IFAD

Investing in rural people

The adoption of improved agricultural technologies

A meta-analysis for Africa

by
Aslihan Arslan
Kristin Floress
Christine Lamanna
Leslie Lipper
Solomon Asfaw
Todd Rosenstock

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Abstract

Understanding the determinants of improved agricultural technology adoption is an important component of increasing agricultural productivity and incomes of smallholders to reduce poverty and hunger, which are the top two Sustainable Development Goals. Among the actions needed to achieve this, particular attention is paid to the identification and promotion of productivity and resilience enhancing agricultural practices. The micro-economic literature on the analysis of the drivers of agricultural technology adoption is well-established since the Green Revolution. Although numerous seminal reviews of this literature have been published, most of these were theoretical or conceptual reviews and focus on earlier literature from continents other than Africa, which is the continent facing the biggest productivity challenge now. This paper synthesizes the findings of this literature focusing on Africa using a meta-data set that brings together the results of 168 recently published papers. We find that most of this literature focuses on agronomic practices and that agroforestry and livestock related studies make up less than one fifth of the total published papers. Eleven determinants, primarily those related to information access, wealth indicators and tenure security, are found to increase adoption more than chance would dictate in the literature. Our findings provide evidence to support recommendations for future policy and research.

1. Introduction

Africa remains the continent with one of the lowest levels of agricultural productivity coupled with high poverty rates, despite recent increases in agricultural growth rates (AASR, 2016). Most of this growth is based on area expansion rather than improved productivity. At the same time, productivity is increasingly vulnerable to climate change and desertification (IPCC, 2018; Ch.5), which threaten progress towards decreasing poverty and hunger while maintaining environmental sustainability as part of the Sustainable Development Goals (SDGs). To address these challenges and harness the poverty reducing power of agricultural growth (Christiaensen et al., 2011), the continent needs increased investments in agriculture, particularly in the identification and promotion of improved agricultural technologies and practices (AASR, 2016).

The first large-scale agricultural productivity increases in developing world were achieved by wide-scale adoption of agricultural technologies during the Green Revolution in 1960s (Evenson and Gollin, 2003; Stevenson et al., 2013). Ever since Green Revolution technologies, which include primarily high yielding crop varieties and chemical fertilizers, were deployed to increase productivity and decrease poverty, economists have tried to analyse the determinants of technology adoption by farmers. [1] Numerous theoretical and empirical articles have been published, providing as many answers to the questions of why farmers adopt (or not) certain agricultural technologies. A number of seminal review pieces have been produced to combine all evidence and provide a conceptual framework to think about the adoption process (Feder and Umali, 1993; Feder, Just and Zilberman, 1995; Sunding and Zilberman, 2001; among others).

Despite this wealth of knowledge, it is still not uncommon to find many researchers and development practitioners trying to answer the same questions in new places or by using new data sources. Continuing interest is partially due to significant improvements in the availability of data sources facilitated by the advancement of technology as well as the continuing persistence of poverty and hunger in parts of the world. Norman Borlaug said, "cereal production in the rain-fed areas still remains relatively unaffected by the impact of the green revolution" in his Nobel Lecture in 1970. This statement remained unfortunately true in parts of Africa at the end of 2015, when progress towards Millennium Development Goals (MDGs) was assessed and SDGs were adopted by the United Nations.[2] Ending poverty and hunger still remain on top of the agenda, making up the first 2 of 17 SDGs, and given that the majority of global poor live in rural areas, agriculture is still the key target sector for efforts to reach these goals.[3] Climate-smart agriculture (CSA) is an overarching approach to agricultural policy, which was developed in this landscape to ensure that agricultural practices promoted improved productivity, even under climate change and capture mitigation benefits, where relevant. The research presented in this paper originated to help understand the determinants of adoption of practices promoted within CSA frameworks in Africa.

Africa and Southern Asia are home to the overwhelming majority of the world’s poor and undernourished, who depend directly or indirectly on agriculture (Casteñada et al., 2018). Therefore, understanding the barriers to the adoption of agricultural technologies remains crucial to these efforts, given the new challenges faced by agriculture ranging from an increasing and increasingly wealthy population with shifting demand patterns to the impacts of climate change (FAO, 2016). Although there are a number of publications that provide a thorough conceptual review of the literature, studies that systematically and quantitatively analyse the current state of

[1] The literature on agricultural technology adoption traditionally uses the term ‘technology’ to refer to improved germplasm, fertilizer and other chemical inputs as well as agronomic practices, such as integrated pest management, that are part of a farm-systems thinking (Evenson and Gollin, 2003). In keeping with the tradition, we use the term improved agricultural ‘technology’ when we refer to this literature. Overall, we use the terms technology and practice interchangeably in this paper to refer to a wide range of technologies and practices that are considered better than the status quo in terms of providing productivity, resource use efficiency or adaptive capacity. They include traditional practices that can provide one or more of these benefits as well as modern agricultural technologies, such as improved seeds.
[2] http://www.nobelprize.org/nobel_prizes/peace/laureates/1970/borlaug-lecture.html
[3] https://sustainabledevelopment.un.org

knowledge on this issue in Africa are scarce. This paper is an effort to fill this gap by combining existing micro-econometric evidence on determinants of adoption (or lack thereof) from a wide range of improved agricultural technologies in Africa using data from 168 published studies and meta-analysis methods.

We provide a brief overview on the status of current knowledge on determinants of adoption in the next section and discuss the relevance of the analysis provided in this paper in the context of the SDGs. In section 3, we discuss the protocol used to compile our data set and provide some descriptive statistics. Meta-analysis results are presented in section 4, and we conclude with recommendations for research and policy in section 5.

2. The current relevance of the adoption literature

The literature on the adoption of agricultural technologies has been advancing since the Green Revolution to understand the drivers of and constraints to the spread of new technologies. Feder et al. (1985) provide a thorough survey of the theoretical and empirical adoption literature in developing countries that preceded their survey. Sunding and Zilberman (2001) provide a more detailed review, including literature on agricultural innovation and research as well as technology adoption. Foster and Rosenzweig (2010) discuss the structural models behind the findings of reductionist empirical models of farmer technology adoption. These seminal papers highlight the complexity of agricultural technology adoption decisions that are subject to multiple uncertainties (e.g. prices, weather, labour availability) and market constraints (e.g. for inputs and output, credit, information), making the empirical analyses challenging.

The increasing number of empirical studies in the literature has facilitated a number of meta-analyses and review pieces. Prokopy et al. (2008, 2019), Baumgart-Getz et al. (2012), Carlisle (2016) and Ranjan et al. (2018) all reviewed the adoption of agricultural innovations with a conservation motivation in the United States. Other review and synthesis papers include Knowler and Bradshaw (2007); Tey and Brindal (2012); Wauters and Mathijs (2014); and Liu, Bruins, and Heberling (2018). Most recently, Munguia and Llewellyn (2020) provided a synthesis of the findings of earlier literature. Nonetheless, rigorous studies using a meta-analysis framework specifically focused on Africa remain an important gap in this literature, which we address in this paper.

