Invited paper presented at the 6th African Conference of Agricultural Economists, September 23-26, 2019, Abuja, Nigeria

Farmer Risk Perceptions about Conservation Agriculture: Insights from Malawi

Lawrence Mapemba*, Associate Professor, Lilongwe University of Agriculture and Natural Resources, Department of Agricultural and Applied Economics, P.O. Box 219, Lilongwe, Malawi. E-mail: lmapemba@luanar.ac.mw

Patrick Ward, Research Fellow, Environment and Production Technology Division, International Food Policy Research Institute, 1201 Eye St NW, Washington, DC 2005, USA. Email: p.ward@cgiar.org

Andrew Bell, Assistant Professor, Department of Environmental Studies, New York University, NY 10003, USA. Email: ab6176@nyu.edu

Edwin Kenamu, Research Analyst, International Food Policy Research Institute, Malawi Strategy Support Program, P.O. Box 31666, Lilongwe 3, Malawi. Email: e.kenamu@cgiar.org

Zephaniah Nyirenda, Policy Research and M&E Analyst, NAPAS: Malawi, Ministry of Agriculture, Irrigation and Water Development, P.O. Box 31666, Lilongwe 3, Malawi. Email: z.nyirenda@cgiar.org

Wupe Msukwa, Research Associate, Social Science and Agribusiness Unit, International Institute of Tropical Agriculture, P.O. Box 30258, Lilongwe 3, Malawi. Email: w.msukwa@cgiar.org

Abstract
This study aims to investigate factors that affect smallholders' perceptions about risks associated with practicing Conservation Agriculture (CA). Data used were collected to understand farmers' decisions in practicing and adoption of three components of CA: zero tillage, mulching and intercropping. We applied a multinomial probit model and our results suggest that farmers, generally, perceive adoption of each CA component as reducing risk of crop damage due to waterlogging, pests and drought. In addition, number of neighbours practicing specific CA components influences farmers' perception of CA as risk-reducing. This underscores the current thinking that agglomeration payments may help improve CA adoption as farmers may skip the trial stage of technology adoption process by observing their neighbours experiences. We further find that various farmers' atttributes, their plots and context affect risk perceptions of the CA components differently. Generally, we see that risk perceptions are unique to individual farmers and farms. This suggests the need to carefully package CA in a way that responds to characteristics of farmers and farms on which they practice agricultural production. Adoption studies of CA and other land management technologies that fail to include agro-ecological factors in analysis but only include socio-economic factors may provide incorrect policy advice.

Key words: Conservation Agriculture, risk perception, adoption, multinomial probit, Malawi

Introduction
The pressure to feed a growing human population without causing damage to the environment has seen widespread promotion of conservation agriculture (CA) practices by agricultural development practitioners and research institutions alike (Pittelkow, et al., 2014).

CA is a package of agricultural practices consisting of minimum soil disturbance, mulching, and intercropping or rotating legumes within a predominant cereals-based cropping system. The combination of these three pillars has been demonstrated to increase the diversity of soil biota, increase the content of soil organic matter, increase soil moisture retention, and preserve the nitrogen content in the soils. Despite a protracted debate over whether CA yields superior agricultural outcomes under smallholder farming systems compared to conventional farming practices (for example see Corbeels, et al., 2013; Giller, et al., 2009), most of the practitioners seem motivated to enhance smallholder farmer adoption of CA. Decades of investment in promoting smallholder farmer adoption of CA practices, however, have been met with limited success in most of South Asia and Sub-Saharan Africa. For example, unlike in South America where about 50 percent of cropland is under CA, only 1 percent of such land is under CA in Kenya, Zambia and Zimbabwe (Corbeels, et al., 2013). The low rates of smallholder farmer adoption of these practices amidst significant investment by governmental and non-governmental agencies in promoting the same has seen a growing number of empirical and meta-analyses aimed at addressing factors that affect adoption of CA. Literature has shown that the probability of a farmer to adopt CA is conditioned on the plot on which CA is practised as well as the farmers characteristics (Ward et al., 2016; Lalani et al., 2016; Ngwira et al., 2014). Knowler and Bradshaw (2007) argued that there are not really any variables that systematically determine the adoption of CA, but that determinants of adoption of CA must be area-specific.

Branca et al. (2011) have reported that adoption of practices like CA is complex with different types of costs accruing to the farmer. The complexity of the process emanates from its dynamic nature, with farmers' typically short planning horizons, perceptions and attitudes towards risks affecting the rate of adoption of CA. Ghadim and Pannell (1999), for example, argued that farmer adoption of new technlogies is essentiallly affected by their perceptions of expected profits, risk attitudes and perception about risks. Indeed, Branca et al. (2011) view risk as a cost which farmers incur in adoption of agricultural practices like CA. Most empirical work, however, completely ignore the role of risk perception and attitudes in adoption of CA with a risk in itself of misguiding policy and program planning around CA. Futhermore, Ramsey et al. (2016) have noted that introduction and intensification of CA practices in farming systems have the potential to introduce new risks and costs to the farming system, thus affecting intensity of adoption of the practices. In certain circumstances, risks associated with adoption of CA may outweigh financial costs in impeding farmer uptake of conservation practices (Sattler & Nagel, 2010).

