



Factors
influencing grain
legume technology
adoption across
Sub-Saharan
Africa

A Meta-Analysis

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Abstract

The population of Sub-Saharan African regions have grown from 230 million to 811 million people in fifty years' time and are expected to grow even faster in the upcoming years. To secure this population with enough food, systematic changes to the African food system are required. To achieve this, improved grain legume seeds and practices have been introduced to farmer households in various regions across Sub-Saharan Africa to enhance crop yield and soil fertility. But research indicated that the adoption rates of these technologies lacked behind expectations. Because of this, this research investigated the average adoption rate across Sub-Saharan Africa. Next to this it investigated whether there are explanatory factors accounting for this adoption rate across Sub-Saharan Africa. This is investigated through meta-analysis. A first selection was made on 87 abstracts and keywords in the timeslot 2000-2018. After which 17 contributions with a total of 27 cases and 9 explanatory factors remained for further analysis. This study contains data from contributions across Uganda, Zambia, Zimbabwe, Ethiopia, Kenya, Tanzania and Nigeria. The samples of all contributions varied from 140 to 2732 households. From the selection, coding and extraction of the data, it could be concluded that mostly external explanatory factors were examined in grain legume technology adoption across studies. Personal or motivational factors have not been researched in great detail. Also the results come from 10 contributions in Eastern Sub-Saharan Africa and data from 7 contributions in Western Africa. The results show an average adoption rate of 41.42% across Sub-Saharan Africa. An heterogeneity test showed that this result was not solely due to chance. To examine whether the 9 explanatory factors have an influence on the adoption rate across Sub-Saharan Africa weighted z-scores, weighted averages and a binomial test were executed on the coefficients of the explanatory factors. The results show that four explanatory factors: *livestock*, *extension contact*, *distance to market* and *farm size* have a proven effect on the adoption decision across Sub-Saharan regions. Of which extension contact and farm size have a proven positive effect on adoption. Meaning that the use of extension contact and a larger farm size seem to enhance the adoption of grain legume technologies across Sub-Saharan Africa.

List of terms

Grain legume technologies The '*innovation*' under investigation. It takes cowpea, common bean, soybean, chickpea, groundnut and pigeon pea into account together with intercropping and crop rotating practices.

Adoption The use (measured as yes/no) of the innovation or the innovation in combination with rotation/intercrop practices, referred to as packages.

Explanatory factors The factors under investigation, possibly influencing the adoption decision.

Sub-Saharan Africa The region in which the research is conducted. It covers all areas neighboring the Saharan region.

Contributing countries These are the countries that were covered in the analysis after the selection of the contributions was done. This study analyses data from Ethiopia, Kenya, Ghana, Nigeria, Zimbabwe, Zambia and Tanzania.

Contributions The studies, papers and articles that were researched to be included for analysis. These were referred to as contributions, since both peer reviewed and non-peer reviewed items were included.

Acknowledgement

Conducting a meta-analysis was challenging but taught me more than I had ever expected about seeds, fertilizer, Sub-Saharan Africa, food shortages, statistics and conducting research in general.

Over the past couple of years it became crystal clear to me that I wanted to focus on sustainability in the broadest sense of the word. Studying at Wageningen University and Research got me interested in food related themes. Especially the importance of improved food systems for the most vulnerable layers of society grabbed my attention. The combination of food with my study in consumer behavior made this topic very interesting. I noticed that food consumption patterns in different parts of the world has to be changed quite rapidly in order to adapt to the changing climate and to secure global food safety. The fact that more food has to be produced, for more people, with a limited amount of resources fascinated me. The opportunity I got from Paul Ingenbleek, to gain more knowledge on food systems in Sub-Saharan Africa by conducting a meta-analysis on grain legume technologies was in this sense; perfect. Because of this, I got the chance to dig deeper in the technological aspects of food security topics. Now I know for sure that the subject matter on consumer behavior in relation to food security in developing regions belongs among the topics I would like to keep working on in my professional career. This all has to do with the chance I got to conduct this meta-analysis in the first place.

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Chapter 1

Introduction

Sub-Saharan African (SSA) countries face challenges in sustainably feeding their population. In the second half of the twentieth century, the population of this continent increased from 230 million to 811 million people (Khan et al., 2014). People living in SSA countries mainly get their nutrition from small-scaled farms (FAO, 2009; Worldbank, 2007). For million farmers cereals such as sorghum (*Sorghum bicolor* (L.) Moench) and maize (*Zea mays* L.) are among the most important food and cash crops (Kahn et al., 2014). Though the main yield of these cereals have declined dramatically over the past decades. This is mainly due to declining soil fertility as a result of monocropping, insect pests and weeds (Sileshi, Gudeta et al., 2008; Ngwira, Aune & Mkwinda, 2012) Plus the climate conditions of increasingly dry and hot weather are not making it easier for farmers to sustain their crop yield (Khan et al., 2014). In order to provide the entire population with enough food, adjustments to Sub-Saharan food production system are required. But support for improving agricultural practices in SSA areas decreased since the nineties. To illustrate this, subsidies for fertilizers were eliminated and opportunities for improving irrigation systems are not being fulfilled (Hilson, 2016). This was encouraged even though fertilizers can overcome the problem of declining soil fertility. Actually the elimination of subsidies made the price of fertilizer in the region among the highest in the world (Sileshi, Gudeta et al., 2008). Such measures make farming not economically rewarding. Resulting in a nadir towards the engagement in agricultural practices. It now seems that farm sizes are reducing and income is also gathered from off-farm sources. This seems to make farming less important as a main source of income, leading to a decreasing interest in farming and lower productivity (Ronner, Descheemaeker, Almekinders, Ebanyat & Giller, 2017; Hilson, 2016).

Contrary it was found that proper use of new technologies and agricultural research may lead to higher productivity and food security (Chand, Prasanna & Singh, 2011). It was found that fertilizer and seed subsidy programs may have enormous effects on the yields of cereals (Ngwira, Aune & Mkwinds, 2012). The programs focused on fertilizer and seeds are often referred to as 'legume technologies'. For the beneficial assumption associated with these technologies, NGO's and governments mainly focused on introducing these technologies at small-scaled farms (Lee, 2005). These technologies include improved grain legume seeds, fertilizers, inoculants, pesticides, herbicides and packages that combine all of these. Packages include crop rotation and intercropping. All of these were launched in various SSA countries (e.g. Nigeria, Tanzania, Kenya, Ethiopia, Uganda and Ghana). With the goal to put biological nitrogen fixation to work for smallholder farmers to enhance soil fertility. After introduction, the technologies were disseminated and promoted in various ways: through free samples, credit systems, demonstration trials, seed distribution systems, trainings, radio broadcasts and text messages. Despite the benefits associated with legume technologies to increase soil fertility and efforts from parties to enhance investments at the farmer level, the adoption rate of these technologies stays behind (Chianu et al., 2011; Franke and De Wolf, 2011). Several causes are brought forward for this adoption gap. These include the lack of access to credit, access to seeds and input- and output market problems (Ngwira, Aune & Mkwinds, 2012; Kunzekweguta, Rich & Lyne, 2017). This leads to a stagnation in the legume adoption process (Asfaw, Shiferaw, Simtowe & Lipper, 2012).

Recent studies examined both the adoption of legume technologies and the effectiveness of dissemination strategies across the SSA region to find possible causes for the stagnation in the adoption process. A comparison of these findings for both topics across the SSA region could provide more precision on the reasons for the low adoption rate of legume technologies. But

this overview is missing. For this reason the aim of this research is to synthesize the study results of contributions on grain legume technology adoption, to find the explanatory factors that influence grain legume technology adoption across Sub-Saharan Africa. This is done by executing a meta-analysis on the explanatory factors that are found across multiple contributions in Sub-Saharan Africa. The main question to be answered in this thesis is therefore to find out which explanatory factors have an influence on the adoption decision of grain legume technologies across Sub-Saharan Africa. To see if studies across the Sub-Saharan region can be compared and if so, what are the explanatory factors that can be compared. A meta-analysis methodology is chosen to provide effect size estimations of the explanatory factors. In this way, it can be evaluated whether the determinants identified in previous contributions are dependent on regions or can be generalized across multiple countries. This is important in policy making and generating effective dissemination strategies. The main question in this research is answered through the following sub questions:

1. How does the adoption rate of grain legume technologies differ across contributions in Sub-Saharan African countries?
2. Which explanatory factors are influencing the adoption of grain legume technologies across included SSA countries?
3. Which explanatory factors differ for contributions across included Sub-Sharan countries?
4. How do significant explanatory factors play a role in determining the adoption of grain legume technologies across Sub-Saharan countries?

A woman wearing a red shirt and a patterned headscarf is bent over, working in a cornfield. She is using a wooden hoe to clear the soil around the young corn plants. The background shows a vast field of corn under a cloudy sky. The image is framed by a semi-transparent grey border with white corner brackets.

Chapter 2

Theoretical background

In recent decades, multiple articles and papers have been presented on the adoption processes of innovations (Dimara & Skuras, 2003; Rogers, 2003; Ghadim & Pannell). A technology innovation is defined as an idea, practice or object that is perceived as novel by an individual. It is or is perceived as new or a new alternative by an individual and can serve new means to solve a problem (Rogers, 2010; Feder & Umali, 1993). With regard to technology adoption, there are two directions at which adoption can be defined. At the micro level, technology adoption can be defined as the individual process to choose whether or not to make use of a technology, by taking the usage intensity into account (Rogers, 2003). At the macro level, technology adoption can be defined as the continuous use of an innovation by examining a firm or household over a period of time (Feder & Umali, 1993; Feder et al., 1985). A clear distinction has to be made between adoption intention and actual adoption. The first entails the potential use of a novel innovation. While the latter can be defined as the actual use of an innovation (Rogers, 2003). This research focuses on the latter, since the contributions that are examined measure the use of grain legume technologies rather than the intention to do so.

Besides Rogers' (2003) distinction between initial adoption and actual adoption, the scholar emphasizes the role of innovation theory in decision-making. This theory is based on four phases in innovation adoption: the first are early adopters who dare to take risks and can be viewed as opinion leaders. Applying this to agricultural technologies, it should be noticed that this group is significant in gathering trust amongst the larger crowd of farmers. Apart from the phases in innovation adoption, Roger (2003) further recognizes that individuals make innovation evaluations based on the technology's relative advantage, compatibility, complexity, trialability and observability. The complexity of technologies seems to have a negative effect on adoption behavior (Oke et al., 2014; Arts, Frambach & Bijmolt, 2011). Arts, Frambach & Bijmolt (2011) further state that the remaining factors such as trialability and observability are generally positively related to the adoption of novel innovations. Even though trialability is highly dependent on extension services such as demonstration trails and trainings (Jayne, Mather & Mghenyi, 2010). But the literature states that the economical profitability of agricultural technologies seems to be the most important factor in a technology's adoption potential (Meijer et al., 2015).

Next to the factors identified by Rogers' (2003), marketing literature on agricultural innovation technology adoption focuses largely on personal perceptions and individual decision-making, managerial abilities and risk preferences (Ghadim & Pannell, 1999; Arts, Frambach & Bijmolt, 2011). But whether or not a new technology will be adopted by farmers depends also on other factors, such as extension strategies (Arts, Frambach & Bijmolt, 2011). Agricultural extension can be viewed as the entire contribution of organizations that support and facilitate services to people engaged in agricultural production. With the goal of solving problems, obtaining information, skills and technologies to better their livelihoods and well-being. Most extension services include governmental agencies, non-governmental organizations, private sector parties and farmer organizations (Davis, 2008)

From the marketing literature the importance is recognized to understand the factors that are influencing decision-making at the heart of the individual (Arts, Frambach & Bijmolt, 2011). Especially risk and uncertainty seem to play a role in the adoption process, as marginal farmers have to deal with a high level of uncertainty on a daily basis (Meijer et al., 2015). Also, nutrition literature addresses the perceived risk aversion at the level of the individual that is attached to novel food technologies (Hansen et al., 2003; Hoeffler, 2003). Jerneck and Olsson (2014)

illustrated that farmers who have not fulfilled their physiological and safety needs are less likely to adopt newly introduced agricultural technologies (Maslow, 1943). This stands in contrast to those farmers who enjoy higher standards of food security. Those farmers have higher chances of getting engaged with new agricultural innovations. They seem to look for more economical rewarding opportunities in order to improve their own situation (Jerneck and Olsson, 2014). Also, Musa et al., (2005) found that the socio-economic status of individuals affects the accessibility and exposure to agricultural technology, which further affects adoption behavior. Applying this to Rogers' (2003) innovation theory, it could be important to identify these farmers as opinion leaders in the dissemination of agricultural technologies across larger groups of farmers.

The agricultural literature on adoption views individual decision-making as decision-making at the household level. Larger decisions are made at the aggregate level, which refers to decision-making at regions. Compared to the debate in marketing literature on risk and uncertainty in adoption decision making, the agricultural literature on innovation technology adoption seems to focus more on the interrelationship that might exist between the adoption of technologies. Most agricultural technologies are presented in packages (Feder et al., 1993). If an household already uses fertilizer, it might have an influence on the adoption of improved seeds. Or if an household adopts improved seeds it might influence the changes of the adoption of inoculants (Feder et al., 1985; Kassie et al., 2013). Other scholars argue that the adoption of agricultural technologies should be viewed as a process that may involve the uptake of only one or two of three parts of a technology (Giller et al., 2009; Pannell et al., 2014). An example includes the uptake of solely crop rotation, excluding the uptake of fertilizer or inoculants that are traditionally treated all together as one technology. But up until now, most researchers seems to be treating all technology components separately, measuring the uptake of agricultural technologies as an inseparable dichotomous variable (Kassie et al., 2012; Arslan et al., 2014; Pedzisa et al., 2015). Meaning that multiple factors contribute in this decision-making process and that multiple decision-making theories have to be combined to provide a clear image of this process (Meijer et al., 2015).

Taking the previous literature into account, this research defines the technology adoption decision as to whether an household actually uses improved grain legume seeds or packages. The latter referring to the use of crop rotation, intercropping techniques together with grain legume seeds or legume seeds in combination with fertilizer. In the case of grain legume packages, adoption counts as 'yes' if at least one component of the package has been applied on the field.



Chapter 3

Methodology

3.1 Research design

Meta-analysis is a quantitative method for generalizing empirical study results in the form of analyzing effect sizes (Rosenthal & Rubin, 1978; DerSimonian & Laird, 1986). The goal of this research is to synthesize research results by statistically analyze the effect sizes of different studies. As presented by figure 1, the statistical analysis of effect sizes can be investigated by through meta-analysis. Comparing meta-analysis to the alternatives presented, it seems to provide the most solid evaluation of a comparison of multiple studies. For a narrative review, the conclusions that are drawn, cannot be checked. Informal vote counting and formal vote counting solely base conclusions on the number of significant ‘*positive*’ or significant ‘*negative*’ results (Card, 2015). A meta-analysis is more powerful than all of these methods, since it can provide a *magnitude* of the effect, thus can provide more information about the effect size of explanatory factors on grain legume technologies. For this reason it is decided to focus on conducting a meta-analysis for this research, to generalize findings as specific and reliable as possible.