Although the behavioural model behind farmer optimisation leading up to technology adoption (or not) is dynamic and complex, there are a large set of variables that are common across empirical studies to explain adoption behaviour. These range from socio-economic variables (e.g. age, education, marital status), wealth indicators – some of which can be a proxy for risk aversion – (e.g. land holding size, income, asset holdings/values) and agro-ecological variables (e.g. plot slope, soil quality, rainfall, temperature, location controls), to variables capturing market imperfections (e.g. access to credit, insurance, and information; distance to markets) as well as the influence of social networks (e.g. group membership, number of social connections). A recent special issue of the *Applied Economic Perspectives and Policy* journal provides the most up-to-date review of the literature on the adoption of agricultural innovations (Pannell and Zilberman, 2020). A review of this literature is outside the scope of this article, and we only discuss its current relevance in the light of recent development discourse on agricultural productivity and sustainability with a focus on Africa.

The first 2 of the 17 SDGs adopted in 2015 focus on ending poverty and hunger by 2030. These goals were only partially achieved by the MDGs. Although the number of people in extreme poverty around the globe has declined by more than half since 1990, sub-Saharan Africa (SSA) is the only continent that missed the target of halving this proportion (41 per cent compared to the 2015 target of 28 per cent). SSA has also missed the target to halve the proportion of undernourished people, which stays at 23 per cent (compared to the target of 16 percent), whereas developing regions as a whole have almost reached the target by decreasing the proportion of undernourished people from 23 to 13 per cent (MDG, 2015).

The SDGs picked up where the MDGs left off, recognizing the importance of a much wider range of interacting goals to achieve the sustainability agenda. An important aspect has been accounting for the effects of climate change by not only having a ‘climate action’ goal per se but also building into the other goals’ explicit targets to build resilience for the poor and vulnerable. Specifically, the targets of SDG 2 aim to double the agricultural productivity and incomes of smallholders through the implementation of resilient agricultural practices (among other things). Many of the technologies studied in the adoption literature have the potential to improve productivity and some also have expected resilience benefits. These include, improved crop varieties, soil and water management techniques and agroforestry to deal with a variety of climatic shocks that are expected to become more frequent and severe with climate change (Vanlauwe et al., 2017). Therefore, a systematic review of the barriers to the adoption of agricultural technologies in SSA is needed to provide a thorough understanding of the literature to date and support action towards achieving the SDGs.

The origins of the research presented in this paper come from the international and regional discourse on CSA, which contributes to the efforts to achieve SGDs. CSA is one of the approaches developed to deliver the needed increases in agricultural productivity and incomes while building resilience to climate change and capturing mitigation co-benefits, where possible (FAO, 2010; Lipper et al., 2014). Since its introduction to the international agricultural development and climate change agenda, CSA has received significant attention and has been taken up by many international, regional, sub-regional and country-level institutions (including international development donors). A Global Alliance for Climate-Smart Agriculture was established in 2014, followed by many regional/sub-regional alliances for CSA. To date, many publications have documented agricultural practices that have CSA characteristics (FAO, 2013; 2014; 2017; Neate, 2013). However, there is no blueprint for CSA, because "many improved agricultural practices may be CSA somewhere, none are likely to be CSA everywhere" (Rosenstock, pers. comm.).

Recognizing the need for a systematic review of the scientific evidence on the contributions to food security, adaptation and mitigation of a large set of improved agricultural practices, the World Agroforestry Centre in collaboration with the CGIAR Research Program on Climate Change, Agriculture and Food Security, Food and Agriculture Organization (FAO) and the International Center for Tropical Agriculture, has been leading the Climate-Smart Agriculture Compendium (the CSA compendium) initiative. The CSA compendium team has screened more than 150,000 published scientific studies relevant for CSA, covering 73 agricultural practices that are often cited as CSA to create a final library of more than 7,000 studies to be part of a meta-analysis (Rosenstock et al., 2015).[4] The CSA compendium can assess the productivity, adaptation and mitigation effects of practices, but it cannot answer the questions on what drives their adoption. To that end, another initiative was created to rigorously document the socio-economic factors related to the adoption/not of practices covered in the compendium. This paper is based on the data set that resulted from this initiative, which is explained in detail in the next section.

[4] The literature screened through this effort is based on controlled experiments (in the lab or on in the field) to assess the productivity, adaptation and mitigation effects of included practices.

3. Meta-data from the adoption literature

The agricultural practices captured in the CSA compendium are categorized in five thematic areas: (i) agronomy, (ii) agro-forestry, (iii) livestock, (iv) post-harvest, and (v) energy systems. Most of the agricultural practices in the first three thematic areas are also found in the socio-economic literature that analyses the barriers to/determinants of their adoption using various methodologies. To conduct a meta-analysis on the barriers to adoption, a protocol was developed to screen this literature and to decide whether to include/exclude each publication in the database created for this study.

The agricultural practices included in our protocol are the same as those in Rosenstock et al. (2015), which were selected through an exhaustive literature review and discussions with multiple development partners that invest in the identification and promotion of improved agricultural practices and technologies to improve productivity and resilience.[5] We developed a new search string to screen online databases of published research on the barriers to adoption of these practices. We used the combination of 'practice' and 'barriers' search strings in SCOPUS – the largest abstract and citation database of peer-reviewed literature – to identify a large pool of articles with the potential to be relevant for our meta-database.[6] The initial search (conducted in 2016) yielded 1,113 published papers that contained the combinations of the keywords in practices and barriers search strings.

All papers were screened by a team of five research assistants in two stages: (i) the titles and abstracts were screened using the inclusion criteria for practices, barriers and location of interest (Africa); and (ii) full texts of articles that were included and accessible were screened for final inclusion into the database and extraction (table 1). The resulting list of articles were then complemented with a recursive search conducted using the reference list of articles included in the database (i.e. relevant references cited in screened articles not already captured were screened using the same criteria). The database was further updated in 2018 to ensure that newer publications were captured. The final meta-database includes information from 168 articles (5,621 data points) that analyse the determinants of adoption of around 90 practices in 23 countries in Africa. The data points refer to the estimated coefficients of determinants of adoption reported in each paper. If a paper analysed multiple practices, we captured the coefficients from each practice, and if multiple specifications were presented, we captured the coefficients from the most robust specification.

[5] The CSA compendium practices identified through literature review were screened and prioritized during discussions with experts from various development partners: international agricultural research centres (e.g. CGIAR, FAO), international non-governmental organisations (e.g. Care International, Concern International, Oxfam, World Vision, CRS, etc.), international/bilateral development finance institutions (e.g. World Bank, USAID) and continental and regional institutions (e.g. NEPAD, COMESA) (Rosenstock et al., 2015).

[6] The barriers search string created for this paper is presented in annex A. Please see Rosenstock et al. (2015) for a full set of search strings for practices as well as productivity, adaptation and mitigation benefits.