In the few studies that have explicitly incorporated the role of risk in agricultural technology adoption, farmers' attitudes and perceptions towards risks are usually used as independent variables in understanding the technology adoption process (Ramsey et al., 2016; Ghadim & Pannell, 1999; Ngwira et al., 2013; Kuehne et al, 2017; Greiner et al., 2009; Pannell et al., 2014; Cavatassi et al., 2011; Shively, 2001). To the extent that factors that condition risk preferences are also correlated with technology adoption decisions, causal inference on the effect of risk preferences on technology adoption will be biased. Ward et al., (2016) studied heterogeneity in farmers' preferences for CA technologies in rural Malawi, and they observed that farmers' exposure to various sources of production risk – specifically insufficient rainfall and increased insect pressure – significantly affected farmers' willingness to adopt various CA practices. Although they did not specifically assess farmers' perceptions regarding the riskiness of various CA practices, they observed correlation between farmers'past risk experience and their forward-looking willingness to adopt various agricultural practices. Nevertheless, filling this knowledge gap and drawing more concrete conclusions about the perceived riskiness of the different CA practices, and further gaining more insight into the factors that affect farmers' perceptions will enhance researchers' and development practitioners' ability to fully understand smallholder farmers' adoption of CA practices. This paper evaluates farmers' risk perception associated with adoption of components of CA. Do smallholder farmers perceive risk of crop loss due to waterlogging, pests or diseases when they adopt CA in full or components of it.

To foreshadow our results, we find that, in our sample, farmers generally perceive adoption of each CA component as reducing the risk of crop damage due to waterlogging, pests and drought. In addition, the number of neighbours practicing specific CA components is highly correlated with farmers perceiving adoption as risk-reducing. This is consistent with other recent studies (e.g., Ward et al., 2018; Bell et al., 2018) that have found that adoption of CA is highly and positively correlated with the density of peer adoption of CA. Generally, we see that risk perceptions are unique to individuals' personal and farm characteristics. Given the idiosyncratic nature of perceived risks, this may explain the high rates of partial adoption of CA (e.g., Ward et al., 2018) rather than adoption of the complete CA package. In their study, Pedzisa et al. (2015) acknowledges the importance of agro-ecology as a major factor that influences adoption and sustained use of CA. Thus, by further illuminating the role of risk perceptions in constraining the adoption of this environmentally-friendly suite of agricultural practices, the present study makes important contributions to the agricultural development and sustainability literatures.

Theory

Consider a farmer assumed to maximize the utility of anticipated farm profits, and assume the uncertainty around farm profits is solely a function of production uncertainty (i.e., there is no uncertainty regarding input or output prices). The farmer's technology choice involves either using traditional or new technology on a plot of land. The random utility theory says that the farmer chooses a technology that maximizes the utility of expected profits, subject to random perturbations and errors in optimization, conditional on their income and other constraints. The farmer evaluates the likely utilities (profits) that will accrue to them if they adopt the new technology compared to when they decide to continue using the traditional technology. If we let $U[E(\pi_t)]$ and $U[E(\pi_n)]$ be the utility associated with expected profits accrued through practicing the traditional and the new technologies, respectively, the farmer adopts the new technology if and only if $U[E(\pi_n)] > U[E(\pi_t)]$.

We assume a stochastic production function along the lines of the model originally proposed by Just and Pope (1978). If a particular input (or production technology) is perceived to be risky, by definition, the variance term in the production function is increasing with an increase in the use of the input. This, in turn, should lead to a divergence between the (expected) marginal product and the objective input or technology cost. It can be shown that risk averse farmers do not equate the value of the (expected) marginal product of an input with its cost, and therefore risk averse farmers under-utilize risky inputs relative to a risk-neutral producer, even if the input's riskiness is only perceived. In the context of CA, therefore, we should expect that farmers' perceptions about risks associated with CA adoption, and their risk preferences affect the rate and extent of adoption of the farming pratice.

Despite the effect of respondent use of heuristics in evaluating risks, empirical applications have shown that risk perception can be effectively studied along five key dimensions (for example see Ramsey et al., 2016 and van der Linden et al., 2015). According to Ramsey et al.

(2016), farm characteristics (e.g., slope, soil type, soil quality), farmer characteristics (e.g., gender, education level of the farmer, age, etc), experience with CA practices, the environment (e.g., number of neighbours practicing CA technologies), as well as beliefs and attitudes may affect farmers extent of CA adoption.

The farmer characteristics influence our modeling of risk perceptions in two ways. Firstly, the socioeconomic variables are used to account for the farmer's cultural background. As Kellstedt et al. (2008) and O'Connor et al. (1999) have shown, people with higher socioeconomic status tend to have lower risk perceptions compared to people with lower socioeconomic status. Ramsey et al. (2016), however, note that the effect of farmer characteristics on risk perceptions is not conclusive. They also note that a number of previous studies have not found any correlation between risk perceptions and farmer characteristics like education and age of the farmer. Regardless of there being little or no correlation with risk perceptions, van der Linden (2015) argue that the farmer characteristics should be included in model specification as control variables to help in assessing the net effect of the rest of the variables.

Farm characteristics are likely to affect farmer risk perception, though the direction of influence is not clear. For example, it is possible for farmers with larger plot areas to perceive adoption of CA practices as less risky as larger plot areas allow such farmers to take the risk by adopting the technology on a proportion of their land. Farmers with big plots of land may also perceive some CA practices as exposing them to more risk when they apply them on larger areas of land (Ramsey et al., 2016). Furthermore, farmers growing crops in termite-prone plots may perceive mulching as being especially risky, as leaving residues in the field may increase termite pressure resulting in considerable crop damages. On the other hand, the numbers of successes and failures of neighboring farmers practicing CA have the potential to affect how they perceive the riskiness of CA.

Ramsey et al. (2016) reported that farmers attitudes and beliefs affects how they perceive risks associated with CA practices. These beliefs and attitudes include farmers' risk orientation, their perception of how CA could affect soil quality as well as soil erosion, and pesticide and insect build-up. Generally, a risk averse farmer is expected to have higher risk pereception of crop damage due to CA adoption than a neutral farmer. Likewise, a farmer who thinks that adoption of, say mulching, will reduce weeds on the plot is likely to have a perception of lower risk associated with mulching adoption.

