The Potential of Conservation Agriculture on Crop Yield In The Democratic Republic of Congo

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O POTENCIAL DA AGRICULTURA DE CONSERVAÇÃO NO RENDIMENTO DAS CULTURAS NA REPÚBLICA DEMOCRÁTICA DO CONGO

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RESUMO

Objetivo: Uma das razões para promover a agricultura de conservação (AC) na África Subsaariana é a sua associação com o aumento do rendimento das culturas para os pequenos agricultores. No entanto, o aumento e a estabilidade de rendimento atribuída a AC permanecem sem um debate consistente e harmonizado. O estudo avaliou o impacto de AC no rendimento das culturas, bem como os factores que conduzem à adopção e os desafios que os agricultores enfrentam quando utilizam AC em Kisangani, República Democrática do Congo.

Referencial teórico: O estudo utilizou a teoria unificada da aceitação e utilização de tecnologia.

Método: Um questionário estruturado foi administrado aleatoriamente a 192 agricultores praticantes de AC para recolher dados através de um processo de amostragem em vários estágios. Foram utilizadas análises descritivas e de regressão logística multinomial para examinar associações e possíveis preditores que influenciassem a adopção de AC e o rendimento das culturas.

Resultados e conclusão: Os resultados mostram que a AC têm um impacto positivo no rendimento das culturas, particularmente para a mandioca e o arroz. Além disso, os agricultores são impelidos a utilizar a AC devido ao aumento do rendimento e de fertilidade do solo, sendo ambos obtidos ao longo do tempo. O estudo sugere a utilização de fertilizantes orgânicos produzidos localmente para melhorar o resultado imediato esperado pelos agricultores. A deficiência de cobertura do serviço de extensão é um constrangimento maior, que se traduz na falta de conhecimento sobre a prática de AC, especificamente a rotação inadequada de culturas e as práticas agronómicas, que resultam na baixa produção de milho. O estudo recomenda que o sector agrícola melhore a sensibilização e as sessões de formação com os agricultores sobre a AC.

Implicações da pesquisa: Os resultados implicam que a AC seja promovida minimizando as limitações e maximizando os factores motivadores, a fim de produzir mais alimentos de forma sustentável.

Originalidade/valor: A originalidade do estudo reside em investigar a viabilidade e relevância das AC na perspectiva dos beneficiários, bem como testar a teoria do efeito da agricultura de conservação no contexto de Kisangani, República Democrática do Congo.

Palavras chaves: agricultura de conservação, rendimento das culturas, impacto, factores, constrangimentos, adopção

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THE POTENTIAL OF CONSERVATION AGRICULTURE ON CROP YIELD IN THE DEMOCRATIC REPUBLIC OF CONGO

ABSTRACT

Purpose: One of the reasons for promoting conservation agriculture (CA) in Sub-Saharan Africa is its association with an increase in crop yield for smallholder farmers. However, the yield increase and stability attributed to CA remain without consistent and harmonised debate. The study assessed the impact of CA on crop yield, as well as the factors driving adoption, and the challenges that farmers face when using CA in Kisangani, Democratic Republic of Congo.

Theoretical framework: The study employed the unified theory of acceptance and use of technology as its theoretical framework.

Method: A structured questionnaire was randomly administered to 192 CA farmers to collect data through a multistage sampling process. Descriptive and multinomial logistic regression analyses were used to examine associations and possible predictors influencing farmers' adoption and crop yield.

Results and conclusions: The results show that CA has a positive impact on crop yields, particularly for cassava and rice. In addition, farmers are impelled to use CA because of increased yield and soil fertility, both of which are achieved overtime. The study suggests using organic fertilisers locally produced to enhance the immediate outcome expected by farmers. The lack of extension service coverage is a major constraint, which translates into a lack of knowledge about CA in the farmers' practices, specifically inappropriate crop rotation and agronomic practices, which result in low maize yield. The study recommends the agricultural sector improve CA awareness and training sessions with farmers.

Research implications: The results imply that CA should be promoted by minimising limitations and maximising motivating factors in order to produce more food in a sustainable manner.

Originality/value: The study's originality lies in investigating the feasibility and relevance of CA from the beneficiaries' perspectives, as well as testing the theory of the effect of conservation agriculture within the setup of Kisangani, Democratic Republic of Congo.

Keywords: conservation agriculture, crop yield, impact, drivers, constraints, adoption

1 INTRODUCTION

Food demand, combined with declining soil fertility and climate change, has cast doubt on agriculture's future and sustainability. Yield-enhancing and natural conservation technologies have been better approaches to address the problems. Consequently, many research institutions and organisations have shifted their focus to investigating, promoting and implementing environmentally friendly technologies (Rust et al., 2020; Singh & Singh, 2017). In sub-Saharan Africa (SSA), an attempt has been made to address the sustainability of smallholder farmers, productivity and environmental impacts (Brown et al., 2018b). The idea stems from the knowledge that these technologies have the potential to increase farm yield while restoring the environment (Mango et al., 2020). Following several years of conflict that resulted in food insecurity in the Democratic Republic of Congo, empowering farmers by training them about CA, a more sustainable alternative to slash and burn agriculture, could alleviate food insecurity and fight poverty while restoring the environment. The main point of CA is its emphasis on environmental, social, and economic solutions in agriculture for the generation of current and future needs (Coulibaly et al., 2021). Although CA has long been recognised as a solution to the problems associated with food demand, declining soil fertility, erosion and climate change (Hulst & Posthumus, 2016; Verma, 2021), there have been conflicting views in the literature regarding its effects on smallholder farmers (Ndah et al., 2018).

