0.284)	(0.335)			
NAIVS for inorganic				2.580***	0.786***	2.426***				2.510***	0.603*	2.430***
fertilizer ($NAIVS_{it\_fert}$)				(0.376)	(0.301)	(0.350)				(0.398)	(0.325)	(0.363)
NAIVS for maize seed				0.267	0.148	0.108				1.028*	0.324	0.979
($NAIVS_{it\_seed}$)				(0.535)	(0.372)	(0.578)				(0.551)	(0.478)	(0.603)

Notes: Robust standard are in parentheses. To control for time-invariant unobserved household heterogeneity, time-averages of household characteristics were included in the model but not reported in Table A4. I, S, and SI denote "Intensification", "Sustainable", and "SI", respectively, where base category is "Non-adoption". *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.

Table A5: APEs of other (non-NAIVS-related) factors affecting household use of practices in the various SI categories

	CRE-MNL with voucher receipt			CRE-MNL with voucher redemption		
Variables	I	S	SI	I	S	SI
Male-Headed HH	-0.004	0.023	-0.025	-0.005	0.024	-0.027
	(0.019)	(0.029)	(0.017)	(0.019)	(0.029)	(0.017)
Age of HH head	-0.002	0.002	-0.001	-0.002	0.002	-0.001
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
Education of HH head	0.006***	-0.004	0.004*	0.006***	-0.005	0.004*
	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)
Family labor	-0.011	0.033***	0.000	-0.011	0.034***	-0.001
	(0.008)	(0.011)	(0.007)	(0.008)	(0.011)	(0.007)
Total cultivated land	-0.003	-0.001	-0.006**	-0.004	-0.001	-0.006**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Off-farm income	0.002	0.034	-0.032**	0.000	0.036	-0.033**
	(0.016)	(0.029)	(0.015)	(0.016)	(0.028)	(0.015)
Farm assets	-0.000	-0.000*	0.000	-0.000	-0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock ownership	0.001	0.066***	0.042***	0.002	0.067***	0.041***
	(0.014)	(0.025)	(0.013)	(0.014)	(0.025)	(0.013)
Access to credit	0.026	-0.041	0.062***	0.026	-0.045	0.066***
	(0.021)	(0.047)	(0.024)	(0.021)	(0.046)	(0.022)
Extension from	0.031	-0.048	0.034*	0.032*	-0.045	0.034*
gov't/NGO	(0.019)	(0.040)	(0.021)	(0.019)	(0.039)	(0.021)
Extension from	0.003	0.084	0.043*	0.003	0.084	0.044*
cooperative	(0.028)	(0.080)	(0.023)	(0.028)	(0.080)	(0.022)
Cooperative	0.020	0.013	0.010	0.020	0.013	0.010
	(0.014)	(0.023)	(0.013)	(0.014)	(0.023)	(0.013)
Input supplier	0.007	-0.023	0.020	0.007	-0.021	0.019
	(0.012)	(0.022)	(0.014)	(0.012)	(0.021)	(0.014)
Drought/Flood	0.036	-0.074*	0.026	0.032	-0.075*	0.023
	(0.026)	(0.042)	(0.025)	(0.026)	(0.042)	(0.024)
Crop disease/Pests	0.012	-0.045	0.016	0.010	-0.041	0.013
	(0.029)	(0.052)	(0.030)	(0.028)	(0.052)	(0.030)
Rainfall	-0.000	0.000	-0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Soil nutrient constraint	0.008	-0.413***	-0.041	0.007	-0.414***	-0.040
	(0.042)	(0.127)	(0.031)	(0.043)	(0.127)	(0.031)
Inorganic fertilizer price	0.000***	-0.000	0.000	0.000***	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Real price of maize	-0.000	-0.000*	-0.000	-0.000	-0.000*	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Real price of rice	0.000**	-0.000	0.000	0.000**	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bean price	0.000	-0.000	-0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Groundnut price	-0.000	0.000**	0.000	-0.000	0.000**	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table A5 (cont'd)

Variables	CRE-MNL with voucher receipt I	S	SI	CRE-MNL with voucher redemption I	S	SI
Plot size	0.003*	0.002	0.007***	0.003*	0.002	0.007***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
Plot tenure	-0.010	0.038	0.024	-0.008	0.038	0.025
	(0.021)	(0.038)	(0.022)	(0.021)	(0.038)	(0.022)
Distance from home	0.000	-0.011***	0.001**	0.000	-0.011***	0.001**
	(0.001)	(0.003)	(0.000)	(0.001)	(0.003)	(0.000)
Distance from main road	-0.002	0.006**	-0.003	-0.001	0.006*	-0.003
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
Distance from market	-0.000	0.001	-0.001	-0.000	0.001	-0.001
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Good soil quality	0.011	-0.046**	-0.012	0.012	-0.046**	-0.011
	(0.012)	(0.022)	(0.012)	(0.012)	(0.022)	(0.012)
Poor soil quality	-0.038	-0.031	0.039	-0.038	-0.031	0.038
	(0.029)	(0.049)	(0.024)	(0.029)	(0.049)	(0.025)
Flat plot slope	0.098**	-0.034	-0.018	0.095**	-0.031	-0.022
	(0.048)	(0.056)	(0.031)	(0.047)	(0.055)	(0.030)
Moderate plot slope	0.086*	0.001	-0.021	0.083*	0.005	-0.026
	(0.047)	(0.055)	(0.032)	(0.045)	(0.055)	(0.031)

Notes: To control for time-invariant unobserved household heterogeneity, time-averages of household characteristics were included in the model but not reported in Table A5. I, S, and SI denote "Intensification", "Sustainable", and "SI", respectively. *, **, and *** indicates that the corresponding coefficients are significant at the 10%, 5%, and 1% levels, respectively.