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Unpacking the behavioral intentions of 'emergent farmers' towards mechanized conservation agriculture in Zambia

Godfrey Omulo [a,*], Thomas Daum [a], Karlheinz Köller [b], Regina Birner [a]

[a] Hans-Ruthenberg Institute of Agricultural Sciences in the Tropics, University of Hohenheim, Wollgrasweg 43, 70599 Stuttgart, Germany
[b] Institute of Agricultural Engineering, University of Hohenheim, Garbenstrasse 9, 70599 Stuttgart, Germany

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ABSTRACT

Conservation Agriculture (CA) continues to gain relevance among small and medium-scale farmers in African countries, including Zambia, in response to food insecurity and the adverse effects of climate change. The rise in the number of market-oriented farmers, known as 'emergent farmers,' who acquire and utilize tractors and associated implements for agricultural production, has brought new dynamism to Zambian agriculture. While prior studies emphasize the significance of considering socio-economic and psychological factors in understanding farmers' adoption decisions, the underlying socio-economic and psychological determinants influencing emergent farmers' interest in CA have not been explored. This study examined the behavioral intentions of Zambian emergent farmers concerning Mechanized Conservation Agriculture (MCA) using the Decomposed Theory of Planned Behavior constructs: attitudes, perceived behavior control, subjective norms, and farmers' background factors. We surveyed 119 emergent farmers from selected districts and analyzed their responses through descriptive statistics and Spearman's rank correlation coefficient. We employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess the relationships among behavioral constructs (attitude, perceived behavioral control, and social norms) and the intention to adopt MCA. The results indicated that the positive attitude of Zambian emergent farmers had a significant impact (path coefficient = 0.24) on their intention (mean = 4.51) to adopt MCA on at least part of their farms. Perceived behavioral control, which measures perceived ability, resources, and skills for practicing MCA, also had a significant impact on intention (path coefficient = 0.37). Factors such as media influence, social influence, technical training, and extension services had positive but insignificant effects on farmers' intention to adopt MCA. Background factors, including overall farm size, farmer's age, area under CA, and years of CA use, showed a positive and significant correlation with farmers' intention to adopt MCA. These findings underscore the crucial socio-psychological facets of emergent farmers, which can be valuable for policymakers and practitioners aiming to harness their potential in promoting and enhancing sustainable agricultural approaches like MCA in Zambia.

1. Introduction

Conservation agriculture (CA) has been practiced globally, adhering to its three core principles: reduced soil disturbance, permanent soil cover, and crop rotation/diversification (FAO, 2009; Kassam et al., 2018). Research evidence shows that CA boosts agricultural productivity (Mupangwa et al., 2017; Wekesah et al., 2019), improves soil quality (Thierfelder and Wall, 2010), reduces soil erosion (Baudron et al., 2012), decreases labor demands (Spaling and Kooy, 2019), and enhances household income and food security (Arslan et al., 2014; Ngoma, 2018) compared to conventional farming systems (Stevenson et al., 2014; Sánchez et al., 2018). However, critical perspectives highlight challenges of CA such as slow or partial adoption (Brown et al., 2017; Giller et al., 2011), herbicide reliance (Giller et al., 2009), donor dependency (Pedzisa et al., 2015), labor intensiveness for smallholder farmers (Rodenburg et al., 2020), initial yield reduction (Giller et al., 2009), residue management conflicts (Thierfelder et al., 2013), and regional limitations (Pittelkow et al., 2015).

CA has been advocated in sub-Saharan Africa (SSA) and Asia, particularly among smallholder farmers, as a sustainable, resilient, and climate-smart farming approach (Thierfelder et al., 2017; Sánchez et al., 2018). Despite a 211% increase in SSA's CA land area from 2009 to 2018

* Corresponding author.
E-mail address: omuloh@gmail.com (G. Omulo).

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(0.48–1.5 Mha), it still represents only 1% of global CA land and 1.1% of Africa's cropland area (Kassam et al., 2018). This limited adoption persists despite substantial promotion and research efforts by development agencies and research organizations (Andersson and D'Souza, 2014). This suggests the necessity for more tailored and region-specific approaches to meet the needs and realities of SSA farmers. In Zambia, the adoption of CA remains relatively low, with less than 30% of farmers reported as adopters compared to non-adopters (Brown et al., 2017; Kassam et al., 2009).

Amid Zambia's low adoption and productivity of CA, recent adjustments in land ownership and farming practices have led to a rise in medium-scale farmers, commonly termed "emergent farmers" (Sitko and Jayne, 2014). These market-oriented farmers employ various levels of mechanization, such as animal-drawn ploughs (ADP) or tractors, to efficiently manage their larger farms and also provide mechanization services to smallholders (Sitko and Jayne, 2014; Adu-Baffour et al., 2019). Since the lack of mechanization has been a major impediment to CA adoption in Zambia, the utilization of mechanization by these emergent farmers offers a unique opportunity to extend mechanization solutions to farmers who do not possess ADP or the means to purchase tractors but can hire them. Consequently, the growth of medium-scale farmers is increasing the demand for mechanization, particularly tractors and associated implements, to enable them to effectively cultivate their expansive land holdings and compete favorably in the market (Jayne et al., 2019).

There is limited knowledge regarding whether emergent farmers are practicing CA (Sitko and Jayne, 2014; Westengen et al., 2018; Omulo et al., 2022b). Given that ownership of tractors and significant land holdings are strong motivators for CA adoption, understanding the intentions of emergent farmers to employ mechanization methods is crucial for promoting increased CA adoption and productivity (Zulu-mbata et al., 2017). Emergent farmers are considered the "missing link" in the broader adoption of Mechanized Conservation Agriculture (MCA) (Omulo et al., 2022b).

While previous studies have explored the drivers of CA adoption, typically emphasizing economic, exogenous factors, and farm characteristics (Foguesatto et al., 2020), there has been limited investigation into the social and psychological factors that may influence farmers' decision-making. Although there is no universal predictor of CA adoption (Foguesatto et al., 2020), there is a lack of understanding regarding emergent farmers' intentions and perceptions related to MCA in Zambia. Recent research has emphasized the importance of examining the intrinsic attitudes, perceptions, norms, and values that significantly influence farmers' decision-making regarding specific agricultural practices (Delaroche, 2020; Foguesatto et al., 2020; Tama et al., 2021; Atta-Aidoo et al., 2022; Bagheri and Teymouri, 2022).

This paper addresses the research gap in three ways. First, it examines the background characteristics that drive the adoption or dis-adoption of MCA among emergent farmers. Second, it investigates the attitudes and intentions of emergent farmers regarding the use of MCA practices on their farms, considering a period starting from the current season and extending for at least the next three years. This approach takes into account the time needed for the tangible impact of transitioning from conventional practices to CA, which typically becomes evident after 3–5 years to avoid initial yield penalties, a major cause of CA dis-adoption (Giller et al., 2009; Giller et al., 2015; Williams et al., 2018). Recent research highlights that medium-scale farmers, being more market-oriented and constrained by economic factors, may not be willing to wait for extended periods to decide on CA adoption (Omulo et al., 2022a). Farmers beginning to adopt MCA are expected to experience improvements in soil properties and crop yield stability after at least three years. Third, the study explores how attitudes, subjective norms, perceived behavioral control, and background factors influence emergent farmers' intentions to practice MCA on their farms. This socio-psychological characterization provides an analysis of factors influencing farmers' decision behavior, which is often overlooked by studies focusing on the economic and biophysical aspects of CA. Therefore, the primary objective of this study is to assess the intentions and perceptions of emergent farmers regarding MCA in Zambia using an empirical socio-psychological approach, specifically the Decomposed Theory of Planned Behavior (DTPB). By uncovering these less-recognized dimensions of emergent farmers, the study offers essential insights for policymakers and practitioners to develop effective approaches and strategies for promoting and strengthening mechanized CA in Zambia.

