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EVALUATING THE POTENTIAL FOR IMPROVED AND SUSTAINABLE ADOPTION OF CONSERVATION AGRICULTURE IN NORTHERN NAMIBIA

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ABSTRACT

The study evaluated the potential for improved and sustainable adoption of conservation agriculture in five regions in Namibia namely, Omusati, Kunene, Oshikoto, Ohangwena, and Oshana. Conventional system of farming involves, monoculture and deep soil tillage with ox-drawn ploughs with limited mechanisation. These practices are unproductive and unsustainable given increased uncertainty due to climate change.Therefore, conservation agriculture was introduced in the regions through the Food and Agricultural Organisation's (FAO) assisted programme. The aim of the programme was to lower vulnerability by increasing the resilience of the smallholder farmers in the selected regions to adapt to climate change risks through the implementation of Conservation Agriculture (CA) and other complementary Good Agricultural Practices (GAPs).

The hypothesis is that increased CA knowledge would enhance improved outcomes. An empirical estimation of the relationship between the farmers learned CA skills, and the level of CA outcome was carried out using econometrics method. One hundred and forty-four farmers were sampled from the selected regions. The result indicates that additional CA knowledge may result in farmers' improving their General Agricultural Practices. In order words, farmers are more likely to improve weeding than

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not, the area planted is more likely to increase than decrease and fertilizer application is more likely to increase significantly than not. There is an increase in the ordered log-odds of moving from a lower to a higher outcome level. For instance, a one-unit increase in the farmers' CA knowledge will result in 0.05 unit increase in ordered log-odds of being in the higher category for the ‘area planted’ outcome variable while the other variables in the model are held constant. The same relationship applies to other outcome variables for farmers' improved knowledge. In addition, the sustainability of the CA project was investigated. Using a probit probability choice model, it was found that CA adoption will increase in the future in these regions. The result shows that farmers are willing to adopt CA and continue practising it on the condition that benefits such as increased yield, training and household consumption are guaranteed. This is because, increased yield, training and household consumption increased the probability that farmers will continue CA adoption.

Keyword: Conservation agriculture; Good agricultural practice; Adoption; Drought; Willingness; Minimal tillage; Soil fertility

Introduction

Since Namibia's independence in 1990, managing and conserving the natural resource stock such as the agricultural land is a priority. This is because agriculture provides stimuli for economic growth and development due to the multiplier effects. In Namibia, agriculture significantly contributes to the Gross Domestic Product (GDP) and is a significant source of employment, especially in the rural economy that constitutes about 70% of the population. According to the Labour Force Participation Survey in 2018, Agriculture, Forestry and Fishing together employed twenty-three per cent of the workforce more than any other sector. At the 2018 prices, the sectors contributed twelve per cent to the GDP; agriculture alone contributed 4.6 per cent – this is the justification for the prioritization of agricultural transformation in the Namibian vision 2030.

Since most Namibians live in rural areas, rural agricultural transformation is important. Namibia has a population size of 2.3 million (Namibia Statistics Agency (NSA), 2016). About forty-eight per cent are urban dwellers. In the year 2016, rural dwellers were fifty-two per cent of the population compared to seventy-two per cent in 1991 (NSA, 2016). Population projections show that from the year 2015 to 2030, the Namibian population would grow from 2.28 million to 2.96 million – a thirty per cent increase (NSA, 2014). According to the regional population estimate in Table 1, more people are located in the Northern region of Namibia comprising: Omusati, Oshana, Ohangwena, Oshikoto, Kavango East, Kavango West, and the Zambezi. With the projected increase in population, the rural dwellers might be under pressure to migrate to the urban areas. Estimates show that during the years 1991 to 2016, the rural composition of Namibia decreased by twenty per cent due to migration (NSA, 2015, 2016). More migration pressure is, however, expected from the regions with a high rural population such as Kavango West, Ohangwena, Omusati, Oshikoto and Kunene (Table 1). According to the poverty estimate in Table 1, these regions are amongst those with the highest poverty rate in the country, with Zambezi, Kavango, and Oshikoto leading the rest (NSA, 2012). Significant push factors to urbanization amongst others include; the low landholding capacity of rural dwellers and the decline in the agricultural production. Other factors include poverty, drought, and the limited capacity for mechanization. Landholding and its deprivation have root in Namibia's colonial history and has a significant influence in her agricultural characterization.

Due to historical delineation, Namibia has a dual agricultural landscape comprising the well-resourced and highly mechanized commercial agrarian sector with more substantial landholding and the communal subsistence farmers that farm on marginal land. According to NSA (2018), freehold (commercial) land constitutes fourthy-two per cent of land ownership; customary land ownership is thirty-five per cent, state land is twenty-three per cent. There are 39.7 million hectares of freehold agricultural land, out of this, previously advantaged commercial farmers own 27.9 hectares (Seventy per cent) whereas, previously disadvantaged farmers own 6.4 million hectares (Sixteen per cent), government (state) owns 5.4 million hectares (Fourteen per cent) (NSA, 2018). Due to the limited land holding capacity and lack of mechanization by rural farms, subsistence agriculture is the dominant practice in Northern Namibia. Subsistence implies that extensive agriculture exists on a marginal piece of land whereby, either, more crop production is on the same piece of land (inter-cropping), or the cultivation of one type of crop in succession on one piece of land (monocropping) every planting season. Subsistence farming is, however, predominant in Ohangwena (Sixty per cent), Omusati (Fifty-nine), Kavango West (Fifty-seven per cent) and Oshikoto (Fourthy-two per cent) (See table 1). This type of practice adversely affects soil functions such as primary soil productivity (resulting in low yield); carbon sequestration (resulting in the loss of organic carbon); nutrient cycling (resulting in the loss of soil minerals); water regulation (resulting in the lack of soil moisture retention); and biodiversity (resulting in the loss of biodiversity) (Ghaley, Rusu, Sandén, Spiegel, Menta, Visioli, Sullivan, Gattin, Delgado, Liebig, Vrebos, Szegi, Michéli, Cacovean & Henriksen, 2018). However, changing climatic patterns accompanied by the low and variable rainfall, and the lack of adequate capacity to cope with climate-related risk by the farmers in an arid country such as Namibia with the bizarre climatic record exacerbates these conditions. During the years 2008, 2009 and 2011, extreme floods destroyed crops, livestock, and properties in the low-lying flood-prone regions such as Kavango, Omusati, Oshana, Ohangwena and Zambezi (Ministry of Regional and Local Government, Housing and Rural Development (MRLG, HRD), 2011). The flood was due to the high inflows in the Cuvelai basin, Kwando, Kavango and Zambezi Rivers due to the above-normal rainfall in the neighbouring countries, Angola and Zambia, which flow inland across low-lying flood plains (MRLG, HRD, 2011). Unlike floods, drought event is more rampant. The report by Kerdiles, Rembold, & Pérez-hoyos (2015) shows that 1994 to 1995, 2012 to 2013 and 2014 to 2015 agricultural seasons were the driest in recent years in Namibia. The years 2012 to 2013 and 1994 to 1995 were affected by severe drought with minimal accumulated national rainfall of 150 mm less than the catchment area average of 225 mm. According to the report, December 2014 to February 2015 period were ranked as the 2nd driest after 1995 for the Northern regions and the 4th driest for all other regions for the past 27 years (Kerdiles et al., 2015). Currently, the 2018 to 2019 season was recorded as one of the worst drought-stricken years with average national rainfall of 48 mm up to April 2019 (Namibian Meteorological Service (NMS), 2019). Consequently, there is a limiting constraint on agricultural production, albeit, inefficient, resource exhausting, and unproductive traditional farming practices in rural areas.

In the wake of these prevailing circumstances, it is appropriate to adopt a strategy to cushion the effects of adverse climatic events and find an alternative to enhance agricultural productivity. An alternative to the conventional farming practices that result in higher output per unit of input while maintaining soil structure in the presence of climatic uncertainty is Conservation Agriculture (CA) farming system. Theoretically, there are three major CA principles, a) minimal mechanical soil disturbance, b) the maintenance of permanent soil organic cover, and c) the diversification of crop species (Food and Agriculture Organisation of the United Nation (FAO), 2017). The CA enhances biodiversity thus the natural biological processes such soil aeration, microbial balance, and soil moisture retention are maintained leading to improved soil fertility, soil use efficiency and crop production (FAO, 2017). However, there is a general lack of knowledge of Conservation Agriculture (CA), the essential Resource Saving Technologies (RST) and the Good Agricultural Practices (GAP) amongst the rural farmers. These farming practices and related ecological approaches are vital in the rain-fed cropping systems of Namibia to manage the effects of land degradation and to increase the resilience of farmers to adapt to climate change variability while ensuring food security and sustainability. Managing the risks of extreme events and disasters to climate change is in recent past a world order (Inter-Governmental Panel on Climate Change (IPCC), 2012). Because the consequences of an extreme climate phenomenon have an enormous implication on food security; thus, a threat to sustainable livelihood amongst high vulnerable countries such as Namibia. To mitigate extreme climatic events, strategic steps were taken to implement a climate-smart Conservation Agriculture (CA) amongst the most susceptible rural smallholder farming communities. In pursuit of this objective, a Comprehensive Conservation Agriculture Programme (CCAP) was launched by the Ministry of Agriculture, Water and Forestry (MAWF).

Consequently, a mitigation action plan project was initiated in the year 2015 in the North Central regions of Namibia, namely, Omusati, Kunene, Zambezi, Oshikoto, Ohangwena, Oshana, Kavango East and West. The project was titled**:** **'***Strengthening the capacity of farmers to manage climate-related risks in Northern Namibia'.* The action plan aimed at lowering vulnerability by increasing the resilience of the smallholder farmers in the selected regions to adapt to climate change risks through the implementation of CA and other complementary Good Agricultural Practices (GAPs). The project ended on the 31st of August 2018.

The objective of this paper is to evaluate the potential for improved and sustainable Conservation Agricultural practices in the selected regions. In other words, the research sought to assess the strength of the cognitive knowledge of CA principles impacted on the farmers chosen during the programme, the ability to translate learned skills to a profitable outcome and the sustainability of the CA farming exercise.