An examination of the literature on CA tends to indicate that the Americas and Australia have a high rate of adoption because CA has an impact on farmers' meeting their needs, particularly in terms of productivity, profitability and improved environmental outcomes (Osewe et al., 2021;

Su et al., 2021; Brown et al., 2018a; Mutyasira et al., 2018). Anghinoni et al. (2021); de Freitas & Landers (2014); Osewe et al. (2021); Su et al. (2021) found that farmers who used CA (zero tillage) experienced the benefits of on-farm, an off-farm reduction in public spending, an off-farm environment for society and mitigation of deforestation. In this regard, CA is believed to ensure food security. To achieve the desired benefits, De Freitas & Landers (2014) and Ndah et al. (2018) recommended implementing all CA principles (minimum soil disturbance, vegetative cover and crop rotation). However, implementing all three CA principles appears to be extremely difficult, with smallholder farmers adapting to one or two, depending on resource availability, crop choice in a given season and the system to be used (Umar, 2014). As a result, CA technology has been criticised for failing to align with farmers' resources because CA adoption, just like any other technology, depends on a variety of factors; socio-economic, psychological, and other context-specific (Bourne et al., 2021; Somasundaram et al., 2020). Perhaps this explains the lack of CA adoption and food insecurity in most SSA countries, where farmers face resource constraints as new technology demands additional investments, specifically in reduced tillage equipment, farmers' need for new management skills, input costs and appropriate technical package training.

Evidence shows that the benefits of CA include, but are not limited to, increased yields, reduced labour requirements, reduced soil erosion, maximised input use, flexible farming systems under climate change, reduced production costs, improved environmental conditions, reduced ploughing costs, reduced soil water evaporation and improved soil fertility. Despite evidence supporting CA's benefits in Africa, Mango et al. (2017); Abdulai & Abdul-Rahaman (2020); Kuboja et al. (2021), researchers have also raised concerns about decreased yields, increased labour requirements and lack of vegetative cover in other parts of SSA (Bourne et al., 2021; Brown et al., 2018a). Moreover, increased crop production and profitability, as well as yield stability remain unaffected by rigorous, consistent and harmonised debate (Bourne et al., 2021; Brown et al., 2018a). This perception has resulted in an inconsistency in the understanding of the benefits of CA, highlighting the need for additional research to develop a unified understanding of the impact of CA and the challenges that farmers face when they implement CA in the region. While the debate over the benefits and relevance of CA to smallholder farmers continues, the constraints identified thus far have not been explored further in order to understand the feasibility and relevance of CA within the Kisangani setup, particularly from the beneficiaries' perspectives. The current study contributes to the body of knowledge about the theory of effects of CA and the challenges that come with them in Kisangani, Democratic Republic of Congo (DR Congo). The study specifically (1) examines the factors that drive adoption of CA (2) investigates CA's contribution to farmers in terms of crop yield and (3) identifies constraints to CA application.

2 THEORETICAL FRAMEWORK OF THE STUDY

Farmers who wish to adopt new technologies may do so for a variety of reasons. They may find the technology more efficient and profitable to produce because of its lower labour and farming inputs, more stable and immediate impact, and improved soil nutrients, or they may notice a problem and, in their pursuit of solutions, they are impelled to practice new technology such as CA (Coulibaly et al., 2021; FAO, 2016). In farming systems, the problems include, but are not limited to, soil degradation or declining crop yields due to poor soil fertility that motivate farmers to adopt the new practices. In an attempt to secure food at the household level, farmers make choices and decisions about the use of certain technologies under the constraints and facilitating conditions imposed by their socio-economic characteristics and on-farm resources, as well as community and global challenges. The study employed the unified theory of acceptance and use of technology (UTAUT) theoretical framework to assess the potential of CA (Venkatesh et al. (2016).

The UTAUT has four predictors of users' behavioural intentions (Fig 1): Performance expectancy: the degree to which individuals believe that by using the system, their results will improve when compared to previous ones. For example, an increase in productivity or soil fertility in field can be attributed to using new technology. Effort expectancy is the degree of ease associated with the use of new technology. The other factor is social influence- the degree to which an individual is able to judge which system or technology he or she should follow given the community and global challenges. It is an individual judgement based upon the advantages of current practices over the past as well as social pressure in a given context. The last determinant is facilitating conditions- the degree to which an individual believes that he or she is equipped technically to support the use of the new technology. Facilitating conditions include the availability of inputs, labour, land, etc. Furthermore, UTAUT determines that factors influencing farmers' adoption of technology to improve their livelihood are pervasive and include an internal and external range of forms such as gender, age, occupation, education, and experience, which act as moderators in the model, influencing the predictors to form behavioural intentions as a whole.