Figure 1

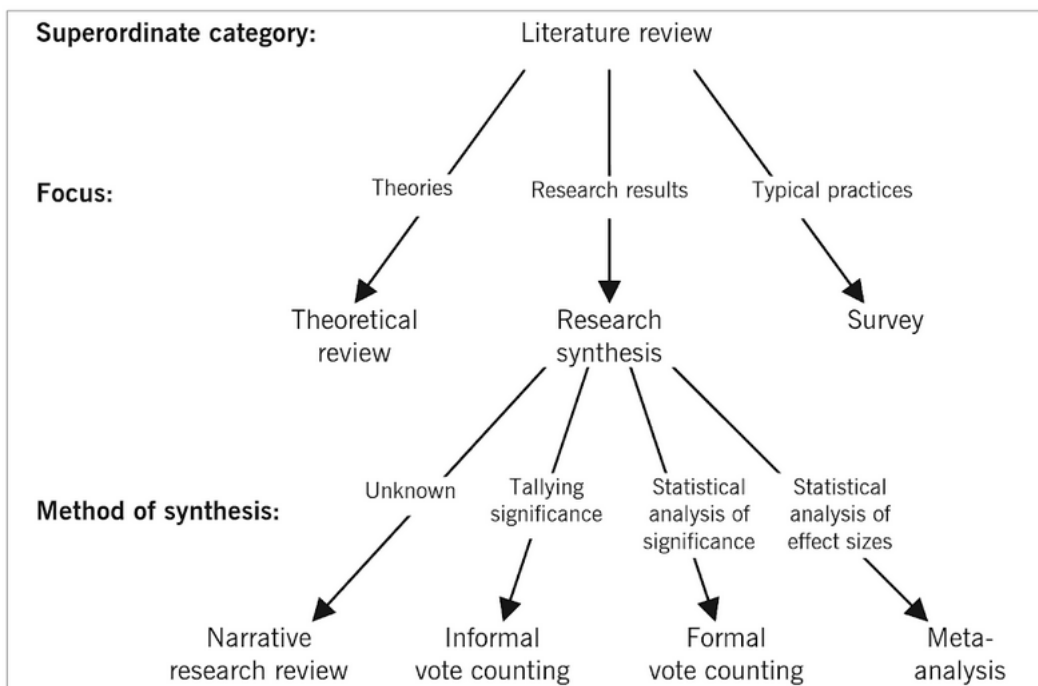


Figure 1: Meta-analysis compared to other types of reviews (Card, 2015).

3.2 Data collection methods

First, the information on grain legume technologies had to be found after which the information on explanatory factors was selected, extracted and analyzed through examining the effect sizes. To do this, the research was divided into two phases:

I The collection and selection of contributions on grain legume technology adoption in Sub-Saharan Africa suitable for analysis.

Aim: gathering, selecting and extracting information on adoption rates and explanatory factors that can possibly influence grain legume technology adoption.

II The analysis of the extracted data on adoption rates and explanatory factors possibly influencing grain legume technology adoption in Sub-Saharan Africa

Aim: finding proof through statistics for explanatory factors that influence grain legume adoption across Sub-Saharan Africa.

Phase I served as a narrative research review, to find data that could be included in the analysis. Phase II of this research included the investigation of the effect sizes, which makes this research a meta-analysis. Table 1 and 2 explain how both research phases were set up.

Table 1

What	Why	How
1. Defining the dependent construct.	The construct under investigation is ' <i>adoption of grain legume technologies</i> '. But this can be measured in different ways across studies. In order to be able to generalize findings, this construct has to be measured in the same way across studies that are involved in this research.	Extensive literature research on studies involving <i>grain legume technologies</i> by the registration of the measurement of the dependent variable per study.
2. Defining inclusion criteria	Inclusion criteria were important to navigate the search and selection of contributions. By setting inclusion criteria, the search for studies regarding <i>grain legume technology adoption</i> were delimited (Flather et al.,)	These inclusion criteria were set based on desk-research on <i>grain legume technologies</i> . Based on the given information, criteria could be set for including contributions.
3. Defining exclusion criteria	Exclusion criteria were important to ensure that primary end-points of the study were reached. This means that the appropriateness and completeness of studies played a large role in defining exclusion criteria.	Exclusion criteria were set based on methodological invalidations across studies e.g. missing values such as sample size, descriptions and measurements.
4. Finding contributions	This was needed to gather the data on adoption rates and explanatory factors and compare findings across Sub-Saharan Africa.	This was done through an extensive literature search in which multiple databases were used. <i>Snowball referencing</i> was applied to make sure that as many as possible contributions were reviewed for inclusion or exclusion, based on the

		criteria set above. Everything was mapped in Microsoft Excel databases.
5. Categorizing explanatory factors	The categorization of explanatory factors was mainly done to create an overview of all information on descriptives and explanatory facts that was present. It served as a guideline on how to decide which explanatory factors were eventually included for the analysis.	The data was categorized by finding ways of to classify data. The explanatory factors were finally categorized by a scheme proposed by Geist and Lambin (2001). A final decision on which explanatory factors were included was based on exclusion criteria.
6. Mapping descriptives	The descriptives give a quantitative summary of the data that was found throughout the search for contributions.	The information of descriptives came from summarizing the information on all contributions included in the analysis. It includes information on <i>region, sample size, interventions, grain legume technologies, number of contributions and practices.</i>

Table 1: Research methods included in phase I of this research

After the data presented in table 1 was gathered, categorized and decisions on explanatory factors were made, phase II of this research took flight. Phase I identified explanatory factors that potentially influenced the adoption of grain legume technologies across Sub-Saharan regions. To find out whether the influence of these factors could be applied to the whole region was investigated by phase II. The way in which the data conducted in phase I is statistically analyzed is presented in table 2.

Table 2

What	Why	How
1. Setting hypotheses for both adoption rate and for each of the explanatory factors.	In order to test whether a directional or significant effect exists, an expected outcome had to be predefined. Through defining hypotheses a statistical test could be applied to prove whether the hypotheses were rejected or approved.	The hypotheses were set by information presented in the literature on expected adoption rates and on the influence an explanatory factor was expected to play on the adoption of grain legume technologies.
2. Setting assumptions	The assumptions were made to exclude possible biases and minimize limitations.	Through examining the contributions through statistical tests or reviews.
3. Defining the effect sizes	The effect size is a quantitative measurement of the magnitude of a	The effect size for this research was based upon the presented data, which

	phenomenon. In order to be able to analyze the statistical effect in a synthesis of studies, the effect size first had to be defined.	involved coefficients, z-scores and SE's. Based on this it was decided to choose the mean weighted average of both coefficients and z-scores.
4. Heterogeneity of Adoption rates	To test whether the adoption rate for grain legume technologies could be explained by chance or other factors. If the result turns out to be heterogenous, it makes sense to explore the explanatory factors, since the difference between adoption rates is then explained by something else than chance.	By executing a Chi-squared test for homogeneity.
5. Weighted averages	To calculate the average adoption rate across contributions. Plus to find the hypothesized effect for each explanatory factor.	By calculating weighted averages for each explanatory factor based on sample size
6. Binomial test	To test whether a true effect exists for the hypothesized direction expected for each explanatory on the adoption decision.	By testing for hypothesized directional effects for each explanatory factor.
7. Combined z-scores	The combination of weighted z-scores provides a statistical measurement to investigate for each explanatory factor the variance compared to the mean. Based on this information the significance of each explanatory factor on the adoption of grain legume technologies across Sub-Saharan Africa could be measured.	By calculating weighted z-scores for each explanatory factor based on sample size.

Table 2: Research methods included in phase II of this research

3.3 Research questions and methods

Besides the overall methodological structure presented in 3.2 of this chapter, it is important to understand exactly how the sub questions of this research will be investigated. The methods that are used are a literature review, chi-squared test, a binomial test and weighted average z-scores.

Table 3

Sub question	Phase I/II	How	Method
Does the adoption rate of grain legume technologies differ across contributions?	Answered by phase II	Finding whether the adoption rates for adoption/non adoption are uniform or dissimilar across included studies. By comparing proportions of adoption rates.	Chi-square test for homogeneity
Which explanatory factors are influencing the adoption of grain legume technologies across included SSA countries?	Answered by both phase I and phase II.	The inclusion of explanatory factors potentially influencing the adoption decision of grain legume technologies were defined in phase I by the extensive literature research. The significance of these factors were decided upon in phase II by defining whether the weighted z-score was significant or not.	Literature research and Weighted z-score method.
Which explanatory factors differ across included SSA countries?	Answered by both phase I and phase II.	A selection took place in phase I of this study to find comparable explanatory factors among contributions. Thus this phase already selected on multiple explanatory factors that differ across regions. Next to this, it depends on the significance of the weighted z-score test of each explanatory factor to see which of the explanatory factors are too different from one another across regions to provide an answer that can be generalized.	Weighted z-score method and literature review.
How do explanatory factors play a role in	Answered by phase II	Hypothesizing the measured positive and	Binomial test

determining the adoption of grain legume technologies?

negative coefficients based on literature. To test this a binominal test is used to determine whether a true directional effect exists.

Table 3: Sub questions and methods

A collection of various dried legumes and pulses, including lentils, chickpeas, and beans, displayed in wooden spoons and bowls on a burlap background. The legumes are arranged in a grid-like pattern, with some spilled onto the surface. The colors range from light beige to dark purple.

Chapter 4

Phase I

4.1 The dependent variable

The distinct dependent variable in this research is: '*Adoption decision*'. This is defined as the decision whether to use improved grain legume seeds or packages. The latter refers to the use of crop rotation, intercropping techniques together with grain legume seeds or legume seeds in combination with fertilizer. The dependent variable in the contributions included in this research is measured on a dichotomous scale and thus measured as: use/no use (Wauters & Mathijs, 2014; Akudugu, Guo & Dadzie, 2012). In the case of grain legume packages, adoption counts as 'yes' if at least one component of the package has been applied on the field.

4.2 Inclusion criteria

The selection of contributions went via inclusion and exclusion criteria. These criteria were set to delimit the scope of this research and to create an insightful database that served as the foundation for the data analysis (Flather et al., 1997). The inclusion criteria were set as follows:

1. *The contributions have to be empirical*
2. *Research has to be conducted in Sub-Saharan Africa*

Governments and NGO's released the same sort of legume technologies within this region. Also, the SSA region has the lowest adoption rate compared to other African regions (Duflo, Kremer & Robinson, 2011).

3. *The contributions are published, printed or had to be otherwise available between 2000 and 2018.*

The introduction of improved legume seeds was heavily promoted during this timeslot (Letaa, Kabungo, Katungi, Ojara & Ndunguru, 2015). The varieties released in this period have resistance to multiple stresses and diseases and are better adjusted to the physical production environment (Letaa et al., 2015).

4. *Research should focus on grain legumes (Cowpea, Soybean, Chickpea, Pigeon pea, Common bean, Groundnut), or packages including the addition of fertilizer or practices regarding legume intercropping and rotation.*
5. *Households are the unit of analysis.*
6. *Each contribution included an intervention.*
7. *Both peer reviewed and non-peer reviewed contributions were included.*
8. *Each contribution focused on explanatory factors potentially influencing grain legume technologies.*
9. *Each contribution is available in English.*

A literature search based on the inclusion criteria was conducted at first. Followed by an online bibliographic search using ScienceDirect, WUR library, Scopus, Google Scholar. The following keywords were used: '*grain legumes*', '*adoption*', '*intensity*', '*drivers*', '*barriers*', '*Sub-Saharan Africa*'. Secondly *snowball referencing* was applied. It was decided to include both peer reviewed and non-peer reviewed contributions, to minimize publication bias. In which publication bias is defined as the tendency to report significant results over non-significant results (Aert, Wicherts & van Assen, 2016). Applying these inclusion criteria led to the search for contributions and a first selection of 87 studies (Appendix; Word - First selection of studies). The selection of these contributions was solely based on keywords and abstracts using specific search terms.

4.3 Exclusion criteria

After the selection of contributions, the data was screened by exclusion criteria. If an exclusion criterion was identified, the contribution was excluded from follow-up participation in the analysis. The following exclusion criteria were set:

1. *If a contribution did not report sample size, it was excluded.*

No comparisons could have been done without taking sample size into account. Sample size in meta-analysis accounts for the possibility to generalize a given outcome towards a population (Nayak, 2010).

2. *If a contribution did not report or lacked coefficients it was excluded.*

This criterion makes it possible to (re)calculate effects such as weighted scores from previous studies.

3. *If an explanatory factor was included in 4 contributions or less, the factor was excluded.*

Fu et al., (2011) state that a minimum of 5 contributions is required to conduct a subgroup analysis.

4. *If an explanatory factor was measured (coefficients and standard-errors) in 4 contributions or less, the factor was excluded.*

Applying the exclusion criteria to the first selection of contributions led to a final selection of 17 contributions that seemed suitable for analysis that together accounted for 9 explanatory factors that were measured at least 5 times across studies by provided coefficients and standard-errors: *household size, livestock, gender, age, education, access to credit, extension contact, distance to market and farm size*. All of these explanatory factors were coded (e.g. is the factor measured on a nominal, ordinal, interval scale). This is presented in Table 4 of this document.

Interestingly, the remaining explanatory factors under investigation all appeared to be external factors. Research defines these factors as forces in one's external environment that one has little or no control over (Altayyar & Beaumont-Kerridge, 2016). These factors are also viewed as factors often influenced by organizations to sustain rapid growth of an innovation (Rogers, 2003). Internal differences in contrast to external factors, refer to personal and cultural values (Vega-Jurado et al., 2008). Research states that external factors driving legume adoption in the SSA region are often mentioned to be context and region specific (Oke et al., 2014; Pannell et al., 2014; Sileshi, Gudeta et al., 2008). Since this research focuses on generalizing results across regions, this feature might have a (tremendous) impact on whether or not the results are actually comparable across regions.

Ojiem, de Ridder, Vanlauwe & Giller (2006) state that multiple external factors in legume adoption can be categorized by three contextual levels: I socio-cultural factors, II agro-ecological factors and III socio-economic factors. The first one can be viewed as all factors that are culture specific. These include values, attitudes and institutions that influence both individual and social behavior in all dimensions of human experience (Harrison, 1992). The second one are all biophysical features identified by Giller and Cadish (1995) that constrain or enhance biological nitrogen fixation in legumes. The last one are all socio-economic factors that influence the adoption decision. These take all financial aspects and social standings into consideration (Boardman, Poesen & Evans, 2003). Although useful, these contextual levels

seem quite broad. Another model proposed by Geist and Lambin (2001), narrowed these categories down into 5 more specific categorical levels in their meta-analysis on tropical deforestation. These include demographic factors, to describe human dynamics. The second, economic factors, include all factors related to commercialization, development, growth or economic change. The third, technological factors, focus on technological change or progress. The fourth, policy and institutional factors, address all factors at which individuals have little or no control and are imposed by humans or institutions. The last, cultural factors related to values, attitudes, beliefs and household behavior (Geist and Lambin, 2001). Following the categorization strategy of Geist and Lambin (2001), the explanatory factors included in this research can be categorized and defined as follows:

Table 4

Category	Antecedent	Definition	Measurement
Technological factors	Distance to market	The distance from an household towards input and output markets. This is measured on a ratio scale.	Measured on an ratio scale – Distance to urban center (km)
Demographic factors	Gender	The distinction between female and male decision-makers within the household (Akudugu, Guo & Dadzie, 2012).	Measured on a nominal scale – 1=Man/0=Woman
	Household size	Household size is viewed as the number of people in the farmer's household.	Measured on an interval scale – Number of family members.
	Age	The existence of an individual measured in years (Akudugu, Guo & Dadzie, 2012).	Measured on an interval scale – Age in years.
Policy and institutional factors	Access to credit	Whether farmers have access to credit. Some farmers borrow money, others have the wealth to count for their own expenses (Feder et al., 1990).	This is measured on a nominal scale – Yes/no access to credit

	Extension contact	Extension is viewed as a service to improve research-based knowledge, to improve the lives of farmers (Davis, 2008)	This is measured in two ways, on an interval scale, by the amount of extension contact per year, measured in days. The second way is by extension contact yes/no.
Economic factors	Livestock	The value of livestock of the household as a source of wealth (Akinola et al., 2010).	Livestock is measured as the number of livestock owned at the household level.
	Farm size	The total farmland possessed by the household (Akinola et al., 2010).	Farm size is measured as the number of hectares (ha) or acres.
	Education	Education is defined as the level of formal education an individual has completed in his/her life.	This factor is measured by the level of education of the household head.