Table 1. Namibian regional profile

Region	**Pop size**	**Total Agri HHs**	**Agri Land-holdings - Crop only**	**HHs not using improved seeds**	**Pop in Urban**	**Pop in rural**	**Poverty by region**	**Subsistence farming**
Year	(2016)	(2014)	(2014)	(2014)	(2016)	(2016)	(2010)	(2018)
Unit	(Number)	(Number)	(%)	(%)	(%)	(%)	(%)	(%)
//Karas	85759	4045	0.1	0.00	61	39	26.9	0.5
Erongo	182402	3704	0.0	0.01	92	8	7.1	0.3
Hardap	87186	1234	0.0	0.00	72	28	26	2.4
Kavango East	148466	59404	21.0	7.74	57	43	55.2	21.5
Kavango West	89313	67123	7.8	8.57	12	88		57.1
Khomas	415780	259	0.0	0.00	95	5	10.7	0.3
Kunene	97865	23639	6.6	1.41	32	68	30.2	13.1
Ohangwena	255510	216984	13.9	19.61	6	94	30.1	60.6
Omaheke	74629	8352	0.1	0.34	42	58	31.1	7.2
Omusati	249885	243619	19.4	27.92	5	95	19.1	58.8
Oshana	189237	97214	17.2	11.26	46	54	19.4	18.9
Oshikoto	195165	131632	6.5	17.03	16	84	44.2	42.1
Otjozondjupa	154342	14263	1.4	0.57	66	34	33.7	2.6
Zambezi	98849	36243	5.9	5.54	29	71	50.2	9.7

Source: Namibian Statistical Agency (NSA) (2010, 2014, 2016, 2018). HHs stands for Households.

Constraints amongst communal farmers

Theoretically, CA implies a mechanism to conserve, improve and sustain natural resources such as soil, water, biodiversity e.t.c. Under CA, the assumption is that the soil functions are restored or maintained, and agricultural production optimized while preserving the environmental system and biodiversity (Dumanski, Terry, Byerlee & Pieri, 1998). In practice, there is more observed complexity in understanding CA than theorized. However, there are great varieties of methods underpinning the concern that perhaps CA is location-specific (FAO, 2018) or scale-sensitive. Typical scenarios may suffice to explain this. Notably, there are differences in agroecological zones, namely; arid, semi-arid, tropical and temperate rain forest zones, that may result in different CA outcomes. For instance, in the dry Savana grassland ecosystem (Eg Namibia), grass mulches are usually unavailable, and the use of crop residue mulch compete with the animal feed alternative (Marongwe, Nyagumbo, Kwazira, Kassam, & Friedrich, 2012). In such an environment, CA practice has a high opportunity cost to the farmers (Marongwe et al., 2012).

Under CA practices, there is a tendency for the existence of scale-efficiency-productivity nexus. The scale of the CA operation may depend on the level of mechanization. For instance, seed application amongst communal farmers is in basins with a hand-held tool, and residue mulch is applied per basin with basal or top-dressed fertilizer to provide a localized effect. It could be made on no-till soil with a Dibble stick, a Jab planter, a direct seeder, and fertilizer distributor, a tractor-drawn seeder and fertilizer applicator or a controlled traffic disc-seeder with satellite guidance (Giller et al., 2015). Thus, different application methods have different scales, efficiency and productivity implications.

Furthermore, the differences in the labour requirement across regions and farms increase farm cost and reduced impact (FAO, 2018; Giller et al., 2015). Under CA, weeding is expected to be more frequent because of the rapid emergence of weeds. In this instance, manual weeding (common amongst rural farmers) is less efficient but more likely to be cost-effective than a cocktail of post-emergence herbicide administered under CA. Besides, post-emergence herbicide application is a risky exercise and requires trained personnel to manage. Herbicide poisoning or the emergence of herbicide-resistant strain may occur if the herbicide is incorrectly administered. Training is given under the CCAP programme in Namibia by the Agricultural specialist from DAWF who are seldom in sufficient number.

Other CA activities include crop rotation, intercropping with cereal crop residue, and intercropping with legumes residue (Thierfelder et al., 2012). Limited Landholding capacity in the previously disadvantaged regions of most African Countries is a significant constraint to crop rotation and intercropping (Gilbert, 2012; Lai, Chan, Halbrendf, Sharig, Roul, Idol, Ray, & Evensen, 2012). This is because most rural farmers cultivate on backyard gardens or communal lands with no capacity to expand. As a result, commercial farms have a better opportunity to increase yield under CA than smallholder farms. However, the recommended legume plants such as Lablab, Cowpea, Pigeonpea, Velvet beans, and common beans do not perform well in most areas (Gilbert, 2012); as a result, there is no large-scale use of these legume intercrops in the common CA practice.

Fundamentally, CA principles are widely accepted (Kassam, 2014). Nevertheless, it is seemingly more than just a simple practice of one or more of the principles, but an inter-related supposedly integrated activities with outcomes realized over periods of sustainable intensification (Dumanski, Terry, Byerlee & Pieri, 1998; Hobbs, Sayre, & Gupta, 2008; Tilman, Balzer, Hill, & Befort, 2011; Marongwe et al., 2012; Kassam, 2014; Vanlauwe et al., 2014). Despite the challenges in CA practice, there is evidence in the literature to support its comparative usefulness. Ghaley et al. (2018) found that CA has positive effects on yield compared to conventional Agriculture. Using Data Envelopment Analysis (DEA), Chan et al. (2017) found that CA improved yield by 60% to 70% in India. Thierfelder et al. (2012) studied crop rotation and intercropping with cereals and legumes in Zimbabwe and found that there is an increase in water filtration and more significant soil carbon sequestration in CA fields than on the adjacent conventional ploughed field. Similar positive results of field trial were obtained with CA by Kabirigi et al. (2015) in Rwanda. Also, Kabirigi et al.

(2015) found that CA benefits vary with rainfall intensity. High rainfall areas had low yield and soil fertility decline due to erosion. Nkala (2012) found that there is a slight improvement in livelihood and crop productivity amongst CA smallholder farmers in Mozambique. The marginal increase relates to a lack of the necessary farm implements, social incentives, and institutional support. These amongst other constraints are overarching across smallholder resource-poor farmers in the developing countries such as Namibia.

Materials and methods

The project evaluation used a survey of the farmers in the selected regions. This section describes the survey process and the econometrics method of data analysis.

Sample and sampling

A survey was conducted in five regions, Omusati, Oshana, Ohangwena, Oshikoto, and Kunene. In these regions, average annual rainfall ranges from 350 -700 mm. The average maximum temperature is usually above 30°C in the summer. The soil structure is predominantly sandy with low water retention capability. The regions are highly dependent on crop farming; the main crops grown are maize and Pearl Millet. As discussed earlier, the vulnerability of these regions to extreme climate events makes them a key target for the CA project.

According to the second progress report of the Namibian FAO funded CA project, approximately 45 000 small-scale farmers benefited from the information dissemination outreach carried out through radio messages, SMS text messages, bulletins, fliers e.t.c. About 5000 farmers benefited through extension services, and farmers field demonstration days conducted by the extension officers from MAWF, Private sector and Non-Governmental Organizations'. Therefore, 2000 was the sampling frame for the present evaluation study. The sample size was determined using the formula:

$$S = N / (1 + N(e) \wedge 2)$$

where, S is the sample size, N is the population size, and e is the level of precision or accuracy of estimating the actual population value. A sample of 333 was calculated using the error margin of 5 per cent; however, only one hundred and forty-four responses were received. The sample was drawn from the list of farmers who participated in the project using a simple random sampling technique. The number of respondents differs per region because the number of participating farmers per region differs. Besides, the resource to reach many farmers that lives deep in the remote hinterland was limited. As a result, twenty-seven farmers were sampled in Kunene, twenty-one in Ohangwena, thirty in Omusati, seventeen in Oshana and forty-nine in Oshikoto. The study also conducted a Focussed Group Discussion (FGD) in all the regions.

Data

Data was collected using structured closed and open-ended questionnaires. Agricultural technical officers from the MAWF were used as enumerators. The collected data includes: a) farmers demographics – age, gender, experience, type of farmer (Whether a Lead, Follower or a Cluster farmer), region and constituency of the farmer, b) Conservation agriculture – data includes awareness of CA and its core principles including the GAPs, c) Information dissemination - the frequency and the source of information, d) Farmer association (CA forum), e) Input availability and use, f) general agricultural practices (Weeding, mulching, intercropping, seeding, etc), g) Credit facilities - whether a farmer has a loan or not, h) Challenges and opportunities, i) yield and yield per centage change, j) residue mulch and type of mulch used, k) training and extension service, and l) government support. The FGD centred on: CA knowledge and its core principles; benefits; effectiveness; efficiency; and sustainability. Farmers' satisfaction with the implementation strategy of CA in their region was discussed. Farmers expressed their concern about the constraints and challenges and suggested the way forward.

Econometrics analysis

Evaluating the potential of CA knowledge

This section discusses the empirical estimation of the relationship between the farmers learned CA skills, and the level of CA outcome achieved. The CA outcome variables are the practices that underlie the entire CA exercise. These are, the *area planted*, *weeding rate*, *fertilizer application*, *herbicide application*, *seed application*, *crop rotation*, *inter-cropping*, and *mulch application*. Presumably, with adequate orientation on CA principles *ceteris paribus,* the level of the outcome variables should be optimized. The implication is that the area planted is expected to increase than not, the weeding rate, fertilizer application and other practices are expected to improve significantly than not. Therefore, the outcome variable, the *area planted* was categorized as *'not increased', 'slightly increased'* and *'greatly increased*'. The categories for the other outcome variable are '*not improved', 'slightly improved'* and '*greatly improved'.* Given the categorization of the outcome variables in the questionnaire, farmers reported the order in which they achieved them. Following the farmer's representation of their knowledge of CA, seven categorical predictors were constructed, these include *moisture retention, erosion control, improved yield, minimal-tillage, soil fertility, soil conservation*, and *do-no-know*. The variable *"do-not-know"* represent a total lack of understanding or misrepresentation of what CA stands for. Each variable takes the value of 1 if it occurs in the bundle of representations given by a farmer; otherwise, zero. The aim is to determine the relationship between the CA practices (outcome variable) and the underlying knowledge of CA (predictors).