1.1. The context of CA in Zambia

Zambia is among the SSA countries where CA is gaining prominence. CA has been in practice in Zambia for over three decades (Thierfelder and Wall, 2009; Thierfelder and Wall, 2010), initially introduced by the Zambian National Farmers Union (ZNFU) in the late 1980 s and actively promoted by the Conservation Farmers Unit (CFU) since 1995 (Abdulai, 2016). The CFU's promotion primarily targets small-scale farmers utilizing hand hoe basins or 'potholing' technology (Ndah et al., 2018; Abdulai, 2016). However, the labor-intensive nature of basin technology appears to discourage CA adoption among small and medium-scale farmers. Instances of dis-adoption and pseudo-adoption have been documented, often linked to farmers' reliance on temporary subsidies from promoting organizations (Brown et al., 2018a). Nonetheless, the Zambian National Agricultural Policy endorsed the adoption of CA technology in 1999 as a strategy for food and nutrition security and climate change mitigation (Andersson and D'Souza, 2014; Abdulai, 2016; Brown et al., 2018a).

Similar to many SSA countries, Zambia is witnessing a shift in land ownership patterns (Diao et al., 2014; Jayne et al., 2016; Gwiriri et al., 2019; Jayne et al., 2019), with the rise of a class of 'emergent farmers' who are medium-scale farmers owning between 5 and 100 ha of land. These emergent farmers employ animal draft power and/or tractors with associated implements (Sitko and Jayne, 2012; Sitko and Jayne, 2014; Ngoma et al., 2016; Samboko et al., 2018; Jayne et al., 2019). In contrast, the number of small-scale farms under 5 ha is declining (Jayne et al., 2016). Recent research by Jayne et al. (2022) revealed that medium-scale farmers now cultivate 34% of farmland (5–100 ha), representing an 11% increase in their share of land cultivated since 2017, while smallholder farmers (less than 5 ha) have seen an 11% decline in the land they cultivate.

While emergent farmers are typically mechanized, non-mechanized small-scale CA farmers without access to mechanization still face labor constraints (Baudron et al. 2019). However, emergent farmers can play a pivotal role as potential CA multipliers by offering mechanized CA services to smallholder farmers who may be discouraged by CA's high labor demands (Jayne et al., 2016; Adu-Baffour et al., 2019; Omulo et al., 2022b). This concept is akin to the mechanization model observed in Brazil, where CA was initially adopted by large-scale mechanized farmers and then extended to small-scale farmers (Vanlauwe et al., 2014; Araújo et al., 2020). Recent studies on the potential of private sector-driven mechanization in Zambia have shown that emergent farmers have the potential to facilitate smallholder mechanization and the adoption of CA (Brown et al., 2018c; Adu-Baffour et al., 2019; Omulo et al., 2022b; Omulo et al., 2022a). Given the increasing labor demand among small and medium-scale farmers in Zambia, mechanization becomes a critical component of CA (Hatibu, 2013; Omulo et al., 2022a).

1.2. Theoretical and conceptual framework

This study applied the Decomposed Theory of Planned Behavior (DTPB) to examine the intentions of Zambian emergent farmers concerning the adoption or non-adoption of MCA over a minimum three-year period. The DTPB serves as a theoretical framework for comprehending how human behavior, encompassing both social and psychological aspects, influences the decision-making process in adopting new technologies, such as agricultural practices (Taylor and Todd, 1995). The DTPB extends Ajzen's Theory of Planned Behavior (TPB) (Ajzen, 1985), which, in turn, builds upon Ajzen and Fishbein's Theory of Reasoned Action (Gold, 2011).

In the Theory of Planned Behavior (TPB), attitudes, subjective norms, and perceived behavioral control contribute to behavioral intentions (Ajzen, 1985). These determinants of intention are shaped by fundamental belief structures like attitudinal beliefs (b_i), normative beliefs (nb_j) and control beliefs (cb_k) (Taylor and Todd, 1995). Consequently, attitude (A) corresponds to attitudinal beliefs (b_i) and reflects the belief that engaging in a behavior results in a particular outcome, influenced by the anticipated assessment of that outcome (e_1). Subjective norm (SN) is structured by a person's normative beliefs (nb_i) about a particular referent (person), subject to the motivation to conform to that referent (mc_i). Perceived behavioral control (PBC) represents one's control beliefs (cb_k), influenced by the perceived facilitation (Pf_k) of the control factor, either hindering or enabling the behavior. Control beliefs indicate the perceived ease or difficulty of executing a particular behavior, with perceived facilitation being a critical determinant (Ajzen, 1991; Taylor and Todd, 1995).

These belief structures give rise to a combination of unidirectional constructs (i.e., $\sum b_i e_i, \sum nb_j mc_j, \sum cb_k Pf_k$), which shows that only a few variables are sufficient to explain intentional behavior (Garay et al., 2019). However, the TPB's three constructs have been found to be limited as they could not highlight the influence of the determinants of intention (Taylor and Todd, 1995). Thus, the relationships between these constructs are not practically significant, and merging the various elements of the cognitive belief structure in TPB into a single concept is challenging (Tao and Fan, 2017). Therefore, Taylor and Todd (1995) suggested either introducing additional variables to enhance the TPB's explanatory power or emphasizing the belief structures that underlie the attitude, perceived behavior control, and subjective norms components of TPB (Shih and Fang, 2004).

Consequently, the DTPB was developed to enhance the understanding and prediction of human behavioral intention under various circumstances. DTPB achieves this by deconstructing the one-dimensional belief constructs into multidimensional belief constructs (Taylor and Todd, 1995). In the DTPB framework, the concept of attitude is disaggregated into perceived usefulness – reflecting the extent to which a technology is perceived as superior to existing alternatives; perceived ease of operation – the measure of how easy an innovation is perceived to be in terms of comprehension and usage; and perceived compatibility – the degree to which a technology aligns with existing values, past experiences, and the needs of potential adopters (Taylor and Todd, 1995). Similarly, the component of perceived behavioral control is divided into personal efficacy – pertains to an individual's confidence in their ability to execute a particular behavior; and perceived resources – relating to the perception of having the necessary resources to engage in the behavior (Taylor and Todd, 1995; Shih and Fang, 2004). This decomposition of belief constructs provides a more comprehensive and clear understanding of how these elements influence behavioral intention (Zeweld et al., 2017).

Furthermore, subjective norms, representing normative influences, are subdivided into distinct factors, including media influence, technical skills training, extension services, and social influence. This division aids in elucidating how various social groups and communication media impact behavior and decision-making. Prior research has shown that mass media, peers, friends, family, training, extension officers, and neighbors can act as sources of information about new practices, shape opinions regarding the attributes of a practice, alleviate uncertainty about the benefits and drawbacks of a practice, adapt the practice to local farm settings, and exert influence on others (Venkatesh et al., 2012). These subjective norms are considered catalyst factors, propelling the adoption of sustainable practices through all stages of the adoption process (Zeweld et al., 2017).

Based on DTPB, this study employed the conceptual framework illustrated in Fig. 1 to elucidate the factors influencing emergent farmers' intentions and decisions regarding the adoption of MCA in Zambia for a minimum three-year period. Prior research has recognized the TPB as a valuable framework for understanding farmers' decision-making processes in adopting various agricultural practices (Zeweld et al., 2017; Nyathi et al., 2020; Bagheri and Teymouri, 2022). Socio-psychological factors have been acknowledged as significant influences on the adoption behavior and decision-making of smallholder farmers (Zeweld et al., 2017).

Furthermore, social systems, including cultural norms and institutional arrangements, have been identified as influential factors shaping the adoption decisions of smallholder farmers in Zambia and Zimbabwe (Nyathi et al., 2020). Understanding farmers' intentions is critical, as they continually confront short-, medium-, and long-term agronomic and economic constraints that necessitate decision-making (Atta-Aidoo et al., 2022; Omulo et al., 2022a). Yet, their decision to adopt or not to adopt a given practice is greatly influenced by both endogenous and external factors (Nyathi et al., 2020; Atta-Aidoo et al., 2022). The framework utilized in this study integrated normative belief aspects, such as social influence, media influence, technical training, and extension services, to enhance the prediction of intentions toward MCA. Additionally, the framework allowed for the exploration of potential interaction effects between these antecedents (Taylor and Todd, 1995).