Table 1. Inclusion/exclusion criteria for identified publications

Inclusion criteria	Exclusion criteria
Practices	
Relevant to one of the practices	Does not include any of the practices
Barriers	
Includes at least one of the barriers/determinants of adoption	Does not include barriers/determinants
Location	
Uses data from at least one country in Africa	No data from African countries
Empirical specification	
Reports econometric analysis of technology adoption (binary or intensity)	Discusses barriers in a conceptual way w/o empirical analysis
Is not a meta-analysis itself	Is a meta-analysis or a review
Uses household/plot level data	Uses data at larger spatial scales
Reports coefficients of all control variables	Reports only significant results

Source: Adapted from table 3 in Rosenstock et al. (2015). See the practice search string in that paper for a full list and annex A for the barriers search string.

3.1. Determinants of adoption captured by data

The protocol above resulted in 384 distinct determinants used as independent variables in technology adoption regressions. These determinants were first reduced to 43 distinct categories based on the expected direction of impact, i.e. distance to road measured in distance and minutes were grouped under one category called 'distance to road'. They were then grouped into larger thematic categories to facilitate the analysis. This process reduced the total number of observations that can be used in the analysis because some determinants could not be categorized, as they were unique or rarely used to allow a separate analysis (e.g. village roundtrip distance to fetch fuelwood, household perception of support during crop failure).

Table 2 lists the most common determinants of technology adoption, grouped under various categories, and the direction of change expected in adoption analyses. Socio-demographic variables are most frequently included in adoption studies. Education is expected to affect technology adoption positively because new technologies require an understanding of the expected returns from a new technology (Huffman 2020). Age is usually expected to be negatively related to adoption, as younger farmers are hypothesized to be more innovative and risk taking; however, older farmers may adopt some technologies faster if the technology is labour saving and the household is labour constrained or if it is a modified version of a traditional practice they have experience with. Household size is commonly expected to increase adoption, as it is used as a proxy for labour availability in places with labour market imperfections, though the exact effect depends on whether the technology is labour saving or increases labour needs. The heterogeneity of these expectations is also documented by Munguia and and Llewellyn (2020).

Table 2. Commonly included determinants of adoption and the direction of change expected

Determinant category	Examples	Commonly expected direction	Frequency
Socio-demographics	Age, education, household size, dependency ratio, female head, married,	Mixed	1,419
Resource endowments	Farm/livestock assets, land size, off-farm income, overall income, wealth index*	Mixed	1,147
Information	Access to extension/information about practice/general information, farming experience, previous use of practice	Positive	592
Bio-physical factors	Land degradation, pests/diseases, plot fertility/slope, soil depth, water access	Mixed	554
Groups/social capital	Farmer group participation, access to government/NGO support, other social capital indicators	Positive	304
Distance to market/road	Distance to market or roads	Negative	273
Credit access	Access to credit	Mixed	212
Tenure security	Secure land tenure	Positive	146
Rainfall/temperature	Annual/seasonal rainfall, past rainfall, seasonal temperature	Mixed	132
Risk and shocks	Shock experience, insecure land tenure	Mixed	131
Labour availability	Household size, number of adults	Mixed	128
Total			5,038

Note: *Wealth indices are usually calculated using principal component analyses in the literature. Source: Authors' own compilations. See annex B for a full list of determinants under each category.

Resource endowments are the second most frequently included determinant group and include various indicators of income, assets and wealth. The effect of these group of variables on adoption is also mixed and depends on the practice at hand. Practices that require up-front investment can be expected to increase with these variables, whereas traditional practices beneficial for soil health or practices adopted due to lack of risk management options (such as diversification) can decrease as wealth increases. Access to information categories include both practice-specific information as well as access to a broader range of information, including prices, market access and experience, and is most unanimously expected to increase the adoption as farmers learn the (short- or long-run) benefits of adopting certain practice. Social capital is also mostly expected to increase adoption of improved practices as farmers learn from each other both how to use practices and the benefits of doing so.

All other determinant groups have mixed signs that depend on the practice at hand as well as all other variables that affect individual adoption decisions. This heterogeneity reflects the case specific characteristics of this literature and underlines the importance of a review piece to distil the overall messages that come out of existing empirical literature focusing on Africa.

3.2. Descriptive statistics

We grouped the improved agricultural practices under three themes that contain similar practices. These themes were further subdivided into practice groups to provide more detail about agricultural practices captured in each. Table 3 includes a summary of the themes, practice groups and the frequency distribution of the observations (i.e. estimated coefficients in adoption models) captured from the primary research articles. Agroforestry includes about 10 per cent of all observations, and the agronomy category includes the bulk of the practices captured by the published literature (represented by about 88 per cent of all observations in our data). The remaining 2 per cent of practices fall under the livestock category.

Table 3. Number of observations by practice group and theme

Themes	Practice groups	Examples	Frequency	%
Agroforestry (AF)	AF intercropping	Planting of trees (nitrogen fixing or other species) among crops	131	2.34
	AF parkland management	Managing parklands	7	0.12
	AF farmer managed natural regeneration	Establishing forest plantations	18	0.32
	AF boundary planting	Live fencing, planting trees around farm boundaries	42	0.75
	AF general	Planting trees for unspecified reasons, home gardening with trees	286	5.20
Agronomy	Water management	Planting basins, terraces, water harvesting	1,156	20.64
	Soil management	Reduced tillage, cover crops, crop rotations	466	8.32
	Nutrient management	Inorganic/organic fertilizers, integrated nutrient management	1,668	29.78
	Crop management	Changing planting dates/crop varieties, intercropping	1,599	28.55
Livestock	Diet management	Improved protein/energy intake, feed supplements	69	1.23
	Pasture management	Improved fodder species/management	19	0.34
	Manure management	Manure storage	5	0.09
	Breed management	Changing breeds	21	0.37
	Fisheries/aquaculture	Integrated aquaculture and agriculture	9	0.16
	Total		**5,496**	**100**

Note: The number of observations between table 2 and 3 are different because some of the observations covered in table 3 refer to coefficients of determinants that are unique to some studies or not common enough to categorize in any one of the studies determinant groups in table 2. Such observations are not included in the analysis. Source: Authors' own compilations.

Table 4 presents the number of distinct studies in each thematic category, where the shares are similar to those in table 3 with a slight increase in agroforestry (18 per cent) and a decrease in agronomy (78 per cent) shares. The observation that the agronomy theme includes the highest number of studies reflects the scholarly attention paid to improved agricultural technologies that were part of the Green Revolution (e.g. improved seed adoption, inorganic fertilizer application, irrigation management) as well as the increasing focus on sustainable agricultural practices after 1990s in the adoption literature (Munguia and Llewellyn, 2020). Rosenstock et al. (2019) reported a similar concentration of scientific knowledge focusing on nutrient and crop management practices in five countries in East Africa. Combined with the fact that most of the scientific literature on these practices focuses on productivity benefits only, these findings underline the need for further research to create similar evidence for other thematic areas (agroforestry and livestock) that are part of important strategies to improve productivity and household resilience to climatic shocks (Jones and Thornton, 2009; Arslan et al., 2017).

