MAPPING ADOPTION OF ISFM PRACTICES STUDY

The Case of Kenya, Rwanda & Zambia

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Introduction

Efforts to determine adoption of new agricultural technologies is key to understanding impacts of research and effectiveness of dissemination methods on food and nutrition security, household income and several other outcomes. Adoption studies have traditionally been conducted using household surveys in which an enumerator administers an in-person interview or through a phone. The recent dramatic development of information technology and widespread use of mobile phones by smallholder farmers in remote areas has opened opportunities for using mobile phones to conduct adoption studies. In 2016, 44% of sub-Saharan Africa (SSA) population owned a mobile phone and 28% owned a smartphone (GSMA 2017). However, mobile phone ownership and use is much higher if considered at household level. Use of mobile phone can help collect useful data in high frequency at a low cost and to reach otherwise hard to reach areas (Croke et al 2012). It is important to ensure that the data collected are representative of the population. Studies have shown that data collected using phones are representative if 80% of the targeted population owns a phone (Croke et al 2012). As SSA households approach this threshold, it is important to investigate effective mobile phone data collection approaches and their validity.

As part of efforts to test effectiveness of using mobile phone to collect data from poor rural households, this study was carried out with an objective of documenting adoption of integrated soil fertility management (ISFM). ISFM is defined as a set of soil fertility management practices that include the use of improved germplasm, mineral fertilizers, and organic inputs combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe et al 2015). ISFM is not a single technology but a set of technology components that are co-applied in the same plot. The concept of ISFM was developed at the Tropical Soil Biology and Fertility (TSBF) Institute of CIAT (TSBF-CIAT) and research started in 1970-80s under the TBSF. The ISFM development included both on-station and on-farm soil fertility trials. It has been tested in sub-Saharan Africa (SSA), both in CGIAR and non-CGIAR institutes; particularly in the Democratic Republic of Congo (DRC), Kenya, and Rwanda and Zambia when mapping of soil diversity started and with the need to determine soil fertility constraints.

Studies have shown that the uptake of ISFM remains low – largely because it is a new paradigm and its promotion by extension service providers is limited. Nkonya et al (2016) observed that only 6% of farmers use ISFM compared to 19% and 25% for inorganic fertilizer and organic inputs respectively. This study was done in three case study countries: Kenya, Rwanda and Zambia using both primary and secondary data collected to document adoption of ISFM. To test and validate new tools for documenting adoption of agricultural technologies, a mobile phone survey was conducted only in Rwanda due to budget constraints. The results are compared with data collected using traditional data collection methods – i.e., in-person household survey – in which an enumerator interviews farmers in person. Secondary data will be used to document adoption of ISFM in Kenya and Zambia and to determine impact of ISFM and drivers of its adoption. The specific objectives of this study are to:

- Determine adoption rate of ISFM in Kenya, Rwanda and Zambia
- Design methodological approaches for determining adoption rate of innovations
- Analyze drivers of adoption of ISFM in the case study countries;
- Analyze impact of ISFM on income and sustainable land management practices

Methodological approaches and data

Mapping adoption of ISFM

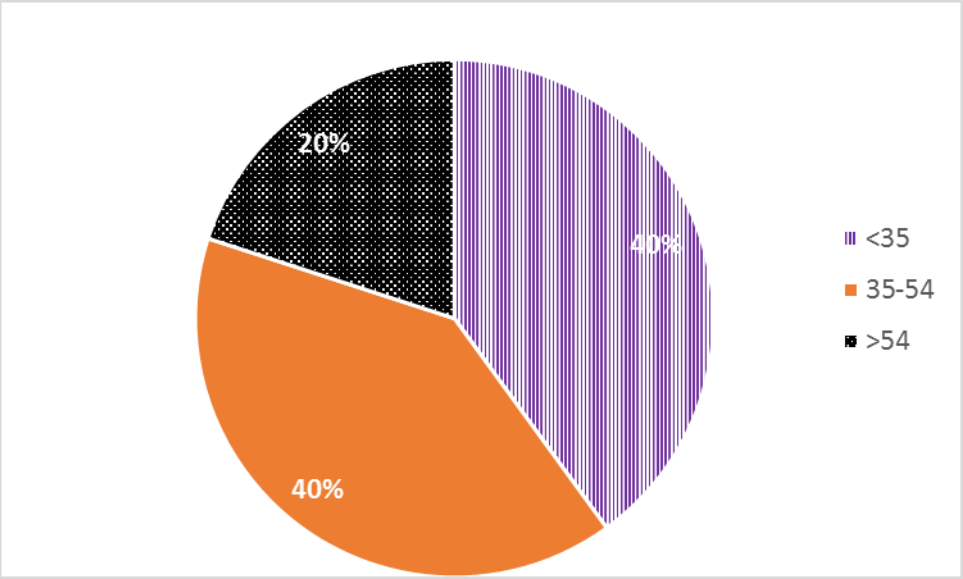
Mobile phone survey approach

We conducted two waves of data collection from 1000 households in Rwanda. The first wave covered all farm operations from planting to crop maturity and the second wave covered harvesting, marketing and other post-

harvest activities. The second wave covered activities ranging from harvesting to marketing. Socio-economic characteristics were also collected to help study drivers of adoption of ISFM. To help reduce non-response bias, respondents were given a US$0.50 air time coupon at completion of the survey. Studies have shown that the non-response is particularly high among older people.

Survey invitations were sent to the mobile phones of respondents and those who voluntarily accepted the invitation took the survey. The first phase wave survey was launched on October 20th 2016 and covered a total of 970 households, which is 97% of the planned sample size of 1000 households in the selected six districts. However, a total of 338 households completed the survey from districts that were not purposively selected. To help reduce this bias, we stratified the respondents across age sets. We used the nationally representative seasonal agriculture survey 2013 to determine the weights of each age set (Figure 1).

Figure 1: Share of rural household head age sets for Rwanda, Seasonal Agriculture survey 2013



Source: Calculated from seasonal agriculture survey 2013

To reflect the socio-economic differences, we used market access and population density to select districts treatment and control districts. We divided the population density into three groups shown in Table 1. Rwanda is the second most densely populated country in SSA – after Mauritius (World Bank 2016). The district with the lowest population density has 178 people per square km (NISR 2014). The highest district level population density is 2127 people per sq. km.

Table 1: District level population density in Rwanda

Population density group	Population density (people/km^2)	Population (Million)	Percent of total population
Low	179-334	6.2	20
Medium	335-509	18.9	60
High	510-2127	6.4	20
Total	577	31.5	100

Source: 2012 Census, NISR (2014).

The 0.008^o x 0.008^o or 0.888km x 0.888km pixel average travel time to the nearest city with at least 50,000 people was used to determine market access. Two market access groups were formed using 5 hours as the cutoff point (Figure 3. Travel time of less than 5 hours was regarded as high market access and more than 5 hours as low

market access. The six districts which benefited from ISFM intervention fall into both low and high market access and all population density groups. There are 2x3 = 6 combinations of market access and population density groups but only three were captured in the six districts selected (

Table 2). However, only three combinations were captured in the six treated villages (

Table 2). Additionally, the treatment sites (where there was a CGIAR intervention) were matched with control sites with comparable agro-ecological and market accessibility conditions. Six districts – namely Bugesera, Burera, Gakenke, Kayonza, Kamonyi, and Musanze benefitted from ISFM programs implemented by Tropical Soil Biology and Fertility (TSBF) and International Center for Tropical Agriculture (CIAT). The matching districts with comparable population density and market access were selected (

Table 2).