Following the categorization, the outcome variables were ordered from low to high. The assumption is that the ordinality is a crude measurement of an underlying interval or ratio scale. Two sets of crude measurements were made. First, the categories '*not increased','slightly increased'* and '*greatly increased*' are assumed to be a measure of land utilization represented by the outcome variable, the '*area planted'. S*econd, the categories *'not improved', 'slightly improved'* and *'greatly improved'* measure '*weeding rate'* and other outcome variables. A shortfall in modelling an ordered outcome is that the distance between adjacent categories is unknown, and not everything about the ordinality is observed. An ordinal scale is modelled as though it represents a latent unobserved interval or ratio scale. The aim is to model the unobserved latent scale of the outcome without requiring that the outcome categories are equidistant (proportional) from each other[1]. An Ordinary Least Square (OLS) estimator cannot be applied to model ordinal relationship. Ordered logit or probit models are appropriate because the equidistant assumption is circumvented (Long and Freese, 2001). Logit or probit models are commonly used approach because they are symmetric around zero though they have different probability distribution assumptions. The ordered probit model assumes normal cumulative distribution function (CDF) whereas; the ordered logit model assumes logistic CDF.

Evaluating the sustainability of CA adoption

In addition to investigating the relationship between CA knowledge and its practices, the study also investigated whether the hypothesized relationship is sustainable. If the farmer's experience with CA is laudable, then their willingness to continue its adoption in the future will be high. Therefore, the willingness to continue CA adoption is a function of many factors. Recall that the primary aim of the CA project is to increase the capacity of the farmers to generate income from the cultivation of available marginal land in the presence of climatic uncertainty. Farmers ought to generate revenue through the sale of marketable produce; therefore; an increased marketable yield per unit of input used would provide a v-

[1] This condition is known as the proportional odds assumption, which states that the odds of observing one outcome to another must be proportion. This assumption is tested prior to the estimation of ordered logit to determine the adequacy of the ordinal regression.

alid incentive to continue CA practice.

On the other hand, the *availability* of food due to surplus production increases food security. Government *support, training* and *mentorship* programmes through *extension services* provides the necessary stimuli for decision making among farming communities in the rural communities. The *peer-to-peer* farmer-driven organizational structure described prior is an enabling strategy that leaves the farmers with the responsibility of sharing skills and passing on experiences to their peers. The expertise gained or skills acquired during the CA exercise is a heritage that farmers will pass on to their wards. The assumption is that the on-farm and off-farm experiences contribute to increasing the farmer's willingness to adopt CA in the future. Therefore, it was hypothesized that willingness to continue CA practice in the future could be predicted by farmer productivity (Yield), government support system, training, extension services, and availability of inputs. Willingness is a categorical variable representing one for the choice to adopt CA in future, zero otherwise. A probit model was used to analyze the hypothesized relationship.

Model specification for ordered logit

An ordered logistic estimation method was used to model the hypothesized relationship between the ordinal outcome variable y and predictors x. By assumption, the observed ordinal variable y is related to an unobserved latent variable y^* which indicates the degree with which an individual farmer achieved the outcome, therefore, y provides incomplete information. Assuming y^* has three threshold levels or cut points, τ. Assume $y = 1, 2, ...m$. Let $m = 3$ be the three levels of y, according to the latent variable approach, the value y depends on whether or not a threshold was crossed. Therefore, the observed y is related to y^* according to the model:

$$
\begin{aligned}
y_i &= 1 \quad if \quad \tau_0 \le y_i^* \le \tau_1 \\
y_i &= 2 \quad if \quad \tau_1 \le y_i^* \le \tau_2 \\
y_i &= 3 \quad if \quad y_i^* \ge \tau_3
\end{aligned} \qquad \text{......(1)}
$$

Where, $y_i = m$, if $\tau_{m-1} \le y_i^* < \tau_m$, for $m = 1, 2....j$. The y is defined over the intervals $\tau_0 = -\infty$ and $\tau_m = +\infty$. The structural model for an individual i is specified as

$$y_i^* = \beta x_i^{'} + \mu_i, \quad i = 1, 2...n \qquad \text{......(2)}$$

Where x is a row vector of covariates assumed strictly independent of μ_i, β is a vector of parameters to be estimated? The μ_i is an error term assumed to be a standardized logistic distribution with mean zero and variance of $\pi^2/3$ (Greene and Henscher, 2009). The logit model estimates a linear function of the independent variable and a set of threshold parameters and then calculates the observed probabilities. The observed probabilities for an outcome i correspond to the likelihood that the estimated linear function, plus random error is within the range of threshold estimated for the outcome. Therefore, for an individual i, the predicted probability is obtained using equation (2),

Model specification for probit regression: future CA adoption

A probit binary choice model was fit to analyze farmers' willingness to adopt CA in the future. The conditional probability of the model has the form,

$$\ln(\pi / 1 - \pi) = \pi_i \equiv \Pr(y_i = 1 / x) = F(\gamma x_i^{'}) = \alpha + \gamma_1 x_1 + \gamma_2 x_2 .....\gamma_k x_k \qquad \text{......(3)}$$

Where π is the probability of future CA adoption, α is the intercept coefficient, γ is the slope coefficient, Xs are sets of predictors explained previously. The α and γ are parameters estimated by the Maximum likelihood method.

Results and discussion

Farmer's demographic characteristics

The Namibian Labour Force Survey (NLFS) (2018) shows that unemployment amongst women was thirty-four per cent compared to thirty-two per cent in men. In addition, the rate of vulnerable employment (for the subsistence farmers category of vulnerability) was higher in women (Forty-two per cent) than forty per cent in men (NSA, 2019). Therefore, most rural project target women participation. In line with expectation, the result of this survey shows that the CA project was women dominated.About sixty-nine were women compared to thirty-one men. The result also shows that older people dominate rural subsistence farming in the selected region because the average age of the interviewed farmers (Household head) was fifty-seven years. The youngest farmer is twenty-eight years, whereas the oldest is eighty-three years. The average farm experience is twenty-six years, whereas the most experienced farmer has farmed for seventy-four years. About eighty-two per cent of the farmers are Lead Farmers (LF), thirty-three per cent are Follower Farmers (FF), and eight per cent are Cluster Farmers (CL). At least seventy-eight per cent of the farmers has had one form of training or the other, while seventy-three per cent said they had extension visits from the authorities. Participation in farmer association is low, only forty-four per cent are members of any CA forum.

Factors limiting the adoption of CA

Farmer's understanding of CA

The farmer's cognitive understanding of what CA stand for after three years of orientation and their ability to identify the core CA principles underlie their ability to apply them. During the survey, farmers were asked to give (in vernacular) a layman's view of what CA stand for and identify its core principle and benefits. The core practices were selected, and a frequency count of the farmer's identification of the CA core principles was recorded for each of the chosen core principles. The frequency count of the farmer's knowledge of CA is shown in Figure 1. At least eighteen per cent of the farmers correctly identified '*minimal soil disturbance'* as one of the core CA practices, about sixteen per cent mentioned, '*mulching'* as key CA practice.'*Improved soil fertility'* was mentioned by twelve per cent of the respondents. About twenty-eight per cent of the farmers either '*do not know'* or have forgotten what CA stand for, an indication that they may likely not practice what they do not know or remember.

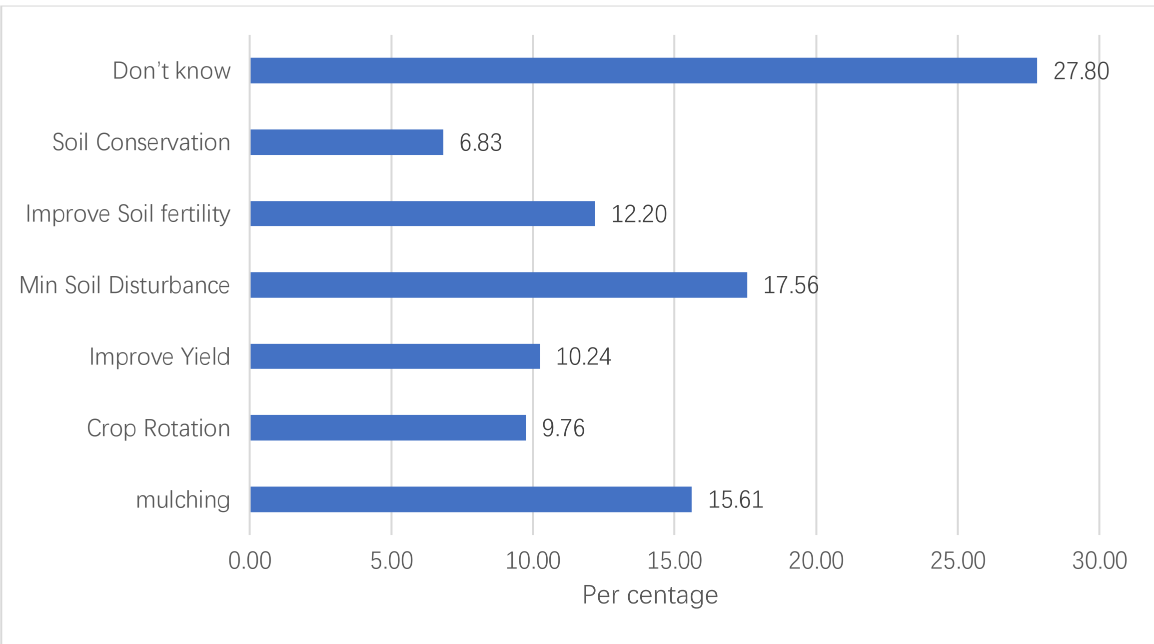

Figure 1: Frequency count of the farmers understanding of CA
Source: Own computation.

Information dissemination and the frequency thereof

Apart from organizing an on-plot demonstration to the farmers, extension personnel and agricultural scientist from MAWF regularly use other media to disseminate information about weather, prices, availability of inputs, seeding, weeding, soil management, herbicide and pest control to the farmers. However, it is not guaranteed that the information dissemination was adequate. Inadequate information would indicate that the farmer operated in silos. During the survey farmers were asked to indicate whether information gathering posed a '*Major*', '*Minor*' or '*No challenge'*. The results show that information gathering posed a big challenge in Kunene and Oshikoto regions compared to Ohangwena, Oshana and Omusati in these three regions, information gathering was not a limiting factor to CA adoption.

Information dissemination is essential, but more pertinent is the frequency of its dissemination. The more frequent farmers receive information about CA, the better. Farmers were asked to order the rate of information distribution into four categories, namely; "*rarely*", "*sometimes*", "*often*" and "*always*". From the survey, 17% of the respondents indicated that they rarely receive information on CA while 32% sometimes received information about CA. Twenty-four per cent of the respondents often receive information, while 27% always receive information. The frequency of information distribution highlights the need for intensification of CA awareness and adoption.