Moreover, this framework facilitated the evaluation of how background factors impact farmers' intentions and behavior. Ajzen (2011) noted that intentions and behavior are often indirectly influenced by background factors through their effects on socio-economic and environmental determinants. It has also been proposed that current studies should focus on how demographic variables affect the variation in farmers' attitudes, subjective norms, and intentions to adopt sustainable agricultural practices (Zeweld et al., 2017).

1.3. Hypotheses and definition of variables

The study incorporated four endogenous latent variables (intention, attitude, perceived behavioral control, and subjective norms) and several exogenous latent variables (media influence, technical training, social influence, extension services, perceived usefulness, perceived ease of operation, personal efficacy, perceived compatibility, perceived resources, and background factors) in order to assess the intentions of emergent farmers regarding the adoption of MCA (Zeweld et al., 2017). A comprehensive definition of these variables used in the study is outlined in Table 1. The unobservable socio-psychological variables were measured using observed indicators or statements, rated on a five-point Likert scale, ranging from "completely disagree" to "completely agree," "most unlikely" to "most likely," and many more (van Dijk et al., 2016).

The study hypothesizes that farmers' intentions to adopt or not to adopt MCA are influenced by their socio-economic characteristics, which serve as background factors (H_1). Consequently, the study examined how socio-economic characteristics or demographic variables, including a farmer's age, gender, education level, and farm size, impact their intentions regarding MCA adoption (de Leeuw et al., 2015; Ajzen, 2015).

H_1. : Emergent farmers' intentions to adopt MCA are positively correlated with their background factors.

The study further hypothesized that exogenous latent variables influence the endogenous variables of the DTPB (H_2-H_6), based on the DTPB conceptual framework illustrated in Fig. 1. These hypotheses were developed in alignment with the DTPB model and assessed the impact of attitudes, perceived behavioral control, and subjective norms on emergent farmers' intentions to practice MCA (Hair et al., 2017).

H_2. : The majority of the sampled emergent farmers in Zambia exhibit positive attitudes and intentions towards MCA.

H_3. : Emergent farmers' intentions regarding MCA are influenced by

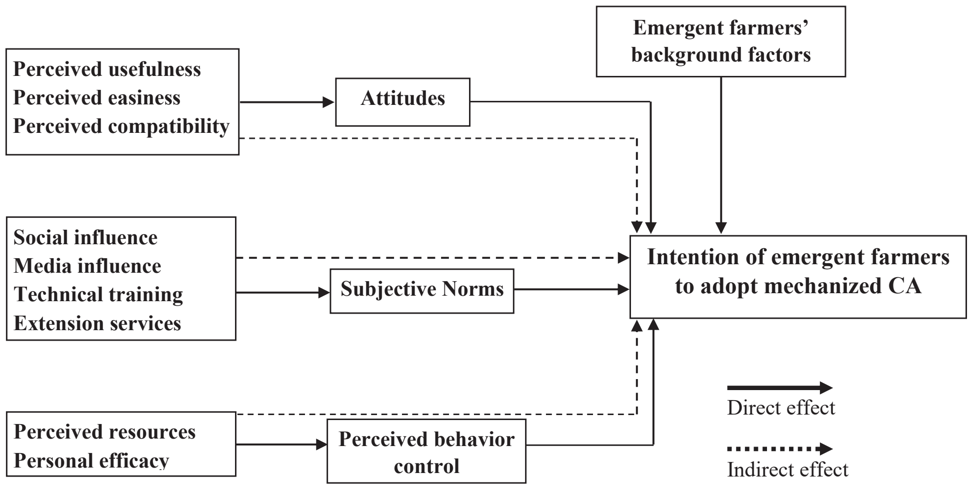

Fig. 1. Extended conceptual framework for behavioural intention of emergent farmers towards mechanized conservation agriculture (MCA).

their attitudes, subjective norms, and perceived controls.

H$_4$. : Attitudes intermediate the positive effects of perceived usefulness, perceived ease of operation, and perceived compatibility on emergent farmers' intentions.

H$_5$. : Perceived control facilitates the positive effects of personal efficacy and perceived resources on emergent farmers' intentions.

H$_6$. : Emergent farmers' intentions to use MCA are influenced by their access to media, social capital, technical training, and extension services.

2. Materials and methods

2.1. Study area and sampling procedure

The study was conducted at the Zambian-German Agricultural Knowledge and Training Centre (AKTC) in Chisamba, Central Province, Zambia. Since 2014, this center has been providing practical training to emergent and commercial farmers in crop production and the operation and maintenance of agricultural machinery. In this study, "emergent farmers" were defined as farmers who own land between 5 and 100 ha, even if they utilize only a portion of it for agricultural purposes. "Mechanized Conservation Agriculture" (MCA) was defined as the practice of conservation agriculture carried out using tractors and associated implements.

The research employed a three-stage sampling approach. First, ten districts were selected in Lusaka, Central, and Copperbelt provinces, based on the findings of a recent survey of emergent farmers conducted by the Indaba Agricultural Policy Research Institute (IAPRI) (Banda et al., 2018). These districts were chosen due to the significant number of emergent farmers reported. Second, emergent farmers were randomly chosen based on their level of mechanization, whether they owned tractors and associated equipment or hired tractor services for their farming activities. Data sources included the AKTC, District Agricultural Coordinators (DACOs), and Extension Officers (EOs).

A total of 251 farmers from the ten selected districts in Central, Copperbelt, and Lusaka provinces were identified. Finally, 190 emergent farmers were randomly selected from the districts using proportionate and random sampling techniques. However, only 119 farmers participated in the survey, based on their consent and their willingness to fill in the questionnaire. The distribution of surveyed emergent farmers per district is depicted in Fig. 2. The districts included Chibombo (20), Kapiri Mposhi (10), Luano (6), Chisamba (8), and Mumbwa (9) in Central province; Chongwe (6), Lusaka (11), and Rufunsa (10) in Lusaka province; and Masaiti (9) and Mpongwe (30) in Copperbelt province. While the data may not be exhaustive and nationally representative due to a smaller sample size, it highlights the status of the emergent farming sector in districts with high numbers of emergent farmers.

2.2. Data collection

A survey questionnaire was developed, pilot-tested, and adjusted. It encompassed demographic information of the farmers and a series of 5-point Likert scale questions regarding their perceptions and attitudes toward MCA. The final data collection phase excluded farmers who had participated in the pilot survey. Approximately 90% of the selected farmers engaged in face-to-face survey sessions led by trained enumerators. However, in light of travel restrictions and challenges posed by the COVID-19 pandemic, the remaining emergent farmers were interviewed via phone by trained enumerators. This data collection process occurred between November 2019 and April 2020.

2.3. Reliability analysis

The reliability of the measurement instrument was assessed using the Cronbach alpha (α) coefficient and composite reliability (CR), in accordance with established procedures (Hair et al., 2019). Reliability is a measure of the consistency and repeatability of an instrument's results across multiple uses (Ziba and Kang, 2019). Some previous studies have applied the compatibility principle to evaluate the robustness of their questionnaires and measurement scales (Atta-Aidoo et al., 2022). In this study, Cronbach alpha and composite reliability were employed to evaluate the internal consistency reliability or the degree of consistency, between the measured items (Boyko et al., 2011). High internal consistency indicates that the items are homogeneous and suitable for unit analysis (Kline, 2016). Typically, reliability values ranging from 0.6 to 0.7 are considered satisfactory to good, and latent variables with values exceeding this range are deemed reliable and acceptable for analytical research (Baumgartner and Chung, 2001).

