SECTION 1. PROJECT TITLE (5%).

'Personalized Agriculture' for smallholder farmers in Malawi: Evidence-based solutions for individual smallholder farmlands

SECTION 2. SUMMARY (5%)

Since the past two decades, maize production in Malawi has faced a major setback due to low rainfall and poor soil fertility leading to massive food crises. Recently, conservation agriculture practices have been applied to smallholder farms in Malawi to improve agricultural output with varying results. This study seeks to understand the factors surrounding low adoption or disadoption of conservation agriculture in Malawi at the individual level. We propose 'personalized agriculture' to help individual farmers overcome their barriers and devise individual farm-based strategies to improve soil fertility and enhance agricultural output. Providing personalized solutions should be able to improve the adoption rate of conservation agriculture among smallholder farmers in Malawi.

SECTION 3. RESEARCH CODES (5%)

Field of Research (FOR)	FOR code	FOR (percent)
Sustainable Agricultural Development	070108	70%
Agricultural Systems Analysis and Modelling	070105	30%

Socio – Economic Objective (SEO)	SEO code	SEO (percent)
Maize	820401	100%

SECTION 4. INTRODUCTION AND BACKGROUND (25%)

Malawi is a small, poor country in southern Africa with a population of approximately 12 million and more than 60% of the people living below the poverty line. The infant mortality is very high and the average life expectancy is quite low due to several chronic health conditions such as malnourishment and HIV/AIDS (Clay *et al*., 2003). Agriculture is the main occupation of the people in this country, and several smallholder farmers rely on their produce for their survival (Trocaire, 2005). Their staple food is maize and most farmers depend on this crop for their nutritional and economical requirements. As a good yield of maize is heavily dependent on climatic conditions, excessive or very low rainfall patterns

greatly affect the production of maize. In such a scenario, the hardest hit group of population is the smallholder farmers who heavily depend on this crop for their survival (Menon, 2007).

Malawi's history is dotted with several natural disasters alternating between drought and floods, destroying several fields and farmers' livelihoods in the process. Between the years 1970 and 2006, Malawi has gone through 40 climate-related disasters, 16 of them occurring after 1990 (ActionAid International, 2006). Heavy dependence on agriculture and unstable weather conditions have forced smallholder farmers to live in a state of vulnerability and poverty for a prolonged period of time (Phiri *et al*., 2005).

The year 1990 brought with it a devastating drought that affected around 6.1 million people in southern Africa. Just as the Malawian farmers were recovering from this drought, heavy rainfall during 2001 led to localized waterlogging destroying several maize fields in its wake and bringing down the annual production of maize by 32%. Due to an incomplete recovery from the 2001 famine, Malawi faced another food crisis in 2005 following a period of drought and destruction of the maize farmlands (Menon, 2007). The food crisis has continued since with an estimated 2.8 million people requiring food assistance on an annual basis. The seasonal hunger rates are high as well with a rate of 57% for rural families and a rate of 36% for urban families (Anderson *et al*., 2018).

Most of the improvement in Malawian agriculture has been funded externally by government-funded schemes or international organizations. While this has contributed to a positive increase in maize production over the past few years, it is, by no means, sustainable. There are severe problems with the agricultural system in Malawi that stands in the way of agricultural progress in the country. Most smallholder farmers are highly resistant to the idea of crop diversification, with around 65% of the total smallholder farmland only growing maize. Due to excessive poverty, farmers hesitate to buy good quality fertilizers for their farmlands deciding to spend their money on food instead. Over time, the soil fertility has been heavily compromised and the land has become unsuitable for most agricultural production (Phiri *et al*., 2012).

One of the ways by which sustainable agricultural productivity can be achieved in Malawi is by adopting conservation agriculture practices to improve soil fertility and resist abrasive climatic conditions. Three important features of conservation agriculture are minimal disturbance of the soil layers, retention of crop residues, and crop diversification. Conservation agriculture has been adopted in several places around the world and its features

have been applied to Malawian smallholder farms as well (Fisher *et al*., 2018). However, low adoption rates have been observed in Malawi showing that Malawian smallholder farmers are either resistant to new practices or lack the resources to adopt conservation agriculture practices in their farmlands (Hermans *et al*., 2020).

Research on different farms in Africa has shown that conservation agriculture systems have major advantages over traditional agricultural practices. Conservation agriculture practices result in deep infiltration of water in the soil layer leading to an increase in produce after only two to three cropping seasons (Thierfelder *et al*., 2017). These practices also lead to a gradual and overall improvement in soil fertility, especially in the organic carbon content of the soil (Powlson *et al*., 2016). This is especially true where crop diversification or alternation is practised which also serves to enhance the heat resistance and drought resistance properties of the crops (Steward *et al*., 2018). The specific practices of conservation agriculture that make it a 'climate-smart' and 'economy-smart' choice has been repeatedly proposed to smallholder farmers in Malawi and other parts of the world to help them become more sustainable and financially stable (Thierfelder *et al*., 2016).