Access to production inputs

Availability of seeds, pesticides, fertilizer, and implements in all four surveyed regions posed a challenge for the successful implementation of the project. Figure 2 represents the respondent's acknowledgement of the availability of CA implements, *pesticides*, *fertilizers*, *seeds*, and *improved seeds*. Tools such as tractors and detachable ripping implements (Tine) were made available to the farmers across the region. Therefore, access to implement was not a limiting factor because the service was provided by the Department of Agriculture, Water, and Forestry. *Pesticides* were never available in most of the regions. Besides, the absence of trained personnel to handle pesticide and herbicide was a problem. Seeds and the use of improved varieties were not a significant problem.

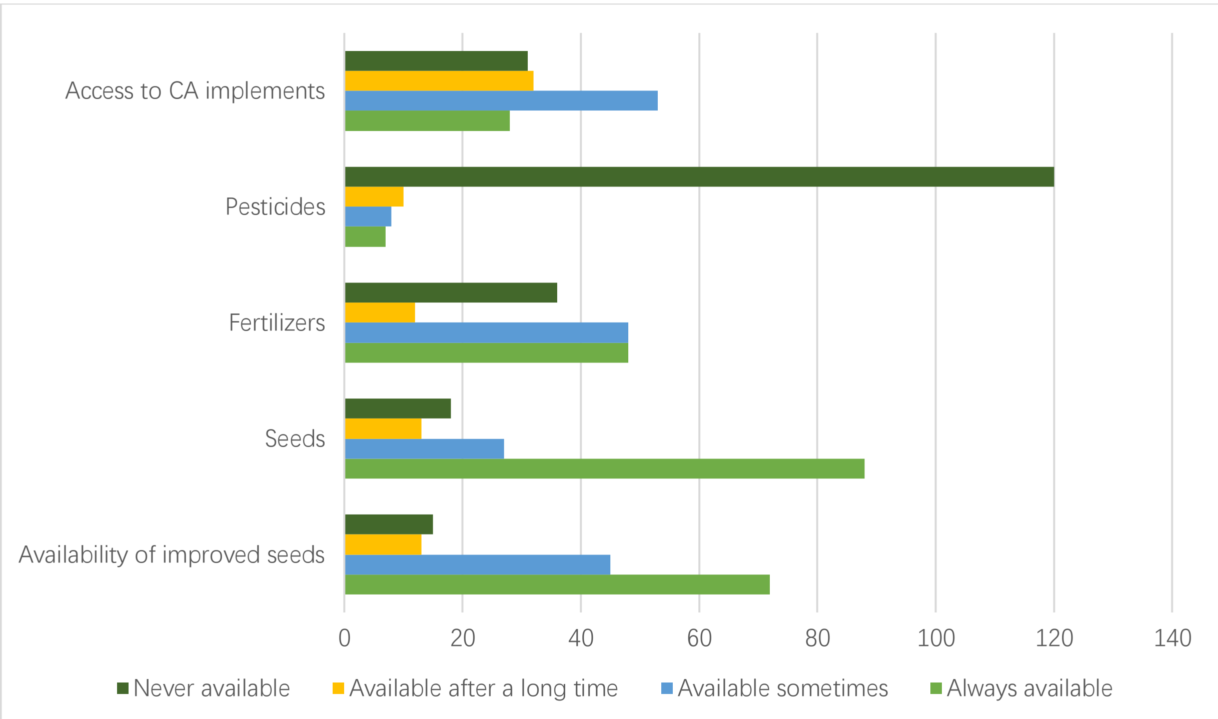

Figure 2: Availability of CA implements and production inputs
Source: Author's own computation.

Access to production inputs by region

Figures 2A to 2B show the availability of production inputs by region, Figures 2A and 2B show that hybrid and local seed varieties were always available to the areas. Fertilizer input was available to Kunene farmers after a long time, whereas, farmers in Omusati faced irregular supply. Figure 2D is a confirmation of the report in figure 2, which indicates, pesticides were never available in most of the regions. The problem is two-fold, on the one hand, trained personnel were lacking, on the other hand, fear of mishandling and the fear of the toxicity effects of pesticides made matters worse, resulting in lack of confidence in pesticide used by the farmers. In some regions, pesticides expired in stock due to lack of use.

Competing use of crop residue mulch

Provision of a residual mulch is vital for the successful implementation of CA. Mulch could be crop residue from the previous year cultivation. Crop residue consists of crop stalks, dead plant parts or dead weed leaves left over after crop harvest. For a usual CA practice, crop residue is to be left in the field to act as a source of cover and other benefits such as i) increased water infiltration, ii) decreased water evaporation, iii) increased water availability to crops, iv) less soil erosion from both water and wind, v) more biological activities, vi) more soil organic matter and availability of nutrients and vii) moderate soil temperatures. However, in the conventional agricultural practice, crop mulch and plant residues are either, burnt, or used as fuel (for cooking and heat generation), compost or as animal feed. Therefore, the use of crop residue for mulch in CA plots competes for its alternative use. The practice comes at a high opportunity cost to the farmer, and it is a limiting factor to CA adoption in the rural communities. The survey investigated crop residue use by the farmers (Figure 3). The result shows that the farmers in the selected regions do not burn crop residue. Composting and the use of crop residue for fuel and heat is not a popular choice either. The popular choice of crop residue use is either as a mulch or as animal feed. Therefore, during a drought, when there is a general lack of fodder for animal feed, it is difficult for farmers to use crop residue for mulch instead of animal feed. This poses a significant limitation to CA adoption in Namibia. Sorghum, pearl millet, and maize stalks are the most widely used crop residue mulch (Figure 3).