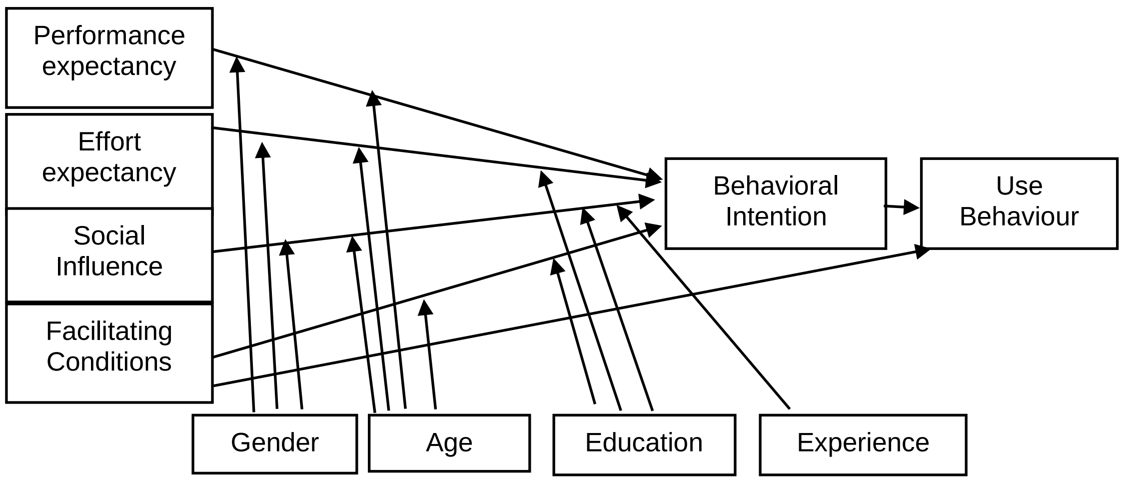

Figure 1 - Adapted unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2016)

3 METHODOLOGY

3.1 Study area description

The information for this study came from a farm household survey conducted in Kisangani (DR Congo) between August 2020 and January 2021. Kisangani (latitude 0^0 30’ 55’’ North, longitude 25^0 11’ 27’’ East) is the north-eastern city of Tshopo province of DR Congo. Kisangani presents abundant rainfall, with an average of 1750mm/year^{-1} and a range of 1500 to 2000mm/year^{-1}. On average, the temperatures range between 22.4^0c and 29.3^0c (Muvatsi et al., 2021). Conservation agriculture is being promoted by public and private extension services in response to ministry of agriculture guidance to produce cereals, tubers and legumes with smallholder farmers. A mixed farming system is commonly used by smallholder farmers to produce maize (*Zea mays*), rice (*Oryza sativa*), cassava (*Manihota esculenta Crantz*), groundnut (*Arachis hypogaea*), soya bean (*Glycine max*), cowpea (*Vigna unguiculata*) and common bean (*Phaseolus vulgaris*). The data came from smallholder farmers and on-farm observations.

3.2 Sample size and sampling procedures

A multistage random sampling procedure with face-to-face interviews was conducted to arrive at the final respondent for the study. In Kisangani, there are many territories where CA is promoted. Therefore, the study first chose the number of territories by using simple random sampling. Second, groups of associations of CA farmers in the targeted territories were also randomly sampled. Third, the households were chosen in the group associations using a simple random sampling method. At his stage, the study administered a close-ended questionnaire that also used random sampling (Ntshangase et al., 2018). This procedure ensured that the sample was accurately represented, making it unbiased and reliable (Ntshangase et al., 2018). In this regard, a total sample size of 192 smallholder farmers' households was surveyed across different localities around Kisangani (Table 1).

Table 1 - Sample size and study locations in Kisangani, DR Congo

Kisangani (DR Congo) -Villages	Frequency
Banalia road Km 25-42	57
Ituri road Km 23	19
Lubutu road Km 26	36
Elephant road Km 12-17	8
Seminary road Km 12-23	72
Total	**192**

3.3 Data collection, source and analysis

The study took a quantitative approach, based on a set of structured questionnaire survey with face-to-face close-ended interviews and on-farm observations to validate what was reported during the interviews. The questionnaire included a list of statements based on the constructs of UTAUT and the use of three CA principles. Specifically, the questionnaire explored issues with CA implementation, field management before and after harvesting, motivating factors and challenges of CA, changes in the household attributed to CA practice, crop system, land preparation, frequency and information flow, reduced tillage equipment, soil quality experience in the field, government investment and participation in CA, and their crop yield assessment measured in kilograms in the 2019/2020 season. On-farm observations included evaluating management practices relating to planting systems, land preparation, weed control measures, and the use of tillage and its associated equipment. The study also collected data on field size for both CA and non-CA systems in order to assess crop yields. This was done to compare crop yields between CA and conventional systems.

The collected data were coded and entered into the Statistical Package for Social Science (SPSS) and Excel for statistical analysis, resulting in descriptive and inferential statistics. Specifically, the study used the test of Tukey HSD all pairwise to compare all crop groups and the test of Welch to determine whether there were significant differences between the groups in the crop yields. This enabled the examination of possible relationships between variables as well as the computation of statistical tests of significance at the level of 0.05.