Table 4. Number of distinct studies by theme

Theme	# of distinct studies	% of studies
Agroforestry	33	17.65
Agronomy	146	78.07
Livestock	8	4.28
Total	**187**	

* Note that 20 papers cover multiple themes; therefore, the total exceeds 168. Source: Authors' own compilations.

Table 5 presents the number of distinct studies by country to identify the countries most studied in the technology adoption literature focusing on Africa. Ethiopia, Kenya and Nigeria are the countries with the largest number of distinct studies, and together, they account for around half of all studies from which data were extracted.[7]

Table 5. Distribution of distinct studies by country

Country	# of distinct studies	% of studies
Benin	3	1.74
Burkina Faso	8	4.65
Cameroon	5	2.91
DR Congo	4	2.33
Ethiopia	39	22.67
Ghana	8	4.65
Ivory Coast	2	1.16
Kenya	23	13.37
Madagascar	2	1.16
Malawi	9	5.23
Mali	1	0.58
Niger	2	1.16
Nigeria	19	11.05
Rwanda	3	1.74
Sierra Leone	1	0.58
South Africa	7	4.07
Sudan	3	1.74
Senegal	1	0.58
SSA	1	0.58
Tanzania	8	4.65
Uganda	9	5.23
West Africa	1	0.58
Zambia	7	4.07
Zimbabwe	6	3.49
Total	**172**	

* Note that two papers cover multiple countries. Therefore the total exceeds 168. Source: Authors' own compilations.

[7] 102 out of the 168 studies in our data were published since 2010, reflecting the recent increase in the availability of large-scale agricultural household data for rigorous empirical studies on technology adoption in Africa.

4. Methodology

Simple vote-count analyses are used to understand how often an independent variable has a significant positive or negative relationship with a dependent variable, along with how often no effect is found. This method is sometimes criticized in the meta-analysis literature because they can oversimplify directional, not just significant, relationships between independent and dependent variables, they do not account for sample size, and are subject to publication bias. Vote-count meta-analyses that simply involve a tally of significant and insignificant results, which in our case are reported coefficients of multiple determinants in adoption studies, are less methodologically rigorous than statistical meta-analyses. However, traditional statistical meta-analyses, by nature, focus on determining the effect across studies of one independent variable on one behaviour, and such an analysis requires information not always reported in primary research. Vote-count meta-analyses, regardless of their shortcomings, are a commonly used method, and results from these types of analyses are easily interpretable (Knowler and Bradshaw, 2007; Prokopy et al., 2008).

Our intent is to provide a broad overview of the predictor variables commonly included in studies of improved agricultural practice adoption in Africa. We also provide researchers and organisations engaged in such projects with usable information about the direction a given variable generally takes with regards to adoption, regardless of significance. Because statistical significance within individual studies is sensitive to sample size and the population from which the sample is drawn, we complement the vote-count meta-analysis with an analysis using the sign test methodology described by Bushman and Wang (2009). The sign test examines whether determinants have hypothesized positive or negative relationships with a given behaviour across multiple studies, thus eliminating the shortcomings of focusing only on significant results.

The sign test procedure was employed by creating binary variables to indicate whether a given determinant coefficient was consistent with the hypothesized direction it was expected to have with the dependent variable. Wilson (1927) binomial confidence intervals for proportions were then estimated. These confidence intervals are used to gauge overall positive or negative effect of a determinant on practice adoption using the following criterion: if the lower bound estimate falls below 0.50, one cannot conclude that the probability of the coefficient in the expected direction is greater than that expected by chance alone. In other words, the confidence intervals cannot include 0.50 nor be entirely below 0.50. We present the minimum, maximum and mean sample sizes along with the number of observations of studies for each determinant category to provide additional information for readers to gauge the applicability of results.

5. Results

5.1. Significance vote-count results

Tables 6a, 6b and 6c present vote-count results for agroforestry, agronomy and livestock practices, respectively. It is important to keep in mind that each observation is a coefficient from a multi-variate analysis of adoption of one of the practices included in the meta-data; therefore, reported results control for a set of livelihood characteristics of households. We present the results by broader categories used in table 2 to deal with the large variation observed in the definitions of determinants used in the included studies. For example, the determinant group called 'information' includes the following independent variables: access to information specific to the improved agricultural technologies, access to extension, access to general information, farming experience and previous use of improved practices. The long list of determinants under each group are presented in annex A.

Table 6a. Vote-count results for agroforestry

Determinant group	Not sig.	Negative	Positive	Total	% not sig.	% - sig.	% + sig.	% included
Information	37	1	26	64	57.8	1.6	40.6	14.8
Resource endowments	47	12	22	81	58.0	14.8	27.2	18.8
Risk and shocks	14	0	3	17	82.4	0.0	17.6	3.9
Bio-physical factors	13	3	5	21	61.9	14.3	23.8	4.9
Dist. to market/road	7	2	8	17	41.2	11.8	47.1	3.9
Socio-demographics	93	7	38	138	67.4	5.1	27.5	31.9
Groups/social capital	13	3	13	29	44.8	10.3	44.8	6.7
Tenure security	9	2	9	20	45.0	10.0	45.0	4.6
Labour availability	11	1	7	19	57.9	5.3	36.8	4.4
Credit access	12	2	2	16	75.0	12.5	12.5	3.7
Rainfall/temperature	6	2	2	10	60.0	20.0	20.0	2.3
Total	**262**	**35**	**135**	**432**	**60.6**	**8.1**	**31.3**	**100**

Table 6b. Vote-count results for agronomy

Determinant group	Not sig.	Negative	Positive	Total	% not sig.	% - sig.	% + sig.	% included
Information	284	41	185	510	55.7	8.0	36.3	11.5
Resource endowments	601	124	294	1019	59.0	12.2	28.9	23.0
Risk and shocks	69	9	32	110	62.7	8.2	29.1	2.5
Bio-physical factors	342	69	107	518	66.0	13.3	20.7	11.7
Dist. to market/road	157	57	35	249	63.1	22.9	14.1	5.6
Socio-demographics	811	153	268	1232	65.8	12.4	21.8	27.8
Groups/social capital	165	24	76	265	62.3	9.1	28.7	6.0
Tenure security	70	9	42	121	57.9	7.4	34.7	2.7
Labor availability	65	15	29	109	59.6	13.8	26.6	2.5
Credit access	118	22	46	186	63.4	11.8	24.7	4.2
Rainfall/temperature	50	18	42	110	45.5	16.4	38.2	2.5
Total	**2682**	**523**	**1114**	**4429**	**60.6**	**11.8**	**25.2**	**100.0**

Table 6c. Vote-count results for livestock

Determinant group	Not sig.	Negative	Positive	Total	% not sig.	% - sig.	% + sig.	% included
Information	9	0	5	14	64.3	0.0	35.7	11.7
Resource endowments	6	4	11	21	28.6	19.0	52.4	17.5
Risk and shocks	0	0	4	4	0.0	0.0	100.0	3.3
Bio-physical factors	5	0	2	7	71.4	0.0	28.6	5.8
Dist. to market/road	3	0	2	5	60.0	0.0	40.0	4.2
Socio-demographics	28	4	9	41	68.3	9.8	22.0	34.2
Groups/social capital	5	0	5	10	50.0	0.0	50.0	8.3
Tenure security	3	0	0	3	100.0	0.0	0.0	2.5
Credit access	1	0	6	7	14.3	0.0	85.7	5.8
Rainfall/temperature	6	1	1	8	75.0	12.5	12.5	0.2
Total	**60**	**8**	**44**	**120**	**50.0**	**6.7**	**36.7**	**100.0**

Note: The significance tally reported include all coefficients that are found to be statistically significant at least at the 10 per cent level. Source: Authors' own compilations.