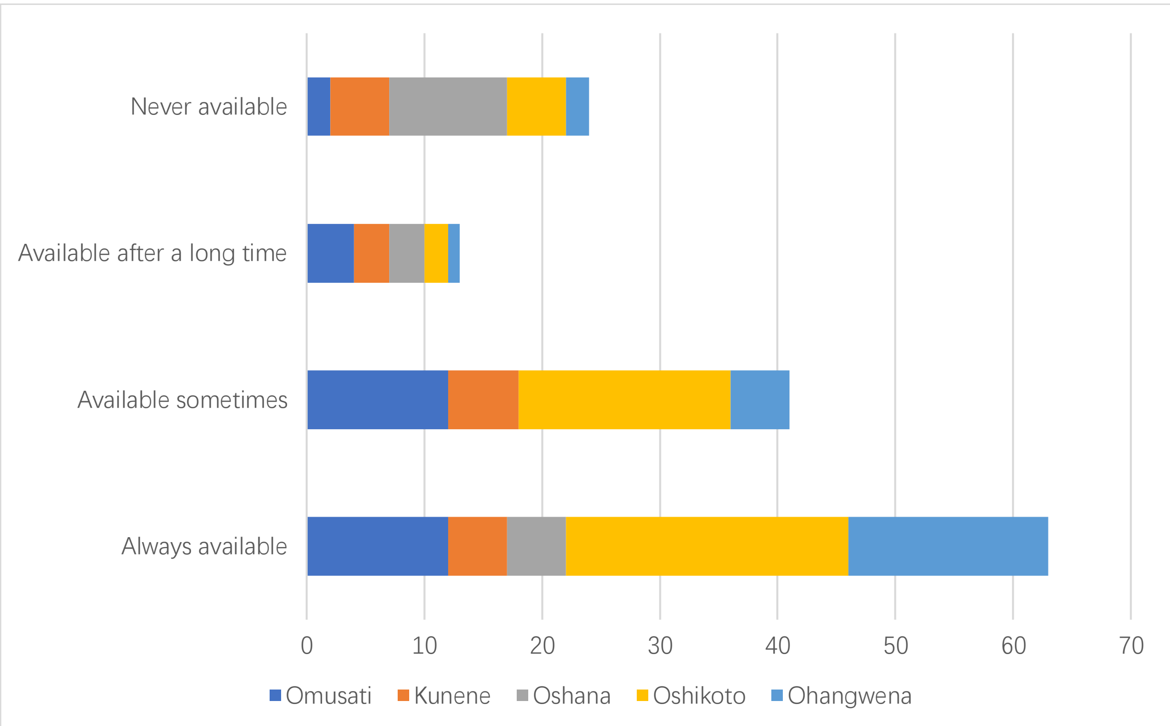

Figure 2A Availability of Hybrid seeds

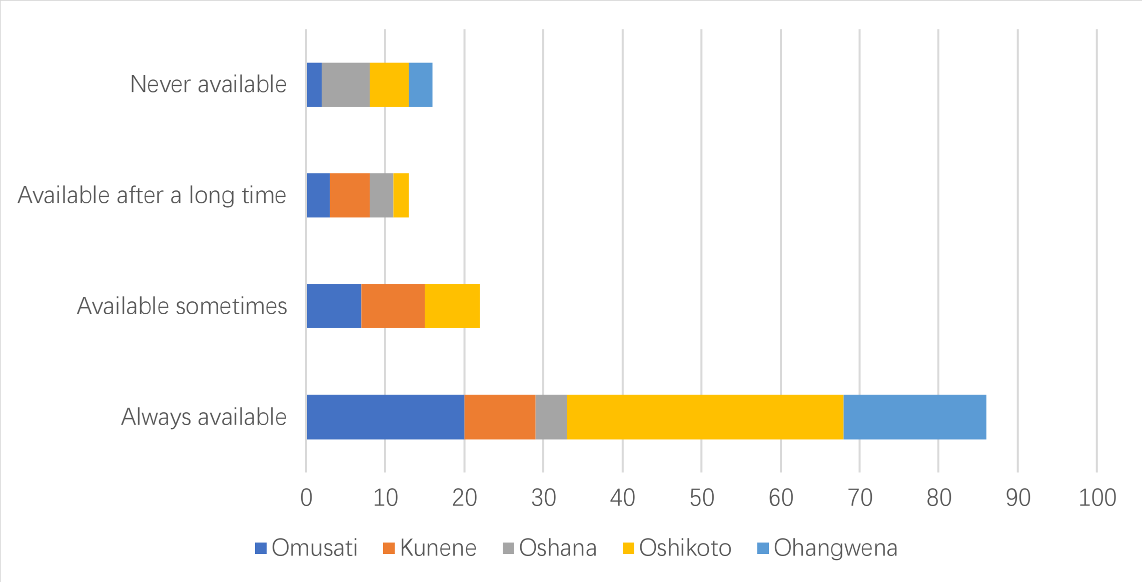

Figure 2 B Availability of local seed variety

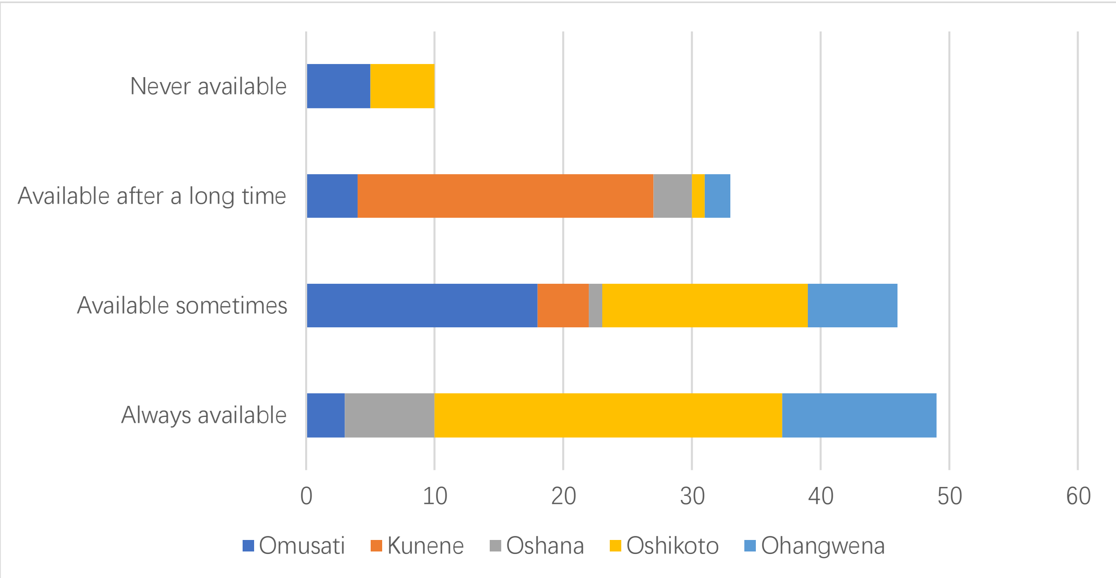

Figure 2 C Availability of Fertiliser

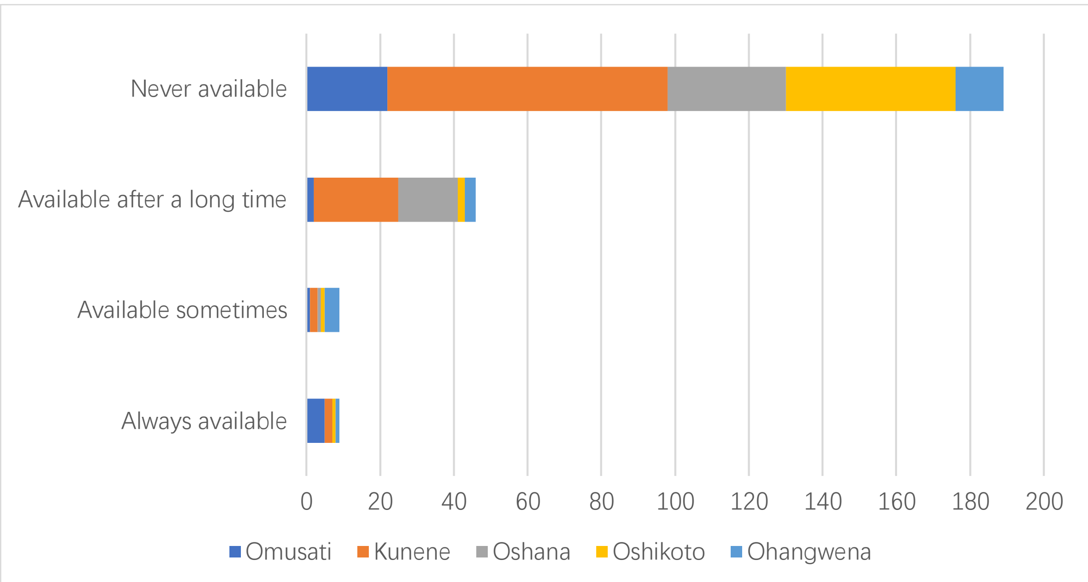

Figure 2 D Availability of Pesticide

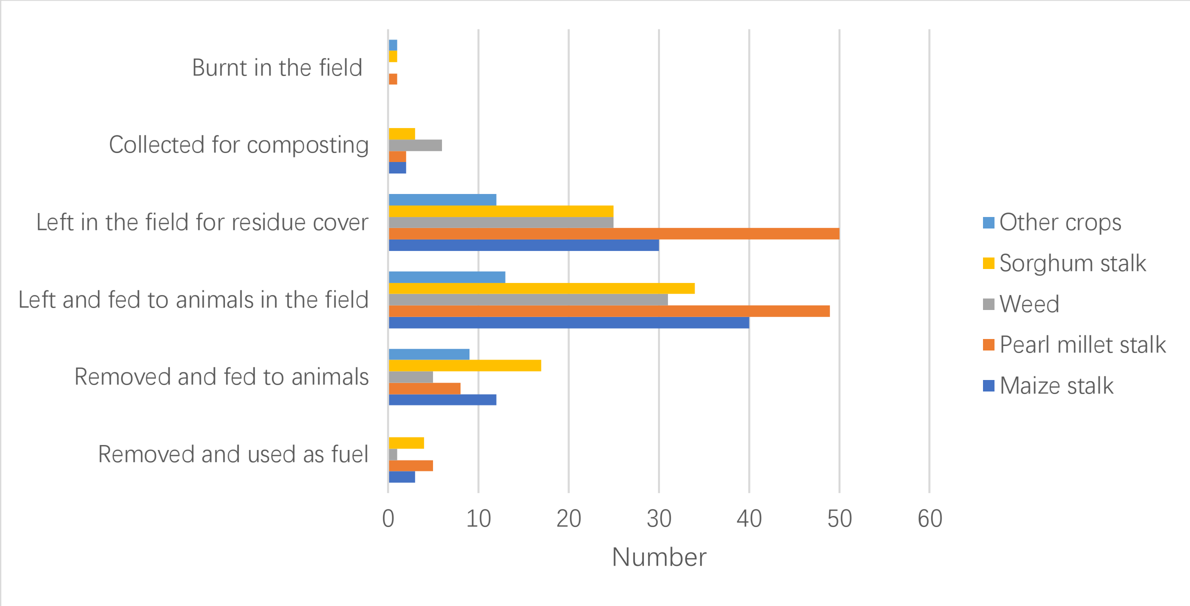

Figure 3: Competing use of crop residue mulch
Source: Authors own compilation.

The Focussed Group Discussions

The data analyzed in the previous sections were obtained during a face-to-face interview with farmers. In this type of discussion, farmers expressed their personal view or experience about the different issues suggested by the enumerator in the questionnaire. This section discusses data obtained from a Focussed Group Discussion (FGD). FGD is a qualitative technique for data collection. The benefit of using FGD are as follows: a) data were collected from a group of people with a focus on a given issue or topics; b) the data collected is a weighted opinion under a peer group, c) it enables the interviewer to gather broader views about a particular issue than an idea of one person, d) It is a better forum for question and answers on issues of clarity. The FGD was organized in four regions, Omusati, Oshana, Kunene and Ohangwena. No FGD was held in Oshikoto because the appropriate logistics were not in place to make it happen. The enumerators used the FGD to seek broader knowledge on stakeholder participation, roles and responsibilities, constraints, challenges, unforeseen circumstances, recommendation and the way forward from the four regions. The information gathered during the FGD is shown in Appendix Table A.

Table A shows that there was a CA forum in Omusati and Ohangwena but not in Kunene and Oshana. CA forum comprises farmers and stakeholders who come together in the common interest of a sustainable CA in Namibia. Stakeholders that provided complementary CA services in the regions include, AgriBank, Regional Council, Farmer Associations, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Namibia's Forestry and Lands (NAFOLA), *Scaling up Community Resilience* (SCORE). The GIZ, NAFOLA, and SCORE are funding NGOs helping the Namibian communities to scale up the banks on agricultural productivity against the wave of climate change. They offer parallel services to FAO's. Their presence is an indication of the integrated and intensified effort to strengthen the CA application in the Northern region. Farmers affirm that the stakeholders facilitated training, exposure tours, input provisions, and gender mainstreaming. They were asked to assess the project in terms of successes and failures. Farmers from Omusati, Oshana, and Ohangwena acknowledged there were yield increases, for Kunene farmers yield was limited by drought and lack of adequate inputs.

The critical challenges encountered by farmers are, lack of spares for the machinery, limited production and human resources, late arrival of inputs, and the competing use of crop residue

(Appendix Table A). Many CA activities did not occur due to drought. The farmers agree a scale-up of CA operation would achieve more results. Though CA goal was not met at the scale commensurate with their efforts in some regions, farmers commend it as a potential source of sustainable food production and food security.

Farmers were asked to suggest the best implementation approach for CA and the way forward. Farmers from Kunene, Omusati, and Ohangwena acknowledged that Lead farmer approach was better, whereas, farmers from Ohangwena identified face-to-face approach. The face-to-face mentoring approach requires a one-on-one administration of CA by the CA facilitators. To achieve the face-to-face model, the ratio of extension officers to farmers must be high – thus a higher implication on project cost. The use of mobile SMS services was not fruitful in most regions due to the lack of network signals in the remote villages. The farmers recommend training agricultural technicians in the relevant field, such as soil chemistry, meteorology, and toxicology. Availability of vehicles limited extension visit, therefore, more transport facilities are needed in the regions. There was a general rollout of CA project to every farmer in the region. Many farmers saw this approach as counterproductive because, some farmers are not keen on changing from the conventional practices to CA as a result, and they are reluctant to practice it. Resources expended on them is a waste because they hardly achieve results. Therefore, farmers recommend CA project for only those farmers who are willing to participate.

Descriptive statistics

Table 2 shows that the general agricultural practices have three levels as previously explained. The Knowledge of CA was categorized as one, zero otherwise. Composite index (Cindexca) of these baskets of knowledge of CA were obtained using principal component analysis (PCA). Farmer's age ranges from 28 years to 83 years. Older farmers may not be active in the farming operation; because they are the household head, they were included in the survey. This is a major shortfall, which, however, may skew the actual demographics and observed characteristics in the sampled population.