A multinomial logistic regression model (MLRM) was also employed to identify predictor variables associated with the adoption of CA: minimum soil disturbance, soil cover and crop rotation (Table 2). The MLRM then generated coefficients (its standard errors and significance levels), which were used to predict a logit transformation of the probability of the adoption of CA. Using the variables in Table 2, a linear model was first run to check the multicollinearity and fitness of the model. The fitness of the model was determined using the chi-square of Pearson and Deviance that the SPSS package generates after the command. The model was then tested with a *p* value of 0.996 Pearson and a Deviance of 0.978 for constraints of CA adoption and a Pearson of 0.996 and a Deviance of 1.000 for factors driving CA adoption, indicating that the model fitted the data well. In other words, the model fits well when the value of *p* is not significant for both Deviance and Pearson after testing using the chi-square in SPSS. Equation 1 also represents the model and shows how the predictors were computed in the model.

$$p_{mi} = \left(\frac{e^{(z_{mi})}}{\sum_{m=0}^{M-1} e^{(z_{mi})}}\right); m = 0 \ldots \mathrm{M} - 1 \quad (1)$$

i=each case of a sample size n; M= Total quantity of categories of the polytomous dependent variable; m= Number of categories coded from 0 to M-1; Yi= Polytomous dependent variable (Y_i = 0; 1; 2; ...); Z_{0i}= Logit of category 0 (reference category); Z_{mi}= Logit; p_{mi}= Probability of occurrence of uptake of CA; B_0= Constant of the equation; B_{mk}= Regression coefficients; X_{ik}= Independent variable k (Predictor k) metric or dichotomous.

Table 2 - Nature of variables used in analysis

Dependent Variables	Variables description	Description/ unity
Minimum soil disturbance	Categorical	0=does not use; 1=use
Soil cover	Categorical	0=does not use; 1=use
Crop rotation	Categorical	0=does not use; 1=use
Predictor variables		
Farming experience	Continuous	Years
Less biotic stress	Categorical	0=no; 1= yes
Gain knowledge	Categorical	0=no; 1= yes
Save cost	Categorical	0=no; 1= yes
Improved soil fertility	Categorical	0=no; 1= yes
Assistance period	Categorical	0=No assistance;1=twice a month; 2=Once a month;3=trimestral; 4=irregular/not specific
Require labour	Categorical	0=no; 1= yes
CA effectiveness	Categorical	0=no; 1= yes
Input cost	Categorical	0=no; 1= yes

Table 2 shows the types of variables that were employed in the analysis of the study, as well as their measurements and descriptive units.

4 RESULTS AND DISCUSSION

4.1 Factors influencing conservation agriculture adoption in Kisangani, DR Congo

Farmers' willingness to adopt new technology can be influenced by how they are influenced by the UTAUT conception (Figure 1). Farmers are goal-oriented, and they seek immediate advantages accruing from technology. With CA, the benefits are not immediately apparent. It improves its performance overtime (Mango et al., 2017; Montt & Luu, 2020). Farmers were asked to explain why they feel impelled to use CA in their fields. As shown in Table 2, increased crop yield (22%) and soil fertility (18%) are the main factors motivating farmers to use CA. Increased yield and soil fertility belong to the category of expected performance of the CA. Both of these factors can only be observed overtime. Farmers are sometimes discouraged from using technology in this situation since their goal is to gain immediate and survival advantages. Apart from that, Mulimbi et al. (2019) have observed that adoption of CA leads to higher income reliability and food security in Maniema, DR Congo. However, Ndah et al. (2018) have argued that the available evidence of CA's leading to higher returns is not applicable to all CA farming contexts. Observation on the field shows that farmers are not motivated to participate in the group associations because extension assistance is not always available, except in locations with good road infrastructure and private-dominated extension services. As can be seen, their objective of increasing crop yield and improving soil fertility is sometimes frustrated because knowledge does not flow as it should to produce a better result. In addition, their belief that the new technology will produce better results than the current conventional system cannot be perceived; rather, it is deceived. In the scenario of knowledge uncertainty, (Umar, 2014) observed that farmers seek survival algorithms rather than profit maximisation. Uncertainty about knowledge refers to inconsistencies and lack of persistency in teaching about technology and the state of not knowing what to practice between the conventional system and what has been learned. This occurs when a newly acquired system (knowledge) is broken and cannot be continued. The finding suggests that extension services should be improved in order to assist farmers accomplish their CA goals and increase food security at the household level.

Table 2 - Factors influencing CA adoption in Kisangani, DR Congo

Parameters	**Percent (n=192)**
Increased crop yield	22
Soil fertility	18
Improved income generation	15
Enhanced tech. skills	14
Improved soil moisture	12
Less biotic stress	10
Reduced soil erosion	9
Total	**100**

The study performed a Spearman's correlation analysis with the objective of evaluating whether there was an association between the perceived factors and the CA adoption. Based on the results (Table 3), the correlation showed a negative and very weak correlation between the adoption of CA and "farming experience" (Rho =-0.197; p = 0.010), and the relationship was statistically significant. This suggests that the more farmers have experience with CA, the less farmers may be willing to use it. Alternatively, the more farmers use the technology for a long time, the more they decelerate using it. Dearing & Cox (2018) and Rogers et al. (2019) have observed the phenomenon as normal. In the beginning, it is normal to observe an increase in adoption of the technology. Later on, the users start decelerating their use of the technology to reach the point of an S-shaped curve over time. An S-shaped curve is a moment of diffusion in which the curve displays a slower rate of adoption as the rate of adoption reaches its plateau and declines as a result of the discontinuance (Rogers et al., 2019). Further, this occurs because of the competing or complementary innovations taking place in the context. Discontinuance can also occur as a consequence of age versus the demand for technology. This suggests that farmers with old experience with the technology will need more assistance from the extension work so that they can continue producing without putting their food production levels at risk. While the theoretical framework claims that experience and age may have a positive or negative impact on the adoption of technology, the current study demonstrates that they have a negative impact.