Table 4: Categorization and definitions of explanatory factors

The categorization of these factors according to the strategy of Geist and Lambin (2001) show that there are no cultural factors included in this research. This emphasizes the fact that the factors included are mainly driven by external forces.

4.4 Descriptives

Of all contributions 5 were peer reviewed, 7 were not and 2 were undefined. An overview of all empirical papers included in the database is presented in the appendix (Appendix; Excel – Link to studies). This comes together with the information on research area, sample size, type of legumes, year of research and methodology of the studies (Appendix; Excel – Descriptives). A short overview of the main descriptives is given below (Table 5).

Table 5

	Contribution	Intervention	Country	Grain Legumes	Technology	Sample size
	1a	Introduction	Ghana	Multiple		898
	1b	Introduction	Ghana	Multiple	Crop rotation	898
	2a	Introduction	Ethiopia	Multiple		355
	2b	Introduction	Ethiopia	Multiple	Crop rotation	355
	3a	Introduction	Ghana	Groundnut		608
	3b	Introduction	Ghana	Cowpea		608
	4	Introduction	Tanzania	Common bean		835
	5a	Various regions	Uganda	Groundnut		355
	5b	Various regions	Uganda	Groundnut		182
	5c	Various regions	Uganda	Groundnut		140
	6	Introduction	Nigeria	Cowpea		462
	7	Introduction	Nigeria	Groundnut		2732
	8	Introduction	Zimbabwe	Multiple	Package	237
	9	Introduction	Ethiopia	Multiple	Package	1920
	10	Introduction	Zambia	Common bean		405
	11	Introduction	Tanzania	Multiple	Rotation	681
	12	Introduction	Tanzania	Pigeon pea		613
	13a	Various regions	Nigeria	Cowpea		388
	13b	Various regions	Nigeria	Cowpea		180
	13c	Various regions	Nigeria	Cowpea		268
	14	Introduction	Nigeria	Soybean	Rotation	400
	15a	Variety 1	Kenya	Pigeon pea		195
	15b	Variety 2	Kenya	Pigeon pea		195
	15c	Variety 3	Kenya	Pigeon pea		195
	15d	Variety 4	Kenya	Pigeon pea		195
	16	Introduction	Nigeria	Multiple	Package	597
	17	Introduction	Tanzania	Pigeon pea	Package	613
Total	27					15510
	11					
	2					
	4					
	2					
	3					
	3					
	2					

Table 5: Main descriptive statistics of contributions included

Interventions in contributions

A couple of contributions showed multiple cases of grain legume technology measurements in their research. For example both groundnut and chick pea were disseminated. When this was the case and applied to separate samples, each of the cases was treated separately. As a result, the total of contributions included in this research are officially 17. But due to the fact that ‘interventions’ within contributions were treated separately in this research if separate samples were accounted for, it sets to total cases under investigation to 27.

Countries and sample size:

Figure 2, represents the sample sizes and regions of the studies included in this research. Previous research indicated that region might have a significant influence on study results and sample sizes are needed to get weighted average results among the studies, therefore it is decided to zoom in on these factors (Oke et al., 2014; Pannell et al., 2014; Sileshi, Gudeta et al., 2008). Each of the red spots indicate one single study without an intervention within the study. Each distinct color represents a study in which an intervention took place. The number of interventions is represented by the number of dots of that specific color (e.g. in Ghana one study took place with two interventions with each including more than 500 households). It is decided that each intervention within a study is viewed as an independent study, therefore representing its own sample size. The vast majority of contributions was conducted in Nigeria (5), Tanzania (4) and Ethiopia (3). Other countries (Uganda, Kenya, Zambia and Zimbabwe) are solely represented by one contribution and Ghana contains 2 contributions. The largest samples can be found in Nigeria (2732 households) and Ethiopia (1920 households). The smallest samples are to be found in Kenya (195 households) and Uganda (140 and 182 households). Next to this it can be stated that most of the contributions were conducted in eastern Africa.

Figure 2: Map of study regions included

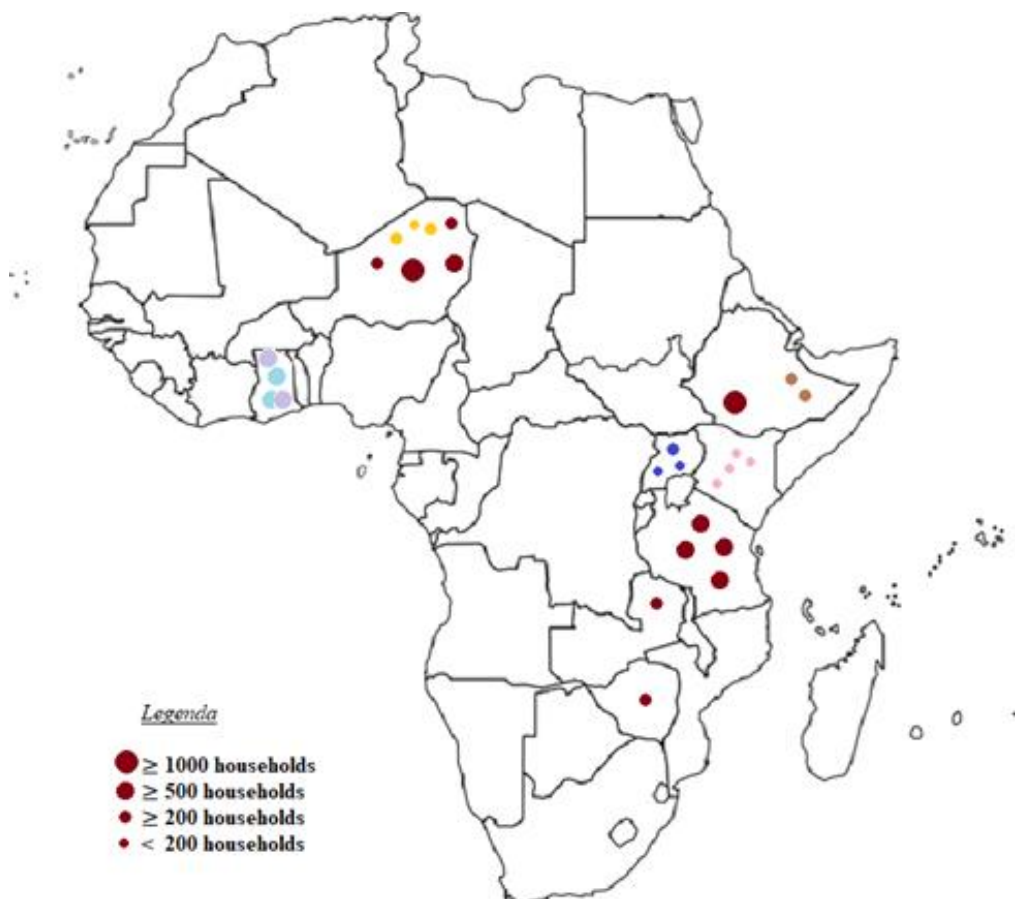


Figure 2: SSA regions included in the meta-analysis

Type of legumes and practices

In total 11 contributions made use of multiple varieties, two studies included cowpea, two contributions included common bean, 5 studies focused on groundnut, pigeon peas were investigated by 6 studies and soybean solely by one. In addition, improved seeds were introduced in 16 contributions without any additional practices. In 4 contributions the combination of improved seed and crop rotation was introduced and in 7 cases, packages were introduced. The latter meaning the combination of improved grain legume seeds with fertilizer.

Selection of explanatory factors

The selection on explanatory factors was done via a step-by-step approach:

1. The first selection based on inclusion criteria on contributions in phase I of this research led to 140 distinct explanatory factors.
2. Applying the exclusion criterion suggested by Fu et al., (2011) for measuring each explanatory factor at least 5 times across studies reduced this amount to 28 distinct explanatory factors (Appendix – Figure A1).
3. After deciding on coefficients as the effect size of interest, the same step was applied once more. All explanatory factors that presented coefficients at least 5 times across studies were included. This reduced the number of explanatory factors further to 17 in total.
4. To recalculate the effect sizes, standard-errors were needed. Therefore the last step was to only include the explanatory factors that presented both SE's and coefficients or already presented z-scores. This led to a final selection of 9 explanatory factors that were analyzed in phase II of this research: *distance to market, access to credit, gender, age, education, livestock, farm size, household size and extension contact*.

4.5 Conclusion phase I

In conclusion, the literature search by following the inclusion criteria led to 140 distinct explanatory factors possibly influencing grain legume technology adoption in Sub-Saharan Africa. After applying the exclusion criteria on these 140 explanatory factors, 9 remained. These explanatory factors are: *distance to market, access to credit, gender, age, education, livestock, farm size, household size and extension contact*. Following the categorization strategy of Geist and Lambin (2001), these appear to be categorized as external factors. Among all explanatory factors that were investigated, it appeared that the focus on internal factors is rather low or even non-existent. From the presented descriptives, it can be concluded that most research took place in Eastern-Africa (10 contributions) versus 7 contributions in Western-Africa. Also, it can be stated that the information coming from peer reviewed contributions and non-peer reviewed contributions is quite balanced. Next to this, the focus on pigeon pea and groundnut seems higher than the focus on other varieties. But it must be recognized that the largest focus of the included contributions is on introducing multiple varieties. Thus it seems that researchers seem to take multiple varieties into account rather than introducing one single grain legume variety.

A close-up photograph of a man with a blue turban and a grey jacket, smiling as he works in a field. He is using silver shears to trim green plants. The background is a blurred field with trees. The image is framed by a semi-transparent grey border with white corner brackets.

Chapter 5

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*Phase II*

Phase II focuses on the statistical analysis of the effect sizes of both *adoption rate* across studies and the *explanatory factors* defined in phase I (Appendix – 12.6). An effect size is defined as the quantitative measure of the magnitude of a phenomenon. In this research the effect size of adoption rate is weighted averages of percentages. The effect size of the explanatory factors are measured through coefficients. By examining these effect sizes, the overall adoption rate is investigated and it is tested whether an overall effect of the explanatory factors exists on the adoption of grain legume technologies across Sub-Saharan Africa.

### 5.1 Hypotheses

Based on the literature, the hypothesized effect of each explanatory factor on the adoption of grain legumes is given in table 5. These hypotheses serve as the guideline to test whether an affect across the Sub-Saharan region exist for (some of) these factors.

**Table 5**

| Explanatory factor | Hypotheses                                                                                                                                                                                                                                                                                                       | Expected direction of coefficient |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Distance to market | The further away an household is located from a market, the smaller the likeliness that adoption of grain legume technologies will take place (Kassie et al., 2012).                                                                                                                                             | -                                 |
| Gender             | It is reported that women are more constrained in terms of access to external inputs and information (Dey, 1981; Doss & Morris, 2001). As a result, male-headed households are more likely to adopt new technologies than their female counterparts.                                                             | +                                 |
| Education          | There is a higher chance to get involved in off-farm activities when education level rises. Contrary the chances of obtaining, using and processing information also rises with education. This can indicate higher rates in favor of adoption (Schultz, 1975; Letaa, Kabungo, Katungi, Ojara & Ndunguru, 2015). | 0                                 |

|                   |                                                                                                                                                                                                                                                                                                                                                      |   |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| Household size    | The number of children seems to negatively affect adoption if it increases opportunity costs of the time spent on agricultural actions (Katungi et al., 2011).                                                                                                                                                                                       | 0 |
| Age               | It is assumed that age influences a farmer's mental attitude to new ideas (Bamire et al., 2010). Younger farmers seem to have a more flexible attitude towards new practices. Older farmers are less likely to adopt new methods.                                                                                                                    | - |
| Access to credit  | Credit constraints negatively influence investments in legume technologies. (Teklewold, Kassie & Shiferaw, 2013).                                                                                                                                                                                                                                    | - |
| Extension contact | It is argued that contact (and possible demonstrations) led by the extension agent has a positive effect on the adoption decision (Bamire et al., 2010).                                                                                                                                                                                             | + |
| Livestock         | It is argued that the higher amount of owned livestock could have a negative effect on the adoption decision as the household rather relies on other sources of income. On the contrary, it is assumed that this leaves room for higher investment risks, therefore contributing to higher chances of adoption decisions (Amsalu & de Graaff, 2007). | 0 |
| Farm size         | It is assumed that a larger farm size contributes to the likelihood of farmers willing to try new varieties on their land. The larger the land area cultivated, the higher the                                                                                                                                                                       | + |

tendency to adopt (Bamire et al., 2010).

Table 5: Hypothesized effect of explanatory factors. + is positive hypothesized effect, - is negative hypothesized effect, 0 is undetermined.

## 5.2 Assumptions

Assumptions were formulated to test for the hypotheses mentioned above.

1. *Each contribution is independent from another.* A couple of contributions contained interventions in their research. These were treated separately if sample sizes in both groups were independent.
2. *All data is gathered through simple random sampling at the contribution level.* It is assumed that all data presented on explanatory factors comes from simple random sampling.
3. *The data on coefficients is normally distributed.* To test whether the data is normally distributed, it was decided to use the Anderson Darling test for checking normality.
4. *Effect size measures in the contributions are comparable.* This is assumed since the contributions only reporting coefficients (and standard-errors) were included and based upon the same scale of measurement.
5. *The available data for each included explanatory factor differs.* Not all contributions in this meta-analysis accounted for the same explanatory factors. Due to this given fact, each explanatory factor will be treated separately.

## 5.3 Heterogeneity of Adoption Rates

It makes sense to investigate the explanatory factors if the adoption rate differs for other reasons than solely chance. If this is the case, the explanatory factors could be checked, to see whether they have an influence on the adoption decision across Sub-Saharan Africa. To test whether the difference in adoption rates is beyond chance, an heterogeneity test is executed. This is done through executing a chi-square test of homogeneity. The chi-square test determines whether the data is distributed identically across different populations.

## 5.4 Z-scores

The data on explanatory factors that was available were coefficients and standard-errors. From this data, z-scores were calculated through the formula presented below.

$$Z = \frac{X}{S}$$

In which  $Z$  represents the z-score of an individual case,  $X$  stands for the coefficient accessible in the data set and  $S$  stands for the standard error. When the standard error was not obtainable, z-scores could not be presented and the explanatory factor value was not included for statistical analysis. After the z-scores were obtained, methods on weighted z-values and weighted coefficients were investigated.

## 5.5 Weighted averages

The aim is to find out which explanatory factors have an influence on the adoption of grain legume technologies. To find this, a mean of the presented data has to be tested against statistical significance. Rather than computing a simple mean of this data, meta-analysis aims to compute the weighted mean, with more weight given to some results and less weight given



to other results. The sample sizes were being taken as weights to compute the average effect size per explanatory factor. The averages provide information on the distribution of the data.