A number of observations stand out in these tables. Overall, 50-60 per cent of all coefficients in our data are not statistically significant. This is consistent with Munguia and Llewellyn (2020), who report a 67 percent non-significant to significant findings ratio in a vote-count that does not have a regional focus. Among the significant findings, access to information seems to matter for all themes, as it has been found to affect the adoption of improved practices positively in more than 36 per cent of the time (i.e. 36-40 per cent of the coefficients extracted from published adoption analyses report this variable to be statistically significant, at least at a 10 per cent level, for all three themes). Resource endowments (including various wealth indicators and access to off-farm income) are significantly correlated with higher adoption of livestock related practices in around 50 per cent of the literature. Exposure to risks and shocks and access to credit stand out as a positive driver of livestock practices in almost all studies that included these variables as a control. These results reflect the role of investment in livestock (though costly) as an ex-ante risk management strategy in the literature focusing on Africa.

Distance to markets/roads is found to be significantly correlated with higher adoption, mostly of improved agroforestry and livestock practices. For agronomic practices, the instances of significant negative correlation with distance are higher than the positive ones (23 vs. 14 per cent), although 63 per cent are not significant. The variable group we call 'socio-demographics', including variables such as age, education, gender and marital status, is one of the most included control variable groups, but they are found not significant in explaining adoption in more than 60 per cent of the cases.

Interestingly, the category of 'social capital/group interactions' is positive and significant in most cases for agroforestry and livestock practices.[8] Most observations in this category (90 per cent) come from papers publishes after 2005, which reflects the increasing understanding of the social context in the adoption literature (Munguia and Llewellyn, 2020; Vanlauwe et al., 2017). Most practices in these categories require bigger up-front investments (e.g. buying new livestock breeds) and longer time horizons (e.g. waiting for trees to grow to provide soil conservation benefits, livestock to fatten) compared to many agronomic practices, such as using improved seeds, fertilizers or integrated pest management. This finding indicates that social interactions matter more for decision making when up-front investments and time horizons increase.

[8] This determinant group includes a large number of indicators of social capital, including membership to farmer organisations, associations and cooperatives, number of relatives/kin in the village, membership to other social/religions groups, number of years households have lived in their village.

Land tenure security is one of the oft-mentioned determinants of adoption in the literature and is expected to increase the incentives to adopt new technologies. We find that almost 45 and 35 per cent of the analyses captured in our data find tenure security to increase adoption of agroforestry and agronomy practices, respectively. Only three studies on livestock technologies included this variable and none found it to be significant in determining the adoption of improved livestock practices. This is to be expected, as livestock may be grazed on communal lands or kept in stalls and fed using crop/household residues (as well as purchased feed), whereas investment in agroforestry and agronomy practices require farmers to be able to reap the benefits from that piece of land, both in the investment year and in the future. The latter is particularly important for agroforestry and agronomic practices that have a long pay-back period.

The determinant group rainfall/temperature is found to be a positive driver of adoption of agronomic practices in 38 per cent of the cases. The positive and negative cases are evenly split for agroforestry and livestock groups. This is expected given that increases in temperature and rainfall are expected to affect adoption of improved practices in opposing ways. For example, while higher rainfall would decrease incentives for adopting soil-water conservation practices, higher temperature would increase them. Therefore, we split rainfall and temperature in the positive and negative sign tests in the next section to unpack these heterogeneities.

The main criticism simple vote-count analyses are subject to includes the fact that all observations receive the same weight, regardless of the sample size, and that publication bias is hard to assume away.[9] We see that most of the determinants in our database have been reported to be not significant for all themes and that the reported percentage of coefficients, if significant, are not consistently in the same direction. We present the sign test results with confidence intervals to address some of these shortcomings in the next section.

5.2. Vote-count with confidence intervals

To increase the value and rigor of the vote-count results presented above, we apply the sign test method mentioned in section 4. We developed hypotheses about the direction each determinant would take in relation to the adoption of improved agricultural practices in our data. We report the results of the positive and negative sign tests first for overall effects and then for mixed effects below.

It is critical to distinguish meta-analysis methods from those analysing primary data. With primary social science data, the unit of analysis is often individual, and the sample is used to estimate population proportions. In the case of meta-analysis, the unit of analysis is each individual paper, the sample is the entire set of included papers and the estimates pertain to the population of papers. That is, when the confidence intervals are estimated, the range represents the proportion of studies finding the positive or negative relationships, not the proportions in the agricultural producer population.

a. Overall effects

Here we present results for selected determinants that are potential policy entry points to increase adoption. These include more finely defined determinants within the larger determinant groups discussed above (see annex A), which can be directly related to a type of policy tool (e.g. types of information, group participation, credit) or used for targeting interventions (e.g. land tenure, shock exposure, wealth).[10] Due to the very high number of combinations between these individual determinants and practices discussed above, we conducted this analysis first for all improved

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[9] Publication bias refers to the higher probability of journals publishing research papers that report significant results rather than non-significant findings. The only such journal addressing this bias was the Journal of Negative Results in Biomedicine in medical sciences, which stopped being published in 2017. A journal for negative/null results in applied economics and social sciences does not exist.

[10] This selection was also driven by the number of times a determinant was included in the studies in our sample to ensure enough degrees of freedom.

practices together, and then focused on a couple of important practices separately to unpack heterogeneity by practice group and direction of impact.

Table 7 reports the selected results of the positive sign tests. Of the 30 determinants hypothesized to have positive relationships with adoption of improved agricultural practices more often than would be expected by chance, 18 (60 per cent) actually exhibited this relationship. Table 7 shows 15 of these determinants that could be considered policy entry points, and we find that 11 exhibited this relationship.[11] By comparing these results to the percentage of observations for each of the determinants, the benefit of calculating the confidence intervals becomes apparent: although the share of positive results exceed 50 per cent for each determinant, confidence intervals show that not all are positively related to adoption in a statistically significant way.