The correlation showed a positive and weak relationship between CA adoption and "less biotic stress" (Rho = 0.241; p = 0.001), "knowledge gaining" (Rho = 0.320, p = 0.000), "saving cost" (Rho = 0.232, p = 0.002) and "improved soil moisture" (Rho = 0.268, p = 0.000) respectively. The most striking observation to emerge from Table 3 is the non-significant linear correlation with the increased crop yield, which was unexpected with CA technology as farmers reported that the increased yield was the major reason why they decided to use CA technology. However, the association is also expressed by the linear relationship between the use of CA technology and "saving costs," such that farmers who use CA technology have higher "saving costs" in their households. Specifically, the correlation is related to the capacity of farmers to "save costs" as a result of the use of CA in terms of reduced ploughing costs and reduced production costs.

A similar linear relationship was found between the use of CA and "less biotic stress," as shown in Table 3. This indicates that when farmers use CA, they gain the advantage of less biotic stress in their fields, as reported by one of the farmers in Kisangani, "We experienced damage and losses caused by insects and diseases in our fields. However, after some years of using CA, the diseases were significantly reduced and the crops grew well." This is also in line with improved soil fertility. The challenge is that not all farmers have access to this knowledge to profit from it. Therefore, the government is called upon to massively upscale the use of CA combined with good agronomic practices, including improved seeds. The result supports the proposed theoretical framework as CA adoption relates to reduced expected effort (Venkatesh et al., 2016), notably saving operation costs, less biotic stress and reducing labour requirements during CA application.

A study in Southern Africa has shown that benefits have not always been guaranteed under the CA (Montt & Luu, 2020). Thus, the benefits accrued from CA depend on a variety of factors and the combined implementation of different practices, of which most African smallholder farmers are unaware due to the lack of extension services. The study argues that, in addition to addressing the problem of extension service, CA the package should be promoted, taking into account the context's demands in terms of its specific adaptation, applicability, soil types, crops and farm system characteristics. Future studies are called upon to evaluate soil type and the adaptation of the existing crops to the system of CA.

Table 3 - Degree of association between CA adoption factors and CA adoption in Kisangani, DR Congo Spearman (Rho) correlation coefficient, (n=191)

variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. CA adopted	1								
2. Assistance period	0.138 0.062	1							
3. Farming exp.	-0.197* 0.010	0.027 0.727	1						
4. Increased crop yield	0.091 0.218	0.194** 0.008	-0.143 0.062	1					
5. Improved soil moisture	0.098 0.187	0.164* 0.025	-0.233** 0.002	0.603** 0.000	1				
6. Less biotic stress	0.241** 0.001	0.161* 0.028	-0.180* 0.019	0.392** 0.000	0.444** 0.000	1			
7. Knowledge gain	0.320** 0.000	0.202** 0.006	-0.165* 0.031	0.423** 0.000	0.457** 0.000	0.528** 0.000	1		
8. Saving cost	0.232** 0.002	0.150* 0.042	-0.186* 0.015	0.510** 0.000	0.616** 0.000	0.593** 0.000	0.612** 0.000	1	
9. Improved soil fertility	0.268** 0.000	0.181* 0.014	-0.221** 0.004	0.428** 0.000	0.562** 0.000	0.691** 0.000	0.550** 0.000	0.673** 0.000	1

* p≤0.05; **p≤0.01; ***p≤0.001 (2-tailed)

Regression analysis was used to explain the causal relationship between the predictor variables and CA adoption. The model of regression compared each category group against the reference category (minimum soil disturbance). In Table 4, the first set of coefficients, "knowledge gain" was found to be a negative significant predictor (b =-2.176, SE = 0.855, *p* = 0.011) in the model. The result suggests that farmers with less knowledge about the CA system were less likely to adopt the soil cover crop system, but would more likely adopt minimum soil disturbance. The odds ratio of 0.114 indicates that for every unit of "knowledge gain" about the CA system, the odds of farmers adopting the soil cover system changed by a factor of 0.114. This implies that the more farmers understand better about the CA, the more the time to adopt soil cover technology over the minimum soil disturbance alone will decrease by a factor of 0.114 times.

In the second set of coefficients of Table 4, once again, "knowledge gain" was found to be a negative significant predictor (b =-1.596, SE = 0.542, *p* = 0.003) in the model. The result suggests that farmers with less knowledge about CA were less likely to adopt a crop rotation system, but would more likely adopt minimum soil disturbance. The odds ratio of 0.203 indicates that for every unit of knowledge gained about CA, the odds ratio of farmers adopting crop rotation changed by a factor of 0.203 times.