Table 2 Descriptive stats

Variable	Mean	Std.Dev	Min	Max
Weed rate	1.7569	0.7314	1	3
Area planted	2.2500	0.9424	1	3
Fertiliser application	1.8472	0.9031	1	3
Herbicide application	2.7083	0.6464	1	3
Seed application	1.7292	0.8546	1	3
Weed application	1.6458	0.8318	1	3
Crop rotation	1.5556	0.7825	1	3
Inter cropping	1.7778	0.8885	1	3
Mulch application	1.9167	0.8731	1	3
Kn residual mulch	0.2222	0.4172	0	1
Kn crop rotation	0.1389	0.3470	0	1
Kn improved yield	0.1458	0.3542	0	1
Kn minimal soil disturbance	0.2500	0.4345	0	1
Kn improved soil fert	0.1736	0.3801	0	1
Kn soil conservation	0.0972	0.2973	0	1
Don’t know	0.3958	0.4907	0	1
cindexca	0.0006	3.9986	-5.32	10.95
Farm expirience	26.4861	15.9781	1	74
Age	57.4097	13.3811	28	83
Gender	0.3125	0.4651	0	1

Training	0.7847	0.4124	0	1
Extension sevice	0.7292	0.4459	0	1
Lead farmer	0.5694	0.4969	0	1
Follower farmer	0.3542	0.4799	0	1
Cluster farmer	0.0764	0.2665	0	1
Member of CA grp	0.4444	0.4986	0	1
Labour	0.8403	0.3676	0	1

Empirical results

This section discusses two empirical results: the result of the ordered logistics regression and the binary probit estimation of CA sustainability. There are eight ordered outcome variables; therefore, eight logit regression models were fit against a set of regressors. The odds of observing equidistant proportion among the outcome variables were tested using Brant (1990) test. The test checks whether the relationship between each pair of outcome group is the same, that is, the coefficient that describes the relationship between, say, *not increased* versus *slightly increased* and *greatly increased* is proportional to the relationship that describes *slightly increased*, and *greatly increased, e.t.c.* The same applies to the outcome variables *not improved, slightly improved* and *greatly improved*. Brant (1990) test is shown in Table 2. The null hypothesis of the test is that the ordered outcomes are equidistant from each other. The Brant (1990) test is distributed as a chi-square test with the degrees of freedom equal to the number of regressors. The equidistant assumption is violated if a significant chi-square statistic is observed; otherwise, it is satisfied. The results show that the test was not rejected in the majority of the tests. However, Long and Freese (2001) suggest that Brant (1990) tests can over-reject the null in small samples; therefore, additional diagnostic tests was needed to confirm the adequacy of the model.

A typical way is to fit a generalized ordered logit assumption and compare the results. To achieve this, Maarten Buis (2013) joint test of the parallel assumption was performed. The joint tests is a likelihood ratio test, a score test, a Wald test, a Wolfe-Gould test, and a Brant test. These tests compare an ordered logit model with the fully generalized ordered logit model. The Maarten Buis (2013) test is shown in Table 2. A significant chi-square test statistic suggests a violation of the parallel regression assumption. The majority of the tests do not reject the assumption, thereby confirming the previous results. In addition, the Akaike Information Criteria (AIC) supports the parallel assumption by selecting ordered logit as the correct model (Table 2). Wald's test shows the models fit the data.

Table 2. Test of equidistant assumption

Variables	Model 1[2] (χ^2)	Model 2 (χ^2)	Model 3 (χ^2)	Model 4 χ^2	Mode 6 (χ^2)	Model 7 (χ^2)	Model 8 (χ^2)
Brant (1990) test of proportional odds assumption (parallel regression):							
	4.65	6.80	4.04	2.16	2.80	2.30	10.20
All	(0.460)	(0.236)	(0.544)	(0.827)	(0.731)	(0.807)	(0.170)
	0.08	0.39	1.39	0.76	0.51	1.37	0.49
Cindexca	(0.775)	(0.531)	(0.238)	(0.383)	(0.477)	(0.242)	(0.485)
	0.02	1.54	1.56	0.02	0.01	0.19	0.18
Labour	(0.883)	(0.215)	(0.212)	(0.891)	(0.932)	(0.666)	(0.670)
	4.31	3.97	0.00	0.75	1.38	0.07	3.13
Farmexp	(0.038)	(0.046)	(0.997)	(0.385)	(0.239)	(0.795)	(0.077)

[2] Dependent Variables for models 1-8 are as shown in Table 3**.**

Age	1.06 (0.303)	0.98 (0.322)	0.18 (0.674)	0.03 (0.864)	0.47 (0.493)	0.01 (0.910)	6.23 (0.013)
Memcagrp	0.93 (0.010)	1.24 (0.266)	0.20 (0.657)	0.03 (0.856)	0.86 (0.354)	0.04 (0.842)	1.14 (0.286)
Maarten Buis (2013) test of proportional odds assumption (parallel regression):							
Wolfe Gould	4.90 (0.428)	7.69 (0.174)	4.74 (0.448)	3.32 (0.650)	2.61 (0.760)	1.98 (0.852)	6.41 (0.268)
Brant	4.65 (0.460)	6.81 (0.236)	4.04 (0.544)	2.16 (0.827)	2.80 (0.731)	2.30 (0.807)	10.20 (0.070)
Score	28.12 (0.000)	6.80 (0.236)	4.70 (0.453)	5.24 (0.380)	2.68 (0.749)	2.17 (0.825)	8.33 (0.139)
Likelihood Ratio	36.07 (0.000)	7.83 (0.166)	5.05 (0.410)	5.13 (0.400)	2.64 (0.755)	2.16 (0.827)	8.43 (0.134)
Wald	21.81 (0.001)	6.75 (0.240)	4.83 (0.437)	4.26 (0.513)	2.65 (0.754)	2.18 (0.824)	8.98 (0.110)
Diagnostic test: Wald joint test of significance:							
χ^2 **(5)**	16.71 (0.000)	26.66 (0.000)	54.95 (0.000)	8.55 (0.128)	57.27 (0.000)	67.93 (0.000)	50.79 (0.000)
Model comparison using AIC:							
Logit	236.32	282.67	217.77	178.23	179.12	182.27	227.21
GLogit	210.25	303.45	222.73	183.09	186.48	190.11	228.78

Note: Figures in parenthesis are P> χ^2 . Glogit = Generalised logit.

Ordered Logistics regression

Table 3 shows the results for the ordered logistic regression. The composite index of CA knowledge has a positive and significant relationship with the entire outcome variables. The result indicates that additional CA knowledge may likely result in farmers' moving from a lower to a higher category. That is, farmers are more likely to greatly improve weeding than not, the area planted is more likely to increase than decrease and fertilizer application is more likely to increase greatly than not. There is an increase in the ordered log-odds of moving from a lower to a higher outcome level. For instance, a one-unit increase in the farmers' CA knowledge will result in 0.05 unit increase in ordered log-odds of being in the higher category for the "area planted" outcome variable while the other variables in the model are held constant. The same relationship applies to other outcome variables with respect to farmers' improved knowledge. Farm labour use had little influence on any of the outcome variables. The result is as expected because the CA operation was government-assisted. Tractors services were either free or at subsidized prices in the regions, and labour use was predominantly family labour. Farm experience, age and membership of a CA group, had relatively little influence in explaining the farmer's decision to practice CA because learned skill within the short period did not wholly dominate farmers' decision to practice CA because traditional or indigenous knowledge is difficult to reverse in a short period of time. The Wald test of the joint significance of the model parameters is reported in Table 3. Overall, the test was rejected signifying the models fit the data.

Table 4 reports the calculated and the predicted probabilities of achieving the events described previously. The frequency counts of the events are shown in Panel A. From the total observation of 144, the fraction of the probabilities classified into various categories were calculated. The calculated probabilities are compared with the sample average predicted probabilities from the ordered logit model in Panel B. The predicted chances are lower than the calculated expectations due to the imposed smoothness in equation (2) considering the unobserved cut points - thus a better categorization of the data. The sample average predicted probabilities for the outcome variables (Panel B) shows that the probability of observing a higher category was more than a lower group.

Table 5 shows the conditional marginal effect of predictors on the estimated probabilities at the sample mean. A small change in CA knowledge resulted in a significant increase in the likelihood of observing more considerable improvement in the GAPs in the regions. This effect was more apparent in the third outcome categories of the GAP models than in other models. Other predictors showed mixed result across the GAP models and the outcomes.

Table 3. Ordered logistic regression estimates

Dependent Var	**Regressor**	**Coefficient**	**P-value|**	**Wald Test**
Model 1: Area Planted	cindexca	0.0501	0.0260	16.71 (0.0051)
	labour	0.9638	0.0540	
	farmexp	0.0236	0.0880	
	age	-0.0105	0.5320	
	memcagrp	-0.1252	0.7570	
Model 2: Weeding Rate	cindexca	0.0156	0.0440	26.66 (0.0001)
	labour	0.4724	0.9580	
	farmexp	0.0139	0.0550	
	age	0.0152	0.0680	
	memcagrp	0.3531	0.0000	
Model 3: Fertiliser application	cindexca	0.1920	0.0000	54.95 (0.0000)
	labour	-0.7531	0.1810	
	farmexp	0.0006	0.9640	
	age	0.0206	0.1790	
	memcagrp	-0.3283	0.4370	
Model 4: Herbicide application	cindexca	0.0736	0.0120	8.55 (0.1283)
	labour	-0.8940	0.2070	
	farmexp	-0.0106	0.5680	
	age	0.0232	0.3590	
	memcagrp	-0.3325	0.4380	
Model 5: Seed application	cindexca	0.1969	0.0000	50.26 (0.0000)
	labour	-1.4720	0.0120	
	farmexp	-0.0253	0.1160	
	age	0.0125	0.5170	
	memcagrp	-0.0093	0.9840	
Model 6: Crop rotation	cindexca	0.2136	0.0000	57.27 (0.0000)
	labour	-0.2038	0.8080	
	farmexp	-0.0013	0.9290	
	age	0.0048	0.7720	
	memcagrp	-0.4685	0.3160	
Model 7: Inter cropping	cindexca	0.2546	0.0000	67.93 (0.0000)
	labour	0.7830	0.1980	
	farmexp	-0.0456	0.0040	
	age	0.0392	0.0250	
	memcagrp	0.4457	0.3460	
Model 8: Mulch application	cindexca	0.2129	0.0000	50.79 (0.0000)
	labour	0.0185	0.9740	
	farmexp	-0.0187	0.2020	

	age	0.0273	0.1650
	memcagrp	0.7898	0.0480

Figures in parenthesis are Wald test p-values.