Given the climatic and economic conditions of smallholder farmers in Malawi, conservation agriculture has been introduced and practiced in different ways on smallholder farms in the region (Andersson & D'Souza, 2014). It has been proposed to address problems of high rural population density, low livestock densities, water shortages, and low soil fertility (Ngwira *et al*., 2014). Studies conducted on farms in the central and southern parts of Malawi have reported significant increase in maize yields when using conservation agriculture practices when compared with traditional practices such as the ridge and furrow systems (Thierfelder *et al*., 2013). Improvement in household economies and food security of smallholder farmers has also been reported for the adoption of agro-ecological farming methods (Kangmennaang *et al*., 2017).

Despite its many benefits, recent studies aimed at understanding the adoption and benefits of conservation agriculture practices in Malawi has found different degrees of adoption in different smallholder farms across the region. In fact, this is an observed trend across smallholder farmers around the world that they are resistant to adopting conservation agriculture practices on their farmlands (Habanyati *et al*., 2018; Chinseu *et al*., 2018). In certain areas such as Zambia, abandonment of conservation agriculture practices has been reported after employing it for two to three cropping seasons (Arslan *et al*., 2014). Some

studies have reported a shift from manual practices to mechanized practices under the conservation agriculture methods umbrella, especially in regions where labour is expensive and/or unavailable (Grabowski *et al*., 2014). Recent reports based on research conducted in six districts in Malawi have shown that only 18.5% of smallholder farmers were practicing conservation agriculture practices on only 10% of their farms. This represents a total of just 2.1% of cultivable area of Malawian farms (Ngwira *et al*., 2014). Some reasons for this may be lack of defined methods to adopt under the umbrella of conservation agriculture practices, promotion of different practices in different regions, and unreliable performance criteria to measure the outcomes of conservation agriculture adoption on farmlands (Chinseu *et al*., 2018).

The reasons for disinterest and low adoption of conservation agriculture practices by smallholder farmers in Malawi may be either biological or economic. Biological reasons include increase in the amount of weeds, competing for crop residues, insufficient land to practice crop rotation, and crop diseases that often accompany practice of conservation agriculture (Holden and Lunduka, 2014). More significant are the economic constraints of farmers that prevent them from investing in soil manure, risk protection, and appropriate supplements and implements (Holden and Quiggin, 2017). Smallholder farmers often fail to observe the benefits of conservation agriculture first-hand on their farms leading to their disheartenment and dis-adoption of these practices. Studies show that the increase of yield using conservation agriculture practices is gradual rather than sudden; however, when farmers do not see an increase in yield during the first one or two seasons, they are more likely to give up rather than wait for the improvements (Baudron *et al*., 2011; Corbeels *et al*., 2014).

There is a considerable gap between advocacy of conservation agriculture practices and expectations of smallholder farmers in adopting these practices. People who advocate conservation agriculture practices to smallholder farmers focus on yield improvement and economic gains. However, when these do not happen immediately, farmers tend to lose hope and shift to traditional agriculture practices. On the other hand, advocators of conservation agriculture do not stress factors such as retention of soil moisture and climate risk management, which are more relevant to the Malawian smallholder farmers' requirements (Simelton *et al*., 2013). Another major problem of smallholder farmers who choose to adopt conservation agriculture is using dead mulch for improving the fertility of their soil. Crop residues from small farms are not sufficient to provide enough soil cover which increases

competition between farmers. In instances where farmers need to transport crop residues for enhancing their soil fertility, they face problems with transport cost and disease transmission (Williams, 2008). These types of issues faced by smallholder farmers in practicing conservation agriculture makes them more likely to switch to traditional methods that gives them instant results (Rogers, 2003).