Empirical model and estimation strategy

Let us assume a CA practice W, also assume that farmer i has j potential perceptions (either waterlogging, pests or termites attack, or drought) of risks of damage to crops associated with adoption of conservation agriculture practice as opposed to practicing conventional farming. The latent variable for the *j*th perception $j = 1,...,3$ is

$$y_{ij} = x_i \alpha_j + \xi_{ij},$$

where *y* is the perception, x_i is a $1 \times k$ row vector of observed independent variables for the *i*th farmer, and α_j is a vector of regression coefficients related to the 3 CA practices while $\xi_{i,1},...,\xi_{i,3}$ are random error variables distributed independently and identically standard normal. If farmer i has j perception about the riskiness of a CA practice, taking the difference between the latent variable and any of the $J-1$ others yields,

$$\begin{aligned} \upsilon_{ijk} &= y_{ij} - y_{ik} \\ &= x_i\left(\alpha_j - \alpha_k\right) + \xi_j - \xi_k \\ &= x_i\gamma_{j'} + \varepsilon_{ij'} \end{aligned} \qquad (1)$$

where $j' = j$ if $j < k$ and $j' = j-1$ if $j > k$ such that $j' = 1,\ldots,J-1$. The model has a $\operatorname{var}\left(\varepsilon_{ij'}\right) = \operatorname{var}\left(\xi_{ij} - \xi_{ik}\right) = 2$ and $\operatorname{cov}\left(\varepsilon_{ij'}, \varepsilon_{il'}\right) = 1 \;\; \forall \;\; l \neq j$. The term in the log-likelihood that corresponds to risk perceptive k is $\operatorname{prob}\left(\text{perception}\, k\right) = \operatorname{prob}\left[y_k > y_j, j = 1,\ldots,J, j \neq k\right]$. The probability of this perception is

$$\begin{aligned} \operatorname{prob}\left(\text{farmer } i \text{ has } k \text{ perception}\right) &= \operatorname{prob}\left(\upsilon_{i1k} \leq 0,\ldots,\upsilon_{\mathrm{i,J-1,k}} \leq 0\right) \\ &= \operatorname{prob}\left(\varepsilon_{1i} \leq -x_i\gamma_1,\ldots,\varepsilon_{1,\mathrm{J}-1} \leq -x_i\gamma_{J-1}\right) \end{aligned}$$

Not all J of α_j in equation 1 are identifiable, though. In order to facilitate model identification, one of the perceptions is set to a zero vector where it becomes a base category against which the rest of the perceptions are compared. In this study, perception of lower risks was the base outcome. Since the risk perceptions were assumed independent the model was estimated using multinomial probit.

Data

Data for the study were collected from a representative, cluster sample of 30 households that were randomly drawn from each of the sampled 66 villages in the Shire River Basin in southern Malawi. Although some of the survey participants were from treatment, not all received the treatment. Thus the data are representative of the villages included in randomized controlled trial, but were not necessarily directly involved. The data were collected between September and October of 2016 in Balaka, Machinga and Zomba districts.

These data are a result of a project that was initiated in 2014. Our sampling strategy entailed initially constructing a large number of simple random samples of 60 villages each, drawn from a pooled list of all villages in five Extension Planning Areas (EPAs) riparian to the Shire River in the aforementioned districts. The resulting random selection of participant villages maximized the minimum distance between any two participating villages. The selected villages were then either assigned to one of six treatment groups or to the control group. Though during implementation a total of 66 villages were visited by the field teams with extension messages about CA. To ensure uniform distribution of extension messages, the project partnered with the Department of Land Resources Conservation (DLRC) in the Ministry of Agriculture, Irrigation and Water Development, and the National Smallholder Farmers Association of Malawi (NASFAM), which were responsible for delivering extension messagesto farmers.

In the two years of the project, farmers were first given the opportunity to voluntarily register to participate, thereby committing to practice CA in exchange for subsequently receiving their alotted incentive, conditional upon compliance. Farmers were allowed to register up to a maximum of 1 acre of land on which they would practice CA. These registration efforts were undertaken in October of each year, in preparation for the corresponding rainy season.

Following the culmination of the growing season, program monitors visited treatment villages to assess the degree of compliance among participating farmers, while also collecting data from registrant households that could later be used for studying patterns of program compliance and noncompliance.

Using first year data, Ward et al (2018) observed that only 24 percent of registrants in the treatment villages were fully compliant. It was therefore, necessary to assess the risk factors that deter farmers from adopting CA, despite many years of public and private extension efforts in sensitizing farmers about the expected benefits of CA. As such, the endline questionnaire included questions on the perceived risk of damage due to waterlogging, pests and drought for adopting zero tillage, mulching and intercropping/crop rotation. Before presenting results on farmer risk perceptions about CA, we first present summary statistics in table 1 about the households in our sample to give the context of the population under study.