Table 4 Calculated and predicted probabilities

Calculated Probabilities – Panel A				Predicted Probabilities – Panel B			
Variable	**Categories**	**Freq**	**Prob**	**Margins**	**Delta method Std.Error**	**Z-stat**	**P>|z|**
Area Planted	NINC	50	0.3472	0.3496	0.0370	9.44	0.00000
	SINC	8	0.0556	0.0557	0.0192	2.89	0.00400
	GINC	86	0.5972	0.5947	0.0389	15.27	0.00000
Weeding Rate	NIMP	60	0.4167	0.4087	0.0387	10.56	0.00000
	SIMP	59	0.4097	0.4144	0.0412	10.07	0.00000
	GIMP	25	0.1736	0.1769	0.0300	5.90	0.00000
Fertilizer rate	NIMP	71	0.4931	0.4878	0.0327	14.91	0.00000
	SIMP	24	0.1667	0.1661	0.0298	5.57	0.00000
	GIMP	49	0.3403	0.3460	0.0281	12.31	0.00000
Herbicide application	NIMP	14	0.0028	0.1051	0.0249	4.23	0.00000
	SIMP	12	0.0012	0.0840	0.0231	3.64	0.00000
	GIMP	117	0.0034	0.8108	0.0317	25.58	0.00000
Seed application	NIMP	77	0.5347	0.5503	0.0284	19.36	0.00000
	SIMP	29	0.2014	0.1975	0.0295	6.70	0.00000
	GIMP	38	0.2639	0.2522	0.0278	9.08	0.00000
Crop rotation	NIMP	90	0.6250	0.6207	0.0283	21.90	0.00000
	SIMP	28	0.1944	0.1980	0.0316	6.27	0.00000
	GIMP	26	0.1806	0.1813	0.0244	7.42	0.00000
Inter cropping	NIMP	76	0.5278	0.5340	0.0261	20.46	0.00000
	SIMP	24	0.1667	0.1636	0.0281	5.82	0.00000
	GIMP	44	0.3056	0.3024	0.0267	11.34	0.00000
Mulch application	NIMP	61	0.4236	0.4214	0.0300	14.04	0.00000
	SIMP	34	0.2361	0.2384	0.0339	7.03	0.00000
	GIMP	49	0.3403	0.3402	0.0297	11.47	0.00000

Note: NINC = Not Increased, SINC = significantly increased, NIMP = Not improved, SIMP = Significantly Improved, GIMP = Greatly Improved.

Table 5 Marginal effects of predictors on estimated probabilities at the sample mean

Outcome variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Outcome 1								
	-0.0111	-0.0075	-0.0472	-0.0056	-0.0487	-0.0462	-0.0636	-0.0473
Cindexca	(0.023)	(0.043)	(0.000)	(0.010)	(0.000)	(0.000)	(0.000)	(0.000)
	-0.2142	-0.0060	0.1852	0.0679	0.3637	0.0441	-0.1954	-0.0041
Labour	(0.057)	(0.958)	(0.181)	(0.215)	(0.011)	(0.809)	(0.198)	(0.974)
	-0.0052	-0.0064	-0.0002	0.0008	0.0063	0.0003	0.0114	0.0042
Farmexp	(0.088)	(0.054)	(0.964)	(0.554)	(0.116)	(0.929)	(0.011)	(0.193)
	0.0023	0.0066	-0.0051	-0.0018	-0.0031	-0.0010	-0.0098	-0.0061
Age	(0.531)	(0.069)	(0.178)	(0.354)	(0.517)	(0.773)	(0.026)	(0.155)
	0.0278	0.3090	0.0808	0.0252	0.0023	0.1014	-0.1113	-0.1755
Memcagrp	(0.757)	(0.000)	(0.439)	(0.429)	(0.984)	(0.314)	(0.346)	(0.490)
Outcome 2								

	-0.0008	0.0036	0.0090	-0.0042	0.0251	0.0347	0.0297	0.0071
Cindexca	(0.132)	(0.063)	(0.071)	(0.021)	(0.003)	(0.000)	(0.001)	(0.278)
	-0.0162	0.0029	-0.0355	0.0512	-0.1877	-0.0331	0.0913	0.0006
Labour	(0.138)	(0.958)	(0318)	(0.232)	(0.058)	(0.809)	(0.204)	(0.975)
	-0.0004	0.0031	0.0000	0.0006	-0.0032	-0.0002	-0.0053	-0.0006
Farmexp	(0.178)	(0.065)	(0.965)	(0.575)	(0.163)	(0.929)	(0.024)	(0.392)
	0.0002	-0.0032	0.0010	-0.0013	0.0016	0.0008	0.0046	0.0009
Age	(0.547)	(0.087)	(0.254)	(0.368)	(0.526)	(0.773)	(0.059)	(0.377)
	0.0021	-0.1500	-0.0155	0.0191	-0.0012	-0.0761	0.0520	0.0262
Memcagrp	(0760)	(0.005)	(0.516)	(0.445)	(0.984)	(0.327)	(0.367)	(0.343)
Outcome 3								
	0.0120	0.0039	0.0382	0.0098	0.0235	0.0115	0.0339	0.0402
Cindexca	(0.024)	(0.052)	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)
	0.2304	0.0031	-0.1498	-0.1191	-0.1759	-0.0110	0.1042	0.0035
Labour	(0.055)	(0.958)	(0.169)	(0.209)	(0.009)	(0.810)	(0.255)	(0.974)
	0.0056	0.0033	0.0001	-0.0014	-0.0030	-0.0001	-0.0061	-0.0035
Farmexp	(0.088)	(0.073)	(0.964)	(0.561)	(0.118)	(0.928)	(0.009)	(0.203)
	-0.0025	-0.0034	0.0041	0.0031	0.0015	0.0003	0.0052	0.0052
Age	(0.531)	(0.081)	(0.187)	(0.352)	(0.517)	(0.774)	(0.035)	0.164)
	-0.0299	-0.1590	-0.0653	-0.0443	-0.0011	-0.0253	0.0593	0.1492
Memcagrp	(0.757)	(0.001)	(0.426)	(0.430)	(0.984)	(0.298)	(0.347)	(0.054)

Note: Figure in parenthesis are the p-values

Willingness to continue CA adoption

The major challenges facing the implementation and adoption of the concept of CA in the rural Namibian communities are (but not limited to) drought, limited skilled extension personnel, late and inadequate supply of inputs, input cost, the tenacity of GAPs applications and so on. These challenges put pressure on farmers who marginally agree to adopt CA practices. Nevertheless, there is the tendency that some farmers may want to opt-out of the CA practice in future if the climatic conditions deteriorate further, and there is an increase in the opportunity cost of engaging in CA. To investigate the willingness of the farmers to continue to practice CA in the future, a probit choice model was fit. The model was used to investigate the relationship between farmers' willingness and a set of covariates such as training, yield-difference, household consumption (hhcon.), farm labour, and farmer's status (Whether a farmer is a "lead-farmer", "a follower-farmer "or "a cluster-farmer").

Table 6 shows the probit estimates of farmer's willingness to continue CA adoption. The results indicate that farmers that received intensive training on CA practices are more likely to continue than those who did not receive training. Part of the training schedule involves a tour trip of major CA trial projects in other countries. For instance, farmers and some stakeholders from the selected regions visited CA demonstration farms in Zambia. On the other hand, the improved yield was a motivating factor for farmers. Differences in yield had a positive influence on whether a farmer is likely to continue practising CA. Farmers' status did not significantly influence farmers' willingness to continue. Being either a lead or a follower farmer has no significant influence on farmer's future participation in CA compared to a cluster farmer. Lead-farmers got all the assistance and implements to be successful so that the follower-farmers can copy from them. The cluster farmers are groups of farmers located in clusters that mimic activities of each cluster in the neighbourhood. They are more likely to learn by observing members of a cluster than a single isolated lead-farmer in the countryside.

Table 7 shows the conditional marginal effects of these variables on the probability of CA continuity. As depicted by the sign of the coefficient in Table 6, the marginal impact of variables shows by how much marginal change in the training, yield, household consumption, and farmers' economic status influenced participation. An additional unit of instruction offered to the farmers will increase their zeal to participate by 2.9% other variables remain constant. Also, if a farmer's yield increases by extra one unit, it will cause a 3.3% increased motivation to continue practising CA other variables remain constant. On the other hand, contrary to expectation, being a lead farmer or a follower farmer is not a motivating factor towards future CA practice.

The predicted probability of farmer's willingness to practice CA in the future is 92%. At the regional level, it was 81% in Kunene, and 94% in Ohangwena. Others include Omusati (94%), Oshana (93%) and Oshikoto (95%).

Table 6 Probit estimates of farmers willingness to continue adopt CA.

Variables	Coefficients	Robust Standard Error	z	P>|z|
training	1.2048	0.3589	3.36	0.0010
ffollower	-5.8167	0.7109	-8.18	0.0000
flead	-6.5731	0.8074	-8.14	0.0000
yielddiff	1.3758	0.4514	3.05	0.0020
hhcon	0.8553	0.4148	2.06	0.0390
labour	0.7264	0.5616	1.29	0.1960
constant	5.1923	0.1287	40.35	0.0000
Obs	144			
Wald Chi2(4)	363.77			
Prob > Chi2	0.0000			
Pseudo R2	0.4267			
Log Pseudo likelihood	-23.6814			

Table 7 Conditional marginal effects of predictors on the estimated probability of farmers willingness to adopt CA in the future

Continue CA	Margin	Delta method Standard Error	Z-Stats	P>|z|
Training	0.0292	0.0168	1.7400	0.0830
Follower Farmer	-0.1411	0.0828	-1.7000	0.0890
lead Farmer	-0.1594	0.0955	-1.6700	0.0950
Yielddiff	0.0334	0.0178	1.8800	0.0610
hhcon	0.0207	0.0157	1.3200	0.1860
labour	0.0176	0.0107	1.6400	0.1000

Conclusions

The study evaluated the potential for improved and sustainable adoption of Conservation Agricultural Practices in Northern Namibia. A CA project titled: *'Strengthening the capacity of farmers to manage climate-related risk in the Northern Namibia'* was initiated in 2015. The aim was to lower the vulnerability of farmers by increasing their resilience to climate change risk. The project was for three years, thereafter, in the year 2018, the MAWF, in collaboration with FAO commissioned an evaluation of the impact of the CA project on adopters. Also, evaluating the possibility of continuity amongst adopters was paramount. The study assessed CA practices in Omusati, Kunene, Oshikoto, Ohangwena, and Oshana regions where CA intervention took place. One hundred and forty-four farmers were sampled from the selected regions. The result indicates that additional CA knowledge may likely result in farmers' improving their General Agricultural Practices. In other words, farmers are more likely to improve weeding than not, the area planted is more likely to increase than decrease and fertilizer application is more likely to increase significantly than not. There is an increase in the ordered log-odds of moving from a lower to a higher outcome level. For instance, a one-unit increase in the farmers' CA knowledge will result in 0.05 unit increase in ordered log-odds of being in the higher category for the "area planted" outcome variable while the other variables in the model are held constant. The same relationship applies to other outcome variables for farmers' improved knowledge.