In Malawi, the various conservation agriculture practices promoted for smallholder farmers are crop diversification, organic manure, inorganic fertilizers, planting basins, no-till, hybrid seeds, specialized equipment for planting, and measures for soil and water conservation. Owing to the single traditionally grown crop in the region, crop diversification is not heavily stressed for smallholder farmers in Malawi. Data from smallholder farms in Malawi have highlighted a very short lifespan of conservation agriculture practices coupled with a marked disinterest in the technology leading to increasing disadoption of the practices. Disadoption indicates farms which adopt conservation agriculture practices for some time and switch to traditional practices due to dissatisfaction with the new practices. The reasons for disadoption are not widely studied; however, the data that is available shows several implementation issues such as weed infestation, difficulty in construction of planting basins, and use of extension agents. Surveys show that around 46% of the smallholder farmers in Malawi consider conservation agriculture to be unsuitable for them, and among those that consider it to be suitable, several farmers mention various challenges in adopting these practices (Chinseu *et al*., 2018). Previous experience of traditional agriculture practices have led Malawi into a heavy food crisis that has spanned at least two decades and it is now essential that smallholder farmers in Malawi adopt newer measures to avoid falling into the poverty and devastation cycle again.

Just as the concept of ‘personalized medicine’ promises to treat people keeping individual physiological and biochemical factors in mind, the concept of ‘personalized agriculture’ needs to be devised so that smallholder farmers can overcome their barriers in adopting newer agriculture practices. The concept of ‘One Solution Fits All’ is not the best way to go especially for smallholder farmers due to high rates of illiteracy, adherence to traditional methods, and insufficient funding available. Currently, most agricultural policies only see the larger picture and provide a wide array of best practices that fall into the broader context of agricultural problems faced by farmers. Relevant agencies need to bear in mind that individual farmers have very different perspectives about agriculture that is dependent on

their social, cultural, and economic context. The individual needs and requirements of smallholder farmers in small pockets of the country need to be understood, and personalized agricultural remedies need to be provided so that they can adopt suitable and sustainable agricultural practices on their farmlands. These practices need to align with their views on the best methods to practice agriculture so that the proposed methods to improve soil fertility and enhance the quality of crop yield can be accepted and implemented positively. Reported specific findings such as weed infestation, lack of access to fertilizers and specialized equipment, and resistance to crop diversification need to be individually addressed so that these types of issues don't contribute to high rates of disadoption in smallholder farmers in Malawi. Complete support needs to be provided to smallholder farmers who decide to adopt conservation agriculture practices until the time that they see a satisfactory improvement in their farming practices and crop yield. If possible, manure for the soil and hybrid seeds can be provided at subsidized rates initially so that smallholder farmers are not discouraged by the high economic costs of conservation agriculture practices.

SECTION 5. AIMS, SIGNIFICANCE & INNOVATION (10%)

This study aims to provide personalized solutions to smallholder farmers in Malawi for adopting conservation agriculture practices on their farms in order to increase their rate of implementing these practices. These personalized solutions will be offered after understanding individual reasons for disadoption of conservation agricultural practices, and the solutions will be tailored to each farmer's specific farming beliefs and requirements.

This project is significant because there is no study till date that has focused and quantified individual factors that affect the disadoption rates of conservation agriculture practices in smallholder farms in Malawi. People are resistant to adopting newer agricultural practices and they switch to traditional methods at the first sign of an undesirable outcome. Another significance of this project is that no study or research design has focused on providing personalized solutions to farmers after understanding their individual reasons for disadopting conservation agriculture practices. Although there are certain common reasons that have emerged in previous interviews, different farmers face different issues on their fields regarding weed infestation, soil fertility, funding investments, and climatic conditions. Understanding the individual mindsets of farmers will help recommend individualized agriculture practices that can benefit smallholder farmlands in the region. Previous surveys

have identified weed infestation, lack of access to fertilizers, and resistance in implementing crop diversification as some of the factors that govern disadoption of conservation agriculture practices. Identifying and addressing individual requirements such as providing herbicides, fertilizers, and educating farmers on how to perform crop rotation can encourage farmers to make their farmlands more sustainable. In the larger context, an increase in the number of farmlands employing sustainable agricultural practices in Malawi will reduce dependence on external funds and exports, and improve the food and economic status of the country. It will also help smallholder farmers in Malawi become more resistant to extreme climatic conditions such as floods and droughts and increase their preparedness for natural climatic disasters.

This work is innovative as it brings the concept of personalizing methods and systems to the field of agriculture. Just as the concept of personalized medicine aims to provide customized health solutions to patients, so does the concept of personalized agriculture aim to understand the reasons for disadoption of conservation agriculture practices on an individual level and specifically address these reasons. The individual needs of farmers in impoverished and inaccessible regions have never been fully studied and considered, and this study will enable understanding various factors that govern smallholder farmers' mindsets. It will also enable tailoring customized agricultural solutions based on the individual needs of the farmers so that they can overcome their personal inhibitions and adopt conservation agricultural practices. If personalized agriculture practices are successfully implemented in Malawi, the results can be extrapolated to smallholder farms in different parts of the world which suffer from ignorance and lack of resources. This can lead to better agricultural practices on smallholder farms, increase in agricultural output, and increase in revenue for the farmers.