The four determinants that were not positively related to adoption more often than chance would dictate were access to practice-specific information, family size, land degradation/infertility and overall income. The finding that the adoption of improved practices is not facilitated by land degradation suggests that farmers may not be able to overcome other constraints to adoption, even if they wanted to address the land fertility issues with improved soil management practices. Similarly, having access to practice-specific information only is not able to address other constraints that limit adoption.

[11] See annex C for the full results of the directional tests.

Table 7. Selected determinants hypothesized to be positively related to improved agricultural practice adoption (across all practice groups)

Determinant	# of studies	# of times included	% positive in data set	Confidence interval		Hypothesis correct?
				LB	UB	
Access to practice-specific information	29	107	0.59	0.49	0.68	No
Access to credit	70	212	0.61	0.55	0.68	Yes
Access to extension	96	297	0.71	0.66	0.78	Yes
Access to information	13	24	0.75	0.55	0.88	Yes
Family size	99	276	0.54	0.48	0.59	No
Farmer group participation	57	146	0.75	0.67	0.81	Yes
Labour availability	53	128	0.70	0.62	0.78	Yes
Land degradation/infertility	30	120	0.53	0.44	0.62	No
Land size	112	354	0.66	0.61	0.71	Yes
Livestock assets	86	267	0.60	0.54	0.66	Yes
Off-farm income	56	160	0.59	0.51	0.66	Yes
Overall income	19	90	0.52	0.42	0.62	No
Secure land tenure	38	146	0.67	0.59	0.75	Yes
Wealth index	43	157	0.73	0.65	0.80	Yes
Temperature	12	49	0.78	0.64	0.87	Yes

Note: Temperature is usually measured by average annual, seasonal or long-term temperature in the studies that included it as an explanatory variable. Source: Authors' own compilations. LB = lower bound. UB = upper bound.

Several determinants had lower bounds that were above 0.6 (i.e. more than 60 per cent of studies find positive relationships between these variables and improved practices): access to extension (66-78 per cent), farmer group participation (67-81 per cent), labour availability (62-78 per cent), land size (61-71 per cent), wealth (65-80 per cent) and temperature (64-87 per cent). Access to general information through extension and farmer groups (not just practice-specific information) stands out again as a positive determinant of adoption. Land size and wealth index are both welfare indicators, and findings indicate an overall disadvantage for less wealthy households. The finding that higher temperatures (annual, seasonal or long-term averages) increase adoption more often than would be by chance suggests that the improved practices included are perceived as a coping strategy by farmers.

Table 8 shows the results of negative sign tests. We find that none of the determinants expected to affect adoption negatively exhibit this relationship in our database. The finding that distance variables are not negatively associated with adoption indicates that more isolated plots and farmers are not necessarily disadvantaged in terms of improved practice adoption – holding everything else constant. Those farmers with good soil quality and access to water are also not less likely to adopt these practices in the literature. That insecure land tenure's effect on adoption is not significant in negative tests, but secure land tenure was significant in positive tests, which seems puzzling. However, negative test results are weaker with an upper bound (0.59) that is lower than the lower bound of the positive tests (0.67); therefore, we put more weight on the positive test results in interpretation. Although high temperatures were found to affect adoption positively, higher rainfall was not found to affect it negatively in the literature more often than would be expected by chance.

Table 8. Selected determinants hypothesized to be negatively related to improved agricultural practice adoption

Determinant	# of studies	# of times included	% negative in data set	Confidence interval		Hypothesis correct?
				LB	UB	
Distance (home-plot)	30	110	0.55	0.46	0.64	No
Distance to markets/roads	72	271	0.50	0.44	0.56	No
Insecure land tenure	31	90	0.46	0.36	0.59	No
Land fragmentation	20	41	0.61	0.46	0.74	No
Plot fertility (moderate-good)	27	144	0.44	0.37	0.53	No
Soil depth (moderate-deep)	3	39	0.41	0.27	0.57	No
Water access	12	37	0.43	0.29	0.59	No
Rainfall	22	75	0.28	0.19	0.39	No

Note: Rainfall is usually measured by annual, seasonal, long-run average or lagged rainfall. Source: Authors' own compilations.

b. Testing mixed effects separately

Some determinants are expected to affect the adoption of different practices in opposing ways, as discussed above, and if this is the case, the directional hypotheses developed above for all practices together can lead to somewhat contradictory findings. This underlines the importance of including practice characteristics in adoption analyses, along with the adopter and contextual characteristics, as discussed by Munguia and Llewellyn (2020).

For example, indicators of wealth and overall income (i.e. credit, land size, livestock, off-farm income, overall income, asset-based wealth index) may positively affect the adoption of practices that require up-front cash investments (e.g. use of improved seeds or fertilizers), while they may be expected to negatively affect the adoption of practices with no or little cash outlay required (e.g. traditional varieties with certain resilience characteristics, use of organic manure, intercropping with legumes), which are sometimes considered/promoted as sustainable agricultural practices. Wealth and income indicators are also often used as proxies of risk aversion, whereby risk averse households are expected to shy away from investing in new and risky investments, such as improved seeds. Taken as indicators of time horizon, these indicators will also affect the adoption of practices differently: the shorter the time horizon of a household, the more adoption of practices with immediate returns at the expense of longer term sustainability of productivity (Table 9).

Given the importance of understanding the determinants of modern input use and the use of sustainable land management practices in SSA, we develop further hypotheses to explore potentially opposing relationships between wealth and income indicators and the adoption of specific practices. We select these practices in the agronomy group because modern input use (seeds and fertilizers), which were at the core of the Green Revolution remains low (despite subsidy programmes in many countries), and the sustainable land management practices have been increasingly promoted with mixed results in the continent (Vanlauwe et al., 2017). We focus on wealth-signalling determinants here, as income/wealth is found to be positively correlated in adoption in many studies (Munguia and Llewellyn, 2020) and they can act as proxies of other behavioural characteristics that can help targeting. Thus, we test hypotheses that these wealth-signalling determinants have positive impacts on the use of inorganic fertilizers but negative impacts on all other nutrient management practices and positive impacts on the use of improved seeds but negative impacts on all other crop management practices.

Table 9. Nutrient and crop management practices hypothesized to be affected in opposing ways by wealth/income

Nutrient management/fertilizers	**Practices included**
Inorganic fertilizers (+)	Inorganic inputs (N/P/K and combinations), urea, generic mineral fertilizer, altered use of chemical fertilizers
Other nutrient management (-)	Manure, composting, organic fertilizer, green manure, residue retention
Crop management/seeds	**Practices included**
Improved seeds (+)	Drought tolerant seeds, high yielding/improved seeds, short duration seeds, hybrid seeds
Other crop management (-)	Crop diversification, legume intercropping, changing planting dates, crop rotation

Source: Authors' own compilations. N = nitrogen. P = phosphorus. K = potassium.

Table 10 shows the results of the positive hypothesis tests. We do not present the results of the negative hypothesis tests because none of the hypothesized negative relationships between wealth-signalling determinants and other crop/nutrient management practices were found to occur more than chance would indicate in the literature.