The formula used to calculate the weighted average of each coefficient is given as follows:

$$\bar{x} = \frac{\sum_{i=1}^n w_i \cdot x_i}{\sum_{i=1}^n w_i} = \frac{w_1x_1 + w_2x_2 + \dots + w_nx_n}{w_1 + w_2 + \dots + w_n}$$

In which  $w_i$  stands for the weighted average ( $n$  of study  $x_i$ ) and in which  $x_i$  stands for study  $k1$ ,  $k2$ , ...

### 5.6 Binomial test

To find out *how* the explanatory factors play a role in the adoption of grain legume technologies, can be investigated through executing a binomial test. With regard to this study, the 'how' involves the magnitude of the explanatory factor on the adoption decision as either having a positive or negative effect on the decision. The hypothesized outcome for each explanatory factor is presented (Table 2).

A one-sided test is conducted for each explanatory factor that has a directional hypothesized effect (either + or -). A two-sided test is conducted for each explanatory factor for which an undetermined effect is hypothesized. The formula for the binomial test is given as follows:

$$b(r; n, P) = \binom{n}{r} P^r (1 - P)^{n-r} \quad \text{Where} \quad \binom{n}{r} = \frac{n!}{r!(n-r)!}$$

In which  $b$  is the probability of ( $r;n,P$ ) successes out of  $n$  number of trials with  $P$  reflecting the probability of success (either *positive direction*, or *negative direction*) on a given trial.

### 5.7 Combining weighted z-scores

It is decided to execute the weighted Z-test. According to Whitlock (2005) and Zykin (2011), this method has more power and precision compared to most executed Fisher's combined probability test. The weighted Z-test is also preferred over the Z-transforming test. Based on sample sizes the Z-test can obtain as much power as the Lancaster's method in which Fisher's z-test is generalized. The formula that is used to calculate the weighted z-scores for each explanatory factor is the following:

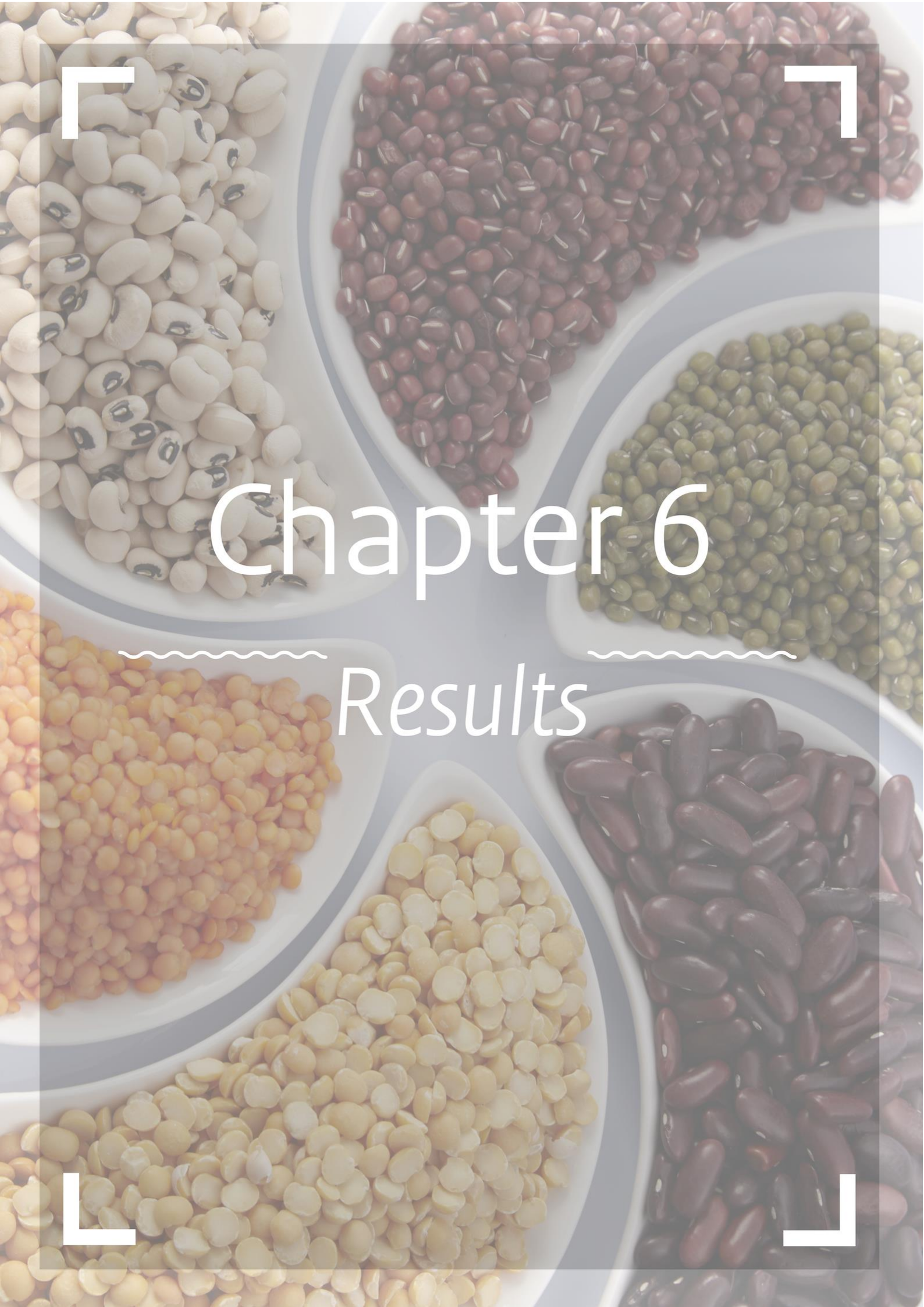
$$Z_w = \frac{\sum_{i=1}^k w_i Z_i}{\sqrt{\sum_{i=1}^k w_i^2}}$$

In which  $Z_w$  is the weighted z-score,  $k1$  ..  $k2$  are the independent studies,  $w_i$  stands for the weight given to each z-score (sample size) and  $Z_i$  is the z-score for each independent measurement.

The p-value for each construct was then computed given the following formula:

$$p_Z = 1 - \Phi \left( \frac{\sum_{i=1}^k w_i Z_i}{\sqrt{\sum_{i=1}^k w_i^2}} \right)$$

In which  $p_Z$  denotes the p-values for a weighted z-score and  $\Phi$  represents the standard normal cumulative distribution.



# Chapter 6

## Results

### 6.1 Adoption rates

The first results are presented on the *adoption rate across Sub-Saharan Africa*, which is presented in Table 6. This table shows that the average adoption rate of grain legume technologies across seven countries is 41.42%. This states that 6.424 households have adopted grain legume technologies across the regions included in this research. But 9.086 households have not adopted grain legume technologies across the same regions.

**Table 6**

| Authors                                   | Adopters      | Total sample (n) |
|-------------------------------------------|---------------|------------------|
| Teklewold, Kassie & Shiferaw (2012)       | 23%           | 898              |
| Teklewold, Kassie & Shiferaw (2012)       | 53%           | 898              |
| Ahmet et al., (2017)                      | 52%           | 355              |
| Ahmet et a., (2017)                       | 39%           | 355              |
| Asante, Villano, Patrick & Battese (2017) | 36%           | 608              |
| Asante, Villano, Patrick & Battese (2017) | 38%           | 608              |
| Letaa et al., (2015)                      | 26%           | 835              |
| Shiferaw, Okello & Muricho, (2010)        | 59%           | 945              |
| Kristjanson et al., (2005)                | 41%           | 462              |
| Ndjeunga et al., (2013)                   | 31%           | 2732             |
| Kunzekweguta, Rich & Lyne (2017)          | 21%           | 237              |
| Admassie & Ayele, (2009)                  | 79%           | 1920             |
| Hamzakaza et a., (2014)                   | 27%           | 405              |
| Kassie et al., (2012)                     | 17%           | 681              |
| Simtowe (2011)                            | 19%           | 613              |
| Abdoulaye, Amaza, Tegbaru & Alene (2010)  | 34%           | 388              |
| Abdoulaye, Amaza, Tegbaru & Alene (2010)  | 57%           | 180              |
| Abdoulaye, Amaza, Tegbaru & Alene (2010)  | 30%           | 268              |
| Akinola et al., (2010)                    | 31%           | 400              |
| Otieno (2010)                             | 63%           | 195              |
| Otieno (2010)                             | 67%           | 195              |
| Otieno (2010)                             | 49%           | 195              |
| Otieno (2010)                             | 37%           | 195              |
| Binam et al., (2014)                      | 49%           | 597              |
| Amare, Asfaw & Shiferaw (2011)            | 34%           | 613              |
| <b>Weighted total</b>                     | <b>41.42%</b> | <b>15510</b>     |

Table 6: Adoption rates across Sub-Saharan Africa in relation to grain legume technologies.

### 6.2 Chi Square for homogeneity

The adoption rates presented in Table 6 serve as the foundation for the Chi-squared ( $\chi^2$ ) test (Appendix – Figure A2). The results from the  $\chi^2$  test state that the  $\chi^2$  value with 24 degrees of freedom =2538,73. Testing this against alpha 0.05 (36.42) gives the result that  $\chi^2$  is larger than the critical value and therefore the Null-hypothesis: all adoption rates are equal, is rejected. This

means that there is a significant difference between the adoption rates across studies and thus the adoption rates. Because of this, it is decided to investigate the explanatory factors that have been identified through the literature search, to see whether they could be part of the explanation of this difference in adoption rates.

### 6.3 Analyses on explanatory variables

Three different types of analyses have been applied to the explanatory factors to test whether these factors influence the adoption decision of grain legume technologies:

1. **Weighted average coefficients:** serve as a foundation to see how the information for each explanatory factor is distributed.
2. **Binomial test:** To test the hypotheses for the explanatory factors, to investigate the directional effect of each factor on the adoption decision.
3. **Weighted z-scores:** To test which of the explanatory factors have a statistical effect on the adoption decision. This test was applied to find out whether the results could be generalized across regions.

Table 7 shows all outcomes of the three tests. The weighted coefficients are based on the information on coefficients and sample size. The calculations for the weighted coefficients, binomial test and z-scores can be found in the appendix (Appendix – 12.3; 12.4 and 12.5).

#### 6.3.1 Weighted average coefficients

The average calculated coefficient provides a clear image to test the hypothesized directions of the explanatory factors presented in Table 5. It shows that the hypotheses for *distance to market*, *gender*, *age*, *access to credit*, and *farm size* are as expected. *Distance to market*, *age* and *access to credit* seem to have a negative influence on the adoption decision of grain legume technologies. Whereas *gender*, *cooperative membership* and *extension contact and experience* seem to have a positive effect on the adoption decision. Based on the calculated averages, education seems to have a positive influence on the adoption decision. *Household size*, seems to be positively influencing the decision as well, even though this number is close to 0, indicating that the hypothesized effect (undetermined) for this construct is well estimated. *Livestock* seems to have a positive influence on the adoption decision.

#### 6.3.2 Binomial test

For the binomial test it was decided to execute a two-sided binomial test for the explanatory factors of which the directional effect was hypothesized as undetermined. For *gender*, *farm size*, *age*, *access to credit*, *cooperative membership*, *extension contact* and *distance to market* a directional effect was hypothesized. For these explanatory factors a one-sided binomial test was conducted. Altogether, the binomial test led to two significant results: *farm size* and *extension contact*. Thus both hypothesized effects for these explanatory factors are statistically true. This means that both farm size and extension contact have a significant positive effect. For all other explanatory factors, no proven directional effect exists under the binomial test.

#### 6.3.3 Weighted z-scores

The weighted z-score test is used to see whether a general effect exists of an explanatory factor on the adoption of grain legume technologies.

The null-hypothesis for each weighted z-score test is as follows:

*H<sub>0</sub> = The explanatory factor does not have an influence on the adoption decision of grain legume technologies*

*H<sub>a</sub> = The explanatory factor does have an influence on the adoption decision of grain legume technologies.*

These hypotheses entail that a two-sided z-score test is needed. Therefore the critical value is 1.96 under  $\alpha 0.025$ . The p-value is calculated by  $1 - 0.025 = 0.975$  which corresponds to 1.96 as critical value. The results presented in table 7 of this chapter indicate that the explanatory factors *distance to market, extension contact, farm size and livestock* are significant. Thus it can be said that for all included contributions, these factors have an influence on the adoption of grain legume technologies.

**Table 7**

| Explanatory factor          | Range of coefficients | Weighted average coefficient | Hypothesized directional effect on adoption | Positive and negative coefficients | P-value of binomial test | Weighted z-score | P-value of weighted z-score | Sample size of weighted coefficients/z-scores |
|-----------------------------|-----------------------|------------------------------|---------------------------------------------|------------------------------------|--------------------------|------------------|-----------------------------|-----------------------------------------------|
| <i>Distance to market</i> * | 0.36/-0.64            | 0.02                         | Negative                                    | 7 (12)                             | 0.18                     | -2.35            | 0.01*                       | 10219 (19)                                    |
| <i>Gender</i>               | 0.49/-0.74            | 0.07                         | Positive                                    | 11 (7)                             | 0.24                     | 1.50             | 0.13                        | 7108 (18)                                     |
| <i>Education</i>            | 0.50/-0.08            | 0.01                         | Undetermined                                | 12 (9)                             | 0.66                     | 0.73             | 0.47                        | 11942 (22)                                    |
| <i>Household size</i>       | 0.14/-0.41            | 0.01                         | Undetermined                                | 5 (4)                              | 1                        | -0.53            | 0.60                        | 8285 (9)                                      |
| <i>Age</i>                  | 0.49/-1.15            | 0.01                         | Negative                                    | 10 (11)                            | 0.5                      | -0.53            | 0.60                        | 13140 (21)                                    |
| <i>Access to credit</i>     | 0.07/-3.69            | -0.55                        | Negative                                    | 2 (7)                              | 0.09                     | 0.46             | 0.65                        | 5353 (9)                                      |
| <i>Livestock</i> *          | 0.14/-0.12            | 0.03                         | Undetermined                                | 9 (5)                              | 0.42                     | 4.69             | 0.00*                       | 8647 (16)                                     |
| <i>Farm size</i> **         | 1.37/-0.98            | 0.09                         | Positive*                                   | 13 (3)                             | 0.01*                    | 3.11             | 0.00*                       | 7832 (16)                                     |
| <i>Extension contact</i> ** | 1.05/-0.12            | 0.40                         | Positive*                                   | 14 (3)                             | 0.00*                    | 7.43             | 0.00*                       | 8520 (17)                                     |

*Table 7: Results of explanatory factors on the adoption of grain legume technologies*