SECTION 6. APPROACH & METHODS (35%)

The study area will be a minimum of 8 and a maximum of 10 smallholder farms in the southern region of Malawi, as this is the hardest hit area in the recent food crisis. Data regarding the smallholder farms in Malawi will be obtained from the Agricultural Development Extension Officers (AEDOs). This data will be used to narrow down the smallholder farmers who were active participants in the drive to promote conservation agriculture practices in smallholder farms in Malawi. The criteria for selecting the smallholder farms will be those that have adopted conservation agriculture practices for at

least one year and then switched to traditional agriculture practices. The selected smallholder farmers should have adopted at least two of the proposed conservation agriculture practices, and should not currently be implementing those practices in their farmlands. The reason for this is to understand the factors that resulted in these farmers shifting from conservation agriculture to traditional agriculture practices after 1 year of implementation and providing them with individualized solutions to address the specific issues they faced during this period.

The study method will be qualitative and will be conducted in the form of 1 to 2-hour in-depth research interviews with the selected farmland owners. An interpreter will be required to translate questions into the farmers' native language and translate their answers back to English. In order to ensure accuracy and reliability in data collection, software such as Survey Solutions will be used to record and analyze the data. Tablet devices will also be used to record exact GPS locations of the selected farms and to measure the farm area under cultivation. Two interviews will be completed in a day, one in the morning and the other in the afternoon, and the data from all interviews will be correlated once all the interviews are successfully completed.

A detailed interview questionnaire will be prepared that will cover various aspects of their experiences with adopting conservation agriculture practices on their farms. Initially, objective information regarding the farm area under cultivation, crops grown and gross yield will be noted. Following this, the interview will cover topics such as how the farmers were affected during the recent natural disasters and food crisis, and how they managed to restore their farmlands in the aftermath of the devastation. The interview will delve deep into the support received and implemented by the government in terms of hybrid seeds and fertilizers, and the agricultural practices that they follow for best results. The interview questions will also assess the general state of knowledge of the farmers regarding both traditional and conservation agricultural practices and their general perceptions of the advantages and limitations of both these practices. This will help correlate the general beliefs of the smallholder farmers in Malawi with regards to different agricultural practices along with their reasons for disadoption of conservation agricultural practices. The major part of the interview will be focused on understanding the farmers' reasons for adopting conservation agriculture practices, their various points of dissatisfaction with the practices, and the various reasons and events that led up to their disadoption and switching back to traditional agriculture practices. The exact values in terms of yields and profits will be noted during the period of

following both conservation and traditional agriculture practices. The entire interview will be recorded to minimize loss of data with the interviewees' permission.

After all the interviews are conducted, the recorded tapes will be used for retrieving and arranging data so that common patterns can be identified. Initially, all specified reasons for shifting from conservation agriculture practices to traditional agriculture practices will be noted. Relevant codes will be assigned so that all data can be categorized into meaningful brackets that will aid in understanding the farmers' mindsets in disadoption of conservation agriculture. The data will also be estimated based on the percentage of farmers who gave a specific reason for disadoption of conservation agricultural practices in order to inform and drive future research.

In order to provide personalized agriculture solutions for each of the interviewed smallholder farmers, the data obtained from every farmland will be kept separate. For each of the interviews, the data will be analyzed to note down at least 3 to 5 important reasons that the farmers chose to disadopt conservation agriculture practices. This will provide a structured framework to make specific recommendations for each of the farmlands that are individualized and considerate of the factors involved.

Once all the data are categorized thematically, a specific solution will be noted for each reason. For example, if a farmer indicates excessive weed infestation as one of the issues of conservation agriculture, herbicides or subsidies for herbicides will be provided to the farmers to address the issue specifically. Similarly, if soil fertility or inability to implement crop rotation is the issue faced by farmers, specific solutions will be noted to address the issue. Thus, a direct and specific solution will be proposed for each specific reason mentioned by individual farmers in shifting from conservation agriculture practices to traditional agriculture practices.

Care will be taken to ensure that the proposed solutions are reasonable, practical, and implementable on the farmland. Either the solutions or the financial resources for the solutions will be provided based on convenience and availability of resources. Evidence-based literature will be used for making recommendations and other factors such as the willingness of farmers to adopt new technologies, financial constraints, and access to specialized equipment will be considered. Once the recommendations are finalized, the individual farmers who have been interviewed will be encouraged to adopt the same conservation agriculture practices on their farmlands, but this time with the recommended

solutions so that the problems they faced earlier could be overcome. While providing each farmer with proposed methods to overcome their issues, their personal interview data will be reviewed and the specific solution based on the interview response will be provided to the farmers. They will be encouraged to implement conservation agricultural practices along with the personalized recommended solutions for at least 6 months. The smallholder farmers will be required to implement the same conservation agricultural practices that they adopted prior to disadoption in order to estimate if the individualized solutions helped the farmers overcome the specific issues they faced with the practices they chose to adopt initially.