Figure 2: ISFM target districts in Rwanda

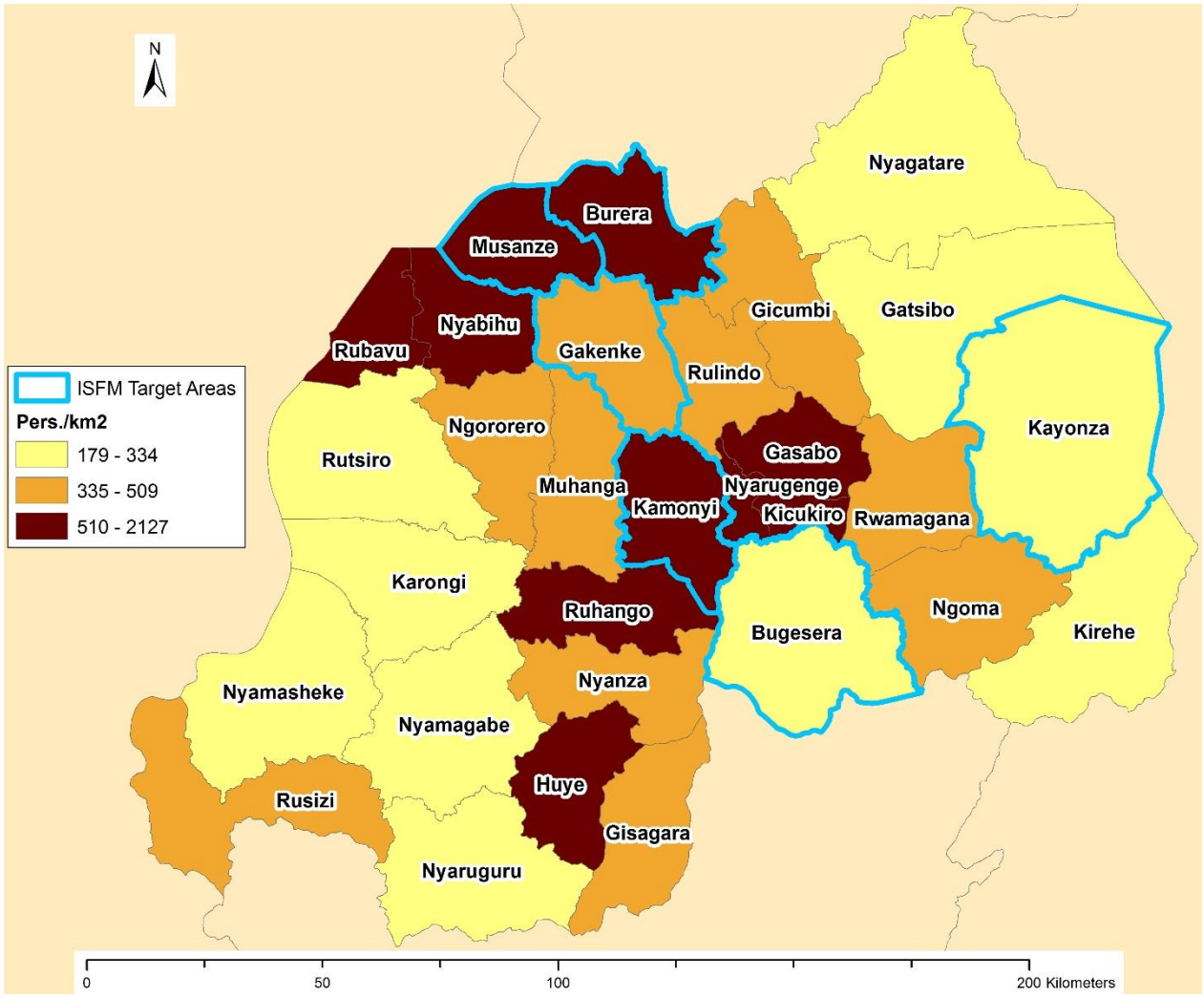
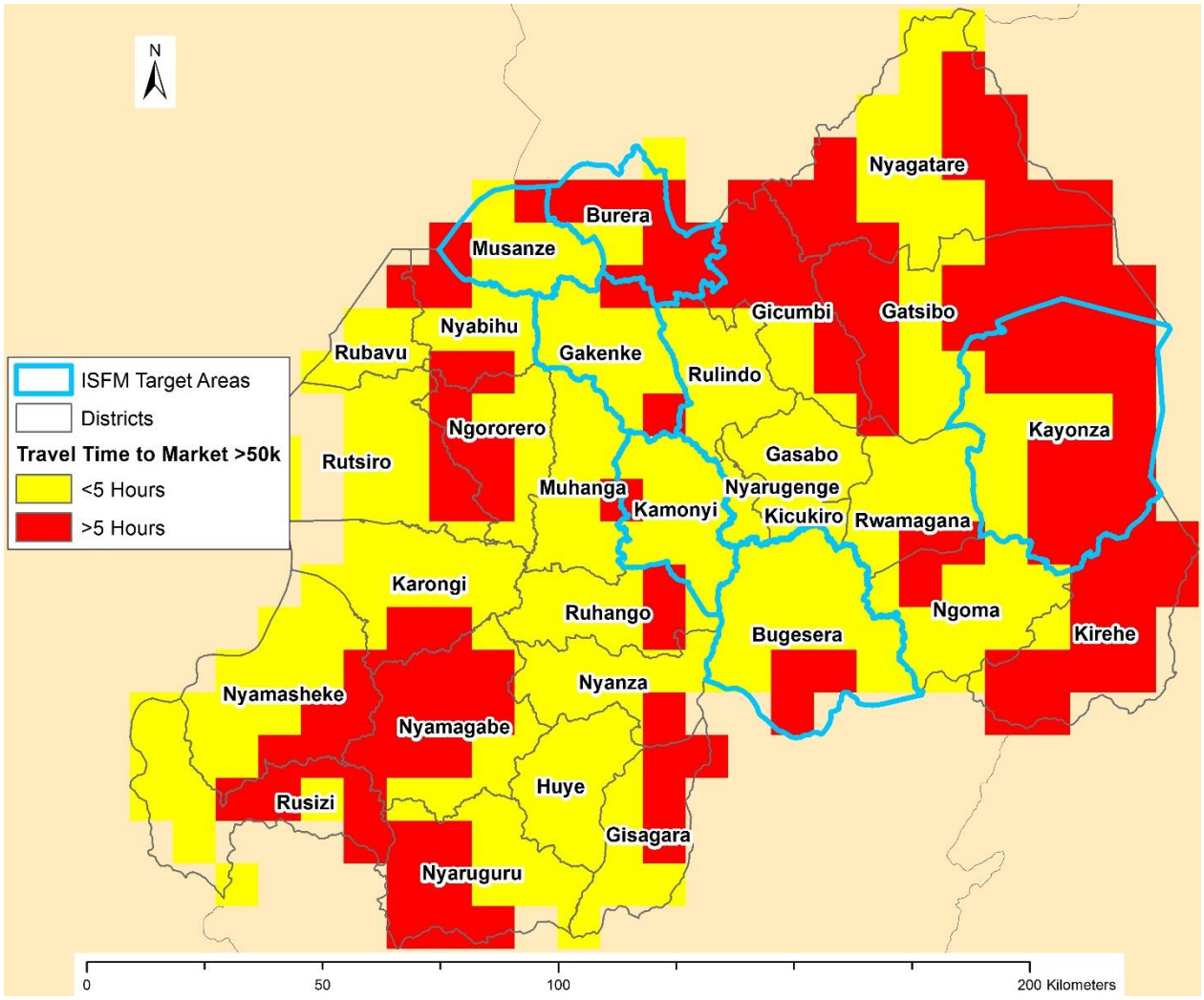


Table 2: Allocation of 1000 household sample across districts and treatment type

Population-Market access	Treatment (ISFM) district	Matching control District	Sample size for treatment & control (each)
Low-Low-High	Kayonza	Nyagatare	85
High-high	Musanze	Huye	180
Medium-High	Gagenke	Rusizi	235
Total			1000

Figure 3: Market access and ISFM treatment placement



Traditional survey approach – the case of Kenya and Zambia

Panel data from Tegemeo Institute (Kenya) from 2000-2010 were obtained but data on organic soil fertility management were not collected. There were questions on manure but no data were collected on agroforestry, crop residue management and other key organic soil fertility management practices. For example, the data did not show any farmer have adopted ISFM. Additionally, Tegemeo panel data were not nationally representative as they focused on maize growing areas. Due to these weaknesses, we used the 2013 Agricultural Sector Household Baseline Survey, which is nationally representative. In Zambia, rural agricultural livelihood survey (RALS) data for

2012 were analyzed to determine ISFM adoption rate and drivers of ISFM adoption. The RALS had all important questions for analyzing ISFM adoption.

Rwanda's seasonal agriculture survey (SAS) of 2013 was used to compare the mobile phone survey results since it collected all necessary information on ISFM adoption. However, no good socio-economic data were collected to allow analysis of ISFM adoption.