Table 4 constructs unique assumptions that may serve as a model to be used when thinking about the promotion and diffusion of CA in Kisangani. The preference for minimum soil disturbance over the other approaches can be attributed to the ease of preparation of soil, reduced input and soil quality improvement. However, this approach may be difficult to implement in Kisangani due to farmers' lack of access to and availability of no-till equipment and herbicides to control weeds. Moreover, implementing minimum soil disturbance necessitates an understanding of the type of soil and machinery to be used, both of which the promoters of CA lack in Kisangani. The study suggests that extension services be improved so that farmers can focus on using not only minimum soil disturbance but also soil cover and crop rotation to achieve better outcomes. Alternatively, the study suggests promoting CA application while taking into account facilitating conditions, including no-till equipment, soil conditions and less environmentally impacting herbicides.

"Knowledge gain" was a predictor of minimum soil disturbance adoption and, as a result, the need to be deepened and spread to more farmers. This implies strengthening capacity-building among farmers in order for them to appropriate and learn about CA as their community property. This will help farmers adopt CA, taking into account not only the ease of one principle over another but also the benefits behind it as a value, which farmers will seek in order to increase crop yield and therefore secure food at household level. Similar literature on agricultural innovations has also stated that awareness and knowledge are the first steps in the process of adopting improved technology (Rogers et al., 2019). However, the study observed that the underlined suggestion is linked to other specific conditions that must be met and solved in Kisangani in the first place. These include increased agricultural investment by the government and stakeholders, extension service coverage, a clear policy of access to farm credit and other inputs, a more efficient market system, government-funded extension programs, and a link between agricultural research and the education system.

Table 4 - Factors impacting CA adoption in Kisangani, Democratic Republic of Congo

CA adopted Vs. Predictors variables		**B**	**Std. Error**	**Wald**	**df**	**Sig.**	**Exp (B)**
Soil cover/ stubble retention	Farming Experience	-0.230	0.209	1.202	1	0.273	0.795
	Less biotic stress	0.512	1.092	0.220	1	0.639	1.668
	Knowledge gain	-2.176	0.855	6.471	1	0.011	0.114
	Saving cost	-0.055	0.910	0.004	1	0.952	0.946
	Improved soil moisture	-0.025	1.078	0.001	1	0.981	0.975
Crop rotation or intercropping	Farming Experience	-0.030	0.102	0.089	1	0.765	0.970
	Less biotic stress	-0.207	0.616	0.113	1	0.736	0.813
	Knowledge gain	-1.596	0.542	8.682	1	0.003	0.203
	Saving cost	0.137	0.521	0.070	1	0.792	1.147
	Improved soil moisture	-0.645	0.603	1.146	1	0.284	0.525

The reference category is: minimum soil disturbance.

4.2 The potential of conservation agriculture on crop yield in Kisangani, DR Congo

The main concern for promoting CA is food demand as a result of soil depletion and climate change challenges. CA is a yield-enhancing and natural conservation technology (Coulibaly et al., 2021). Figure 2 shows the levels of production of rice, cassava and maize in Kisangani. Farmers were asked to provide information on the quantity of production of each crop measured into kilograms per hectare for two systems of production, namely CA and non-conservation agriculture (NCA), fields in the last season. Farmers mainly produced rice, cassava and maize for the two planting systems under diversified crop rotation, whether changing the crops each season, sequential cropping, or mixing crops. Normally, diversified crop rotation is practiced with legumes.

However, it was observed that farmers practice diversified crop rotation with cassava, maize, sweet potato, rice and vegetables in Kisangani.

In addition, it was observed that only a few farmers planted legumes in the study area. Legumes were mostly not planted in both systems of CA and NCA simultaneously. This is the reason why the study was unable to conduct a comparison analysis of crop yields other than the current ones. Although the association of crops can also be done with other crops apart from legumes, it was observed that farmers associated crops inappropriately. The government and private sector should train farmers on how to implement legumes in the fields if the objective is to improve soil structures for long-term application. Alyokhin et al. (2020) have observed that if farmers practice CA in an inadequate manner, little can be gained as it resembles the conventional system, which permits poor production. Further, the conventional system allows the incidence of weeds, insects, and plant diseases to increase as well as decreases the biological property of the soil (inorganic matter).

The tests of Tukey HSD all-pairwise and Welch showed that there was a significant difference between rice and cassava produced under CA (Fig 2). Specifically, farmers had better returns on cassava and rice produced under CA than cassava and rice produced under the non-conservation agriculture planting system. Previous findings also showed an increase in yield in Sub-Saharan Africa as observed in Zambia Ngoma et al. (2021), Malawi Bouwman et al. (2021) and Tanzania (Kimaro et al., 2016). However, there is no record that yield increases are observed over the long-term. Future studies on crop yield may offer more insight into the situation. Since farmers experienced an increase in the crop yield of cassava and rice, the belief is that they have also improved environmental restoration, specifically improving organic matter content, reducing soil erosion, improving soil fertility, etc. In the context of Kisangani, the understanding is now that CA currently has a positive effect on cassava and rice in spite of all the problems that farmers encounter, corroborating what other authors have postulated about the increase in crop yield attributed to the practice of CA (Osewe et al., 2021; Su et al., 2021; Brown et al., 2018a; Mutyasira et al., 2018). Future studies evaluating whether CA reduced labour, erosion, production costs, and soil improvements are required to have a comprehensive understanding of CA in Kisangani.