Table 1: Summary statistics about the households in our sample

Variable	Obs	Mean/Percent	Std. Dev.	Min	Max
Practice CA	1,986	0.264351	0.441098	0	1
practice zero tillage	1,986	0.366062	0.481848	0	1
Practice mulching	1,986	0.453676	0.497975	0	1
Practice intercropping	1,986	0.646526	0.478169	0	1
4yr practice zero tillage	1,657	0.368135	0.482444	0	1
4yr Practice mulching	1,657	0.469523	0.499221	0	1
4yr Practice intercropping	1,657	0.902837	0.29627	0	1
# of years zero tillage	1,663	1.544799	0.899396	1	4
# of year mulching	1,663	1.623572	0.891987	1	5
# of years intercropping	1,663	3.321106	1.058042	1	5
Cultivated area (acres)	1,942	1.193415	1.072361	0.15	26
# of plots managed	1,942	1.764161	0.804414	1	10
Soil type					
Loam	1,942	0.632853	0.482151	0	1
Clay	1,942	0.215242	0.411096	0	1
Other soil types	1,942	0.035015	0.183866	0	1
Soil quality					
Fair	1,942	0.424305	0.494364	0	1
Poor	1,942	0.134398	0.341167	0	1
# of zero till neighbors	1,824	0.94079	1.393033	0	10
# of mulching community member	1,824	27.41173	41.47422	0	500
Treatment village	1,985	0.803023	0.397815	0	1
Access to CA extension	1,986	0.625378	0.484147	0	1
Education					
Primary complete	316	0.10443	0.306303	0	1
Secondary incomplete	316	0.14557	0.353234	0	1
Secondary complete	316	0.091772	0.289162	0	1
Other colleges	316	0.012658	0.111972	0	1
Head sex (Male)	393	0.256998	0.437535	0	1
Head age	393	48.99746	17.615	22	95

Our results show that 26 percent of the households in our sample practice CA. This shows a 2 percent increase in adoption of CA from 24% in 2015 as reported by Wald et al (2016). Our results also show that about 37 percent of sampled households practiced zero tillage, about 45 percent were practicing mulching and about 65 percent were practicing intercropping at the time of data collection. Respondents to the survey were also asked whether they had ever practiced zero tillage, mulching and intercropping in the last four years. About 37 percent of the households in our sample practiced zero tillage, 47 percent practiced mulching and 90 percent practiced intercropping. In terms of mean number of years of practice with the various components of CA, our results show that households that practiced zero tillage, mulching and intercropping did so for 1.5, 1.6 and 3.3 years, respectively. This shows that there is still need for efforts to increase adoption of zero tillage and mulching in the shire river basin.

The study also show that households cultivated on average 1.2 acres of land and most households were managing an average of 1.8 plots. In terms of soil type, about 63 percent of the households reported having plots on loam soils while 22 percent of the households reported having plots on clay soils. With respect to soil quality, 42 percent of households reported having fair soils while 13 percent reported having plots on poor quality soils. As we will demonstrate later, the plots' biophysical characteristic influence whether a farmer undertakes any of the three CA components.

At the community level, sampled households were asked to indicate the number of people undertaking zero tillage and mulching. Our results show that about 1 household undertook zero tillage in a community. Most times, these are lead farmers. It is surprising that even in the presence of lead farmers in the communities, information diffusion is not at an accelerated pace. The average number of households in a community practicing mulching was estimated at 27. This implies there is progress being made with regard to mulching as compare to zero tillage.

In the study, about 80 percent of sampled households were from treatment villages. Furthermore, 63 percent of the households had access to extension on CA. About 25 percent of the households were male headed and the average household head age was estimated at about 49 years.

Risk perceptions about zero tillage, mulching, and intercropping/crop rotation

Table 2 below gives a summary of elicited farmer perceptions of zero tillage. Recall from Table 1, 26 percent of the farmers in the endline survey adopted a complete CA package of zero tillage, mulching and intercropping/crop rotation. Our analysis show that about 25 percent of the farmers did not practice any of the CA technologies while the remainder adopted one or two of the CA practices. If we assume that farmers are rational, then choices made regarding partial adoption of CA components may be influenced partly by their socioeconomic characteristics and environments. It was, therefore, necessary to understand environmental reasons behind farmers' choices of certain components of CA. Firstly, farmers were asked about their perceptions of crop losses due to waterlogging, pests, and drought if they undertook zero tillage on their plots over the coming year.

Table 2: Percentage of farmers who reported expecting higher, lower or no differences in crop damage through waterlogging, pest attacks and drought due to practicing zero-tillage

	Zero Tillage		
Risk perception	**Waterlogging**	**Pests**	**Drought**
Higher	9.40	8.32	9.46
No difference	23.42	28.26	20.87
Lower	67.17	63.42	69.67

Results of the study suggest that fewer than 10 percent of surveyed farmers perceive that practicing zero tillage would increase their exposure to crop loss due to waterlogging, pests, or drought. This is somewhat surprising, given that much of the criticism of zero tillage within CA systems is that it can lead to soil compaction or the build-up of hard pans which can exacerbate problems of waterlogging. Indeed, roughly two-thirds of surveyed farmers perceive that practicing CA would actually lower their exposure to crop loss from these three hazards. The few households that perceive an increase in risk exposure could be few farmlands that have soils with hard pans or that otherwise do not percolate water easily, or are prone to termites attack. Farmers' decision on what land management interventions to adopt depends on their farming experience on interaction between the intervention and farming environment. In their study of comparative performance of CA and smallholder practices, Baudron et al. (2012) observed that farmers perceived both positive and negative consequences on crop yields when they practiced zero-tillage and mulching due to complex interactions with the season and soil type. They reported that farmers considered zero-tillage to have led to soil compaction and crusting, which may have caused inability of water to infiltrate the soil, leading to waterlogging that could also introduce pests and diseases.

Similarly, farmers were asked about their perceptions of crop losses due to waterlogging, pests, and drought if they undertook mulching on their plots over the coming year. Table 3 summarizes farmers' risk perceptions with regards to mulching/residue retention.