A total of 46 survey statements were subjected to Cronbach's alpha and CR analysis. After the analysis, 27 items with alpha values greater than 0.6 were retained to represent both the endogenous constructs and the exogenous variables, as detailed in Table 2. The intention, attitude, perceived efficacy, and perceived resources constructs were represented by three statements each. Technical training, subjective norms, and social influence constructs were represented by four, two, and two statements, respectively. The remaining variables were represented by a single statement, as indicated in Table 2.

Table 1
Definition and description of latent variables used in this study.

Variable	Description of the variable	References
Attitude	The extent to which a farmer feels in favor or against adopting MCA upon weighing its merits and demerits.	Moons and Pelsmacker (2015);Zeweld et al. (2017)
Subjective norms	The extent to which the expectation of important people (referent groups) and information channels impact the behavior and decisions of emergent farmers – social influence.	Taylor and Todd (1995); Moons and Pelsmacker (2015);Ziba and Kang (2019)
Perceived behavioral control	Emergent farmers' perceptions of how easy or difficult it is to practice MCA on their farms. It depends on endogenous and exogenous hindrances or opportunities like one's abilities, know-how, economic status and machinery/ implements.	Taylor and Todd (1995); Moons and Pelsmacker (2015);Zeweld et al. (2017)
Perceived usefulness	The degree to which an emergent farmer believes that practicing MCA will enhance yield, soil fertility, food security and income.	Hsu and Chiu (2004); Moons and Pelsmacker (2015);Zeweld et al. (2017)
Perceived easiness	The extent to which an emergent farmer perceives MCA to be effortless, easy to know, learn and practice.	Hsu and Chiu (2004); Moons and Pelsmacker (2015);Zeweld et al. (2017)
Perceived compatibility	The extent to which an emergent farmer believes that MCA can merge well with the locally accepted values, their prior experience, and present realities.	Taylor and Todd (1995); Hsu and Chiu (2004); Zeweld et al. (2017)
Personal efficacy	The degree of trust an emergent farmer has that he/she can successfully adopt the MCA practices based on their ability, competencies, and knowledge.	Taylor and Todd (1995); Zeweld et al. (2017)
Perceived resources	The extent to which an emergent farmer perceives that he/she has enough resources in terms of land, capital, labor, time, and technical inputs to aid them in performing MCA.	Taylor and Todd (1995); Zeweld et al. (2017)
Media influence	The impact of information from social media such as television, radio, newspapers and magazines on the behavior and decisions of emergent farmers regarding MCA	Moons and Pelsmacker (2015);Zeweld et al. (2017)
Technical training	The extent to which short-term training, workshops, agricultural field days, experience sharing, on-farm demonstrations and exposure visits influence the behavior and decisions of emergent farmers on MCA.	Zeweld et al. (2017);Daxini et al. (2019)
Extension service	The level of influence to perform MCA on emergent farmers due to the information or advice given by agricultural advisory experts, and extension workers.	Zeweld et al. (2017); Al-Zahrani et al. (2019)
Social influence	The degree of influence on MCA practice by important groups (referents) like friends, neighbors, families, communities, local leaders, and farmer groups.	Moons and Pelsmacker (2015);Zeweld et al. (2017)
Background factors	Personality, life values and demographic factors such as education level, age, gender, religion, and income that are considered to influence emergent farmers' intentions towards MCA practice.	Ajzen (2011); de Leeuw et al. (2015)

2.4. Correlation analysis and hypothesis testing

To test hypotheses and investigate potential causal relationships between variables, Spearman's rank correlation coefficient was utilized (Bruijnis et al., 2013; Borges et al., 2014). Spearman's rank coefficient is a non-parametric correlation estimate that assesses the strength of the relationship between two variables based on the rank orders of each ordinal variable or scale. Significance testing was conducted using a two-tailed level of significance (Borges et al., 2014; Kline, 2016). Spearman's correlation is versatile as it does not necessitate linearity, bivariate distribution, or normality in the data (Bruijnis et al., 2013; Touré et al., 2020). Two-tailed Spearman's rank correlations were performed using the means of each construct, the decomposed variables, and the socioeconomic factors. Each bivariate correlation analysis signified the association between two variables on a scale from − 1 to + 1, where positive correlation coefficients indicate a positive relationship, negative coefficients indicate a negative relationship and a coefficient of zero indicates no association between the variables. This approach facilitated the assessment of emergent farmers' intentions toward adopting MCA. Data organization, descriptive statistics, and correlation analyses were conducted using IBM SPSS, version 27.

Subsequently, to evaluate the DTPB model and test the hypotheses, the Partial Least Squares Structural Equation Modeling (PLS-SEM) path modeling technique was employed, utilizing Smart PLS4 software (Hair et al., 2019; Bagheri and Teymouri, 2022; Ringle et al., 2022). PLS-SEM combines principal components analysis with ordinary least squares regressions to estimate partial model structures (Chin, 1998; Hair et al., 2017; Hair et al., 2019). This method is particularly suitable for estimating complex models with numerous constructs, variables, and structural paths without imposing stringent assumptions on the data distribution (Chin, 1998). In contrast, structural equation modeling (SEM) is employed to explore relationships between observed and latent variables, along with the relationships between various latent variables (Chin, 1998). Therefore, PLS-SEM was used to assess the relationships between the underlying independent (exogenous) variables and the dependent (endogenous) variables (Hair et al., 2017; Hair et al., 2019). Moreover, PLS-SEM was preferred over SEM due to the study's relatively small sample size (Hair et al., 2019). PLS-SEM is well-suited for analyzing theoretical frameworks and complex models that involve numerous constructs and multiple items with small sample sizes (Chin, 1998; Hair et al., 2019).

Convergent validity for the model's constructs was assessed using indicator reliability loading (IRL) and average variance extracted (AVE), which show the extent to which indicator variables contribute to the variance of a construct (Chin, 1998; Hair et al., 2017). Typically, an IRL of 0.70 or higher and a minimum AVE value of 0.50 or greater is considered acceptable, indicating that the construct accounts for at least 50% of the variance in its items (Chin, 1998; Hair et al., 2017; Hair et al., 2019; Mohr and Kühl, 2021). The relevance and significance of indicators were further confirmed through a bootstrap procedure involving 5000 subsamples, with weights ≥ 0.1 and loadings > 0.5 being considered satisfactory and statistically significant (Mohr and Kühl, 2021).

In addition, the PLS-SEM aimed to maximize the R^2 values and considered values exceeding 0.50 to moderately explain the variance between the construct and the factors (Hair et al., 2017; Hair et al., 2019). Table 2 demonstrates that all IRL and AVE values were at or above 0.50, confirming that the measurement model exhibited satisfactory discriminant and convergent validity.