We find that the hypothesized positive relationships between four of the wealth-signalling determinants (credit, land size, livestock assets, and the asset-based wealth index) and inorganic fertilizer use were found. However, the expected positive relationships between these determinants and use of improved seeds were not found for any of the determinants except for the composite wealth index.

Table 10. Wealth-signalling determinants: positive hypothesis analysis

	Inorganic fertilizers			**Improved seeds**		
Determinant	Confidence interval		Hypothesis correct?	Confidence interval		Hypothesis correct?
	LB	UB		LB	UB	
Access to credit	0.54	0.82	Yes	0.48	0.78	No
Land size	0.63	0.83	Yes	0.46	0.74	No
Livestock assets	0.58	0.84	Yes	0.51	0.81	No
Off-farm income	0.28	0.63	No	0.43	0.82	No
Overall income	0.25	0.75	No	0.19	0.68	No
Wealth index	0.65	0.95	Yes	0.55	0.88	Yes

Source: Authors' own compilations.

The finding that most wealth indicators significantly increase the adoption of inorganic fertilizers more often than would be expected by chance indicates that despite decades of promotion efforts, the poorest households are still left behind in the increased agricultural productivity achieved in research labs and by richer farmers. For improved seeds, this finding is less strong, as only the composite wealth index is found consistently to increase their adoption, suggesting asset-based wealth, rather than more liquid income, is the driver of adoption.[12] The fact that the same set of variables do not act as a barrier to the adoption of alternative nutrient and crop management practices can give some hope to those promoting sustainable land management practices that are deemed to improve livelihood resilience. Although these findings, when combined, may seem to suggest that wealthier households do not adopt improved inputs at the expense of

[12] Given the complementarities between fertilizers and improved seeds, a joint analysis of the drivers of adoption could shed more light onto the different findings related to these technologies; however, papers in our meta-data do not allow a joint analysis.

alternative/more sustainable practices, this cannot be established here, as it would require an analysis of the intensity of adoption of agricultural practices at the household level, which is not captured by most studies in our database.

Such an analysis would also require looking at combinations of practices, which is an area not well covered in this literature so far. Households naturally manage their crop and livelihood portfolios to balance multiple risks, and hence, adopt multiple practices on same/different plots. The endogeneity issues and data requirements associated with analysing the adoption of multiple practices are increasingly being addressed by methodological innovations, potentially making this area of research more relevant for interventions on the ground.

6. Conclusions and recommendations

We provide a synthesis of the empirical micro-econometric literature on determinants of adoption of a large set of improved agricultural practices in Africa using a meta-data set that covers 168 published papers and more than 5,000 data points. We group the practices captured in our data into three main themes and find that agronomy contributes the bulk of the literature, followed by agroforestry and livestock. The evidence is also unequally distributed among the 25 countries, as more than half of the distinct papers included in our meta-data come from three countries: Ethiopia, Kenya and Nigeria.

The confidence intervals reveal 11 determinants that are positively related to the adoption of improved agricultural practices, in general, across studies and themes. Four of these relate to policy tools (access to extension, access to information, farmer group participation, access to credit); five are related to wealth (land size, livestock assets, off-farm income, overall income and wealth index); one is exposure to high temperatures; and the final one is secure land tenure.

Our findings indicate that policy approaches commonly used to increase uptake of improved agricultural practices are indeed targeting significant determinants of adoption in the African context. They are also generally aligned with recent analyses of determinants of adoption in the broader literature, particularly on the importance of social networks as well as features of the technologies in the adoption decision (Pannell and Zilberman, 2020). Recognition of the importance of collective action is exhibited by the increase in studies examining farmer group participation, which reflects the shift from non-governmental organisations (NGOs) and governments primarily engaging in information provision to participatory approaches that support resilient agricultural systems (FAO 2014, 2017; Vanlauwe et al., 2017). Using farmer groups to enhance peer-to-peer learning, engagement in adaptation strategies and problem solving, and to increase trust and cooperation at the community level, may be an important function of extension services, yet many countries do not have integrated research and extension programmes that fill these needs (FAO, 2017). Contrary to expectations, practice-specific information only was not positively related to improved practice adoption more often than expected by chance. This finding indicates that the relationships underlying broader access to information and extension (not just on one type of technology but also on market access, risk management, etc.), in general, may have a higher impact on the adoption of improved agricultural practices by providing a holistic approach to household decision making.

The effect of land tenure security on productivity and incomes is a long-studied area of research covered by numerous systematic reviews (IOB, 2011; Lawry et al., 2014; Higgins et al., 2017). Although most of these systematic reviews study impacts of tenure security on final outcomes, such as productivity, poverty or income, they also present positive evidence that tenure security contributes to productive and environmentally beneficial investments in agriculture (Higgins et al., 2017). Generally, this literature is usually inconclusive in Africa, where customary land tenure systems tend to be stronger (Lawry et al., 2014). Our finding that tenure security is found to positively relate to adoption of practices suggests that improved practice adoption is likely an intermediate step on the long-impact channel linking improved tenure security to higher incomes and food security (i.e. SDGs 1 and 2), which can be exploited by targeting.

The wealth indicators were found to be positively related with technology adoption, both in the analysis of practices overall and that of inorganic fertilizer adoption separately. Long-standing fertilizer subsidies in many countries in Africa do not seem to be effective in addressing the adoption issue for those least able to afford it. However, it is difficult to come to any sweeping conclusion about the impact of wealth-related determinants on other specific practices. It is likely more effective to use this information to develop programmes focused on increasing access to credit for a broad set of improved practices, for targeting policy tools for specific audiences and identifying potential gaps in current tools. Harnessing synergies between different determinants and contextual factors found to increase adoption more often than chance would dictate is one such approach. For example, targeting those with low livestock assets with group based financial products (especially in areas where grazing lands are managed communally), thus improving access to general as well as livestock related information, is likely to foster adoption of improved livestock practices. Similar synergies should be incorporated into agricultural technology promotion efforts to contribute to progress towards achieving the SDGs.