Impact of adoption of ISFM

Using adoption patterns from the surveys, crop simulation was done to determine the potential impact of ISFM adoption on crop yield, household food and nutrition security and carbon sequestration. Studies have shown that ISFM leads to higher yield and sequesters more soil carbon than the conventional use of synthetic fertilizers only. The simulation of the impact of ISFM was implemented using DSSAT (Decision Support System for Agro-technology Transfer) Cropping System Model (Hoogenboom et al., 2015; Jones et al., 2003). DSSAT integrate the effects of crop systems components and management options, to simulate the states of all the components of the cropping system and their interaction. DSSAT crop models are designed based on systems approach, which provides a framework for users to understand how the overall cropping system and its components function throughout cropping season(s), on daily basis. Site-specific crop model input data was constructed on 5 arc-minute (approximately 10 km) grids across the ISFM target areas. A daily time series (1980-2010) of weather data come from AgMERRA datasets (Ruane et al., 2015). AgMERRA includes information such as minimum temperature, maximum temperature, solar radiation, and precipitation. For each year, two seasons of maize were simulated, where the plantings of first (A) and main (B) seasons occur in March and September, per FAO Cropping Calendar Database. High resolution soil property data come from the Global High-Resolution Soil Profile Database (IRI et al., 2015). Geography of maize in the ISFM target sites was based on Spatial Production Allocation Model (SPAM) (IFPRI & IIASA, 2016). There were 32 grid cells covering the ISFM target sites. In addition to ISFM, to assess the relative effectiveness of ISFM compared to other options for farmers, baseline with no additional nitrogen input, inorganic fertilizer-only, and organic fertilizer-only scenarios were also simulated. Amount of nitrogen application rate in each scenario and the average maize yield responses to the different management practices were based on the analysis of nationally-represented household survey data. Specifically for the nitrogen application rate, ISFM and inorganic fertilizer-only scenarios used 30 and 53 kg[N]/ha, respectively.

Drivers of adoption of ISFM and other soil fertility management practices

The Kenya and Zambia secondary data will be used to analyze drivers of adoption of ISFM, soil organic management practices and inorganic fertilizer. Soil organic management practices include a wide range of practices but those collected in the Kenyan and Zambian survey include application of animal and green manure, compost, and agroforestry. These practices were collected in both surveys. This analysis will help determine policy and strategies to be used to increase adoption of ISFM – which is currently lowest in SSA despite its economic and environmental benefits. We use a Probit model to estimate adoption of ISFM:

$Y^* = \Phi^{-1}(Y) = X\beta_1 + \varepsilon$,
Where Y^* is a latent variable representing adoption of ISFM, given by

$$Y = \begin{cases} 0 \; if \; Y^* \leq 0 \\ 1 \; if \; Y^* \geq 1' \end{cases}$$

Φ is a normally distributed cumulative static with Z-distribution, i.e. $\Phi(Z)\epsilon(0,1)$,
X is a vector of drivers of adoption of SFM practices; and β_i is a vector of associated coefficients i, i=1, 2. $X\beta \sim N(0,1)$; ε is an error term with normal distribution, i.e., $\varepsilon \sim N(0,1)$.

Given that some variables are potentially endogenous, we check robustness of our results by estimating both structural and reduced model equations. Choice of X vector variables is driven by literature[1] and data availability.
The empirical model to be estimated is:
$ISFM_i=\beta_0 + \beta_1 HC + \beta_2 PC + \beta_3 SC + \beta_4 RS + e_i$
Where:
ISFM=1 if household i has adopted ISFM.

HC = human capital – includes household endowment of skills, knowledge and experience that drives productivity (e.g. education, age – which is an indicator of experience, sex of household head or plot owner, etc.; PC is physical capital including ownership of livestock, productive assets, type of building material, etc.; SC is social capital mainly including membership to farmer or other productive groups; RS is rural services including proximity to all-weather road and market. The variables used in each country will differ according to data collected in each country but the model structure will remain the same.

[1] Please see Nkonya et al. (2008) and Di Falco (2014) for a review.

Results

Adoption of ISFM in Rwanda – mobile phone and traditional survey results

Table 3 reports the drop-off, refusal ineligibility and completed mobile phone surveys. Of the 71,113 surveys sent to potential respondents in the first round, only one percent completed their surveys and were eligible – i.e., were in the selected district (in-sample) and had a farm. Ineligibility rate was relatively low and was largely due to being in a district that was not purposively sampled (out-of-sample). Drop-off rate – i.e. starting the survey but not completing it – was quite low – an aspect that shows the questionnaire length and difficult in answering questions were not major factors hindering completion of survey. The non-response rate (93%) is unusually high because one of the strata used in sampling was age of farmers – which reflected results from nationally representative seasonal agricultural survey of 2012/13. As expected, older farmers had the highest non-response rate and younger farmers had the highest response rate (Table 3). Despite repeated reminders, the opt-in rate among older farmers remained low. This underlines one of the key weaknesses of mobile phone surveys – bias against older farmers.

Table 3: mobile phone survey opt-in, refusal, ineligibility and drop-off in phase I

	Count	Percent
Surveys Sent	71,113	100%
Opted in	4,606	6%
Completed survey	970	1%
Dropped off	329	0.5%
Refused	37	0.05%
Ineligible	3,307	5%
Non-response	66,469	93%

Round 2 survey was launched on March 14th, 2017 to retarget the 1,308 respondents from Round 1 which occurred approximately 5 months earlier (October 20th, 2016). GeoPoll sent the surveys to Round 1 respondents' Mobile Subscriber ISDN (MSISDN) or mobile phone numbers that completed Round 1. One challenge is to determine whether the person using the phone is the same person who responded to Round I survey. GeoPoll used demographic questions such as gender, age, and location as verifying questions to ensure the respondents were the same individuals that completed Round 1. The matching was very good as only five round II respondents did not match with round I respondents. The questionnaire had a maximum of 27 questions for respondents to answer pending skip-patterns and routing patterns in the instrument. GeoPoll sent reminder messages to respondents every 72 hours if they had not completed the survey.

Attrition was about 37% (Table 5) – a level that is very high compared to about 25% observed in Tanzania for a mobile phone survey (Croke et al 2012). Eight of the 1,308 households who participated in the first wave no longer had active mobile phone. The number of surveys sent yielded approximately 967 opt-ins to the survey, of which 101 were deemed ineligible because they no longer practice crop production (73) or they planted a crop that was not targeted for this study (23).

Table 4: Comparison of share of mobile phone survey and traditional household survey respondents across age groups

Age group (Years)	2012/13 household survey	2016 mobile
	Percent	
<35	40	93
35-54	40	7.1
>54	20	0.3

NB: Rural households in the seasonal agricultural survey (SAS), which is nationally representative

Approximately 39 respondents dropped-off during the survey, an overwhelming majority of these drop-offs (27 out of 39) occurred within the first four messages that a respondent received. Three respondents refused to take the survey outright, while 330 respondents or 23% of the round I sample did not engage in the survey. GeoPoll concluded data collection on March 27th, 2017.

Attrition is highest in the high market access and high population density districts (Musanze and Huye) (

Table 2) – suggesting that the mobile phone credit given could not have offered significant incentive to the potentially well-off respondents. However, a 41% attrition for a survey using traditional personal interview have been observed in Kenya (Ibid) but are obviously on the high side. It is important to examine if attrition is random, which would pose a lesser problem of small sample rather than attrition bias.

Table 5: Attrition in Round II mobile phone survey

District	Round 1	Round 2	% Sample Attrition
Gagenke	203	123	39.4
Huye	150	79	47.3
Kayonza	62	42	32.3
Musanze	178	96	46.1
Nyagatare	137	85	38.0
Rusizi	128	90	29.7
Out of sample districts	450	314	30.2
Total	1,308	829	36.6
Attrition across treatment type			
Control	789	519	34.2
Treatment	519	310	40.3
Total	1,308	829	36.6

Table 6 shows that there is no significant difference in the selected household characteristics – suggesting that attrition was random and thus attrition bias is insignificant. Yet, the small sample is likely to lead to large standard errors and insignificant results of key outcomes – such as impact of ISFM on crop yield.