The result did not find a significant difference between maize produced under CA and conventional systems (Figure 2). Possible reasons for this include small land areas allocated to maize produced under CA, failure to apply to all three CA principles and failure to comply with agronomic practices required for maize. Similarly, studies have also shown that the impacts of CA on crop yield could be positive or negative. For example, positive effects were observed in Brazil and India (Anghinoni et al., 2021; de Freitas & Landers, 2014). However, negative effects were observed in Europe (Mango et al., 2017). The agriculture sector should evaluate the problems that farmers are facing in relation to maize production. This will assist farmers to maximise their production, as maize is one of the basic cereals most commonly used for consumption in Kisangani.

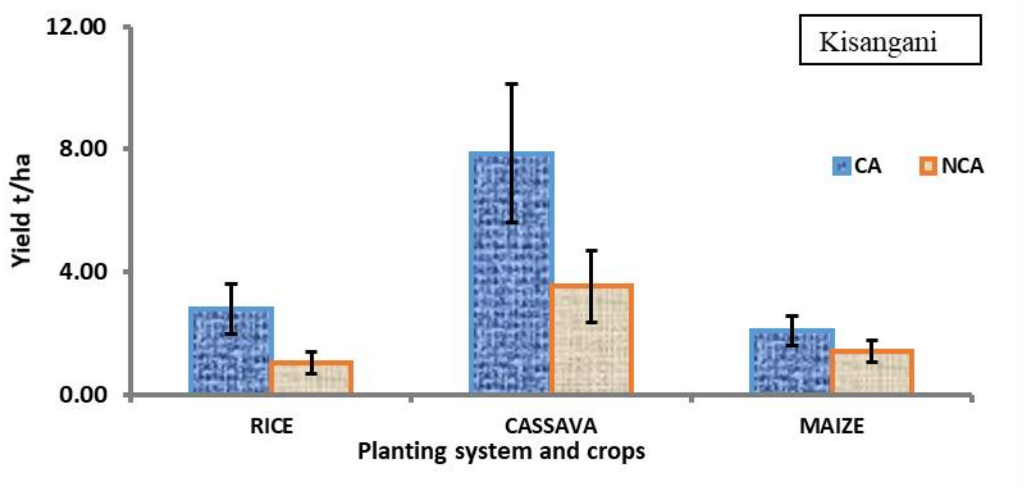

Figure 2 - The performance levels of conservation agriculture and non- conservation agriculture systems in Kisangani

4.3 Challenges of conservation agriculture application in Kisangani, DR Congo

It is evident that CA aids farmers in improving their overall livelihood. Nevertheless, this is contingent on how well the CA program's design and implementation address the constraints. Farmers were asked to mention challenges they face when using CA. Table 5 shows that the most frequently mentioned challenges were a lack of information or training (18%), a lack of farm credit (16%), equipment cost (16%) and herbicide demand (15%). The constraint of lack of information corroborates the aforementioned findings, particularly the factors influencing CA adoption, which the model revealed as farmers' knowledge gain demand. As a result, it is reasonable to conclude that awareness of CA is a major challenge in farmers' decisions regarding whether or not to employ CA practices. Ataei et al. (2021); Mulimbi et al. (2019) and Ntshangase et al. (2018) have also observed that farmers' poor knowledge of new technology is a barrier to CA development. They demonstrated how CA training influenced adoption in Lesotho, South Africa and Malawi. Poor knowledge is associated with an inability to practice CA, specifically in the stages of land preparation, weed control, harvesting and threshing in Kisangani. The skills related to these practices are intensive and alter the agricultural practices of farmers. The study claims that these challenges cannot be solved by the ministry of agriculture alone, and instead require collaboration across organisations, particularly research, universities, and consultants, in order to find a solution. The study also suggests that training be made permanent rather than being limited to demonstrations conducted under farmer field schools, as is currently done. The process includes, establishing local innovator systems to facilitate the exchange of information among farmers, specifically the use of a farmer-to-farmer extension approach to overcome the information access problems and lack of knowledge (Cipriano et al., 2022).

Other challenges are the lack of credit and appropriate equipment for CA. The study found that farmers were found to be unaware of the possibility of obtaining farm credit in a different form to improve production. In addition, it was observed that the government and private sector do not intervene in this matter, whether it is because of a lack of resources or a lack of will. Further, it was observed that farmers work on their own and extension services are primarily provided by the private sector in a limited number of locations. In relation to appropriate equipment for CA, Ataei et al. (2021) have argued that most of the time, even if it is available, it is not suitable for farming systems, climate conditions and farmers' resources. Unfortunately, the study found that reduced tillage equipment is not available, including the unsuitable one, forcing farmers to apply CA with hand hoes in Kisangani. Yet smallholder farmers respond to economic incentives. Ataei et al. (2021) have further observed that the lack of reduced equipment and credit allocation slows the process of CA adoption and leads farmers to dismiss CA as unimportant.