Table 3: Percentage of farmers who reported expecting higher, lower or no differences in crop damage through waterlogging, pest attacks, and drought due to mulching

	Mulching		
Risk perception	**Waterlogging**	**Pests**	**Drought**
Higher	11.2	17.45	3.37
No difference	19.95	22.61	11.3
Lower	68.86	59.95	85.33

Here, nearly 20 percent of farmers perceive retaining and mulching residues as increasing the risk of crop loss due to pests. This is likely due to the increased incidence of termites if crop residues are retained in fields. This phenomena has been observed in some experimental station trials, and emerged through some of the ethnographic interviews reported in Bell et al. (2018). At the same time, nearly 60 percent of farmers perceive mulching as lowering their risk of pests. More than 85 percent of farmers perceive that mulching lowers the risk of crop loss due to drought, which is consistent with much of literature about the benefits of residues for soil moisture retention. Nearly 70 percent of farmers perceive that mulching crop residues reduces their risk of waterlogging, though about 11 percent of them perceived an increase in risk of crop-loss due to waterlogging. This could be true for farmlands that have soils rich in clay, which are poor at water infiltration. Similarly Baudron et al. (2012) observed that mulching led to reduced evaporation, increased infiltration and smother weeds on one hand, but also carried weed seeds and pests.

Finally, farmers were asked about their perceived risk of damage due to waterlogging, pests and drought if they practiced intercropping/crop rotation. Due to population pressure, especially in the southern region where this study was conducted, most farmers possess small and sometimes fragmented landholdings and consequently rarely practice crop rotation. Most farmers practice intercropping for household food diversification. Table 4 below summarizes the results.

Table 4: Percentage of farmers who reported expecting higher, lower or no differences in crop damage through waterlogging, pest attacks, and drought due to intercropping

	Intercropping		
Risk perception	**Waterlogging**	**Pests**	**Drought**
Higher	3.91	8.21	4.18
No difference	28.1	22.93	24.08
Lower	67.99	68.86	71.74

Very few farmers perceived an increase in risks of crop loss due to waterlogging and drought as a result of intercropping. However, a few households (about 8%) perceived an increased risk of pest pressures with intercropping. In some situations intercropping is done to introduce crop that will reduce pest population of the main crop. In most cases in Malawi intercropping is done for food diversification to avoid food shortages that result from monocropping when the crop fails. Intercropping is primarily done between cereal and legume crops for food diversification and security. Sometimes the introduced crop may also introduce more and/or new pests for itself or the main crop. At least 68 percent of the farmers perceived lower risk in pest accumulation due to intercropping or crop rotation.

On the overall, table 5 below gives a summary of the overall farmers' risk perception of practicing the three CA technologies. The summarized results show overall perception of risk of waterlogging, pests or drought as a result of practicing zero tillage, mulching and intercropping.

Table 5: Percentage of farmers who reported expecting higher, lower or no differences in crop damage due to practicing zero-tillage, mulching and intercropping.

	Overall level of risk			
Risk perception	**Zero tillage**	**Mulching**	**Intercropping**	
Higher	10.43	8.42	4.02	
No difference	16.3	7.93	16.2	
Lower	73.26	83.64	79.78	

Overall, the vast majority of farmers perceive that components of CA should reduce their exposure to crop losses. This result would probably not be surprising to many agronomists or development practitioners who have been tirelessly promoting CA for many years, since CA is supposed to have benefits to agriculture by improving soil moisture, humus and reducing soil loss due to water runoff. But some researchers have reported negative consequences to farmers from one or more of these CA components due to differences in soil types or other contextual effects (c.f. Giller, 2009). Piccoli et al. (2017) observed soil compaction in silt-rich soils under CA technologies, which was particularly severe in the farm soils dominated by a coarse texture and low organic content. They also reported that even though CA adds more organic content to improve soil structure, it may ultimately take periods longer than five years to attain new soil equilibrium and in turn exploit the benefits that are provided by CA management.

The rationale behind which farmers suggested heightened perceptions of crop loss risk due to CA are worth pursuing through continued analysis, even though the proportions were lower relative to those perceiving risk reductions. We therefore sought to understand the biophysical characteristic of farmers' plots, especially soil type and topography as well as other effects that explained risk perceptions among farmers.

Empirical results

Marginal effects based on the multinomial probit regressions to understand the factors that led farmers to indicate that a particular CA practice increased, lowered, or had no effect on the perceived risks of crop loss are reported in Table 6 below.

We controlled for whether farmers have been practicing CA over the past four years to gauge whether such practices dispels fears of risks associated with CA. Our results are not statistically significant for zero tillage and mulching. However, for intercropping, we find that current and previous intercropping practice by farmers negatively influence lower risk perception of crop loss. Thus, farmers that practiced intercropping in the past four years had about 8 percent reduced probability of viewing intercropping as posing a lower risk to crop loss. We also asked farmers the number of years they have been practicing each of the components of CA to cement our understanding. We find that the number of years of practicing zero tillage significantly decreases the perception of higher risk of damage to crops by 4.3 percent and increases the perception of lower risk of damage to crop loss by about 5 percent. On the other hand, as the number of years of practicing mulching increase the probability of farmers' perception of higher risk of crop loss reduced by about 4 percent and the probability of farmers' perception of lower risk to crop loss decreased by about 4 percent as well. It could be farmers that have years of experience in mulching do not perceive any risk with the practice so there is a reduced sense of higher or lower risk. However, our results were not statistically significant for intercropping implying that farmers do not relate risk in practicing intercropping as it is already a traditional practice among most farmers.