To validate mobile phone survey efficacy, we compare ISFM adoption rate using mobile phone and traditional survey results. Table 7 shows mobile phone survey results of adoption of certified and recycled improved varieties. There is no comparable traditional 2012/13 household survey (SAS) data since improved seed data were collected without specifying the type of crop. The 2012/13 household survey also did not distinguish between certified and recycled seeds.

Table 6: comparison of characteristics of attrition and non-attritors – to determine attrition bias

	In-sample & out-of-sample			**In-sample only**		
Characteristics	**Attritors**	**Non-Attritors**	**P-Value**	**Attritors**	**Non-Attritors**	**P-Value**
Age of respondent (percent)						
• 15-35 years	91.6	91.9	0.865	92.4	91.6	0.685
• 35-54 years	7.9	7.7	0.890	7.2	7.9	0.718
• Above 54 years	0.4	0.3	0.875	0.2	0.3	0.814
Age	25.1	26.1	0.006***	25.0	26.2	0.003***
% female headed	27.9	27.9	0.997	27.6	27.3	0.919
% grow beans	41.7	40.7	0.728	42.8	42.7	0.968
% grow maize	44.6	46.8	0.458	46.0	46.9	0.790

% grow cassava	29.4	32.2	0.298	28.8	31.8	0.354
% grow potatoes	22.7	24.0	0.608	21.8	23.8	0.493

The mobile phone survey questions on land management and varieties was asking about the last season practices – which was season B (March-June, 2016/17) but some questions were not season specific – e.g. the questions on ISFM practices (improved seeds, inorganic fertilizer and organic soil fertility management practices). This means our results are comparable to the season B traditional household survey. Adoption is especially high for maize and zero for cassava and potato (Table 7). This is expected given that there is no aggressive promotion of improved cassava and potato varieties in the country. Lack of market of improved varieties of cassava and potato also remains one of the key challenges of their adoption.

To help compare the adoption rate of traditional vs SM household survey results, we computed a global adoption rate by treating any farmer who has adopted certified or recycled seeds of bean, maize, plantain, cassava or potato as an adopter. Figure 4 compares the adoption rate of improved seed and ISFM – calculated using mobile phone and traditional household survey data. In general, the mobile phone survey shows significantly higher adoption of both improved seeds and ISFM than the corresponding adoption drawn from traditional household survey. This underlines the refusal bias. The global (across all crops) ISFM adoption drawn from mobile phone survey is about 25%. However, ISFM adoption rate drawn from traditional household survey was 9% and 5% for season B and C respectively. The mobile phone survey combined both seasons since it simply asked if the farmer has used ISFM – regardless of the season. ISFM adoption rate for season C is low (5%) and could be due to the type of crops grown during that season.

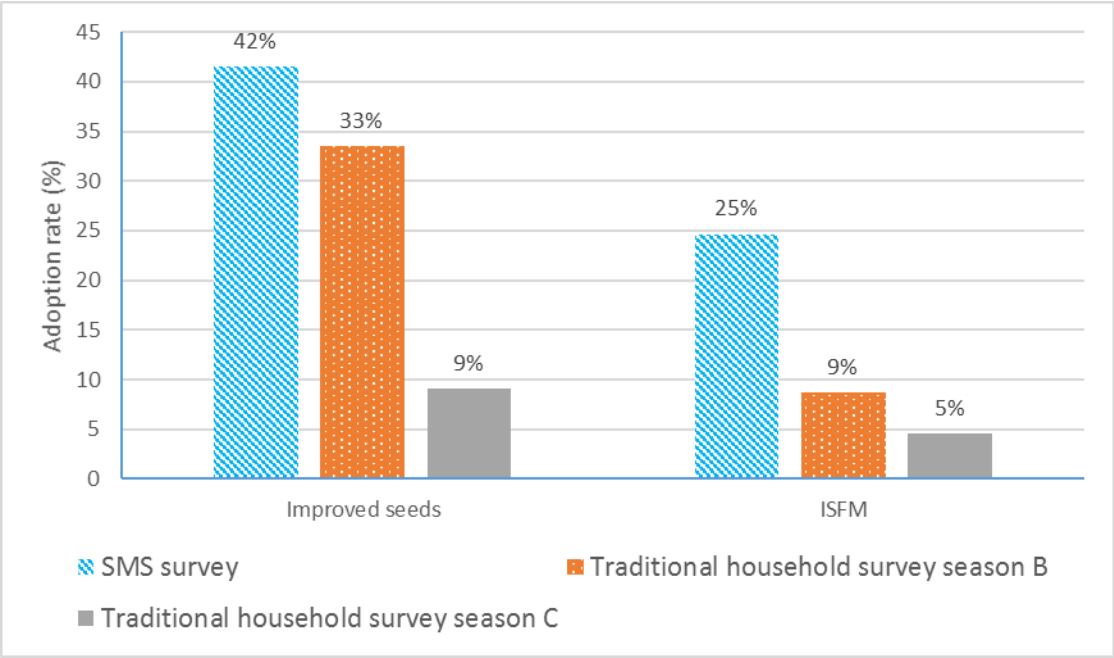
For improved seeds, mobile phone and traditional household survey for season B are different but the difference is not as big as the case for ISFM. Season C results are significantly different to both mobile phone and traditional household survey for season B. This further shows that season C is used for growing potato, cassava and other crops which are planted using traditional varieties. Season C is an off season cropping, generally done in swamp or irrigated areas.

Table 7: Adoption of improved seeds - mobile phone household survey, Rwanda

Crop	certified seed only	including recycled seeds
	Percent of using variety	
Beans	9.07	21.08
Maize	23.98	38.91
Plantain	15.95	15.95
Cassava	0.00	0.00
Potato	0.00	0.00

The comparison between mobile phone and traditional household survey leads to a conclusion that mobile phone survey has a serious bias due to high rate of refusal among older farmers. Thus, use of mobile phone survey should be made bearing in mind the refusal bias.

Figure 4: mobile phone vs traditional household survey comparison of adoption rate of improved seeds and ISFM, Rwanda



Notes: Season B (March-June, 2016/17)
Season C (July-Sept, 2016/17)
Improved seeds include both certified & recycled seeds.

Another serious problem with mobile phone survey is the difficulty of correcting errors or data that are obviously wrong. Crop area and yield are specific examples. Table 8 shows that the yield under ISFM is only 137kg/ha – a level that is only 4% of the corresponding yield reported in the nationally representative survey of 2016. The biggest reason for the low yield reported is the large area reported by farmers. Table 9 shows that the crop area harvested reported in the nationally representative seasonal agricultural survey in 2016 is smaller than 1% of area reported using mobile phone survey in the same year. The percentile distribution of harvested area shows distribution of cropland area – and illustrates the skewed distribution. GeoPoll was asked to address these outliers but were unable to address it. Preventing entry of skewed data by putting low and upper limit could potentially lead to dropouts. Thus, GeoPoll – in agreement with researchers – did not put an upper or lower limit to the harvested area and this allowed for almost any input. This could be addressed by sending a follow-up message asking if the value reported is valid. This was not done in this instance due to budget constraints.

Table 8: Maize yield across

Soil management practice	Mean	Median	SD	N	Yield, SAS survey 2016
	Tons/ha				Tons/ha
ISFM	0.14	0.03	0.27	203	3.3
Fert only	0.18	0.03	0.39	81	2.5

Organic only	0.60	0.60		1		2.3
No inputs	0.16	0.04	0.33	238		1.5
Total	0.16	0.03	0.32	523		

Note: SAS = Seasonal Agricultural survey, 2016, Rwanda Agriculture Board.

Table 9: Crop area harvested, mobile phone survey, 2017

statistics	Maize	Bean	Plantain	Potato
Mean: SAS survey 2016	0.05	0.06	0.10	0.04
Mean: mobile phone survey	8.7	39.0	57.3	44.3
SAS survey area as % of mobile phone survey area	0.57	0.15	0.17	0.09
mobile phone survey area statistics				
• Median	1.6	1.6	4.1	3.7
• SD	27.9	412.1	211.6	212.4
• N	219.1	161.0	108.9	125.2
• Min	0.0	0.0	0.0	0.0
• Max	406.5	8130.1	2032.5	3252.0
• 25% Percentile	0.4	0.4	0.8	0.8
• 50% Percentile	1.6	1.6	4.1	3.7
• 75% Percentile	8.1	9.1	20.3	20.3
• 90% Percentile	20.3	40.7	81.3	81.3

Adoption mapping in Kenya and Zambia

As is common in other countries, adoption of ISFM in Kenya and Zambia is lowest among the four technologies considered – improved seeds, inorganic fertilizer only, organic inputs only and ISFM (Figure 5 and Figure 6). Adoption of improved seeds is high in both countries – an aspect which puts both countries above the adoption rates in SSA, which for maize stands at 33% and 38% in eastern and Southern Africa respectively (Scoones & Thompson, 2011). Adoption of inorganic fertilizer is especially high in Kenya for Irish potato which is grown for commercial purposes. Interestingly, Kenya has much higher inorganic fertilizer adoption than Zambia even though the latter gives generous fertilizer subsidy. This shows the effect of strong input market in Kenya and presence of agroforestry from local and international institutions.