Table 5 - Challenges of conservation agriculture application in Kisangani, DR Congo

Challenges of applying CA in Kisangani	**Percent (n=192)**
Lack of information	18
Lack of farm credit	16
Equipment cost	16
Herbicide demand	15
Labour requirement	13
CA effectiveness	11
High cost of inputs	11
Total	**100**

With the objective of assessing predictors possibly impacting CA application, the study performed regression analysis. The first and second subsets of coefficients (Table 6), "assistance period" of extension services (for farmers not receiving assistance or receiving irregular assistance) was found to be a negative significant predictor for soil cover (b =-1.826, SE = 0.577, p = 0.002) in the model. However, "assistance period" was a positive significant predictor for crop rotation (b = 1.723, SE = 0.796, p = 0.030). For soil cover, the result indicates that for farmers who have challenges applying CA, specifically because of a lower frequency of extension assistance, they are less likely to adopt soil cover, but more likely to adopt minimum soil disturbance. The results also indicate that farmers who do not have access to extension services are more likely to use crop rotation, but would be less likely to use minimum soil disturbance. While the odds ratio of 0.161 indicates the factor of decreasing the possibility of using soil cover over the minimum soil disturbance, the odds ratio of 5.600 indicates the factor of increasing the possibility of farmers using crop rotation over the minimum soil disturbance. "Farming experience" (1 to 5 years) was also found to be a negative significant predictor (b = -1.229, SE = 0.402, p = 0.002) in the model. According to the findings, farmers who had applied CA for up to 5 years were less likely to use soil cover, but more likely to use minimum soil disturbance. The odds ratio of 0.292 further suggests that for every unity of farming experience with CA application, the odds of the farmers using the soil cover principle over minimum soil disturbance would decrease by a factor of 0.292. The other factors (labour requirement, effectiveness of CA and input cost) were not significant in the model.

Among the predictors selected for this study, assistance period of extension service and farming experience are crucial to the application of CA, demanding policy intervention in terms of improving extension services to diffuse CA practices. This confirms what the current study has been arguing about. In this regard, the application of minimum soil disturbance and crop rotation are possibilities that farmers would likely practice given the current challenges of farming. The decision to follow one principle over another is influenced by a variety of factors. In the current study, farmers are mostly influenced by farming experience, extension service coverage and CA equipment. Bilen et al. (2020) have found that the application of CA for smallholder farmers is primarily determined by the technology's suitability for the farmers' needs, economic and social factors and local practices. Moreover, Umar (2014) has found that these factors also influence farmers' partial adoption of CA. Rogers et al. (2019) emphasised the importance of new technology compatibility with pre-existing production systems, because if the technology aspects are all new to the farmers' context system, they may disregard them as unimportant.

Table 6 - Challenges impacting conservation agriculture adoption in Kisangani, Democratic Republic of Congo

CA adopted Vs. Predictors variables		B	Std. error	Wald	df	Sig.	Exp (B)
Soil cover/ stubble retention	Assistance period	-1.826	0.577	10.003	1	0.002	0.161
	Farming experience	-1.229	0.402	9.332	1	0.002	0.292
	Require labour	-18.423	8777.176	0.000	1	0.998	9.973
	CA effectiveness	-36.367	7807.330	0.000	1	0.996	1.607
	Input cost	0.810	1.550	0.273	1	0.601	2.248
Crop rotation/ intercropping	Assistance period	1.723	0.796	4.681	1	0.030	5.600
	Farming experience	0.559	0.945	0.350	1	0.554	1.749
	Require labour	-0.139	1.016	0.019	1	0.891	0.870
	CA effectiveness	-0.223	0.557	0.160	1	0.689	0.800
	Input cost	-0.524	0.682	0.589	1	0.443	0.592

The reference category is: minimum soil disturbance.

5 CONCLUSIONS AND FINAL REMARKS

The paper is one of the few that assessed the impact of CA adoption on crop yield in the Democratic Republic of Congo, as well as the factors driving adoption and the challenges that farmers face when using CA. Notwithstanding controversies and disagreements about CA, the study offers evidence that CA has a positive impact on crop yields, particularly for cassava and rice, which are grown in crop rotation systems. In this regard, the belief is that farmers have also restored soil carbon, reduced soil erosion, etc. Further studies evaluating these elements are required in order to fully confirm or deny what is claimed about CA in Kisangani. The lack of extension service coverage is at the core of the challenge, which translates into a lack of knowledge about CA in the farmers' practices, specifically inappropriate crop rotation and agronomic practices, resulting in the low yield of main grain (maize) for consumption. The lack of extension service remains a fundamental problem because it is the vehicle and facilitating condition through which knowledge about CA can be expanded. The study recommends that the agricultural sector improve CA awareness and training sessions among farmers by facilitating farmers' access to information, creating and supporting collective thinking at all stages of the program's implementation, and organising training sessions to cover the technical and managerial aspects of CA.

In addition, the study indicates that farmers are impelled to use CA because of increased yield and soil fertility. Both factors are achieved overtime. To address this issue and implement CA with success, the study suggests using organic fertilisers that can be easily produced locally to enhance the immediate production expected by farmers. Kisangani's conditions are favourable for the production of organic fertilisers because it rains throughout the year, implying a lot of vegetative cover and the ability of organic matter to decompose easily. Furthermore, because it rains all the time, the rainfall creates a problem of weed control for farmers. In this regard, the study suggests the appropriate use of less environmentally impacting herbicides. Further research is needed to investigate the appropriateness of their use in CA technology to reflect the Kisangani environment and soil responses. This implies the use of herbicides at the appropriate rate, at the appropriate time and in the environment of Kisangani. The study acknowledges that without recognising the proposed conditions, particularly among smallholder farmers in Kisangani, CA will be limited to a few resourceful farmers.

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