Previous studies have shown that size of plot under cultivation tends to affect farmer adoption of CA (see Ward et al., 2018 and Ngwira et al., 2011). The effect of this variable on farmer perception of CA adoption-related risks is generally contested, however, since the direction of effect is not easily predictable. Ramsey et al. (2016) reported that an increase in area under cultivation may increase or reduce the probability that a farmer perceives CA adoption as risk-increasing compared to practicing conventional farming. Our results show that an acre increase in the plot of area that a farmer cultivates reduces the probability that they perceive zero-tillage as posing a higher risk to crop loss by at least 3 percent. Intuitively, farmers with more land for cultivation might prefer to adopt zero tillage rather than conventional tillage because it reduces the amount of labor required for land preparation. Furthermore, since farmers tend to spread the risk associated with any new technologies farmers with large land holdings may use part of the land to practice zero-tillage and the rest for conventional tillage. Similar result was observed when farmers considered practicing mulching. An increase in landholdings reduced the probability of farmer perception of mulching as a higher risk to crop loss by 3 percent and increased the probability of lower risk to crop loss by 2 percent. These results are consistent with Ward et al. (2016), who found that farmers with larger plots have a higher likelihood of adopting zero tillage, and a lower likelihood of intercropping. On the other hand, the results show that as the number of plots owned by farmers increased the probability of farmers' perception of lower risk to crop loss due to zero tillage increased.

Table 6: Marginal effects summarizing mprobit results: Determinants of farmer risk perception about adoption of zero tillage, mulching, and intercropping/crop rotation

	Zero tillage risk			Mulching risk			Intercropping risk		
VARIABLES	Higher risk	Lower risk	No difference	Higher risk	Lower risk	No difference	Higher risk	Lower risk	No difference
Practiced zero till	0.0218	0.0183	-0.04						
	(-0.0193)	(-0.0268)	(-0.0324)						
Practiced mulching				0.00614	0.0232	-0.0293			
				(-0.0168)	(-0.0177)	(-0.0265)			
Practiced intercropping							0.00704	-0.0765*	0.0695
							(-0.0163)	(-0.0457)	(-0.0466)
Years zero tilling	-0.0432***	0.053***	0.0967***						
	(-0.0163)	(-0.0166)	(-0.0229)						
Years mulching				-0.0389***	-0.0354***	0.0744***			
				(-0.0145)	(-0.0128)	(-0.0184)			
Years intercropping							0.00413	0.0147	-0.0188
							(-0.0057)	(-0.0119)	(-0.0117)
Area under cultivation	-0.0374**	0.00481	0.0326	-0.0254*	0.0203*	0.00514	-0.0026	0.00049	0.00211
	(-0.0166)	(-0.0265)	(-0.028)	(-0.0141)	(-0.0114)	(-0.0171)	(-0.0065)	(-0.0191)	(-0.0199)
# of plots managed	-0.00973	0.0362***	-0.0265*	-0.00713	-0.000342	0.00748	-0.0038	0.0023	0.00153
	(-0.0106)	(-0.0129)	(-0.014)	(-0.0114)	(-0.0122)	(-0.0154)	(-0.0065)	(-0.0166)	(-0.0171)
Soil type									
Loam	0.0204	0.0325	-0.0529	0.0655***	-0.00934	-0.0561*	-0.0041	0.0289	-0.0248
	(-0.0281)	(-0.0309)	(-0.0347)	(-0.0207)	(-0.0258)	(-0.0311)	(-0.0182)	(-0.0335)	(-0.0375)
Clay	-0.00121	0.0322	-0.031	0.0334	-0.00352	-0.0298	-0.016	0.00045	0.0155
	(-0.0339)	(-0.0363)	(-0.0493)	(-0.0222)	(-0.0313)	(-0.0356)	(-0.0187)	(-0.037)	(-0.0389)
Other soil types	-0.0291	-0.0308	0.06	-0.0238	0.0172	0.00664	0.00099	-0.0275	0.0265
	(-0.0413)	(-0.0571)	(-0.0678)	(-0.0248)	(-0.0485)	(-0.0543)	(-0.0311)	(-0.0566)	(-0.0653)
Soil quality									
Fair	0.0339*	0.00461	-0.0385	0.000103	0.0289	-0.029	-0.002	-0.0419*	0.0439*
	(-0.0201)	(-0.0227)	(-0.0286)	(-0.0209)	(-0.0178)	(-0.0237)	(-0.0133)	(-0.024)	(-0.0253)
Poor	0.0791**	-0.0438	-0.0353	-0.00602	-0.011	0.017	-0.0008	-0.0085	0.00926