Figure 5: Adoption rate of improved seeds and soil fertility management practices, Kenya, 2015

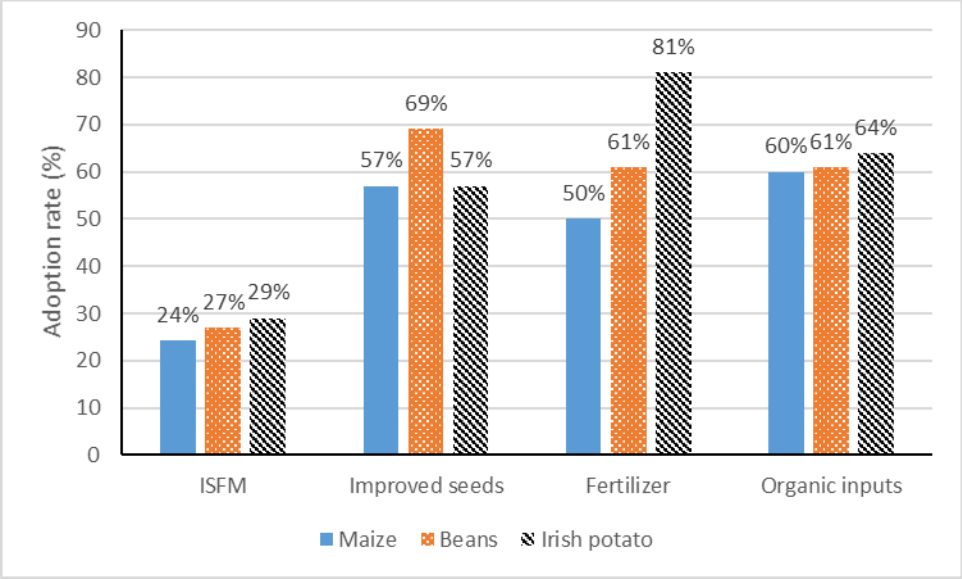
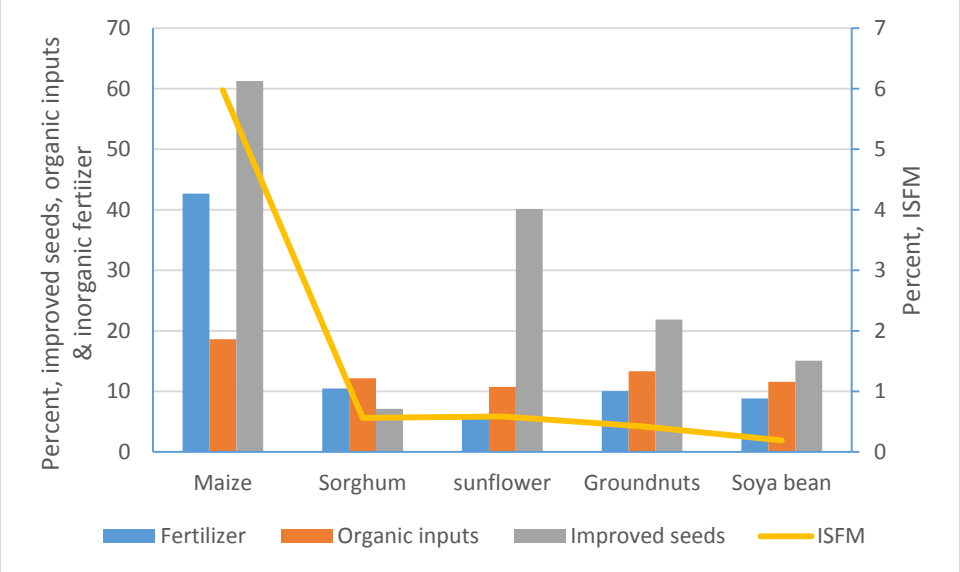


Figure 6 shows adoption of ISFM Zambia is highest for maize and lowest for soybean. This is expected given that maize is Zambia's staple food crop accounting for 49.4% of Zambia's caloric intake (FAO 2013). For maize, inorganic fertilizer only, is the second practice with highest adoption rate but for the other crops reported, farmers reported organic inputs as the second most adopted practice.

Figure 6: Adoption rate of ISFM in Zambia



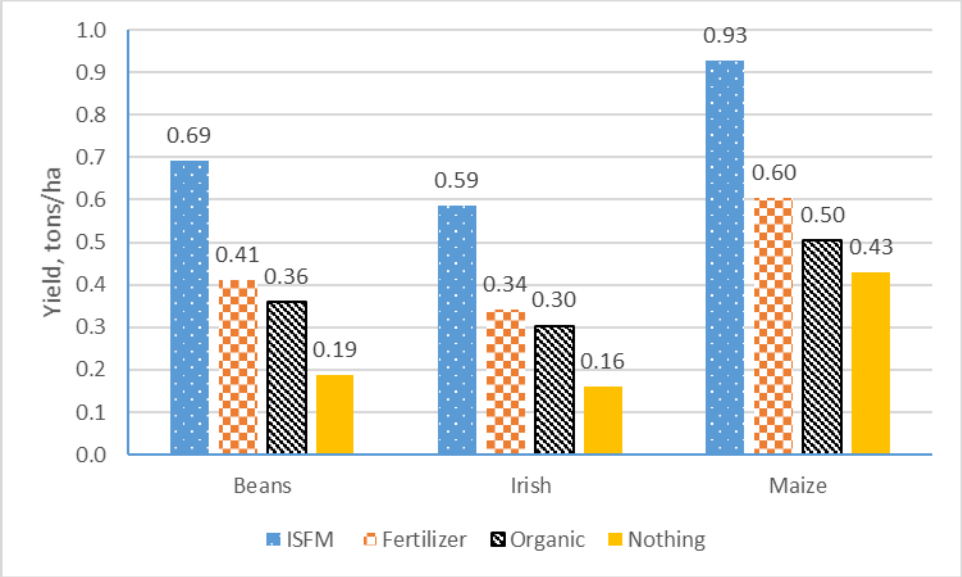
Sources: Calculated from RALS survey 2012

As expected adoption of ISFM shows the highest yield in both countries (Figure 7 and

Figure 8). Its adoption in Zambia increases maize yield by 15%, 21% and 39% if farmer respectively switches to ISFM from fertilizer only, organic inputs and from not input (

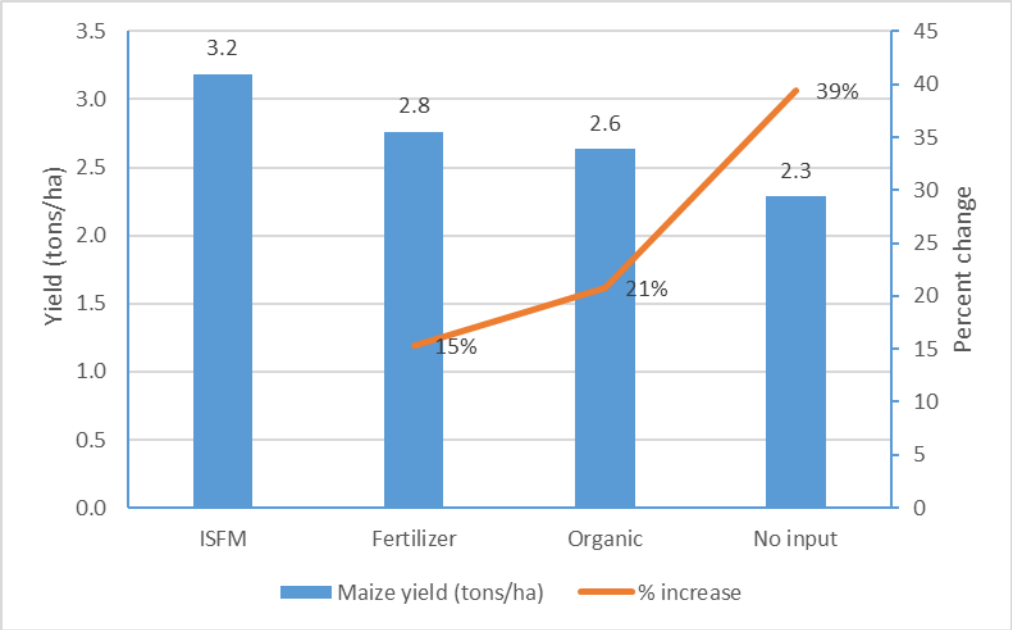
Figure 8). The increase is much higher in Kenya (Figure 6).