Annex A: The 'barriers' search string used to screen the literature

(barrier* OR "financ* capital" OR "access* financ*" OR "credit" OR "insurance" OR "financ* risk" OR "Risk avers*" OR "Risk attitude*" OR "Risk preference*" OR "Risk profile" OR "Discount rat*" OR "High discount*" OR "Time preference*" OR Tenure OR "property right*" OR "open access*" OR "shared access*" OR "comm* access*" OR "common* pool" OR "common* resource*" OR "free rid*" OR "extension servic*" OR "extension capa*" OR "extension resourc*" OR "resource compet*" OR (competition NEAR crop*) OR (competition NEAR livestock*) OR "resource incompatib*" OR "resource crowd*" OR "resource scarc*" OR "land availab*" OR "land scarc*" OR "opportunity cost*" OR "foregone revenue*" OR "foregone income" OR "alternative revenue*" OR "alternative income" OR "transition cost*" OR "transition period" OR "transition burden*" OR "upfront cost*" OR "upfront invest*" OR "initial cost*" OR "initial invest*" OR "startup cost*" OR "startup invest*" OR "input cost*" OR "input pric*" OR "fixed cost*" OR "variab* cost*" OR "labor cost*" OR "labour cost*" OR "labor requirement*" OR "labor intensive" R "labour requirement*" OR "labour intensive" OR "maint* cost*" OR "upkeep cost*" OR "monitor* cost*" OR "income stream*" OR "income flow*" OR "cash flow*" OR "diffuse benefit*" OR "income support*" OR "pric* support*" OR "produc* subsid*" OR "road access*" OR "transport* access*" OR "lack of information" OR " information constraint* " OR " input NEAR constraint* " OR " input NEAR access* " OR "delayed return*" OR "lack of knowledge" OR "aware* of benef*" OR "improved information" OR "technolog* access" OR "cultur* preference*" OR "cultur* norm*" OR "cultur* taboo*" OR "cultur* inertia" OR "social capital" OR "input* access*" OR adopt* OR disadopt* OR attrition* OR pseudo-adopt* OR innovator* OR "early majorit*" OR "late majorit*" OR laggard* OR diffusion OR "abandon* technique*" OR "new technique*" OR "poor enforc*" OR "poor compliance" OR corrupt* OR governance OR (gender NEAR norm*) OR (gender NEAR perception*) OR (gender NEAR belie*) OR (gender NEAR attitude*) OR (women NEAR norm*) OR (women NEAR perception*) OR (women NEAR belie*) OR (women NEAR attitude*) OR "benefit* sharing" OR "transaction cost*" OR "price volatil*" OR "human capital" OR "ecological dynamic*" OR "technical knowledge" OR "technical training" OR "special* training" OR "rainfall NEAR unpredictable" OR "temperature NEAR unpredictable")

Annex B: Determinants grouped under each category

Information		
	Freq.	Percent
Access to SLM/CC/CSA info	107	19.21
Access to extension	299	53.68
Access to info	24	4.49
Farming experience	87	13.82
Use of improved practices	75	8.8
Total	**592**	**100**

Resource Endowments		
	Freq.	Percent
Farm assets	31	2.7
Hectares per hh member	21	1.83
Income from farming	77	6.71
Land size	356	31.04
Livestock assets	267	23.28
Off farm income	163	14.21
Overall income	90	7.85
Wealth	142	12.38
Total	**1147**	**100**

Risks and Shocks		
	Freq.	Percent
Insecure land tenure	90	68.7
Shock experience	41	31.3
Total	**131**	**100**

Bio-physical factors		
	Freq.	Percent
Land degradation/infertility	120	21.66
Pest/disease problem	57	10.29
Plot fertility (moderate-good)	144	25.99
Soil depth (moderate-deep)	39	7.04
Water access	37	6.68
plot slope (moderate-steep)	157	28.34
Total	**554**	**100**

Distance to market/road		
	Freq.	Percent
Distance to markets/roads	273	100
Total	**273**	**100**

Socio-demographics		
	Freq.	Percent
Age of HH	331	23.33
Dependency ratio	31	2.18
Education	430	30.3
Family size	280	19.73
Female head	60	4.23
Male head	261	18.39
Married	17	1.2
Nr of children	4	0.28
Single	5	0.35
Total	**1419**	**100**

Groups/social capital		
	Freq.	Percent
Access to support (gov/ngo)	50	16.45
Farmer group participation	146	48.03
Social capital	108	35.53
Total	**304**	**100**

Tenure Security		
	Freq.	Percent
Secure land tenure	146	100
Total	**146**	**100**

Labor availability		
	Freq.	Percent
Labor availability	128	100
Total	128	100

Credit Access		
	Freq.	Percent
Access to credit	212	100
Total	**212**	**100**

Weather		
	Freq.	Percent
Rainfall (annual mean)	68	54.84
Temperature (average seasonal	49	39.52
Lagged rainfall	7	5.65
Total	**124**	**100**

Annex C: Full results of the directional confidence intervals

Table C1. Determinants Hypothesized to be Positively Related to Improved Agricultural Practice Adoption

Determinant	# of studies	# of times included	% positive in data set	Confidence Interval LB	UB	Hypothesis correct?
Access to SLM/CC/CSA info	29	107	0.59	0.49	0.68	0
Access to credit	70	212	0.61	0.55	0.68	1
Access to extension	96	297	0.71	0.66	0.76	1
Access to info	13	24	0.75	0.55	0.88	1
Access to support (gov/ngo)	20	49	0.55	0.41	0.68	0
Dependency ratio	14	30	0.50	0.33	0.67	0
Education	139	430	0.66	0.61	0.70	1
Family size	99	276	0.54	0.48	0.59	0
Farm assets	10	31	0.58	0.41	0.74	0
Farmer group participation	57	146	0.75	0.67	0.81	1
Farming experience	35	86	0.55	0.44	0.65	0
Hectares per hh member	10	21	0.29	0.14	0.50	0
Income from farming	17	77	0.64	0.52	0.73	1
Labor availability	53	128	0.70	0.62	0.78	1
Land degradation/infertility	30	120	0.53	0.44	0.62	0
Land pressure	5	19	0.84	0.62	0.94	1
Land size	112	354	0.66	0.61	0.71	1
Livestock assets	86	267	0.60	0.54	0.66	1
Male head	91	258	0.62	0.56	0.67	1
Off-farm income	56	160	0.59	0.51	0.66	1
Overall income	19	90	0.52	0.42	0.62	0
Pest/disease problem	9	57	0.47	0.35	0.60	0
Secure land tenure	38	146	0.67	0.59	0.74	1
Shock experience	8	30	0.63	0.46	0.78	0
Social capital	24	108	0.69	0.59	0.77	1
Use of improved practices	23	75	0.65	0.54	0.75	1
Wealth	43	142	0.73	0.65	0.80	1
Temperature	12	49	0.78	0.64	0.87	1
Plot slope (moderate-steep)	26	157	0.62	0.55	0.70	1

Source: Authors' own compilations

Table C2. Determinants Hypothesized to be Negatively Related to Improved Agricultural Practice Adoption

Determinant	# of studies	# of times included	% negative in data set	Confidence Interval LB	Confidence Interval UB	Hypothesis correct?
Distance (home-plot)	30	110	0.55	0.46	0.64	0
Distance to markets/roads	72	271	0.50	0.44	0.56	0
Fertilizer	11	19	0.37	0.19	0.59	0
Insecure land tenure	31	90	0.46	0.36	0.56	0
Land fragmentation	20	41	0.61	0.46	0.74	0
Plot fertility (moderate-good)	27	144	0.44	0.37	0.53	0
Soil depth (moderate-deep)	3	39	0.41	0.27	0.57	0
Water access	12	37	0.43	0.29	0.59	0
Rainfall	22	75	0.28	0.19	0.39	0

Source: Authors' own compilations.

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