	(-0.033)	(-0.0319)	(-0.0453)	(-0.0316)	(-0.0197)	(-0.0354)	(-0.0175)	(-0.0405)	(-0.0418)
# of ZT neighbors	-0.00175	-0.00285	0.0046						
	(-0.00833)	(-0.00923)	(-0.0156)						
# of HH mulching				-0.000779**	-0.000307	0.00109***			
				(-0.000319)	(-0.000374)	(-0.000403)			
# of HH intercropping							-0.0364	-0.0241	0.0605
							(-0.0384)	(-0.106)	(-0.115)
Treatment village	-0.0417	-0.0139	0.0555	-0.0323	0.0372*	-0.00489	0.00702	0.0178	-0.0248
	(-0.0254)	(-0.0312)	(-0.042)	(-0.0256)	(-0.0196)	(-0.0259)	(-0.0125)	(-0.029)	(-0.0272)
Accessed CA extension	0.0085	-0.0460*	0.0375	0.00177	-0.0297	0.0279	0.00313	-0.0620***	0.0588**
	(-0.0186)	(-0.0257)	(-0.0299)	(-0.0205)	(-0.0183)	(-0.0248)	(-0.011)	(-0.0238)	(-0.0246)
Education of HH head									
Primary complete	0.0696**	-0.00342	-0.0661	-0.0324	-0.0159	0.0483	-0.0029	-0.0255	0.0284
	(-0.0333)	(-0.0327)	(-0.0439)	(-0.0214)	(-0.0235)	(-0.0313)	(-0.0149)	(-0.0358)	(-0.038)
Secondary complete	-0.00286	0.0148	-0.0119	-0.0288	-0.0215	0.0504	0.0349	0.022	-0.0569
	(-0.0342)	(-0.0432)	(-0.0541)	(-0.0269)	(-0.0237)	(-0.0354)	(-0.0261)	(-0.0362)	(-0.0452)
Other college training	0.00756	-0.161***	0.154	0.0618	-0.0864***	0.0246	-0.0316***	0.117	-0.0849
	(-0.0966)	(-0.0174)	(-0.1)	(-0.11)	(-0.0147)	(-0.112)	(-0.0066)	(-0.144)	(-0.143)
Graduate, incomplete	-0.102***	-0.161***	0.263***	-0.0935***	-0.0864***	0.180***	-0.0316***	-0.147***	0.178***
	(-0.0112)	(-0.0203)	(-0.0197)	(-0.0117)	(-0.0122)	(-0.0153)	(-0.0066)	(-0.0142)	(-0.0133)
head_sex	-0.00534	0.0567	-0.0513	-0.00912	0.00868	0.00044	-0.0167	-0.0094	0.026
	(-0.0219)	(-0.0374)	(-0.0415)	(-0.0213)	(-0.0189)	(-0.0277)	(-0.0122)	(-0.0254)	(-0.0283)
head_age	0.000184	0.000098	-0.0000854	-0.000297	-0.000295	0.000593	0.000644*	0.00051	-0.0012
	(-0.00065)	(-0.000726)	(-0.000966)	(-0.000711)	(-0.000721)	(-0.000962)	(-0.0003)	(-0.0009)	(-0.001)
Observations	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125	1,125

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Ward et al (2016) have shown that the type of soil on which farmers grow their crops influences the decision to adopt zero tillage. We hypothesized that the soil type also affects the degree to which the farmer perceives CA practices as being risky. We observed an increase in the probability of farmer perception of a higher risk of crop loss due to mulching by about 7 percent when the soils on their land were loam relative to sandy soils. This may be due to the high possibility of waterlogging in loamy soils relative to sandy soils. We expected a similar result for clay soils but the result was not significant though it had the right sign. Furthermore, the results show an increase in the probability that farmers perceived a higher risk of crop damage under zero tillage if they have poor or fair quality soils compared to good quality soils. While these characterizations may be idiosyncratic and subjective, qualitatively this result makes intuitive sense given that lower quality soils require better soil management, which may include incorporation of organic matter into the soil, hence some soil disturbance (e.g., through a disc or through more disruptive tillage).

Ramsey et al (2016) have reported that the successes and failures of neighbouring farmers who practice CA may affect the extent to which a farmer might find adoption of CA to be risky. In this study, we hypothesized that an increase in the number of neighbours practicing various CA practices would signal to a farmer that CA practices were not risky, thus making them perceive adoption of the practices as being risk-reducing. Except for the weak statistically significant effect of number of neighbouring farmers that are mulching on perception of risk of crop loss due to mulching, though the signs were correct we did not observe significant effect of neighbouring farmers practicing zero tillage and intercropping. We observed a decrease in the probability of farmer' perception of higher risk to crop loss due to mulching if the number of neighbours practicing mulching increases. These results seem to suggest that farmers are very observant of their neighbors' farming techniques and outcomes such that taking advantage of this peer-learning behavior would help improve CA adoption. Similar results on peer effects in adoption of CA were reported by Bell et al. (2018), Fisher et al. (2018) and Holden et al. (2018).

We controlled for whether a household is in a treatment village or control village and compared their perceptions of risks. Farmers that adopted CA in treatment villages received incentives and those that encouraged peers to adopt CA received additional incentives. We hypothesized the treatment would dispel risks associated the zero tillage, mulching and intercropping. Most of the results were not statistically significant. We, however, observed that farmers in treatment villages had an increased probability of lower risk perception due to mulching. We found that access to extension services has a positive influence on dispelling the perceive risk resulting from practicing zero tillage and intercropping/crop rotation. There is need for intensive training to farmers on the benefits of CA.

Furthermore, we found consistent results from education variables with household heads that completed primary education having a high perceived risk from zero. Nevertheless, household heads who completed other college training perceived a reduction in lower risk of damage from zero tillage and mulching, and perceived a reduced higher risk of crop loss due to intercropping. Similar observation were made with household heads that did some graduate training though did not complete. There was a decrease in the probability of their perception of crop loss due to practicing zero tillage, mulching and intercropping. These results underscore the importance of education level on farmer understanding of the benefits of CA practices and risk associated with crop loss, increased crop yield and improved soil health. Gender of household head was not statistically significant in explaining farmers' perception of risk associated with adoption of CA. On the other hand, increased in age was associated with increased perception of higher risk with practice of intercropping.

Conclusion and Policy Recommendation

We find strong evidence suggesting that, much as the decision to adopt CA practices are interdependent as reported in previous research, the adoption decision of CA components is strongly influenced by the risk perception that farmers have on the different CA practices, partly due to biophysical characteristics of the soils in the different villages under the project. Adoption studies of CA and other land management technologies that fail to include agro-ecological factors in analysis but only include socio-economic factors may provide incorrect policy advice. We also find that peer influence may be effective in promoting contiguous pieces of land (agglomeration) under CA. Furthermore, we find that past experience in the CA practices, education and extension service provision play critical roles in reducing the perceived risk of crop damage arising from adoption of zero tillage, mulching and intercropping/crop rotation. The findings in this study regarding farmers' perception of risk differ with the different CA components. These suggests that instead of presenting CA as a package of zero tillage, mulching and intercropping, farmers should have the flexibility of adopting the practices in any combination depending on their farming environment as long as they still achieve the goal of improving crop yields while at the same time improving soil health with respect to farmers' soil biophysical characteristics.