3. Results and discussion

3.1. Background characteristics and their impacts on farmers' intention to adopt MCA

Table 3 presents the background characteristics of the sampled

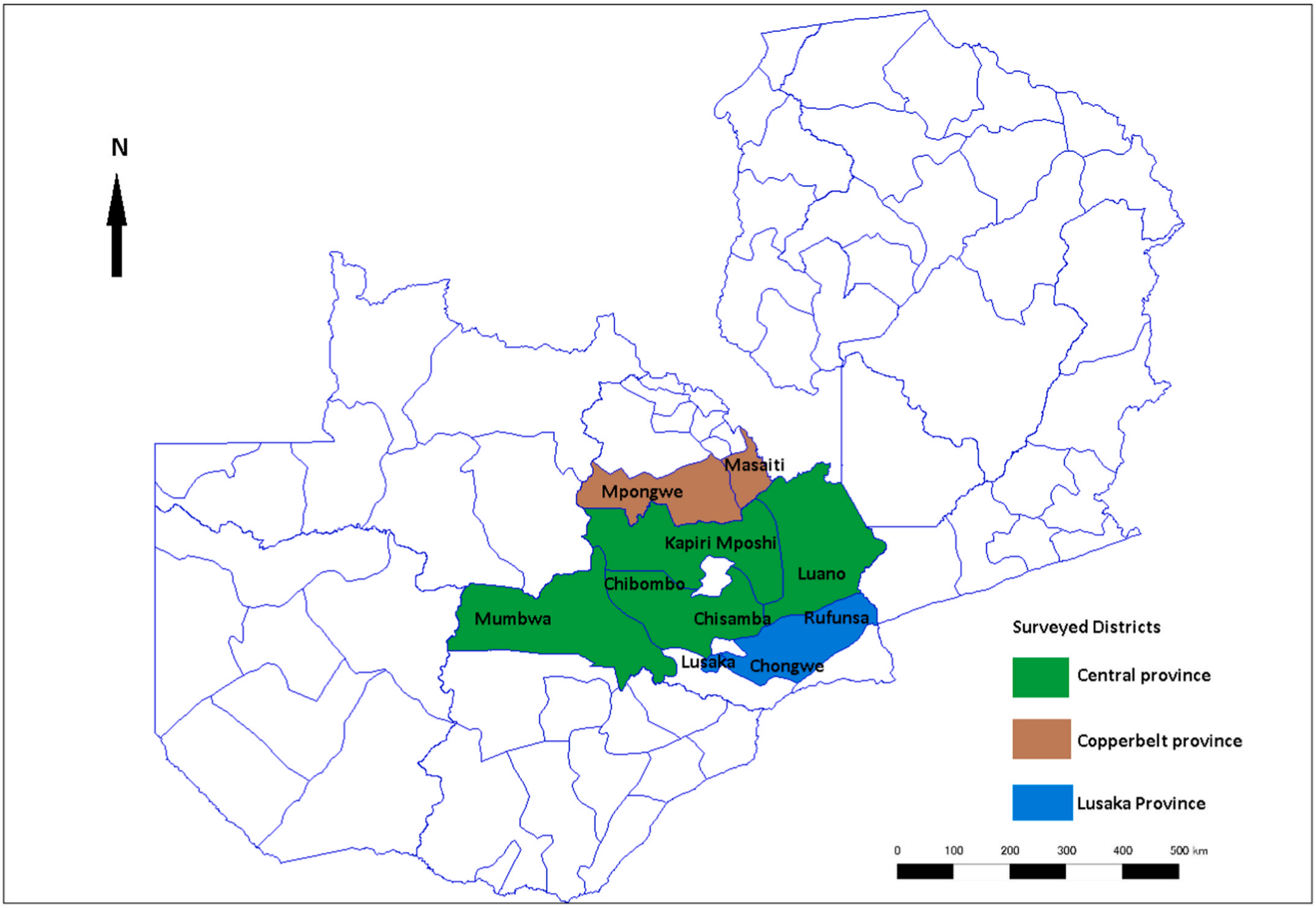

Fig. 2. Map of Zambia showing emergent farmer districts surveyed.
Source: Authors.

emergent farmers. Among the sampled emergent farmers, there were more men than women. A substantial portion, 33%, fell within the age range of 41–50 years, and 40% had attained a secondary school education. The majority of these farmers owned land ranging from 5 to 60 ha, with 30% owning between 60 and 200 ha. However, despite the substantial land holdings, only 28% fully embraced CA, while 40% partially employed CA practices and 32% continued with conventional farming methods. Notably, 18% of the respondents practiced CA on farms larger than 21 ha for a duration exceeding five years. These findings are consistent with prior research by Jayne et al. (2016) and Banda et al. (2018), which reported a relatively lower percentage of female emergent farmers in Zambia. Furthermore, these results underscore the existing gap between CA knowledge and its practical adoption in proportionate scales in Zambia, as highlighted by Brown et al. (2018a). The moderate adoption of CA on larger farms signifies relative progress in CA uptake among emergent farmers in the surveyed districts, aligning with the predictions of Kirui and Joachim (2018), who noted that medium and large-scale farms account for 68% of the land area under CA in Zambia and other Southern African countries.

To gain deeper insights into the influence of background characteristics on emergent farmers' intentions toward MCA, we conducted a correlation analysis between ten background factors (nominal variables) and the mean intention score (an ordinal variable) using the Spearman rank coefficient. While some studies have regarded demographic characteristics as control variables only (Ajzen, 2011; de Leeuw et al., 2015), this study considered these background factors as potentially relevant for understanding emergent farmers' behavioral intentions. Fig. 3 illustrates the correlation relationship between these background factors and emergent farmers' overall intentions regarding MCA.

The analysis revealed that the intention to practice MCA among emergent farmers was significantly and positively correlated with factors such as age, overall farm size, farm size under CA, the full-adoption status of CA, and the number of years practicing CA. On the other hand, there were insignificant positive correlations between education level and farmer districts with their intention to adopt MCA. Gender and the partial adoption status of CA showed insignificant negative correlations, while those who had never adopted CA exhibited a significant negative correlation with the intention to practice MCA. As a result, the hypothesis (H_1) proposing a positive correlation between emergent farmers' intentions to adopt MCA and their background factors was partially accepted.

The notable positive correlations between the age of emergent farmers, the extent of their land under CA, their experience with CA, and their intention to practice MCA indicate that CA experience and landholding play a facilitating role in MCA adoption in Zambia. A farmer's age is a critical factor in shaping their attitude toward modern technologies (Komarek et al., 2019), with young farmers being more open to innovations (Sumberg and Hunt, 2019). This demographic factor can significantly impact their perspective on MCA. Existing research has shown that both land size and age can influence how farmers perceive the usefulness of extension services, as observed in Pakistan (Al-Zahrani et al., 2019). Additionally, Mugandani and Mafongoya (2019) reported that age had a significant impact on the perception of Zimbabwean farmers regarding CA adoption. Those with more farming experience tend to adopt new technologies more readily, while farmers with larger land holdings are more willing to invest in extension services

Table 2
Summary of constructs scales, reliability and validity analysis (n = 119).

Constructs	Items	Respondents rating	Mean	SD	α value	CR	IRL	AVE
Intention	I plan to practice MCA* in the next three years	4.58	4.51	0.74	0.82	0.89	0.85	0.73
	How strong is your intention to practice MCA?	4.50					0.87	
	How likely would you practice MCA?	4.46					0.85	
Attitude	Do you feel practicing MCA is a wise idea?	4.82	4.79	0.57	0.50	0.74	0.65	0.49
	How important is practicing MCA in the next three years?	4.74					0.55	
	How useful is practicing MCA in the next three years?	4.81					0.86	
PBC	I think I am able to practice MCA in the next three years	4.29	4.29	0.93	0.64	0.81	0.86	0.59
Subjective Norms	Most people important to me would think I should do MCA	4.39	4.49	0.84	0.76	0.89	0.92	0.81
	Important family members would think I should do MCA	4.59					0.88	
Perceived usefulness	Practicing MCA would make me food-secure	4.85	4.85	0.44	0.73	0.83	0.78	0.56
Perceived Easiness	MCA is easy to learn	4.49	4.52	0.71	0.89	0.93	0.98	0.77
	MCA is easy to understand	4.54					0.94	
Perceived Compatibility	MCA fits well with my previous farming experience	3.25	3.25	1.43	0.70	0.73	0.97	0.50
Perceived Efficacy	I could practice MCA based on my skills	3.93	3.80	1.05	0.92	0.92	0.87	0.78
	I am knowledgeable enough to practice MCA on my farm	3.77					0.88	
	I have enough competence to practice MCA on my farm	3.71					0.90	
Perceived Resources	I have enough capital/money to carryout MCA on my farm	3.07	3.46	1.24	0.85	0.89	0.86	0.59
	I have enough technical labor to do MCA on farm	3.16					0.84	
	I have machinery & implements to do MCA on my farm	2.55					0.97	
Media Influence	Information I watch on TV would make me do MCA	4.52	4.52	0.74	0.72	0.80	0.81	0.51
Technical Training	Having a short-term training would make me do MCA	4.84	4.81	0.58	0.93	0.94	0.88	0.77
	Attending an MCA workshop would make me practice it	4.82					0.85	
	Participating in an MCA field day would make me practice it	4.83					0.91	
	Attending on-farm MCA demos would make me do it	4.84					0.87	
	Hearing other farmers' experiences would make me do MCA	4.71					0.87	
Social Influence	My neighboring farmers would think I should practice MCA	4.24	4.33	0.86	0.84	0.88	0.88	0.57
	Most people in my community would think I should do MCA	4.13					0.93	
Extension Services	I think extension officers would think I should do MCA	4.79	4.79	0.62	0.70	0.70	0.50	0.50

Notes: Scale rating: 1-most unlikely, 2-slightly unlikely, 3-neutral, 4-slightly likely, 5-most likely, SD – standard deviation, α – Cronbach alpha value, CR – Composite reliability (rho_c), IRL – Indicator reliability loading, and AVE – Average variance extracted. *MCA – using tractors and associated implements for either CA ripping tillage or direct seeding/ no-till, and PBC – Perceived behavior control.