The study also investigated the sustainability of the project. The result shows that farmers are willing to adopt CA and continue practising it on the condition that benefits such as increased yield, training and household consumption are guaranteed. This is because, increased yield, training and household consumption increased the probability that farmers will continue CA adoption.

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Conflict of interest

The authors expressly say there is no conflict of interest to be declared.

References

[1] R, Brant. Assessing proportionality in the proportional odds models for ordinal logistics regression. Biometrics. Vol. (46) 1990: 117-1178.

[2] Chan, Catherine, Brent Sipes, Abouzeid Ayman, Xu Zhang, Patricia LaPorte, Fellipe Fernandes, Aliza Pradhan, Jacqueline Chan-Dentoni, and Pravat Roul. 'Efficiency of Conservation Agriculture Production Systems for Smallholders in Rain-Fed Uplands of India: A Transformative Approach to Food Security'. Land Vol 6 (3) 2017 https://doi.org/10.3390/land6030058.

[3] Dumanski, Julian, Eugene Terry, Derek Byerlee, and Christian Pieri. Performance Indicators for Sustainable Agriculture October 1998. Rural Development Sector, October 1998: 2–18.

[4] Food and Agricultural Organisation. Final Evaluation of the Conservation Agriculture Scaling-up Project Funded by the European Union. September.2018

[5] Food and Agricultural Organisation. Conservation Agriculture 2017. https://doi.org/10.1201/9780203932698.ch15.

[6] Ghaley, Bhim Bahadur, Teodor Rusu, Taru Sandén, Heide Spiegel, Cristina Menta, Giovanna Visioli, Lilian O'Sullivan 'Assessment of Benefits of Conservation Agriculture on Soil Functions in Arable Production Systems in Europe. Sustainability (Switzerland) Vol (3) 2018. https://doi.org/10.3390/su10030794.

[7] N. Gilbert. 'Dirt Poor: The Key to Tackling Hunger in Africa Is Enriching Its Soil. The Big Debate Is How to Do It.' Nature 483 2012: 525–27. https://doi.org/10.1002/cind.8010_9.x.

[8] K.E, Giller, Ken., Jens. Andersson, Marc Corbeels, John Kirkegaard, David Mortensen, Olaf Erenstein, and Bernard Vanlauwe. 'Beyond Conservation Agriculture. Frontiers in Plant Science 6 (OCTOBER) 2015. https://doi.org/10.3389/fpls.2015.00870.

[9] G. Williams and D.A. Henscher. Modelling ordered choices. Department of Economics, Stern School of Business, New York University, New York, NY 10012 2009

[10] Hobbs, Peter, Ken Sayre, and Raj Gupta. The Role of Conservation Agriculture in Sustainable Agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences Vol 363 (1491) 2008: 543–55. https://doi.org/10.1098/rstb.2007.2169.

[11] Inter-governmental Panel on Climate Change. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Climate Change, Disaster Risk, and the Urban Poor 2012. https://doi.org/10.1596/978-0-8213-8845-7.

[12] Kabirigi, Musana, Ngetich, Mugwe, Mukuralinda, Nabahungu, (Ku, and Kenya Nairobi. Journal of Soil Science and Environmental Management Applicability of Conservation Agriculture for Climate Change Adaptation in Rwanda's Situation Vol 6 (9) 2015: 241–48. https://doi.org/10.5897/JSSEM15.0508.

[13] Kassam, Friedrich, Shaxson, Bartz, Mello, Kienzle & Pretty.The Spread of Conservation Agriculture 2014: Policy and Institutional Support for Adoption and Uptake. Field Actions Science Reports Vol 7 (April 2019): 0–12.

[14] Kerdiles, Hervé, Felix Rembold, and Ana Pérez-hoyos. Seasonal Monitoring in Namibia in Northern and Central Namibia. Technical Report European Union Commission 2015

[15] Lai, Cynthia, Catherine Chan, Jacqueline Halbrendt, Linsey Shariq, Pravat Roul, Travis Idol, Chittanrajan Ray, and Carl Evensen. 2012.

Comparative Economic and Gender, Labor Analysis of Conservation Agriculture Practices in Tribal Villages in India. International Food and Agribusiness Management Review Vol 15 (1): 73–86.

[16] Long, Scott, and Jeremy Freese. Regression Models for Categorical Dependent Variables Using STATA. Sociology The Journal Of The British Sociological Association. Vol. Revised ed. https://doi.org/10.1186/2051-3933-2-4, 2001

[17] M. Buis. OPARALLEL Stata module providing post-estimation command for testing the parallel regression assumption; Statistical Software Components S457720, Boston College Department of Economics USA, 2013.

[18] Marongwe, Lungowe Sepo, Isaiah Nyagumbo, Karsto Kwazira, Amir Kassam, and Theodor Friedrich. Conservation Agriculture and Sustainable Crop Intensification: A Zimbabwe Case Study. Integrated Crop Management. Vol. 15.2012

[19] MRLGHRD. Flood Risk Management Plan .2011

[20] Namibian Meteorological Service. Annual Rainfall estimates 2019.

[21] Namibia Statistics Agency.Poverty Dynamics in Namibia: NHIES Surveys. 2012 https://d3rp5jatom3eyn.cloudfront.net/cms/assets/documents/p19dnar71kanl1vfo14gu5rpbkq1.pdf.

[22] Namibia Statistics Agency. Namibian Population Projection 2014: 2011-2041.

[23] Namibia Statistics Agency Namibian Land Statistics, September 2018: 1–48. https://nsa.org.na/.

[24] Namibia Statistics Agency. Namibia Inter-Censal Demographic Survey 2016 Report, 1–136. https://nsa.org.na/.

[25] Namibia Statistics Agency.Namibian 2011 Census: Migration Report 2015 https://nsa.org.na/.

[26] Namibia Statistics Agency.The Namibia Labour Force Survey 2019 Report.

[27] Nkala, Peter. Assessing the Impacts of Conservation Agriculture on Farmer Livelihoods in Three Selected Communities in Central Mozambique. University of Natural Resources and Life Sciences, Vienna, May 2012

[28] Thierfelder, Christian, Stephanie Cheesman, and Leonard Rusinamhodzi. A Comparative Analysis of Conservation Agriculture Systems: Benefits and Challenges of Rotations and Intercropping in Zimbabwe. Field Crops Research Vol 137, 2012: 237–50. https://doi.org/10.1016/j.fcr.2012.08.017.

[29] Tilman, David, Christian Balzer, Jason Hill, and Belinda Befort.Global Food Demand and the Sustainable Intensification of Agriculture. Proceedings of the National Academy of Sciences of the United States of America Vol 108 (50) 2011: 20260–64. https://doi.org/10.1073/pnas.1116437108.

[30] Vanlauwe, Coyne, Gockowski, Hauser, M.Huis ing, Masso, Nziguheba, Schut, and Van Asten. Sustainable Intensification of the African Smallholder. Current Opinion in Environmental Sustainability Vol 8 2014: 15–22.

Appendices A

Table A1 Focused Group Discussions (FGD) Omusati and Kunene Regions

Activities*	Kunene	Omusati
Formation of the CA Forum	There was no CA Forum in the region.	CA forum not functional
Stakeholders/NGO Participation	MAWF	MAWF, Regional council, AgriBank, Farmer's Association
Training Activities received	Farmers were trained on CA	Received training, input allocations, farmers were allocated into groups
Production Input distribution	Inputs received, fertilizer was sold at a subsidized price.	Farmers received production input.
The general success of the project	Drought limited applicability of CA	There was reported yield increases,
Challenges	Limited fund impaired activities	Few implements were received, spares not available, no locally available spares.
Unforeseen circumstances	Drought; many activities did not occur.	Drought,
Project scale-up possibilities	Yes	Yes
Implementation approach	Lead farmer approach preferred	Lead farmer approach preferred,
General recommendations	Transportation for officers, Daily allowance must increase,	Trained technicians needed, increase the daily allowance for technician, tractor insufficient.

*Focused Group Discussion question: What is your opinion about the following subjects?

Table A1 Focused Group Discussions (FGD) for Oshana and Ohangwena

Activities:	Oshana	Ohangwena
Formation of the CA Forum	No CA forum	There is a CA forum
Stakeholders/NGO Participation	GIZ; SCORE; FAO	SCORE; NAFOLA; MAWF; Regional Council; AgriBank
Training Activities received	Framers trained; Field trip to Zambia; Women farmers involved.	Framers trained; Field trip to Zambia; Used demo ploys
Production Input distribution	Received inputs; Rippers; but herbicides arrived late	Received Tines; Tools; Seeds; Legumes; Fertiliser;
The general success of the project	Yes, but limited by drought	Increased CA knowledge; CA demand high; Yield increased
Challenges	Tractor limited; Received herbicides and Tines late,	Competing use of crop residue for CA; fear of crop damage due to toxic herbicides; late arrival of tools such as Tines.
Unforeseen circumstances	Drought; Tractor drivers scarce, contract of drivers expired.	Drought; the Increased cost of weeding; Insect infestation
Project scale-up possibilities	Yes	Yes
Implementation approach	Farmer-to-farmer approach preferred	Preferred lead-farmer approach
General recommendations	Use mobile phones for information dissemination; give free seeds; finance etc.	Need training on agronomy; to avoid moral hazard, target only interested farmers.

*Focused Group Discussion question: What is your opinion about the following subjects?