Figure 7: Impact of ISFM on crop yield, Kenya 2015



Yield change if farmer switches from another soil practice to ISFM in Kenya (%)			
	Beans	Irish	Maize
Fertilizer→ISFM	68.3	72	53
Organic→ISFM	93.0	93	84
Nothing→ISFM	270.8	270	116

Figure 8: Change in maize yield due to switching to ISFM in Zambia



Potential impacts of the full adoption of ISFM in the target sites in Rwanda

Grid-based simulated maize yields from four scenarios over 30-year period (1980-2009) were aggregated for each district, assuming the full adoptions (Figure 9 and Table 10). There were different levels of yield responses across districts, based on their soil characteristics and observed weather patterns, yet the results largely agreed that, compared to the baseline scenario of no inputs, the yield response from ISFM was the highest, followed by either inorganic or organic fertilizers. The ISFM yields were simulated as highly significantly different at 99% confidence interval from the rest of the treatments at all the different ecological locations in Rwanda. The performance of ISFM differed by location, however, with lower yield impacts in Gakenke and Kayonza districts. Statistical difference between inorganic and organic fertilizers was significant in Gakenke and Kayonza, but not significant in others.

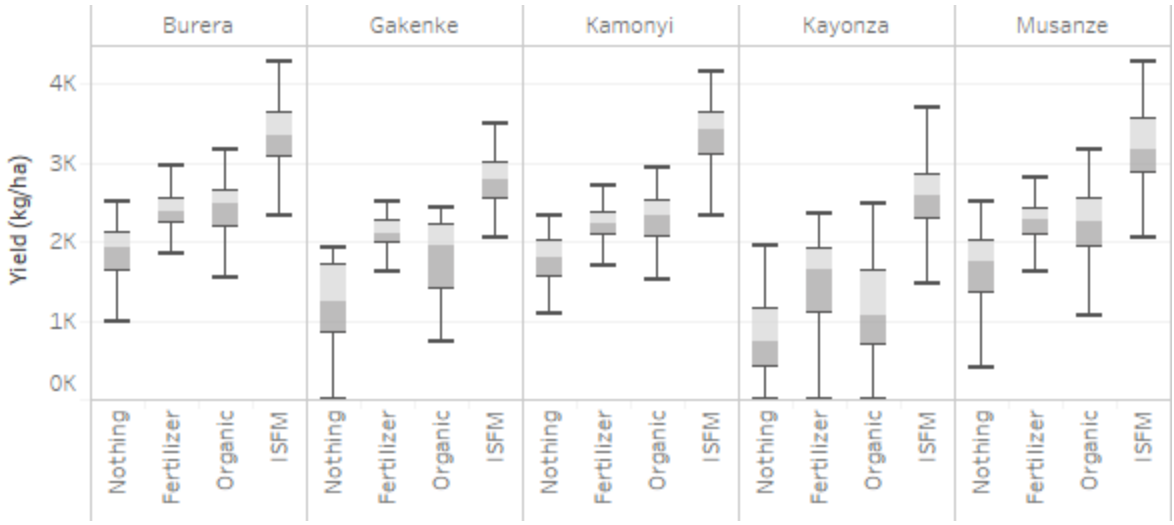


Figure 9 Whisker chart of simulated maize yields for four treatment scenarios at district-level

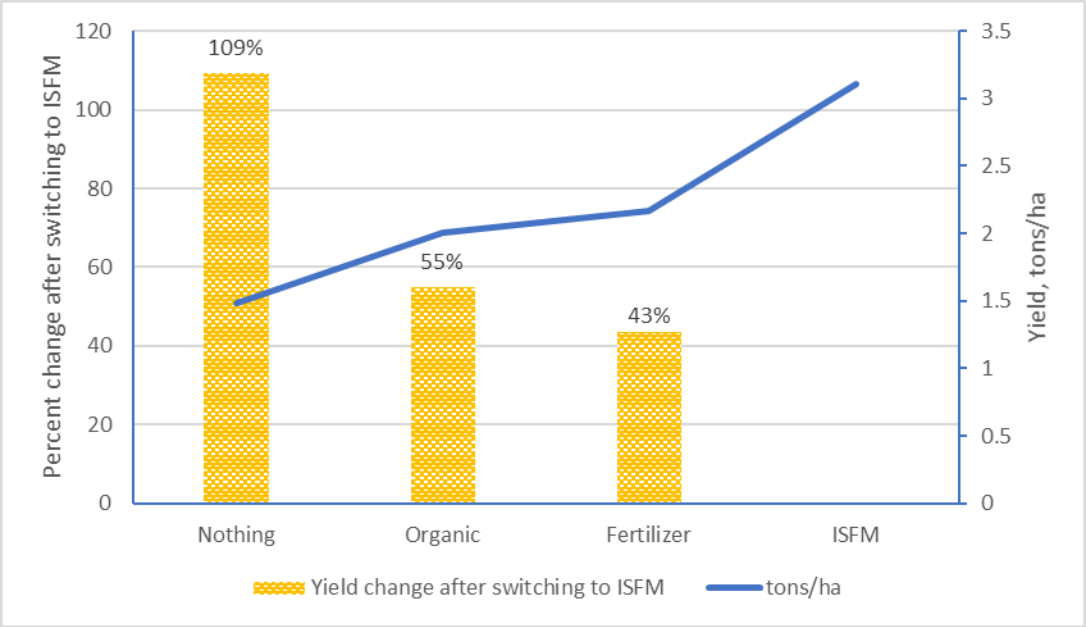
Table 10 Simulated maize yields for four treatment scenarios, aggregated at district-level

Treatments	**Burera**	**Gakenke**	**Kamonyi**	**Kayonza**	**Musanze**
Fertilizer	2439	2169	2280	1630	2320
ISFM	3402	2821	3399	2718	3211
Nothing	1887	1272	1776	837	1655
Organic	2463	1829	2316	1209	2221
Mean Yield Equality Tests (P-Values)					
ISFM=Fertilizer	0.000***	0.000***	0.000***	0.000***	0.000***
ISFM=Nothing	0.000***	0.000***	0.000***	0.000***	0.000***
ISFM=Organic	0.000***	0.000***	0.000***	0.000***	0.000***
Fertilizer=Nothing	0.000***	0.000***	0.000	0.000***	0.000***
Fertilizer=Organic	1.000	0.002***	0.998	0.000***	0.716

On average, farmers can more than double their yields if they switch from no input application practice to ISFM (Figure 10). Yield will increase by 55% and by 43% when after farmers switch from organic inputs and fertilizer respectively. The results underscore the food security and environmental benefits that ISFM holds. As part of implementation of the Rwanda government Strategic Plan for Agriculture Transformation (SPAT), the government has been providing fertilizer subsidy for maize and wheat farmers (MINAGRI 2009). To support adoption of ISFM, the government could incentivize farmers by giving the subsidy vouchers on the condition that farmers have adopted an easily verifiable organic soil

fertility management practice – such as agroforestry. This will serve two important roles – sustainably increasing yield and reducing the amount of fertilizer required. Studies have shown that agroforestry can reduce the recommended variety by more than 50% if leguminous trees are used (Akinnifesi et al 2010). Conditional subsidy will lower the high cost of subsidies or increase area receiving fertilizer. Marenya et al 2014 showed that conditional fertilizer subsidies are highly favorable among farmers.