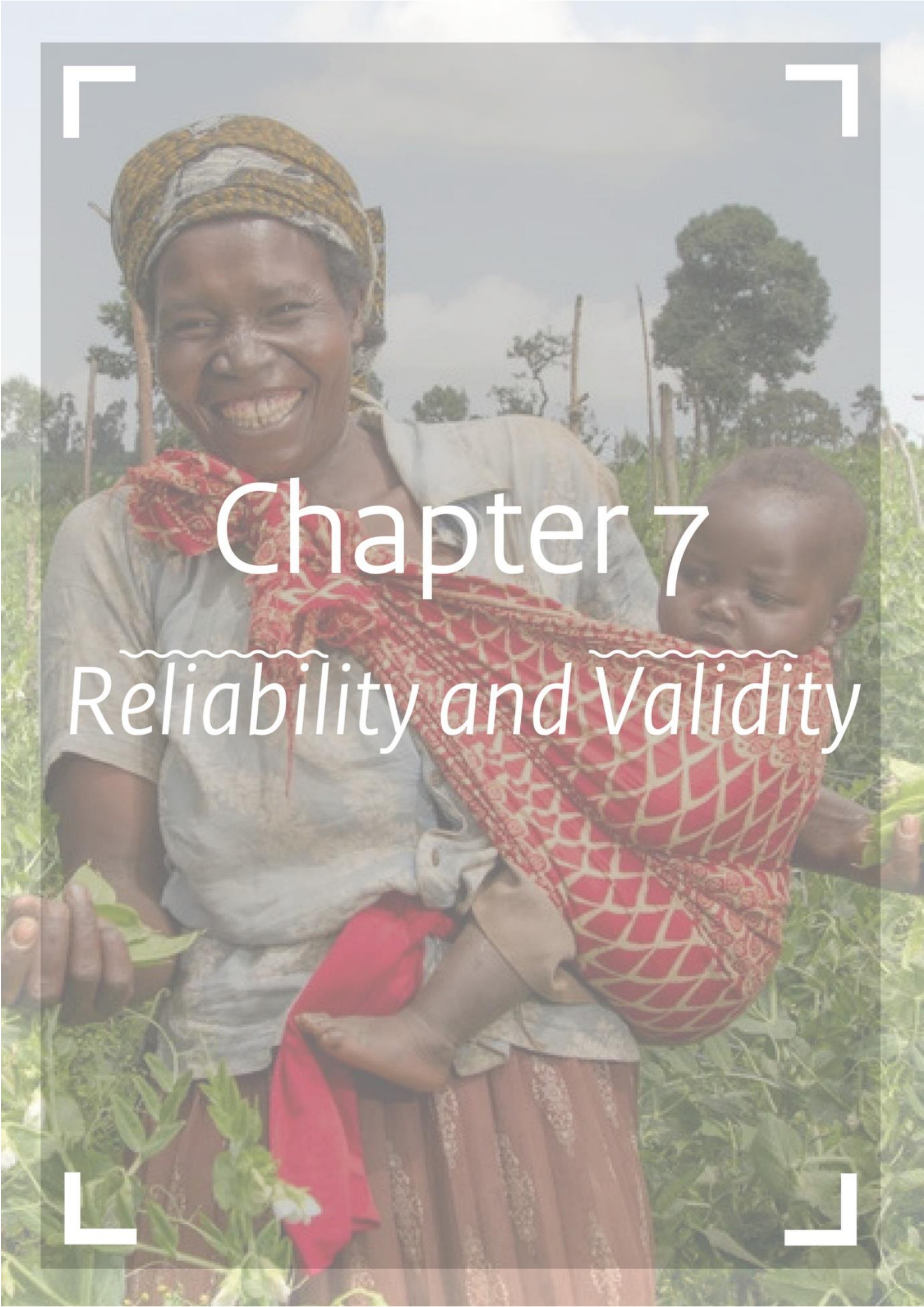
\*\* Both found to be statistically significant at the binomial test and weighted z-score test

\* Found to be statistically significant at either one of the weighted z-score test/binomial test

#### 6.4 Conclusion phase II

Summarizing the results presented in phase II shows that the total adoption rate of grain legume technologies is 41.42% across all included regions. This was expected, since the literature stated that the adoption rate lacks behind expectations. However, the chi-square test on homogeneity of the adoption decision shows that the variation between the adoption rates is too broad to count as a homogeneous data set. Thus the differences between the adoption rates are not solely due to chance. For this reason it made sense to investigate the explanatory factors possibly accounting for these differences. From this explicit investigation it became clear that *livestock*, *farm size*, *extension contact* and *distance to market* have a significant effect on the adoption decision of grain legume technologies across Sub-Saharan countries included in this research. This means that these four factors can be generalized across Sub-Saharan Africa and are thus not region specific. In addition, the directional effect for both extension contact and farm size are shown to have a positive effect on the adoption of grain legume technologies. In practice this means that the number of extension contact days per year, seem to have a positive effect on the adoption decision of grain legume technologies across Sub-Saharan countries. The results also show that a large(r) farm size has a significant positive effect on the adoption of grain legume technologies. This could indicate that households dare to take more risks regarding using grain legume technologies as they have a larger farm and might have more space for trialability. Even though livestock and distance to market have a significant effect on the adoption of grain legume technologies across Sub-Saharan Africa, its directional effect is not ensured. It is assumed that the value of livestock has a positive effect on the adoption decision. Since livestock is a measurement of wealth, it means that the higher the wealth of an household, the higher the likelihood that an household will adopt grain legume technologies. An explanation for this might also be found in a lower risk perception to use grain legume technologies, since the wealthy households might not be dependent on crop failure.





# Chapter 7

## *Reliability and Validity*

## **7.1 Reliability and validity**

This research depends on secondary data and therefore the methodological quality of used contributions in this analysis (Finckh & Tramèr, 2008; Esterhuizen & Thabane, 2016; Flather et al., 1997). It could be the case that either the sample sizes, coefficients or standard-errors of the given studies are not estimated correctly. Also, the literature states that researchers should be careful to avoid studies that published the same subjects or overlapping groups of participants under duplicate publications (Flather et al., 1997). This research dealt with this by securely stating the inclusion and exclusion criteria in selecting contributions. Also the coding of the studies and the interventions that took place in a couple of studies was done with care: when a similar sample size occurred, it was checked whether it could possibly be the same group of participants. Also, the effect size in meta-analysis can be overestimated if publication bias occurs. This was minimized by balancing peer reviewed and non-peer reviewed contributions.

Another important element in dealing with the reliability and validity of meta-analysis is to see whether the results of various studies should have been combined in the first place. In this respect, multiple reviews on meta-analyses state the importance of homogeneity of the data, to analyze whether a general effect exists or whether it is due to chance (Higgins & Thomson, 2002; Borenstijn, Hedget & Rothstein, 2007). Regarding this study, it is important to note that the heterogeneity of the data is accepted. The acceptance follows from the interest of this study: exploring the factors accounting for these differences and finding out whether there are explanatory factors accounting for these differences across a whole region. Next to this, it was assured that the data is similar enough to be compared, by the step-by-step approach in coding both studies and the explanatory factors.



# Chapter 8

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## *Discussion*

A couple of limitations and topics for future research should be addressed. One clear limitation of this study is the limited available capacity. This is important to underscore, since the reliability of the coding of explanatory factors could be biased as only one researcher was involved in this process. This fact might have caused selector and extractor bias (Flather et al., 1997; Felson, 1992).

Another limitation of this study is the fact that interventions have not been coded. The only distinction that has been made with regarding to interventions, was when an intervention in a contribution covered different regions or varieties and at the same time treated sample groups independently. The interrelation of explanatory factors has not been investigated and other ways of intervening were not accounted for. These interventions though, could cause for an effect of covariation.

Some limitations or topics in this research also serve as a foundation for future research:

1. Categorization of research methods: Through categorizing research methods, more insights can be gathered on the different models and methods that are used. By doing this, a clear picture on for example the number of studies accounting for interrelation of factors can be mapped. This is important to compare grain legume technology data in the future, to secure that the models that are used are consistent.
2. Investigate the effect of different interventions: Interventions on grain legume technologies could be coded and tested for covariance. Most grain legume technologies are released by either non-governmental organizations or governmental organizations. These institutions or organizations might provide incentives to households to enhance the adoption of grain legume technologies. These incentives might be in the form of monetary values or free samples. It is important to note that these might have a significant influence on the *actual* adoption of grain legume technologies. The choice of various intervention might have an influence on adoption rates in certain regions.
3. Investigate motivational factors: The innovation theory of Rogers (2003) does not seem to live through research on grain legume technology adoption. In the literature no distinction is made between opinion leaders, early adopters, late adopters and laggards. The literature rather shows the emphasis on the role of external factors in determining the adoption process within agroforestry adoption, especially in the SSA region. External factors in this respect refer to factors that illustrate the geographical context or situation while the adoption decision takes place (Trevino, 1986). Behavioral factors such as psychological and motivational factors influencing the decision-making process in agricultural practices have often been overlooked (Ajayi, 2007; Meijer et al., 2015). Literature emphasizes the role of motivational factors, by distinguishing between intrinsic and extrinsic motivational factors that might influence the adoption process of a new technology (Ryan & Deci, 2000). It is important to investigate these motivational factors in the legume adoption process in greater detail for a couple of reasons: the use of incentives as extrinsic rewards and the lack of intrinsic motivational research in the agricultural domain. Regarding the first matter, Andersson & D. Souza (2014) stated that incentives in the form of input support products such as herbicides, fertilizers and pesticides are often provided by promotional services or NGO's. Farmers seem often convinced to use agricultural technologies by getting governmental incentives in return

(Greiner, Patterson & Miller, 2009). Pricing policies and monetary incentives have shown positive short-term effects, but once the reinforcement is terminated, this effect seems to fall (Plug in America, 2015). Contrary to this, Greiner, Patterson & Miller (2009), state that farmers with high intrinsic motivation for lifestyle pursuit and agricultural conservation have shown higher adoption rates compared to those farmers who are motivated by economic, financial and social goals. For this reason it would be important to find out how intrinsic motivation can be enhanced at the farmer level.

4. Investigate socio-psychological models: Not only motivational factors should be taken into account, but also personal values should deserve more attention. Scholars argue that understanding the personal aspects of consumers is critical in enhancing behavior (Steg & Vlek, 2009; Barbarossa, De Pelsmacker & Moons, 2017). Wouters and Mathijs (2013) emphasized in their meta-analysis on soil conservation practices, the use of more socio-psychological models, such as the Theory of Planned Behavior or the Norm activation Theory (Ajzen, 1991; Schwartz 1973, 1977). It is important to take such perspectives into account since the reasons for households to (not) be willing to use a technology, might derive from factors that are culturally or ethically bound rather than factors that explain situational or contextual levels. There might be all sorts of underlying reasons at a personal level of an household for (not) being willing to use a new innovation, or not being willing to accept a new innovation even though it seems to offer benefits.
5. Multivariate analysis: Also a multivariate analysis could be a good topic for future research. This research is based on one outcome per explanatory factor of which some were measured on a bivariate scale and others on a continuous scale. Future research could investigate more contributions on grain legume technologies by including multivariate data.



# Chapter 9

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## Conclusion

In summary, 41.42% of the households in this research covering Sub-Saharan Africa have adopted grain legume technologies. This data turned out to be not solely due to chance. To find out whether explanatory factors could explain for this variance, it was decided to examine contributions that researched explanatory factors on the adoption of grain legume technologies for a certain region or country in Sub-Saharan Africa. These factors were selected, extracted and coded from contributions using inclusion and exclusion criteria. This resulted in a total of 9 explanatory factors to be investigated in greater detail. From this, it showed that the following four explanatory factors were statistically applicable across Sub-Saharan African countries: *livestock, extension contact, distance to market and farm size (Appendix – 12.7)*. These four factors can be generalized across all participating contributions as having an influence on the adoption decision on grain legume technologies. Important to note here, is that both extension contact and farm size are proven to have a positive effect on the adoption of grain legume technologies. Thus the number of days of extension contact per year has a positive effect on the adoption of grain legume technologies. This emphasizes the importance of personal contact with farmers at the household level, through providing them with information on (how to use) grain legume technologies. It also shows that larger farm sizes provide greater chances of adopting grain legume technologies. This could possibly be explained by the availability of (extra) space to try out grain legume technologies. This might include risk reduction, by having a larger farm to experiment with new technologies.

Distance to market and livestock are proven to have an effect on the adoption decision, but do not have a proven directional effect across Sub-Saharan Africa. This suits with the predefined assumption for livestock, since it is argued that a higher amount of owned livestock could have a negative effect on the adoption decision, as the household rather relies on other sources of income than farming. On the other hand, as livestock refers to an households' wealth status it is argued that a higher amount of owned livestock reduces investments risks at the household level. Thus it could be stated that livestock might contribute to higher chances of adopting grain legume technologies. However, there does not seem to be a proven directional effect, meaning that this effect differs too much across regions or countries. It could therefore be that both scenario's regarding livestock might be true for different regions. Distance to market on the contrary was expected to have a negative influence on the adoption of grain legume technologies. The assumption was that the further away a farm is located from input and/or output markets, the less likely it would be that adoption of grain legume technologies would take place. Even though this explanatory factor is significant, thus having a general effect across Sub-Saharan Africa on the adoption of grain legume technologies, it is thus neither negative nor positive. It might be the case that some households get seeds from their neighbors and use the seeds for their own consumption. In these cases, distance to markets do not mind as much. However, this difference needs to be explored further upon.

The explanatory factors that were measured across included Sub-Saharan countries, but all together did not provide an effect on the adoption of grain legume technologies are: *access to credit, age, gender, education and household size*. It could be that the influence of these factors on the adoption of grain legume technologies varies per region, as research states that external factors driving legume adoption in the Sub-Saharan African region are often mentioned to be context and region specific (Oke et al., 2014; Pannell et al., 2014; Sileshi, Gudeta et a., 2008).



# Chapter 10

## *Policy implications*



The results can be translated to some recommendations regarding policy mechanisms. As the results indicate, extension contact and large farm sizes seem to have a positive effect on the adoption of grain legume technologies across various regions. To enhance extension contact, policy makers should assess which form of extension contact is desired at the farmer level. Research states that farmer field schools and farmer-to-farmer approaches seem to be very effective. Next to this, scholars argue that participatory programs and demand-driven approaches seem to work best (Davis, 2008). Extension programs should serve facilitation purposes and could aim to strengthen market access, to minimize market distance. Also, it could be aimed to create *a shared value system*, in which governments and/or NGO's can work together with farmer communities to exchange, create knowledge and build trust.

This seems important for a couple of reasons: there are two main scenario's assumed to be true for households that have high values of livestock: either they engage in trials regarding new agricultural practices, or they dissociate themselves from farming. The latter could be a result of the negative image of African farmers that still seem to exist in European countries. This image still seems to reflect a marginal image of African farmers who can only sustain their own family with their crop yields (Vice Versa, 2018). It is assumed that because of this, youngsters in African countries might not want to engage in farming. Since the African population is growing and soon the African working force will mostly consist of people below the age of 25, it is important to find ways to engage people in farming.

One way to do this is through testing the integrated farm plan (PIP approach) in extension programs (Kessler et al., 2016). This plan was created through a multiscale approach and it aims to trigger intrinsic motivation at the farmer level through a farmer-to-farmer approach. As suggested in chapter 8 of this study, intrinsic motivation is suggested as an important element to investigate in greater detail with regard to grain legume technology adoption. Next to this, the PIP approach believes in a farmer-to-farmer approach, which is also underscored as important in transferring knowledge about grain legume technologies. PIP works through enhancing sustainable farm-management while reinforcing off-farm activities. The underlying belief regarding the PIP approach is that farmers' intrinsic motivation is triggered through providing farmers with the power to invest in their future through bottom-up rural development in cooperation with extension services. In which extension services solely have a facilitating role. Conventional extension approach which were implemented through top-down approaches led to loss of trust between farmers and extension workers (Davis et al., 2010). This was followed-up by farmer-field-school approaches. But the PIP approach takes the farmer-field-schools one step further by focusing more on learning-by-doing in combination with transferring motivation, vision and passion. One way to do this is by creating farmer contests, which proved to be effective in the Bolivian Andes (Kessler and de Graaff, 2007). This differs from providing farmers with monetary incentives as it focuses more on learning and eveloping. This approach is suggested as it is very accessible for low-income farmers and women (Duveskog, 2013).