References

Baudron F, Tittonell P, Corbeels M, Letourmy P & Giller KE, 2012. Comparative performance of CA and current smallholder farming practices in semi-arid Zimbabwe. Field Crops Research 132: 117-128.

Bell AR, Cheek JZ, Mataya F & Ward PS, 2018. Do as the did: Peer effects explain adoption of CA in Malawi. Water 10, 51; doi:10.3390/w10010051.

Branca G, McCarthy N, Lipper L, & Jolejole MC, 2011. Climate Smart Agriclture: A synthesis of empirical evidence of food security and mitigation benefits from improved cropland management. Working paper series 3, Mitigation of Climate Change in Agriculture (MICCA) Programme, FAO, Rome.

Cavatassi R, Lipper L & Narloch U, 2011. Modern variety adoption and risk management in drought prone areas: insights from the sorghum farmers of eastern Ethiopia. Agricultural Economics 42: 279-292.

Corbeels M, de Graaff J, Ndah HT, Penot E, Baudron F, Naudin K, Andrieu N, Chirat G, Schuler J, Nyagumbo I, Rusinamhodzi L, Traore K, Mzoba HD & Adolwa IS, 2014. Understanding the impact and adoption of CA inAfrica: A multi-scale analysis. Agriculture, Ecosystems and Environment 187: 155-170.

Ghadim AK & Pannell DJ, 1999. A conceptual framework of adoption of an agricultural innovation. Agricultural Economics 21: 145-154.

Giller KE, Witter E, Corbeels M & Tittonell P, 2009. CA and smallholder farming in Africa: The heretics' view. Field Crops Research 114: 23–34.

Greiner R, Patterson L & Miller O, 2009. Motivations, risk perceptions and adoption of conservation practices by farmers. Agricultural Systems 99: 86-104.

Just RE & Pope RD, 1978. Stochastic specification of production functions and economic implications. Journal of Econometrics 7(1): 67-86.

Kellstedt PM, Zahran S & Vedlitz A, 2008. Personal Efficacy, the Information Environment, and Attitudes Toward GlobalWarming and Climate Change in the United States. Risk Analysis, 28(1): 113-126. doi:10.1111/j.1539-6924.2008.01010.x

Knowler D, & Bradshaw B, 2007. Farmer's adoption of CA: a review and synthesis of recent research. Food Policy 32: 25-48.

Kuehne G, Llewellyn R, Pannell DJ, Wilkinson R, Dolling P, Ouzman J & Ewing M, 2017. Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. Agricultural Systems 156: 115-125.

Lalani B & Wauters E, 2016. Smallholder farmers' motivation for using cnservation agriculture and roles of yield, labour and soil fertility in decision making. Agricultural Systems 146: 80-90.

Ngwira A, Johnsen FH, Aune JB, Mekuria M & Thierfelder C, 2014. Adoption and extent of CA practices among smallholder farmers in Malawi. Journal of Soil and Water Conservation, 69(2): 107-119.

Ngwira AR, Thierfelder C, Eash N & Lambert DM, 2013. Risk and maize-based cropping systems for smallholder Malawi farmers using CA technologies. Experimental Agriculture 49(4): 483-503.

O'Connor RE, Bord RJ & Fisher A, 1999. Risk Perceptions, General Environmental Beliefs, and Willingness to Address Climate Change. Risk Analysis, 19(3): 461-471.

Pannell DJ, Llewellyn RS & Corbeels M 2014. The farm-level economics of CA for resource-poor farmers. Agriculture, Ecosystems and Environment, 187(1): 52-64.

Pedzisa T, Rugube L, Winter-Nelson A, Baylis K & Mazvimavi K, 2015. Abandonment of CA by smallholder farmers in Zimbabwe. Journal of Sustainable Development 8(1): 69-82.

Piccoli I, Schjønning P, Lamandé M, Furlan L & Morari F, 2017. Challenges of CA practices on silty soils. Effects on soil pore and gas transport characteristics in North-eastern Italy. Soil & Tillage Research 172: 12-21.

Pittelkow CM, Liang X, Linquist BA, Jan van Groenigen K, Lee J, Lundy ME, van Gestel N, Six J, Venterea RT & van Kessel C, 2014. Productivity limits and potentials of the principles of CA. Nature 517: 365-368.

Ramsey SM, Bergtold JS, Canales E & Williams JR, 2016. Farmers' Risk Perceptions of Intensified Conservation Practices On-Farm. Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, July 31-August 2, Massachusetts, Boston, USA.

Sattler C & Nagel UJ, 2010. Factors affecting farmers' acceptance of conservation measures—A case study from north-eastern Germany. Land Use Policy 27: 70–77.

Shively GE, 2001. Poverty, consumption risk, and soil conservation. Journal of Development Economics 65 (2): 267-290.

van der Linden S, 2015. The social-psychological determinants of climate change and risk perceptions: Towards a comprehensive model. Journal of Environmental Psychology 41: 112-124.

Ward P, Bell AR, Droppelmann K & Benton TG, 2018. Early adoption of CA practices: Understanding partial compliance in programs with multiple adoption decisions. Land Use Policy 70: 27-37.

Ward P, Bell AR, Parkhurst GM, Droppelmann K & Mapemba L, 2016. Heterogenous preferences and the effects of incentives in promoting conservatin agriculture in Malawi. Agriculture, Ecosystems and Environment 222: 67-79.