Figure 10: Yield change after adoption of ISFM



When the trends of simulated soil organic carbon (SOC) content changes over the simulation time period for each treatment was aggregated, it was clearly shown that the adoption of ISFM notably increased SOC over time compared to other scenarios (Figure 11), contributing to the soil fertility improvements, enhanced soil moisture holding capacity, and thus increased yields.

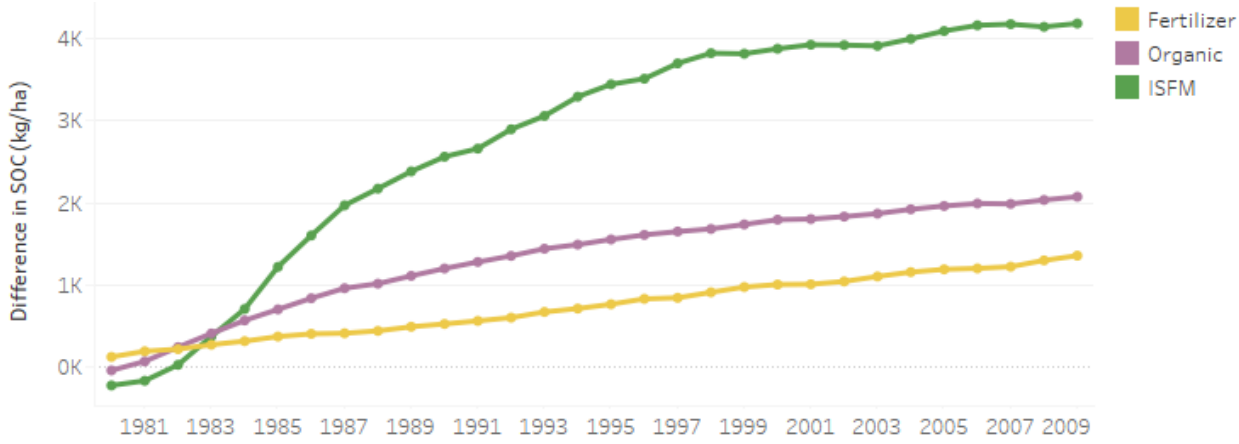
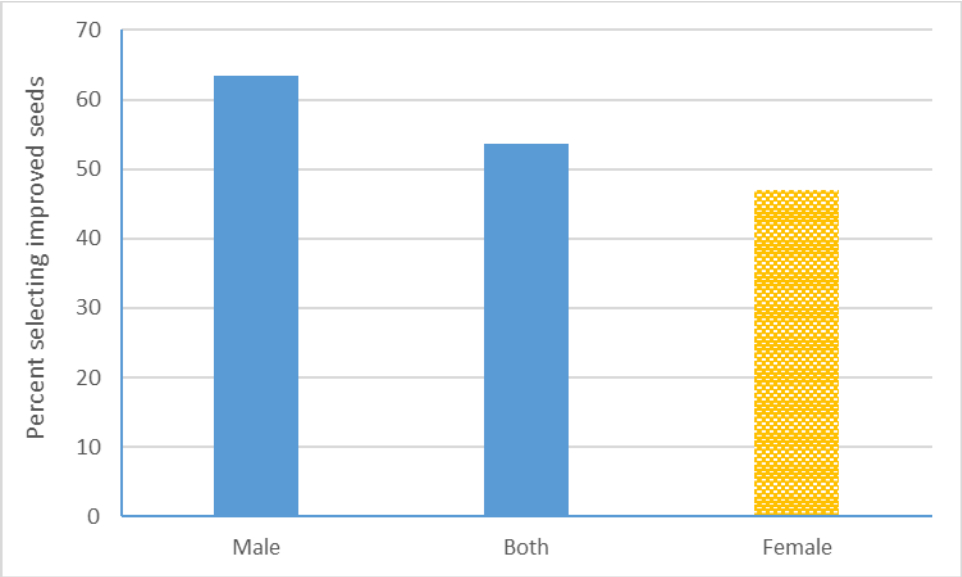


Figure 11 Aggregated trends of soil organic carbon changes over the simulation time period

Drivers of adoption of ISFM in Kenya and Zambia

The odds of adopting ISFM in Zambia is lower if seed selection were done by a female household member (

Figure 13: Maize seed selection across gender



As expected access to rural services increases adoption of ISFM in both Zambia and Kenya (Table 11 &

Table 12). Proximity to district headquarters and being in urban area in Zambia and to all-weather road in Kenya increases the propensity to adopt ISFM. Access to market has no significant effect in both countries. This could be due to strong relationship of access to market and roads or district headquarters.

Access to general agricultural extension and agroforestry advisory services increases adoption of ISFM in Kenya but has no significant effect in Zambia. Belonging to farmer groups also increases propensity to adopt ISFM. the results demonstrate the need for access to rural services and the role it plays in increasing adoption of ISFM.

Table 11). This is due to the likelihood of female choosing unimproved varieties. Likewise, likelihood of adopting ISFM in Zambia is lower if main decision maker for the plot or household head is female.[2] Likewise, male-headed households are more likely to adopt IFSM than female-headed households (

[2] No data on plot ownership or decision making were collected in the Kenyan 2015 survey.

Table 12).

While education does not have significant impact on adoption of ISFM in Zambia, it has strong impact in Kenya – as expected. Empirical evidence from Africa has shown that education is associated with higher adoption of agricultural technologies and productivity (Alene and Manyong 2007; Appleton and Balihuta 1996) – especially those related to knowledge intensive technologies like ISFM (Bationo et al 2007).

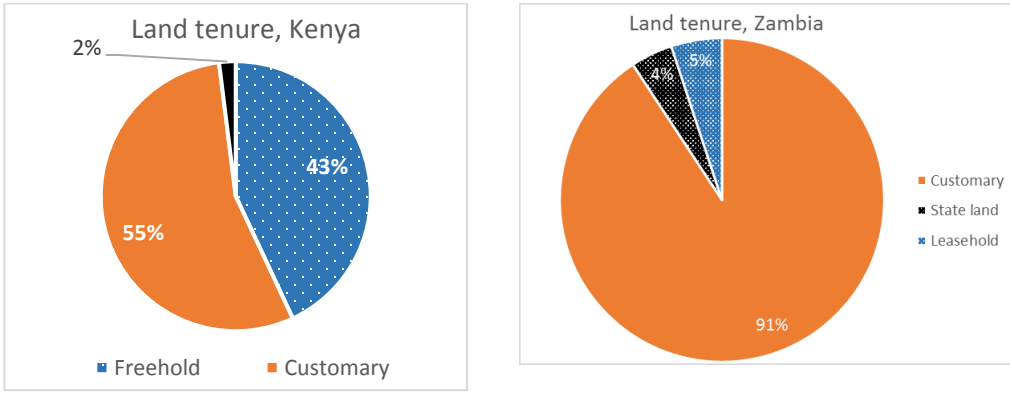
Number of adults – representing family labor – has no effect on adoption of ISFM in Zambia but has a negative effect in Kenya. It was expected that family labor will increase adoption of ISFM since the technology is labor intensive – especially if it involves biomass transfer (Nkonya et al 2015). The unexpected results could be due to other poverty factors associated with large families – which could constrain ISFM adoption.

Land tenure has no effect on adoption of ISFM in Zambia (Table 11) but having freehold (with land title) in Kenya increases the propensity to adopt ISFM (

Table 12). The difference in land tenure system in the two countries could be behind these differing results. Kenya has three main types of land tenure but customary and freehold are the major types (Figure 12). The three types of land tenure in Kenya are consistent with the constitution, which set trust land (Section 202, subsection 5) – land held by the county council for the benefit of people residing in the area and operated according to customary law. Freehold tenure is the formal land tenure which - after cartographic surveys – is given land holders for perpetual ownership (GoK 2002).

According to Zambia's land act of 1995, the President holds the land on behalf of the Zambian people. An individual could acquire a leasehold for a period not exceeding 99 years but there is no freehold system in Zambia but the Act recognizes the customary land tenure. As is the case in many African countries, the customary land tenure in Zambia is the dominant tenure type (Figure 12) and the limited variability of land tenure type explains its weak impact on adoption of ISFM.

Figure 12: Land tenure in Kenya and Zambia



Cropland size has no effect on adoption of ISFM in Kenya but it significantly increases adoption in Zambia – contrary to the inverse land productivity theory (Lamb 2003). Land size reflects wealth and financial ability to adopt ISFM.