Throughout the process of implementation of conservation agricultural practices along with individualized solutions, the smallholder Malawian farms will be visited at least once a week to acquire regular updates about the progress. These visits will also aim to understand any issues the farmers may currently be facing with the adoption of recommended solutions on their farms. In case any issues are indicated by the smallholder farmers, these issues will be addressed promptly and appropriately in order to encourage maximum compliance of the farmers.

The growth of crops on the individual farmlands will be tracked through an entire season of implementing the recommended solutions, and the total agricultural produce will be calculated and noted. The quality of the crops will be analyzed, and the increase (or decrease) in yield from the previous season to the current season will be estimated. Based on the results, the degree of implementation of the conservation agriculture practices and accompanying recommendations may be altered to maximize agricultural output. The suitability of the conservation agricultural practices will also be analyzed and altered to ensure maximum yields from the farmland.

SECTION 7. BUDGET (5%)

Item	Explanation	Cost
Vehicle mileage	700 km @ 75c/km	$525
Interpreter costs	15 hours @ $50/hr	$750
Provision of resources to farmlands	Provision of herbicides, fertilizers, and specialized equipment	$1000
Total		**$2275**

Vehicle mileage: 10 trips to field sites for conducting interviews and collecting data for analysis. Rates are based on use of a pool vehicle. When possible, if 2 to 3 farms are located in proximity, their interviews will be conducted on the same day to save vehicle costs. Following interviews, analysis of yield will also require travel to the field sites after implementation of recommended solutions.

Interpreter costs: An interpretor is absolutely essential to communicate with the Malawian smallholder farmers so that they are encouraged to share information during the interview.

Provision of resources: This covers all recommended solutions that are provided to smallholder farmers for implementation after the interviews are completed. It includes herbicides, fertilizers, specialized equipment, and other resources based on the data collected during interviews.

Tape recorder for recording the interviews will be borrowed from the University, and computer and internet facilities will be provided by the University.

SECTION 8. CAPABILITIES AND TRACK RECORD (5%)

The University of _____ is actively involved in the upliftment of smallholder farmers through careful and critical analysis of their agriculture practices. Several groups of this University have studied the implementation and feedback of different types of agriculture practices in smallholder farms in disaster-affected areas. A lot of research here is focused on developing new approaches in agriculture that can improve soil fertility, improve plant immunity, and increase agricultural output. Professor _____ of this University is an ardent supporter of conservation agriculture practices and strongly believes that this is the future of sustainable agriculture in the world. S/he leads a team of highly motivated research students, research assistants, and postdoctoral fellows who are involved in various forms of research in the domain of conservation agriculture practices and sustainable development. Their experience and understanding of individual conservation agricultural practices is based on in-depth knowledge and direct involvement in research, and their recommendations will be extremely insightful in determining the best ways to address individual issues faced by smallholder farmers in Malawi.

When making recommendations based on the data collected from smallholder farmers, the inputs of the local government and non-government agricultural agencies will also be extremely helpful, as they are directly involved in devising new agriculture practices. These agencies are involved in a lot of fieldwork and they are in constant touch with the farmers to understand their needs and requirements, and to uplift their economic status. Their recommendations for narrowing the region of Malawi to be included in the study and identification of farmers who disadopted conservation agriculture practices after 1 year will be extremely insightful.

The chemicals and equipment that will be distributed to the farmers based on personalized recommendations will be obtained under local government subsidized programs. The information regarding these programs will be obtained from local agricultural agencies that are involved in the provision of subsidized agricultural resources to farmers. This will ensure that the resources are available to the farmers in the future, and will cultivate the habit of making use of the available resources to improve agricultural output. It will also help lower the financial burden on farmers for addressing secondary issues related to farming practices making them more likely to invest in conservation agricultural practices in the future.

The interpretor used for interpreting the interviews has a track record of interpreting several interviews for the University, and is extensively experienced in qualitative data collection methods. The person is a localite and is extremely well-versed with the cultural and social contexts of the farmers. He is extremely familiar with the local slangs, terms, and phrases used by the farmers and can help in the accurate recording of farmers' responses. Also, as he is familiar to the region, he will be an ideal candidate to extract meaningful information from the farmers by helping in the drafting process of research questions.

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