Table 3
Respondents' background factors.

Type	Category (N = 119)	Frequency	Percentage (%)	Type	Category (N = 119)	Frequency	Percentage (%)
Gender	Male	102	86	Districts	Chibombo	20	17
	Female	17	14		Chisamba	8	7
					Kapiri Mposhi	10	8
Age (years)	< 30	10	8		Luano	6	5
	30–40	28	24		Mumbwa	9	8
	41–50	39	33		Chongwe	6	5
	51–60	27	23		Lusaka	11	9
	> 60	15	13		Rufunsa	10	8
Education level	Primary	23	19		Masaiti	9	8
	Secondary	48	40		Mpongwe	30	25
	Certificate/diploma	39	33				
	Bachelors	9	8	Crops under CA	Maize	98	78
Farm size (ha)	< 5	9	8		Soya bean	78	66
	5–20	28	24		Groundnuts	27	23
	21–40	27	23		Beans	10	8
	41–60	20	17		Sorghum	2	2
	61–100	13	11		Cowpeas	2	2
	101–200	17	14				
	> 200	5	4	Status of CA	None	38	32
Area under CA	None	38	32	Adoption	Partial[1]	48	40
use (ha)	< 5	23	19		Full[2]	33	28
	5–20	37	31				
	21–40	12	10	Years of CA use	0	38	32
	41–60	4	3		1–4	56	47
	61–100	3	3		5–10	20	17
	> 100	2	2		> 10	5	4

Notes: [1]Application of at least two CA aspects: minimal soil disturbance, crop rotation or residue retention. [2]Application of three CA principles of minimal soil disturbance, crop rotation and residue retention.

(Al-Zahrani et al., 2019). This may be true for MCA adoption.

The utilization of tractors in agriculture has been observed to increase with the age of farmers in various regions, including Zambia, Kenya, Zimbabwe, and Niger (Kirui, 2019). The fact that 40% of the surveyed emergent farmers had attained a secondary education is a noteworthy detail, signifying their potential to learn and operate machinery and related implements, which is crucial for MCA implementation. Educational attainment is significant as it is a proxy for human capital in agriculture (Komarek et al., 2019), and it is closely tied to knowledge and proficiency in handling agricultural machinery, equipment, and tools (Kirui, 2019). However, the absence of any significant correlation between gender, educational level, district of

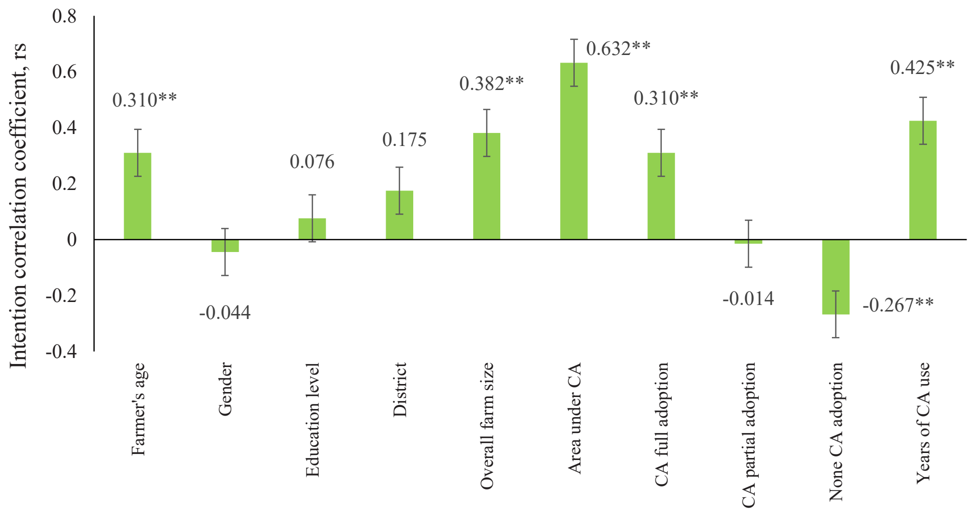

Fig. 3. Relationship between emergent farmers' background factors and their intention towards MCA. Note: r_s – Spearman correlation coefficients, * * – Significant at the $p < 0.01$ level (2-tailed), N = 119.

operation, and the intention to adopt MCA suggests that the socio-economic constraints faced by emergent farmers transcend gender, education, and geographic location (Corales et al., 2019). Nevertheless, emergent farmers who exclusively practice conventional farming are less inclined to embrace MCA in the future compared to their counterparts who have already partially or fully adopted CA practices.

3.2. Influence of TPB constructs on emergent farmer's intentions towards MCA

The intention of emergent farmers to practice MCA over at least a portion of their farms for the next three years was generally high. The mean scores of the three intention statements averaged 4.51, with 63% of respondents rating this variable positively (as shown in Table 2). Additionally, the Cronbach's alpha (α) and CR values for these three intention statements were 0.82 and 0.89, respectively, both exceeding the minimum acceptable threshold of 0.6. Consequently, the mean of the three statements was deemed a reliable representation of the behavioral intention construct.

Likewise, emergent farmers displayed positive attitudes towards MCA. The mean score for the three attitude statements was 4.79, with 84% of respondents rating. The CR value was 0.74, while the Cronbach's α coefficient was 0.50, which was the recommended minimum value. According to Kumar (2019), lower Cronbach's coefficients for attitude have been tolerable in other studies when the overall level of internal consistency of TPB constructs is acceptable (see Greaves et al., 2013; Halder et al., 2016; Kline, 2016). Thus, the three attitude statements were retained, and their means were used to measure the attitude construct effectively. Consequently, the hypothesis (H_2) asserting that the majority of emergent farmers in Zambia maintain positive attitudes and intentions toward MCA was confirmed.

The majority of emergent farmers displayed a strong belief in their ability to practice MCA on their farms for the next three years. The mean scores for perceived ability and know-how were 4.29 and 3.96, respectively, indicating their confidence in their competence. Perceived resources, on the other hand, received a mostly neutral rating of 3.29. The overall mean score for perceived behavioral control was 3.85, with 51% of respondents expressing confidence in their ability. However, Cronbach's α coefficients for perceived know-how (0.34) and perceived resources (0.43) fell below the recommended threshold of 0.6. Consequently, these two statements were excluded, and only perceived ability was retained to represent the PBC construct. The overall Cronbach's α and CR values for the PBC construct were 0.64 and 0.81, respectively, which met the acceptable criteria.

The subjective norms of emergent farmers largely depended on the opinions of other people (57%) and family members (70%), who were deemed important and supportive of the idea of practicing MCA on their farms (as shown in Table 2). The mean score for the two statements used to assess the SN construct was 4.49, with 64% of respondents indicating agreement. The Cronbach's α coefficient and CR values for these two SN statements were 0.76 and 0.89, respectively, which were above the recommended minimum values. Consequently, the mean results for these two statements were employed to characterize the SN construct.