Number of livestock has no effect on adoption of ISFM in Zambia but has a negative effect in Kenya. Other studied have shown that having livestock increases biomass production (manure) and provides animal power to biomass transfer (Nkonya et al 2015). The negative effect of number of livestock could be due to the less dependency on crop production among households who are predominantly livestock keepers.

Figure 13: Maize seed selection across gender

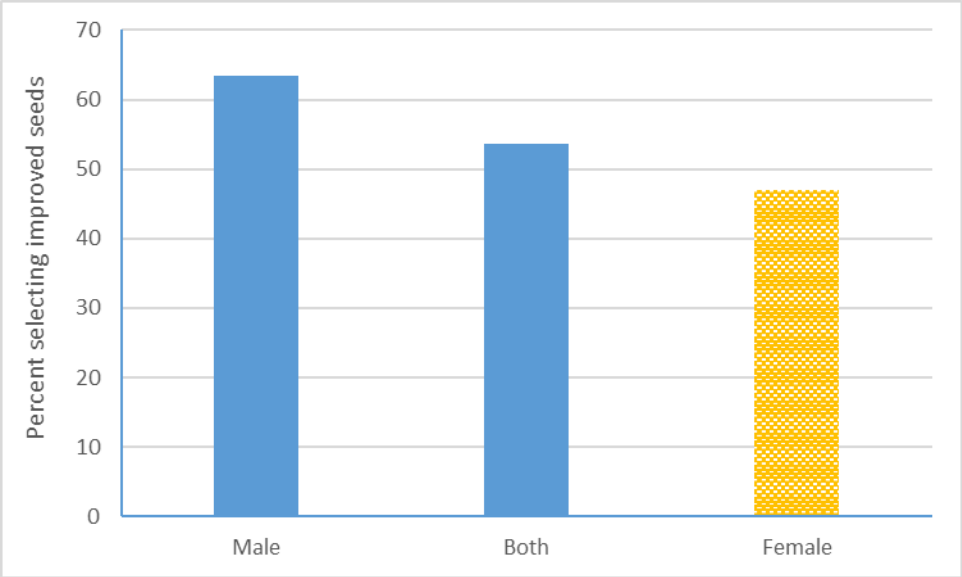


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Table 11: Drivers of adoption of ISFM – Zambia

Covariates	Structural model	Reduced model
	Probit Maximum Likelihood coefficients	
Human capital		
Sex of person who chose seed (cf male)		
• Female	-0.132***	-0.132***
• Both	-0.087	-0.087
Sex of plot who decides on plot use (cf male)		
• Female	-0.092**	-0.092**
• Both	-0.080	-0.083
Male household head	0.434*	0.426*
Education of household head	0.020	0.020
Number of adults in household	0.000	0.000
Age of household head	0.010	0.010*
Physical capital endowment		
Plot land tenure (cf customary)		
• Leasehold	0.098	0.096
• State-owned	0.029	0.028
Total cropland area (ha)	0.170***	0.170***
Value of productive assets (ZKW)	$9.76e^{-11}$	$-2.48e^{-10}$
Value of all assets (ZKW)	$5.70e^{-11}$	$4.04e^{-10}$
Tropical livestock Units (TLU)	0.001	0.002
Rural services		
Distance (km) to:		
• Road	$-3.5e^{-05}$	0.0002
• District headquarters	-0.010***	-0.010***
• Agricultural market	0.002	0.002
Have access to:		
• Price information	0.056	
• Advisory services on agricultural production	-0.033	
• Group member	-0.029	
Rural residence (cf town)	-0.191***	-0.189***
Constant	-2.531***	-2.521***

Table 12: Drivers of adoption of ISFM, Kenya

	Probit maximum likelihood coefficients	
	Structural	reduced
Human capital		
Male-headed household	0.098***	0.108***
Education of household head (cf no education)		
• Primary	0.399***	0.420***
• Post-primary	0.470***	0.498***
Number of adults	-0.005***	-0.004***
Physical capital		
Farmsize	0.000	-0.0001
Land tenure (Freehold)		
• Customary	-0.167***	-0.171***
• Leasehold/rented	-0.228**	-0.260**
TLU	-0.018***	-0.017***
Access to rural services		
Distance (km) to market	$3.73e^{-06}$	$4.76e^{-06}$*
Distance (km) to all-weather road	-0.005***	-0.006***
Belong to farmer group	0.202***	
Received general agricultural extension	0.075**	
Received agroforestry extension services	0.225***	
Have access to credit services	0.230***	
Constant	-0.983***	-0.933***

TLU=Tropical Livestock Units: conversion factors to TLU: Cattle = 0.7, Sheep = 0.1, Goats = 0.1, Pigs = 0.2, Chicken = 0.01 & Donkey=0.5

Conclusions and policy implications

As uptake of mobile phone among farmers approaches the 80% level – regarded as statistical threshold for being representative of a population, use of mobile phones to conduct household survey is increasingly becoming a viable option. There are many advantages of using mobile phone surveys over the traditional in-person survey approach – including low cost and possibility of conducting frequent surveys to capture data that are not easy to remember. As part of efforts to obtain a representative sample, we stratified farmers in Rwanda across age sets and assigned weights for each set that matches the nationally representative household survey. The refusal rate among the old farmers was very high. Results of this study show that use of mobile is heavily biased towards young farmers.

Another serious problem with mobile phone survey is the difficulty of correcting errors or data that are obviously wrong. For example, the mobile survey in Rwanda showed maize yield for plots receiving integrated soil fertility management (ISFM) was only 137kg/ha – a level that is only 4% of the corresponding yield reported in the nationally representative survey of 2016. The biggest reason for the low yield reported is the large area reported by farmers. The polling company administering the mobile

phone survey (GeoPoll) was asked to address these outliers but were unable to address it. We decided not to put upper and lower limits to prevent entry of skewed data – as this could potentially lead to dropouts. This could be addressed by sending a follow-up message asking if the value reported is valid. This was not done in this instance due to budget constraints.

Adoption rate of ISFM obtained using mobile in Rwanda for the largely young farmers shows the same pattern as the in-person household survey – that is, adoption rate of ISFM is lowest. Similarly, adoption of ISFM in Kenya and Zambia is lowest among the four technologies considered – improved seeds, inorganic fertilizer only, organic inputs only and ISFM. Adoption of improved maize seeds is higher in Kenya and Zambia than the average in sub-Saharan African countries – which stands at 33% and 38% in eastern and Southern Africa respectively. Interestingly, Kenya has much higher inorganic fertilizer adoption than Zambia even though the latter gives generous fertilizer subsidy. This shows the effect of strong input market in Kenya and presence of agroforestry from local and international institutions.

Simulation results shows that ISFM can more than double maize yields if farmers switch from no input application to ISFM. The yield will increase by about 43% if farmers switch from fertilizer only to ISFM. Yield trend of ISFM also shows sustainable production and sequesters significantly higher quantities of carbon. Despite these food security and environmental benefits, ISFM adoption is low. There is need for promoting more aggressively adoption of ISFM and providing incentives for its adoption. For example, governments of Rwanda and Zambia subsidize fertilizer only. Farmers can be incentivized to adopt ISFM by giving conditional fertilizer subsidy. That is, farmers can receive subsidy vouchers if they have adopted easily verifiable organic soil fertility management practices. For example, nitrogen-fixing agroforestry trees can be easily seen and subsidies vouchers could be given to farmers who have planted trees on their farms. Adoption of nitrogen-fixing agroforestry trees can simultaneously reduce amount on inorganic fertilizer required and increase yield.

In addition to incentives, several other factors affect adoption of ISFM. Having freehold tenure in Kenya increases adoption of ISFM but land tenure has no effect on adoption of ISFM in Zambia. This is probably due to the limited variability of land tenure types in Zambia. As expected access to rural services increases adoption of ISFM in both Zambia and Kenya. Access to general agricultural extension and agroforestry advisory services increases adoption of ISFM in Kenya but has no significant effect in Zambia. One of the reasons for the weak impact of access to extension services is the limited capacity of providing advisory services of the relatively new ISFM paradigm. There is need of providing short-term training to in-service extension agents and including ISFM in colleges and universities to equip the students of the new soil fertility approaches.

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