# Chapter 11

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# Chapter 12

Appendix

|                                     | Count | Measurement                 | Studies                                                                       |
|-------------------------------------|-------|-----------------------------|-------------------------------------------------------------------------------|
| Household size                      | 24    | Number                      | 1,2,4,5,6,8,9,10,11, 12,14,15,16,17,18,19,20,21,22,23,24,27,28,29             |
| Livestock                           | 19    |                             | 1,2,4,5,6,7,8,9,11,13,14,15,16,17,20,21,26,28,29                              |
| Gender                              | 19    | Dummy                       | 2,3,4,5,11,12,13,16,18,19,20,21,23,24,25,26,27,28,29                          |
| Farm size                           | 23    | Ha                          | 2,3,4,5,6,7,8,9,13,14,15,16,19,20,21,23,24,25,26,27,28,29                     |
| Use of fertilizer                   | 5     |                             | 2,12,24,27,28                                                                 |
| Yield                               | 10    |                             | 2,8,10, 11, 12,18,21,22,24                                                    |
| Illiteracy                          | 5     | Proportions                 | 2,5,11,14,20                                                                  |
| Age                                 | 23    | Number                      | 3,4,5,6,8,9,10,11,13,14,15,16,17,18,19,20,21,22,23,24,26,27,28                |
| Education                           | 20    | Years, level                | 3,4,6,7,8,10,11,13,14,15,16,17,18,19,21,23,25,26,28,29                        |
| Access to credit                    | 10    | Proportions                 | 3,8,11,18,19,20,22,26,28,29                                                   |
| Access to extension services        | 8     | km                          | 3,4,13,16,18,19,21,24                                                         |
| Credit                              | 8     |                             | 4,5,9,11,14,17,18,28                                                          |
| Location / regions                  | 7     |                             | 4,8,21,23,24,27,28                                                            |
| Experience                          | 7     |                             | 5,7,13,19,21,22,26                                                            |
| Cooperative membership              | 12    | Proportions                 | 5,11,15,16,18,19,20,21,24,25,28,29                                            |
| Extension contact                   | 13    | Frequency, proportions      | 5,6,7,12,14,17,18,19,20,22,26,28, 29                                          |
| Participation in training/trial     | 8     | Proportions                 | 5,10,12,13,16,18,19,22                                                        |
| Off-farm activities                 | 5     |                             | 3,5,24,26,28                                                                  |
| Distance to market                  | 12    | Hours, km                   | 5,6,7,8,12,14,16,18,22,24,26,29                                               |
| Access to seed                      | 5     |                             | 6, 8,22, 24,28                                                                |
| Access to market information        | 6     |                             | 3, 4,5,6,19,27                                                                |
| Ownership of ICT, TV, radio and pho | 7     |                             | 7,8,10,11,18,21,27                                                            |
| Dependents                          | 6     | Frequency, ratio            | 7,8,11,14,16,17                                                               |
| Total workforce                     | 10    |                             | 8,9,11,12,13,21,24,26,27                                                      |
| Non-livestock value                 | 5     |                             | 8, 11,12,15,21                                                                |
| Cultivated land                     | 11    | log, ha                     | 8,9,10,12,13,15,18,21,24,28                                                   |
| Occupation                          | 6     |                             | 11,12,21,23,24,28                                                             |
|                                     |       |                             |                                                                               |
|                                     |       |                             |                                                                               |
| <b>Legenda:</b>                     |       | Explanatory factor variable | has been measured at least 5 times both coefficients and SE's                 |
|                                     |       | Explanatory factor variable | has been measured at least 5 times across contributions (coefficients)        |
|                                     |       | Explanatory factor variable | has been measured at least 5 times across contributions (various measurments) |

Figure A1: Selection of explanatory factors

| Adopters Non Ado Total |                                                                                                      |             | Expected     | Expected_Outcome | Expected  | Expected_Outcom | Adopters (O-E)2 | (O-E)2/E | Non adopters (O-E)2 | (O-E)2/E | SUM            |
|------------------------|------------------------------------------------------------------------------------------------------|-------------|--------------|------------------|-----------|-----------------|-----------------|----------|---------------------|----------|----------------|
| 207                    | 691                                                                                                  | 898         | 0.41*898     | 368              | 0.59*898  | 530             | 25921           | 70,44    | 25921               | 48,9     | 70,44          |
| 476                    | 422                                                                                                  | 898         | 0.41*898     | 368              | 0.59*898  | 530             | 11664           | 31,7     | 11664               | 22       | 31,7           |
| 185                    | 170                                                                                                  | 355         | 0.41*355     | 146              | 0.59*355  | 209             | 1521            | 10,42    | 1521                | 7,3      | 10,42          |
| 138                    | 217                                                                                                  | 355         | 0.41*355     | 146              | 0.59*355  | 209             | 64              | 0,44     | 64                  | 0,3      | 0,44           |
| 219                    | 389                                                                                                  | 608         | 0.41*608     | 249              | 0.59*608  | 359             | 900             | 3,61     | 900                 | 2,5      | 3,61           |
| 231                    | 377                                                                                                  | 608         | 0.41*608     | 249              | 0.59*608  | 359             | 324             | 1,3      | 324                 | 0,9      | 1,3            |
| 221                    | 614                                                                                                  | 835         | 0.41*835     | 342              | 0.59*835  | 493             | 14641           | 42,8     | 14641               | 29,7     | 42,8           |
| 555                    | 390                                                                                                  | 945         | 0.41*945     | 387              | 0.59*945  | 558             | 28224           | 72,93    | 28224               | 50,6     | 72,93          |
| 190                    | 272                                                                                                  | 462         | 0.41*462     | 189              | 0.59*462  | 273             | 1               | 0        | 1                   | 0        | 0              |
| 847                    | 1885                                                                                                 | 2732        | 0.41*2732    | 1120             | 0.59*2732 | 1612            | 74529           | 66,54    | 74529               | 46,23    | 66,54          |
| 50                     | 187                                                                                                  | 237         | 0.41*237     | 97               | 0.59*237  | 140             | 21609           | 222,77   | 21609               | 154,35   | 222,77         |
| 1517                   | 403                                                                                                  | 1920        | 0.41*1920    | 787              | 0.59*1920 | 1133            | 532900          | 677,13   | 532900              | 470      | 677,13         |
| 109                    | 296                                                                                                  | 405         | 0.41*405     | 166              | 0.59*405  | 239             | 3249            | 19,57    | 3249                | 13,59    | 19,57          |
| 116                    | 565                                                                                                  | 681         | 0.41*681     | 279              | 0.59*681  | 402             | 26569           | 95       | 26569               | 66       | 95             |
| 115                    | 498                                                                                                  | 613         | 0.41*613     | 251              | 0.59*613  | 362             | 18496           | 73,69    | 18496               | 51       | 73,69          |
| 132                    | 256                                                                                                  | 388         | 0.41*388     | 159              | 0.59*388  | 229             | 729             | 4,58     | 729                 | 3,18     | 4,58           |
| 103                    | 77                                                                                                   | 180         | 0.41*180     | 74               | 0.59*180  | 106             | 841             | 11,36    | 841                 | 7,93     | 11,36          |
| 80                     | 188                                                                                                  | 268         | 0.41*268     | 110              | 0.59*268  | 158             | 900             | 8,18     | 900                 | 5,7      | 8,18           |
| 124                    | 276                                                                                                  | 400         | 0.41*400     | 164              | 0.59*400  | 236             | 1600            | 9,76     | 1600                | 6,8      | 9,76           |
| 123                    | 72                                                                                                   | 195         | 0.41*195     | 80               | 0.59*195  | 115             | 1849            | 23,11    | 1849                | 16,08    | 23,11          |
| 131                    | 64                                                                                                   | 195         | 0.41*195     | 80               | 0.59*195  | 115             | 2601            | 32,51    | 2601                | 22,6     | 32,51          |
| 96                     | 99                                                                                                   | 195         | 0.41*195     | 80               | 0.59*195  | 115             | 256             | 3,2      | 256                 | 2,23     | 3,2            |
| 72                     | 123                                                                                                  | 195         | 0.41*195     | 80               | 0.59*195  | 115             | 64              | 0,8      | 64                  | 0,56     | 0,8            |
| 293                    | 304                                                                                                  | 597         | 0.41*597     | 245              | 0.59*597  | 352             | 2304            | 9,4      | 2304                | 6,55     | 9,4            |
| 208                    | 405                                                                                                  | 613         | 0.41*613     | 251              | 0.59*613  | 362             | 1849            | 7,37     | 1849                | 5,12     | 7,37           |
| <b>Total</b>           | <b>6538</b>                                                                                          | <b>9240</b> | <b>15778</b> |                  |           |                 |                 |          |                     |          | <b>48,9</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>22</b>      |
| <b>Legenda</b>         | Expected percentage for adopters is 6538/15778*100                                                   |             |              |                  |           |                 |                 |          |                     |          |                |
|                        | Expected percentage for non adopters is 9240/15778*100                                               |             |              |                  |           |                 |                 |          |                     |          |                |
|                        | Chi square test statistic = Sum of (observed-expected)2/expected                                     |             |              |                  |           |                 |                 |          |                     |          |                |
|                        | Degrees of freedom: (r-1)*(c-1) so this will be (25-1)*(2-1) = 24                                    |             |              |                  |           |                 |                 |          |                     |          |                |
|                        | The Chi-square distribution table provides 36.42 under alpha 0.05. 2538,7 > 36.42 so H0 is rejected. |             |              |                  |           |                 |                 |          |                     |          |                |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>29,7</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>50,6</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>0</b>       |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>46,23</b>   |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>154,35</b>  |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>470</b>     |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>13,59</b>   |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>66</b>      |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>51</b>      |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>3,18</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>7,93</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>5,7</b>     |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>6,8</b>     |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>16,08</b>   |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>22,6</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>2,23</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>0,56</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>6,55</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>5,12</b>    |
|                        |                                                                                                      |             |              |                  |           |                 |                 |          |                     |          | <b>2538,73</b> |

Figure A2: Chi-Square test for adoption rates across Sub-Saharan Africa

## 12.1 Chi-Square test for homogeneity

To conduct a chi-square test for homogeneity, a couple assumptions had to be met:

- Simple random sampling is applied
- The variable under study is categorical
- The expected frequency count is at least 5

$$H_0 = k_1 = k_2 = \dots k_{25}$$

$$H_a = k_1 \neq k_2 \neq \dots k_{25}$$

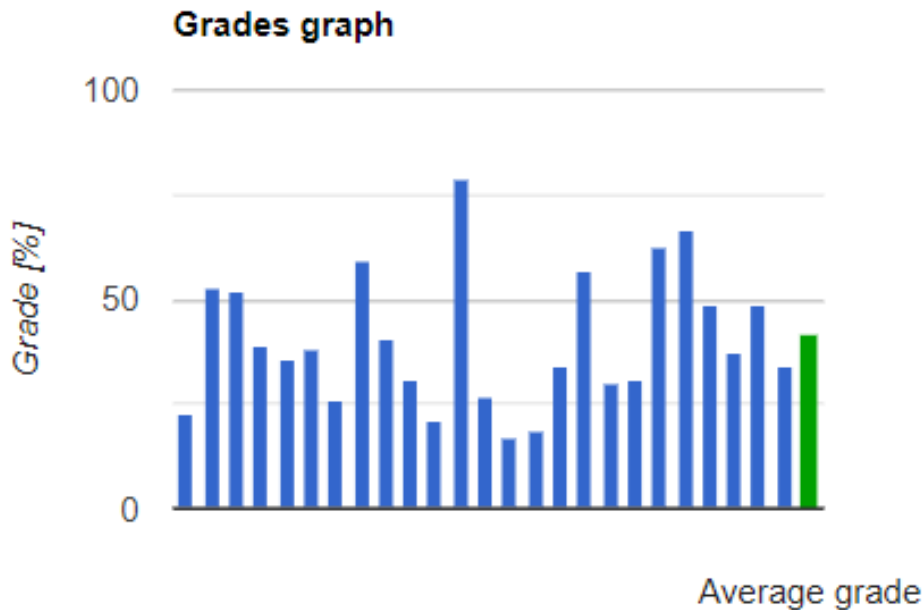
In which  $k_1 \dots k_{25}$  are the *adoption rates across studies*.

The  $\chi^2$  value with 24 degrees of freedom = 2538,7 Testing this against alpha 0.05 (36.42) gives that  $\chi^2$  is larger than the critical value and therefore  $H_0$  is rejected. This means that the differences between adoption rates are not only due to chance.

## 12.2 Adoption rates

### Calculation weighted adoption rate:

$$\frac{(898 \times 23 + 898 \times 53 + 355 \times 52 + 355 \times 39 + 608 \times 36 + 608 \times 38 + 835 \times 26 + 945 \times 59 + 462 \times 41 + 2732 \times 31 + 237 \times 21 + 1920 \times 79 + 405 \times 27 + 681 \times 17 + 613 \times 19 + 388 \times 34 + 180 \times 57 + 268 \times 30 + 400 \times 31 + 195 \times 63 + 195 \times 67 + 195 \times 49 + 195 \times 37 + 597 \times 49 + 613 \times 34)}{(898 + 898 + 355 + 355 + 608 + 608 + 835 + 945 + 462 + 2732 + 237 + 1920 + 405 + 681 + 613 + 388 + 180 + 268 + 400 + 195 + 195 + 195 + 597 + 613)} = 653567 / 15778 = 41.42$$



## 12.3 Calculations of the weighted coefficient average

**Household size**  $(462 \times -0.012790 + 2762 \times -0.039 + 237 \times -0.4127 + 1920 \times 0.0278 + 681 \times 0.063 + 613 \times 0.0710 + 400 \times -0.011 + 597 \times 0.0037 + 613 \times 0.1429) / (462 + 2762 + 237 + 1920 + 681 + 613 + 400 + 597 + 613) = 0.00166225$

**Livestock**  $(898 \times -0.04 + 898 \times -0.01 + 355 \times -0.115 + 355 \times 0.069 + 835 \times 0.13 + 355 \times 0.020 + 182 \times -0.008 + 140 \times -0.024 + 1920 \times 0.0165 + 402 \times 0.000 + 681 \times 0.005 + 613 \times 0.0529 + 400 \times 0.022 + 613 \times 0.1410) / (898 + 898 + 355 + 355 + 835 + 355 + 182 + 140 + 1920 + 402 + 681 + 613 + 400 + 613) = 0.02455762$

**Gender**  $(898 \times 0.14 + 898 \times 0.09 + 355 \times 0.318 + 355 \times -0.481 + 355 \times -0.039 + 182 \times -0.109 + 140 \times 0.063 + 402 \times 0.443 + 681 \times -0.087 + 613 \times 0.4499 + 388 \times 0.00 + 180 \times 0.17 + 268 \times 0.12 + 195 \times -0.741 + 195 \times -0.142 + 195 \times 0.343 + 195 \times 0.496 + 613 \times -0.1496) / (898 + 898 + 355 + 355 + 355 + 182 + 140 + 402 + 681 + 613 + 388 + 180 + 268 + 195 + 195 + 195 + 195 + 613) = 0.06765826$