The high intention of emergent farmers to adopt MCA was rooted in their current plans, the strength of their commitment, and their likelihood of practicing it for the next three years. Their positive attitudes toward MCA were linked to their perception of it as a wise, important or useful idea, motivating them to practice it in at least a portion of their farms in the next three years. Notably, the perception of owned resources and personal know-how did not significantly influence their PBC regarding MCA. This suggests that emergent farmers considered their ability to practice MCA in the next three years as the most crucial factor. Consequently, the study implies that the low economic status and technical expertise of emergent farmers could lead them to perceive MCA as a challenging practice. These results align with the findings of Borges et al. (2014), which emphasized the importance of knowledge and skills in shaping farmers' perceived behavioral control over improved natural grassland practices.

The social pressure exerted on emergent farmers regarding MCA was largely attributed to the high expectations of their family members and significant others. This suggests that emergent farmers would be more inclined to adopt MCA if they perceived that their reference groups held it in high regard. These findings align with existing literature. Borges et al. (2014) similarly observed that favorable evaluations of improved natural grassland techniques among Brazilian cattle farmers were influenced by their intentions and attitudes toward these practices. Similarly, Senger et al. (2017) found that farmers with positive intentions and attitudes were more open to diversifying their agricultural production.

Spearman's rank correlation coefficients (r_s) indicated significant positive correlations between attitude (r_s =0.427, $p < 0.01$), perceived behavioral control (r_s =0.630, $p < 0.01$), and subjective norms (r_s =0.410, $p < 0.01$) with the behavioral intention of emergent farmers regarding MCA (as presented in Table 4). Notably, the correlation between perceived behavioral control and the behavioral intention was stronger than that between attitude and subjective norms. The research hypotheses were subjected to path model analysis (Fig. 4), evaluating

Table 4
Spearman (r_s) correlation coefficients among constructs used to predict emergent farmers' intentions towards MCA in Zambia.

Constructs	Intention	Attitude	Perceived behavior control	Subjective norms
Attitude	.427 **	1.000	-	-
Perceived behavior control	.630 **	.361 **	1.000	-
Subjective norms	.410 **	.208 *	.430 **	1.000
Perceived usefulness	.357 **	.226 *	.331 **	.390 **
Perceived easiness	.425 **	0.158	.325 **	.290 **
Perceived compatibility	.215 *	0.093	.200 *	0.077
Personal efficacy	.591 **	.308 **	.644 **	.298 **
Perceived resources	.531 **	.087	.410 **	.281 **
Media influence	.176	.102 *	.281 **	.240 **
Technical training	.323 **	.318 **	.369 **	.276 **
Social influence	.302 **	.023	.236 **	.308 **
Extension service	.282 **	.285 **	.292 **	.219 *

Notes: ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed)

the total path coefficient effects (direct impacts) of the decomposed factors, namely attitudes, SN, and PBC, on the intention to adopt MCA. Furthermore, the determination coefficients (R^2) were calculated to indicate the total variance in intention accounted for by the model's constructs. As depicted in Fig. 4, attitude and PBC had significant and direct impacts of 0.243 and 0.368, respectively, on the intention to adopt MCA, whereas SN exhibited an insignificant and direct impact of 0.074 on behavioral intention. The R^2 value (0.50) and the AVE values of 0.49, 0.59, and 0.81 (as presented in Table 2) for attitude, PBC, and SNs, respectively, signified that these constructs collectively explained 50% of the variance in intention. Therefore, the hypothesis (H_3) that the intention of emergent farmers toward MCA is influenced by their attitudes, SNs, and PBC was confirmed.

3.3. Influence of decomposed TPB Constructs on emergent farmers' intentions

The Spearman's rank correlation coefficient (r_s) results in Table 4 show the relationships between the three exogenous latent variables (perceived usefulness (PU), perceived easiness (PE), and perceived compatibility (PC)) and attitude. While all three variables exhibited positive correlations with attitude, only PU displayed a significant correlation with attitude. Conversely, all three variables displayed significant positive indirect correlations with intention.

Fig. 4 presents the hypothesis testing results including path coefficient paths and R^2 values, conducted using Smart-PLS 4 (Ringle et al., 2022). Table 5 outlines the impacts (both direct and indirect) of independent constructs on the intention to adopt, presenting path coefficients, t-values, and *p*-values. Fig. 4 highlights that perceived usefulness (pc=0.645) and perceived compatibility (pc=0.086) had a positive and direct impact on attitude, while perceived easiness (pc=−0.002) had a negative direct impact on attitude. The R^2 value for attitude (50%) suggests that the variance in farmers' attitudes toward MCA is moderately explained by the examined factors. This is corroborated by the significantly positive indirect impact of perceived usefulness (pc=0.157, $p < 0.01$), the positive indirect impact of perceived compatibility, and the negative indirect impact of perceived easiness on intentions to adopt MCA (Table 5). Consequently, the hypothesis (H_4) that attitude intermediates the positive effects of perceived usefulness,

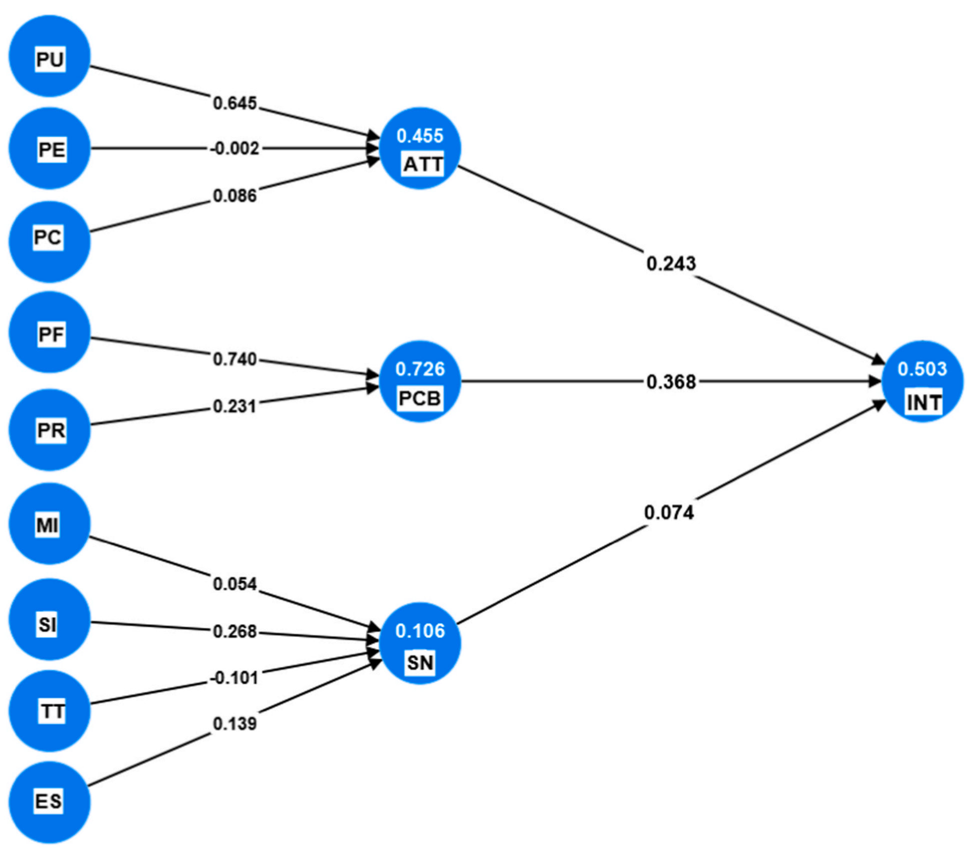

Fig. 4. A path model of intention to adopt MCA and the various constructs. Inner models show total path coefficient effects, and the TPB constructs show the R^2 values. Note: INT – Intention to adopt MCA, ATT – Attitude, PBC – Perceived behavior control, SN – Subjective norms, PU – Perceived usefulness, PE – Perceived easiness, PC – Perceived control, PF – Perceived efficacy, PR – Perceived resources, MI – Media influence, SI – Social influence, TT – Technical training, ES – Extension services.