**Farm size**  $(355 \times 0.027 + 355 \times -0.020 + 608 \times -0.01 + 608 \times 0.00 + 835 \times 0.006 + 355 \times 0.053 + 182 \times 0.089 + 140 \times 0.103 + 1920 \times 0.0340 + 681 \times 0.173 + 400 \times -0.008 + 195 \times 1.367 + 195 \times 0.668 + 195 \times 0.101 + 195 \times -0.983 + 613 \times 0.3469) / (355 + 355 + 608 + 608 + 835 + 355 + 182 + 140 + 1920 + 681 + 400 + 195 + 195 + 195 + 195 + 613) = 0.08531993$

**Extension contact:**  
 $(355 \times 0.004 + 355 \times 0.001 + 608 \times 1 + 608 \times 1.05 + 835 \times 0.004 + 1920 \times 0.777 + 613 \times 0.0666 + 388 \times 0.13 + 180 \times 0.27 + 268 \times 0.28 + 400 \times 0.133 + 195 \times 0.281 + 195 \times 0.364 + 195 \times 0.115 + 195 \times 0.754 + 597 \times 0.054 + 613 \times 0.134) / (355 + 355 + 608 + 608 + 835 + 1920 + 613 + 388 + 180 + 268 + 400 + 195 + 195 + 195 + 195 + 597 + 613) = 0.40153413$

**Age:**  $(898 \times -0.01 + 898 \times -0.07 + 355 \times 0.043 + 355 \times -0.036 + 608 \times 0.056 + 608 \times -0.002 + 355 \times 0.493 + 182 \times 0.318 + 140 \times 0.142 + 2732 \times 0.052 + 1920 \times -0.0042 + 405 \times 0.001 + 681 \times 0.155 + 613 \times -0.0002 + 400 \times 0.011 + 195 \times -0.750 + 195 \times -1.146 + 195 \times -0.786 + 195 \times 0.495 + 597 \times 0.265 + 613 \times -0.0187) / (898 + 898 + 355 + 355 + 608 + 608 + 355 + 182 + 140 + 2732 + 1920 + 405 + 681 + 613 + 400 + 195 + 195 + 195 + 195 + 597 + 613) = 0.01375664$

**Education:**  $(608 \times -0.078 + 608 \times -0.032 + 835 \times 0.001 + 355 \times 0.027 + 182 \times 0.046 + 140 \times 0.051 + 2732 \times 0.370 + 237 \times 0.0173 + 1920 \times -0.0099 + 402 \times -0.048 + 681 \times -0.067 + 613 \times 0.0112 + 388 \times 0.04 + 180 \times 0.01 + 268 \times -0.07 + 400 \times -0.017 + 195 \times 0.496 + 195 \times -0.001 + 195 \times 0.347 + 195 \times 0.404 + 613 \times -0.0256 + 597 \times 0.16) / (608 + 608 + 835 + 355 + 182 + 140 + 2732 + 237 + 1920 + 402 + 681 + 613 + 388 + 180 + 268 + 400 + 195 + 195 + 195 + 195 + 613 + 597) = 0.09661727$

**Access to credit**  $(898 \times -0.17 + 898 \times -0.04 + 355 \times -0.605 + 355 \times -0.323 + 835 \times 0.067 + 402 \times 0.0313 + 613 \times -3.690 + 400 \times -0.417 + 597 \times -0.066) / (898 + 898 + 355 + 355 + 835 + 402 + 613 + 400 + 597) = -0.5450522$

**Cooperative membership**  $(355 \times 0.413 + 355 \times -0.147 + 355 \times 0.449 + 182 \times 0.570 + 140 \times 0.445 + 681 \times 0.001 + 388 \times 0.38 + 180 \times -0.26 + 268 \times 0.26 + 400 \times -0.088) / (355 + 355 + 355 + 182 + 140 + 681 + 388 + 180 + 268 + 400) = 0.16817978$

**Distance to market**  $(898 \times -0.1 + 898 \times -0.01 + 608 \times 0.60 + 608 \times 0.28 + 835 \times -0.001 + 355 \times -0.191 + 182 \times -0.048 + 140 \times -0.163 + 462 \times -0.02043 + 237 \times 0.0134 + 1920 \times -0.0149 + 405 \times -0.012 + 681 \times 0.000 + 613 \times 0.0128 + 195 \times 0.223 + 195 \times -0.192 + 195 \times 0.361 + 195 \times -0.641 + 597 \times -0.0256) / (898 + 898 + 608 + 608 + 835 + 355 + 182 + 140 + 462 + 237 + 1920 + 405 + 681 + 613 + 195 + 195 + 195 + 195 + 597) = 0.02351907$



## 12.4 Binomial test

The assumptions of a binomial test are the following:

1. There is a fixed number  $n$  of observations
2. The  $n$  observations are independent
3. Each observation falls into one or two categories
4. The probability of success is the same for each observation

*Household size:* The hypothesized effect for household size is estimated to be undetermined. Therefore it will be tested whether an actual effect for household size exists. This provides the following hypothesis for the binomial test.

$$H_0 = P=0.5$$

$$H_a = P \neq 0.5$$

In which  $n$  is 9 (the total amount of observations for household size) and  $K$  is 5 - the number of successes, which in this case is the number of positive coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for household size is two-sided, since the effect direction is hypothesized as undetermined. This leads to the following outcome:

| n | k | p   | q   |
|---|---|-----|-----|
| 9 | 5 | 0.5 | 0.5 |

Parameters of binomial sampling distribution:

|                                    |
|------------------------------------|
| mean = 4.5                         |
| variance = 2.25                    |
| standard deviation = 1.5           |
| binomial z-ratio = (if applicable) |

| P: exactly 5 out of 9                |            |
|--------------------------------------|------------|
| Method 1. exact binomial calculation | 0.24609375 |
| Method 2. approximation via normal   |            |
| Method 3. approximation via Poisson  |            |
| P: 5 or fewer out of 9               |            |
| Method 1. exact binomial calculation | 0.74609375 |
| Method 2. approximation via normal   |            |
| Method 3. approximation via Poisson  |            |
| P: 5 or more out of 9                |            |
| Method 1. exact binomial calculation | 0.5        |
| Method 2. approximation via normal   |            |
| Method 3. approximation via Poisson  |            |

| For hypothesis testing               | P: 5 or more out of 9 |          |
|--------------------------------------|-----------------------|----------|
|                                      | One-Tail              | Two-Tail |
| Method 1. exact binomial calculation | 0.5                   | 1.0      |
| Method 2. approximation via normal   |                       |          |
| Method 3. approximation via Poisson  |                       |          |

The two-tailed p-value is 1.0 which is greater than  $\alpha 0.025$ . *Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for household size in relation to the adoption of grain legume technologies in this study.*

*Livestock:* The hypothesized effect for livestock is estimated to be undetermined. Therefore it will be tested whether an actual effect for livestock exists. This provides the following hypothesis for the binomial test.

$$H_0 = P=0.5$$

$$H_a = P \neq 0.5$$

In which  $n$  is 14 (the total amount of observations for livestock) and  $K$  is 9 - the number of successes, which in this case is the number of positive coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for livestock is two-sided, since the effect direction is hypothesized as undetermined. This leads to the following outcome:

| n  | k | p   | q   |
|----|---|-----|-----|
| 14 | 9 | 0.5 | 0.5 |

Parameters of binomial sampling distribution:

|                                         |
|-----------------------------------------|
| mean = 7                                |
| variance = 3.5                          |
| standard deviation = 1.8708             |
| binomial z-ratio = +0.8 (if applicable) |

| P: exactly 9 out of 14               |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.122192382813 |
| Method 2. approximation via normal   | 0.120839       |
| Method 3. approximation via Poisson  |                |
| P: 9 or fewer out of 14              |                |
| Method 1. exact binomial calculation | 0.910217285156 |
| Method 2. approximation via normal   | 0.908984       |
| Method 3. approximation via Poisson  |                |
| P: 9 or more out of 14               |                |
| Method 1. exact binomial calculation | 0.211975097656 |
| Method 2. approximation via normal   | 0.211856       |
| Method 3. approximation via Poisson  |                |

| P: 9 or more out of 14               |                |                |
|--------------------------------------|----------------|----------------|
| For hypothesis testing               | One-Tail       | Two-Tail       |
| Method 1. exact binomial calculation | 0.211975097656 | 0.423950195312 |
| Method 2. approximation via normal   | 0.211856       | 0.423711       |
| Method 3. approximation via Poisson  |                |                |

The two-tailed p-value is 0.424 which is greater than  $\alpha 0.025$ . **Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for livestock in relation to the adoption of grain legume technologies in this study.**

*Gender:* The hypothesized effect for gender is estimated to be positive. Therefore it will be tested whether an actual effect for gender exists. This provides the following hypothesis for the binomial test.

$$H_0 = P < 0.5$$

$$H_a = P > 0.5$$

In which  $n$  is 18 (the total amount of observations for livestock) and  $K$  is 11 - the number of successes, which in this case is the number of positive coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for gender is one-sided, since the effect direction is hypothesized as positive. This leads to the following outcome:

| n  | k  | p   | q   |
|----|----|-----|-----|
| 18 | 11 | 0.5 | 0.5 |

Calculate

Reset

Parameters of binomial sampling distribution:

|                                          |
|------------------------------------------|
| mean = 9                                 |
| variance = 4.5                           |
| standard deviation = 2.1213              |
| binomial z-ratio = +0.71 (if applicable) |

| P: exactly 11 out of 18              |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.121398925781 |
| Method 2. approximation via normal   | 0.120131       |
| Method 3. approximation via Poisson  |                |
| P: 11 or fewer out of 18             |                |
| Method 1. exact binomial calculation | 0.881057739258 |
| Method 2. approximation via normal   | 0.881279       |
| Method 3. approximation via Poisson  |                |
| P: 11 or more out of 18              |                |
| Method 1. exact binomial calculation | 0.240341186523 |
| Method 2. approximation via normal   | 0.238852       |
| Method 3. approximation via Poisson  |                |

| For hypothesis testing               | P: 11 or more out of 18 |                |
|--------------------------------------|-------------------------|----------------|
|                                      | One-Tail                | Two-Tail       |
| Method 1. exact binomial calculation | 0.240341186523          | 0.480682373046 |
| Method 2. approximation via normal   | 0.238852                | 0.477704       |
| Method 3. approximation via Poisson  |                         |                |

The one-tailed p-value is 0.24 which is greater than  $\alpha 0.05$ . **Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for gender in relation to the adoption of grain legume technologies in this study.**

*Farm size:* The hypothesized effect for gender is estimated to be positive. Therefore it will be tested whether an actual effect for farm size exists. This provides the following hypothesis for the binomial test.

$$H_0 = P < 0.5$$

$$H_a = P > 0.5$$

In which  $n$  is 16 (the total amount of observations for livestock) and  $K$  is 13 - the number of successes, which in this case is the number of positive coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for farm size is one-sided, since the effect direction is hypothesized as positive. This leads to the following outcome:

| n  | k  | p   | q   |
|----|----|-----|-----|
| 16 | 13 | 0.5 | 0.5 |

Calculate    Reset

Parameters of binomial sampling distribution:

|                                                               |
|---------------------------------------------------------------|
| mean = 8                                                      |
| variance = 4                                                  |
| standard deviation = 2                                        |
| binomial z-ratio = +2.25                      (if applicable) |

| P: exactly 13 out of 16              |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.008544921875 |
| Method 2. approximation via normal   | 0.009245       |
| Method 3. approximation via Poisson  |                |
| P: 13 or fewer out of 16             |                |
| Method 1. exact binomial calculation | 0.997909545898 |
| Method 2. approximation via normal   | 0.99702        |
| Method 3. approximation via Poisson  |                |
| P: 13 or more out of 16              |                |
| Method 1. exact binomial calculation | 0.010635375977 |
| Method 2. approximation via normal   | 0.012225       |
| Method 3. approximation via Poisson  |                |

| P: 13 or more out of 16              |                |                |
|--------------------------------------|----------------|----------------|
| For hypothesis testing               | One-Tail       | Two-Tail       |
| Method 1. exact binomial calculation | 0.010635375977 | 0.021270751954 |
| Method 2. approximation via normal   | 0.012225       | 0.024449       |
| Method 3. approximation via Poisson  |                |                |

The one-tailed p-value is 0.01 which is smaller than  $\alpha$  0.05. ***Therefore the null-hypothesis is rejected. This means that there is a significant directional effect for farm size in relation to the adoption of grain legume technologies in this study.***

Age: The hypothesized effect for age is estimated to be negative. Therefore it will be tested whether an actual effect for age exists. This provides the following hypothesis for the binomial test.

$$H_0 = P < 0.5$$

$$H_a = P > 0.5$$

In which  $n$  is 21 (the total amount of observations for age) and  $K$  is 11 - the number of successes, which in this case is the number of negative coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for age is one-sided, since the effect direction is hypothesized as positive. This leads to the following outcome:

| n  | k  | p   | q   |
|----|----|-----|-----|
| 21 | 11 | 0.5 | 0.5 |

Calculate    Reset

Parameters of binomial sampling distribution:

|                                       |
|---------------------------------------|
| mean = 10.5                           |
| variance = 5.25                       |
| standard deviation = 2.2913           |
| binomial z-ratio = +0 (if applicable) |

| P: exactly 11 out of 21              |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.168188095093 |
| Method 2. approximation via normal   | 0.16874        |
| Method 3. approximation via Poisson  |                |
| P: 11 or fewer out of 21             |                |
| Method 1. exact binomial calculation | 0.668188095093 |
| Method 2. approximation via normal   | 0.66874        |
| Method 3. approximation via Poisson  |                |
| P: 11 or more out of 21              |                |
| Method 1. exact binomial calculation | 0.5            |
| Method 2. approximation via normal   | 0.5            |
| Method 3. approximation via Poisson  |                |

| P: 11 or more out of 21              |          |          |
|--------------------------------------|----------|----------|
| For hypothesis testing               | One-Tail | Two-Tail |
| Method 1. exact binomial calculation | 0.5      | 1.0      |
| Method 2. approximation via normal   | 0.5      | 1        |
| Method 3. approximation via Poisson  |          |          |

The one-tailed p-value is 0.5 which is larger than  $\alpha 0.05$ . ***Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for age in relation to the adoption of grain legume technologies in this study.***

*Education:* The hypothesized effect for education is estimated to be undetermined. Therefore it will be tested whether an actual effect for education exists. This provides the following hypothesis for the binomial test.

$$H_0 = P=0.5$$

$$H_a = P \neq 0.5$$

In which  $n$  is 21 (the total amount of observations for education) and  $K$  is 12 - the number of successes, which in this case is the number of positive coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for education is two-sided, since the effect direction is hypothesized as undetermined. This leads to the following outcome:

| n  | k  | p   | q   |
|----|----|-----|-----|
| 21 | 12 | 0.5 | 0.5 |

Calculate    Reset

Parameters of binomial sampling distribution:

|                                          |
|------------------------------------------|
| mean = 10.5                              |
| variance = 5.25                          |
| standard deviation = 2.2913              |
| binomial z-ratio = +0.44 (if applicable) |

| P: exactly 12 out of 21              |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.140156745911 |
| Method 2. approximation via normal   | 0.139572       |
| Method 3. approximation via Poisson  |                |
| P: 12 or fewer out of 21             |                |
| Method 1. exact binomial calculation | 0.808344841003 |
| Method 2. approximation via normal   | 0.809603       |
| Method 3. approximation via Poisson  |                |
| P: 12 or more out of 21              |                |
| Method 1. exact binomial calculation | 0.331811904907 |
| Method 2. approximation via normal   | 0.329968       |
| Method 3. approximation via Poisson  |                |

| For hypothesis testing               | P: 12 or more out of 21 |                |
|--------------------------------------|-------------------------|----------------|
|                                      | One-Tail                | Two-Tail       |
| Method 1. exact binomial calculation | 0.331811904907          | 0.663623809814 |
| Method 2. approximation via normal   | 0.329968                | 0.659937       |
| Method 3. approximation via Poisson  |                         |                |

The two-tailed p-value is 0.66 which is larger than  $\alpha 0.025$ . *Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for education in relation to the adoption of grain legume technologies in this study.*

*Access to credit:* The hypothesized effect for access to credit is estimated to be negative. Therefore it will be tested whether an actual effect for access to credit exists. This provides the following hypothesis for the binomial test.

$$H_0 = P < 0.5$$

$$H_a = P > 0.5$$

In which  $n$  is 9 (the total amount of observations for access to credit) and  $K$  is 7 - the number of successes, which in this case is the number of negative coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for access to credit is one-sided, since the effect direction is hypothesized as negative. This leads to the following outcome:

| n | k | p   | q   |
|---|---|-----|-----|
| 9 | 7 | 0.5 | 0.5 |

Parameters of binomial sampling distribution:

|                                          |
|------------------------------------------|
| mean = 4.5                               |
| variance = 2.25                          |
| standard deviation = 1.5                 |
| binomial z-ratio = _____ (if applicable) |

| P: exactly 7 out of 9                |            |
|--------------------------------------|------------|
| Method 1. exact binomial calculation | 0.0703125  |
| Method 2. approximation via normal   |            |
| Method 3. approximation via Poisson  |            |
| P: 7 or fewer out of 9               |            |
| Method 1. exact binomial calculation | 0.98046875 |
| Method 2. approximation via normal   |            |
| Method 3. approximation via Poisson  |            |
| P: 7 or more out of 9                |            |
| Method 1. exact binomial calculation | 0.08984375 |
| Method 2. approximation via normal   |            |
| Method 3. approximation via Poisson  |            |

| P: 7 or more out of 9                |            |           |
|--------------------------------------|------------|-----------|
| For hypothesis testing               | One-Tail   | Two-Tail  |
| Method 1. exact binomial calculation | 0.08984375 | 0.1796875 |
| Method 2. approximation via normal   |            |           |
| Method 3. approximation via Poisson  |            |           |

The one-tailed p-value is 0.09 which is larger than  $\alpha$  0.05. ***Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for access to credit in relation to the adoption of grain legume technologies in this study.***

*Extension contact:* The hypothesized effect for extension contact is estimated to be positive. Therefore it will be tested whether an actual effect for extension contact exists. This provides the following hypothesis for the binomial test.

$$H_0 = P < 0.5$$

$$H_a = P > 0.5$$

In which  $n$  is 17 (the total amount of observations for extension contact) and  $K$  is 14 - the number of successes, which in this case is the number of positive coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for extension contact is one-sided, since the effect direction is hypothesized as positive. This leads to the following outcome:

| n  | k  | p   | q   |
|----|----|-----|-----|
| 17 | 14 | 0.5 | 0.5 |

Calculate

Reset

Parameters of binomial sampling distribution:

|                                          |
|------------------------------------------|
| mean = 8.5                               |
| variance = 4.25                          |
| standard deviation = 2.0616              |
| binomial z-ratio = +2.43 (if applicable) |

| P: exactly 14 out of 17              |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.005187988281 |
| Method 2. approximation via normal   | 0.005771       |
| Method 3. approximation via Poisson  |                |
| P: 14 or fewer out of 17             |                |
| Method 1. exact binomial calculation | 0.998825073242 |
| Method 2. approximation via normal   | 0.998222       |
| Method 3. approximation via Poisson  |                |
| P: 14 or more out of 17              |                |
| Method 1. exact binomial calculation | 0.006362915039 |
| Method 2. approximation via normal   | 0.007549       |
| Method 3. approximation via Poisson  |                |

| P: 14 or more out of 17              |                |                |
|--------------------------------------|----------------|----------------|
| For hypothesis testing               | One-Tail       | Two-Tail       |
| Method 1. exact binomial calculation | 0.006362915039 | 0.012725830078 |
| Method 2. approximation via normal   | 0.007549       | 0.015099       |
| Method 3. approximation via Poisson  |                |                |

The one-tailed p-value is 0.00 which is smaller than  $\alpha 0.05$ . ***Therefore the null-hypothesis is rejected. This means that there is a significant directional effect for extension contact in relation to the adoption of grain legume technologies in this study.***



*Distance to market:* The hypothesized effect for extension contact is estimated to be negative. Therefore it will be tested whether an actual effect for distance to market exists. This provides the following hypothesis for the binomial test.

$$H_0 = P < 0.5$$

$$H_a = P > 0.5$$

In which  $n$  is 10 (the total amount of observations for distance to market) and  $K$  is 7 - the number of successes, which in this case is the number of negative coefficients. The test proportion is 0.5, to test whether there is an effect. The hypothesis for distance to market is one-sided, since the effect direction is hypothesized as positive. This leads to the following outcome:

| n  | k  | p   | q   |
|----|----|-----|-----|
| 19 | 12 | 0.5 | 0.5 |

Calculate    Reset

Parameters of binomial sampling distribution:

|                                                     |
|-----------------------------------------------------|
| mean = 9.5                                          |
| variance = 4.75                                     |
| standard deviation = 2.1794                         |
| binomial z-ratio = +0.92            (if applicable) |

| P: exactly 12 out of 19              |                |
|--------------------------------------|----------------|
| Method 1. exact binomial calculation | 0.09610748291  |
| Method 2. approximation via normal   | 0.094813       |
| Method 3. approximation via Poisson  |                |
| P: 12 or fewer out of 19             |                |
| Method 1. exact binomial calculation | 0.916465759277 |
| Method 2. approximation via normal   | 0.916027       |
| Method 3. approximation via Poisson  |                |
| P: 12 or more out of 19              |                |
| Method 1. exact binomial calculation | 0.179641723633 |
| Method 2. approximation via normal   | 0.178786       |
| Method 3. approximation via Poisson  |                |

| For hypothesis testing               | P: 12 or more out of 19 |                |
|--------------------------------------|-------------------------|----------------|
|                                      | One-Tail                | Two-Tail       |
| Method 1. exact binomial calculation | 0.179641723633          | 0.359283447266 |
| Method 2. approximation via normal   | 0.178786                | 0.357573       |
| Method 3. approximation via Poisson  |                         |                |

The one-tailed p-value is 0.18 which is larger than  $\alpha$  0.05. *Therefore the null-hypothesis cannot be rejected. This means that there is no significant directional effect for distance to market in relation to the adoption of grain legume technologies in this study.*

## 12.5 Calculations for weighted z-scores

Following the formula stated in 5.7, following calculations were executed to obtain weighted z-scores:

### Household size

Contributions included: (10, 13, 14, 16, 18, 22, 24)

**Calculation:**  $(2732*2.6)+(237*0.39)+(1920*2.86)+(681*0.53)+(613*1.017)+(597*1.48)+(613*3.572) = 2537.97$

$/ \sqrt{(2737^2)+(237^2)+(1920^2)+(681^2)+(613^2)+(597^2)+(613^2)} = 2537.97/3574.65 = \mathbf{0.71}$

### Livestock

Contributions included: (4a, 4b, 5a, 5b, 6a, 6b, 7, 14, 16, 18, 24)

**Calculation:**  $(898*-1)+(898*-0.167)+(355*-2.5)+(355*1.725)+(608*2.31)+(608*0.33)+(835*10.8)+(1920*0.576)+(681*1.67)+(613*1.9)$

$+ (613*1.16) = 13418.99 / \sqrt{(898^2)+(898^2)+(355^2)+(355^2)+(608^2)+(608^2)+(835^2)+(1920^2)+(681^2)+(613^2)+(613^2)} = 13418.99/\sqrt{8203110} = \mathbf{4.69}$

### Gender

Contributions included: (4a, 4b, 5a, 5b, 6a, 6b, 7, 14, 16, 21a, 21b, 21c, 21d, 24)

**Calculation:**  $(898*0.93)+(898*0.6)+(355*1.4)+(355*-2.15)+(405*1.367)+(681*-0.56)+(613*1.28)+(388*0.00)+(180*0.17)+(268*0.12)+(195*2.29)+(195*0.48)+(195*1.49)+(195*2.02)+(613*-0.57) = 2861.955 / \sqrt{(898^2)+(898^2)+(355^2)+(355^2)+(405^2)+(681^2)+(613^2)+(388^2)+(180^2)+(268^2)+(195^2)+(195^2)+(195^2)+(195^2)+(613^2)} = 2861.955 / 1910.77 = \mathbf{1.50}$

### Farm size

Contributions included: (5a, 5b, 6a, 6b, 7, 14, 16, 21a, 21b, 21c, 21d, 24)

**Calculation:**  $(355*0.79)+(355*-0.6)+(608*-0.1)+(608*0)+(835*0.4)+(1920*2.25)+(681*2.08)+(195*2.10)+(195*1.38)+(195*0.19)+(195*2.26)+(613*1) = 7846.48 / \sqrt{(355^2)+(355^2)+(608^2)+(608^2)+(835^2)+(1920^2)+(681^2)+(195^2)+(195^2)+(195^2)+(195^2)+(613^2)} = 7846.48/\sqrt{6366633} = 7846.48/2523.219 = \mathbf{3.11}$

### Age

Contributions included: (5a, 5b, 6a, 6b, 14, 15, 16, 18, 21a, 21b, 21c, 21d, 22, 24)

**Calculation:**  $(355*1)+(355*-0.92)+(608*1.09)+(608*-0.039)+(1920*-2.6)+(405*0.16)+(681*0.798)+(613*-0.004)+(195*0.64)+(195*0.96)+(195*0.66)+(195*0.49)+(597*2.007)+(613*1) = -1365.91 / \sqrt{(355^2)+(355^2)+(608^2)+(608^2)+(1920^2)+(405^2)+(681^2)+(613^2)+(195^2)+(195^2)+(195^2)+(195^2)+(597^2)+(613^2)} = -1365.91/\sqrt{6565611} = -1365.91/2562.35 = \mathbf{-0.53}$

### Education:

Contributions included: (6a, 6b, 7, 13, 14, 15, 16, 19a, 19b, 19c, 21a, 21b, 21c, 21d)

**Calculation:**  $(608 \cdot -2.067) + (608 \cdot -0.467) + (835 \cdot 0.2) + (237 \cdot 0.044) + (1920 \cdot -1.25) + (405 \cdot 1.92) + (681 \cdot -0.89) + (388 \cdot 0.05) + (180 \cdot -0.06) + (268 \cdot -0.13) + (195 \cdot 3.29) + (195 \cdot 0.01) + (195 \cdot 2.58) + (195 \cdot 3.29) = -1829.824 / \sqrt{(608^2) + (608^2) + (835^2) + (237^2) + (1920^2) + (405^2) + (681^2) + (388^2) + (180^2) + (268^2) + (195^2) + (195^2) + (195^2) + (195^2)} = -1829.824 / \sqrt{6213776} = -1829.824 / 2482.745 = \mathbf{-0.73}$

**Credit**

Contributions included: (4a, 4b, 5a, 5b, 7, 15, 18, 19a, 19b, 19c, 22)

**Calculation**  $(898 \cdot -1.5) + (898 \cdot -0.4) + (355 \cdot -3.8) + (355 \cdot 2.05) + (835 \cdot 5.15) + (405 \cdot 1.1) + (613 \cdot -1.33) + (388 \cdot 0.04) + (180 \cdot 0.01) + (268 \cdot -0.07) + (597 \cdot -1.737) = -890.919 / \sqrt{(898^2) + (898^2) + (355^2) + (355^2) + (835^2) + (405^2) + (613^2) + (388^2) + (180^2) + (268^2) + (597^2)} = -890.919 / \sqrt{1926.93} = \mathbf{0.46}$

**Extension contact**

Contributions included: (5a, 5b, 6a, 6b, 7, 18, 21a, 21b, 21c, 21d, 22, 24)

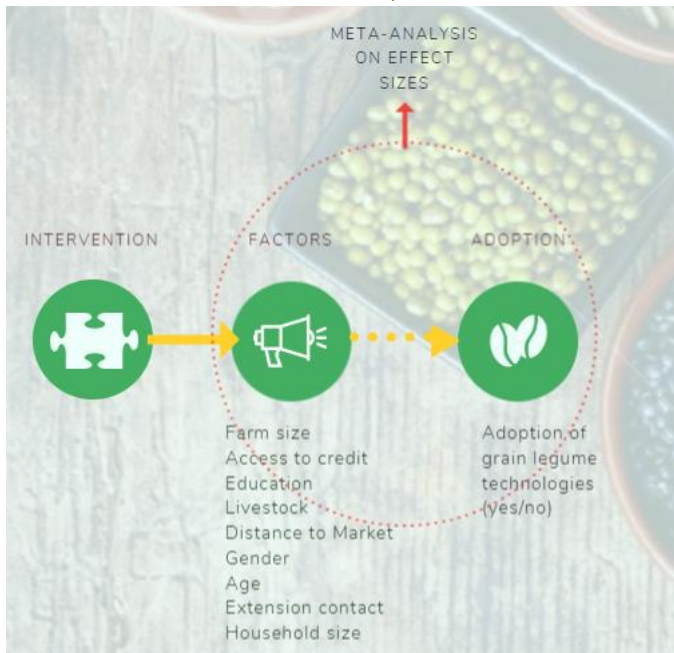
**Calculation**  $(355 \cdot 2) + (355 \cdot 0.5) + (608 \cdot 6.56) + (608 \cdot 6.67) + (835 \cdot 1.33) + (613 \cdot 0.65) + (195 \cdot 0.64) + (195 \cdot 0.89) + (195 \cdot 0.31) + (195 \cdot 0.9) + (597 \cdot 2.61) + (613 \cdot 1.675) = 12762.685 / \sqrt{(355^2) + (355^2) + (608^2) + (608^2) + (835^2) + (613^2) + (195^2) + (195^2) + (195^2) + (195^2) + (597^2) + (613^2)} = 19183.86 / \sqrt{2948650} = 12762.685 / \sqrt{2948650} = \mathbf{7.43}$

**Distance to market:**

Contributions included: (4a, 4b, 6a, 6b, 7, 13, 14, 15, 16, 18, 21a, 21b, 21c, 21d, 22)

**Calculation**  $(898 \cdot -1) + (898 \cdot -0.1) + (608 \cdot 4) + (608 \cdot 1.867) + (835 \cdot -1) + (237 \cdot 0.017) + (1920 \cdot -3.39) + (405 \cdot -4) + (681 \cdot 0) + (613 \cdot 0.52) + (195 \cdot 0.29) + (195 \cdot 0.20) + (195 \cdot 0.54) + (195 \cdot 0.89) + (597 \cdot -1.8) = -6761.875 / \sqrt{(898^2) + (898^2) + (608^2) + (608^2) + (835^2) + (237^2) + (1920^2) + (405^2) + (681^2) + (613^2) + (195^2) + (195^2) + (195^2) + (195^2) + (597^2)} = -6761.875 / \sqrt{8303994} = \mathbf{-2.35}$

## 12.6 Framework on meta-analysis



*Phase II research focus*

## 12.7 Explanatory factors influencing grain legume technology adoption



*Conclusion on explanatory factors in relation to the adoption decision of grain legume technologies.*