Table 5
The impacts of the independent constructs on the dependent construct (intention to adopt MCA).

Dependent	Independent	Direct	Indirect	Total	t-value	*p*-values
Intention	Attitude	0.243	-	0.243	3.424	0.001 **
	Perceived behavior control	0.368	-	0.368	4.856	0.000 **
	Subjective norms	0.074	-	0.074	0.948	0.343
	Perceived usefulness	-	0.157	0.157	3.186	0.001 **
	Perceived easiness	-	-	-0.000	0.023	0.982
	Perceived compatibility	-	0.021	0.021	0.921	0.357
	Personal efficacy	-	0.272	0.272	4.754	0.000 **
	Perceived resources	-	0.085	0.085	2.370	0.018 **
	Media influence	-	0.004	0.004	0.236	0.814
	Technical training	-	-0.007	-0.007	0.289	0.772
	Social influence	-	0.020	0.020	0.741	0.459
	Extension service	-	0.010	0.010	0.478	0.632
	Background factors	0.277	-	0.277	4.984	0.000 **

Note: ** are significantly different at both $p < 0.05$ and $P < 0.01$respectively.

perceived ease of operation, and perceived compatibility on the intentions of emergent farmers to adopt MCA was partially rejected.

The decomposed exogenous variables exhibited positive correlations with attitude. These findings indicate that emergent farmers' attitudes toward MCA extend beyond the common indices used to measure the usefulness of CA. While it is widely acknowledged that CA practices enhance yields, income, and environmental sustainability (Mugandani and Mafongoya, 2019), the perceived key motivators for emergent farmers included not only the potential for better yields, improved soil fertility, and higher profits but also food security. Although 58% of emergent farmers believed that MCA could be comprehended and learned with ease, its actual application was perceived as challenging. This may be attributed to the requisite technical skills necessary for tractor and implement operation, resources to hire for the services, weed control, and residue management challenges (Mugandani and Mafongoya, 2019). The fact that MCA aligns well with their previous farming experiences was neutral to emergent farmers. However, MCA was perceived as incompatible with widely accepted practices such as ploughing, residue burning, open grazing, and mole hunting. These results indicate that emergent farmers consider the usefulness of MCA practice as the most significant attribute. While perceived easiness and compatibility are important, they exert minimal influence on emergent farmers' attitudes. Nevertheless, perceived usefulness, easiness, and compatibility all have a significant positive indirect effect on the behavioral intention of emergent farmers.

The results from Spearman's rank correlation coefficients (r_s) in Table 4 demonstrate that the two exogenous latent variables, perceived efficacy and perceived resources, were positively and significantly correlated with PBC. Personal efficacy displayed a stronger positive correlation with PBC (r_s =0.644, $p < 0.01$) than perceived resources. Similarly, both variables exhibited significant positive indirect correlations with intention.

As depicted in Fig. 4, perceived efficacy (pc=0.740) and perceived resources (pc=0.231) had a positive and direct impact on PBC. Table 5 illustrates that perceived efficacy and perceived resources have positive and significant indirect impacts on farmers' intentions to adopt MCA. The high R^2 value for PBC indicates that perceived efficacy and perceived resources sufficiently explained 72.6% of the variance. Therefore, the hypothesis (H_5) asserting that perceived behavioral control facilitates the positive effects of personal efficacy and perceived resources on the intention of emergent farmers toward MCA was accepted.

The perceived efficacy of adopting MCA for the next three years showed a strong correlation with perceived behavioral control. About 49% of emergent farmers believed they could effectively engage in MCA based on their skills, competence level, and existing knowledge. They also perceived that financial resources, technical labor, tractors, and implements were essential requirements for MCA. This suggests that financial constraints, along with the availability of tractors, implements, and technical labor, represented the primary challenges faced by emergent farmers. A study by Nyathi et al. (2020) also found that limited financial access and labor-saving equipment influenced the perception of smallholder farmers regarding CA. Additionally, Lalani et al. (2016) noted that high knowledge and skill requirements contributed to the dis-adoption of CA, and addressing these factors reduced production risk and uncertainty among small and medium-scale farmers. However, land size and time availability did not contribute significantly to the PBC construct, likely because 75% of emergent farmers owned between 21 and 500 ha of land and may not have been engaged in other time-intensive socio-economic activities besides farming. Nevertheless, Sitko and Jayne (2014) reported that emergent farmers required time for off-farm work to increase their capital base for land and asset acquisition. The significant positive indirect correlation between perceived efficacy, resources, and intention underscored the influence of skills, knowledge, competence, capital, labor, and machinery on emergent farmers' perceptions of MCA.

According to Spearman's rank correlation coefficients (Table 4), there was a significant positive correlation among the four exogenous latent variables: media influence (MI), technical training (TT), social influence (SI), and subjective norms (SN). However, only three of these variables exhibited a significant positive indirect correlation with emergent farmers' intention to practice MCA. The positive correlation between media influence (r_s =0.176, $p = 0.055$) and intention (INT) was not significant. The path model presented in Fig. 4 shows that only MI, SI, and ES had positive direct impacts on subjective norms, while the impact of TT was negative. Furthermore, Table 5 demonstrates that MI, SI, and ES had insignificant positive impacts on farmers' intention to adopt MCA, while TT had an insignificant negative indirect impact. The R^2 value (11%) indicates that these factors could not adequately explain the variance in the subjective norm construct. Consequently, the hypothesis (H_6) that emergent farmers' intentions to use MCA are influenced by their access to media, social capital, technical training, and extension services was rejected.

The decomposed subjective norm variables, including media influence, technical training, social influence, and extension services, exhibited an indirect positive correlation with intention. Notably, television had a measured influence, while radio, newspapers, and magazines were not perceived to significantly impact emergent farmers' intentions. This observation can be attributed to the nature of MCA as a practice that requires hands-on experience, where theoretical knowledge alone, without visual aids, may be less effective. Many farmers prefer watching MCA being demonstrated rather than reading or listening about it. Practical and technical training methods, such as short-term training, agricultural workshops, farmer field days, on-farm demonstrations, and shared experiences with other farmers, played a highly significant role ($\alpha = 0.93$, CR=0.94) in shaping emergent farmers' perceptions and intentions to adopt MCA.

The social influence to adopt MCA was primarily derived from neighboring farmers (44%) and community members (40%) already practicing CA. This aligns with the effectiveness of peer learning and observational learning methods facilitated by farmer-to-farmer knowledge exchange and other participatory approaches adaptable to local farming contexts, as noted by Lalani et al. (2016). Similarly, Nyathi et al. (2020) observed that peer learning processes influenced CA adoption among smallholder farmers in Choma, Zambia. Farmers often feel motivated to conform to social referents and are more inclined to adopt new practices when encouraged by their peers. A study investigating the adoption criteria for CA and machinery learning in Malawi found that when neighbors adopted CA practices, it exerted positive peer pressure that increased CA adoption (Bell et al., 2018). In contrast, social influence from family members, friends, and community-based farmer organizations like cooperatives had limited positive effects on emergent farmers' MCA adoption. This may be attributed to the fact that not all family members, friends, or cooperative members are engaged in farming or have knowledge of CA practices. Additionally, cooperatives in Zambia serve both conventional and CA-oriented farmers, contributing to the varied impact. Studies exploring the influence of cooperative membership on the adoption of sustainable practices have reported divergent views. In the Netherlands, membership in a cooperative with subsidized agri-environmental measures did not significantly shape norms or influence the intention to adopt such practices by farmers. However, cooperative members with unsubsidized measures were more influenced by group norms concerning the benefits of agri-ecological measures (van Dijk et al., 2015, 2016).

The impact of extension services on emergent farmers' perceptions and attitudes towards MCA was primarily linked to the availability of extension services provided by extension workers. These findings align with Nyathi et al. (2020), who noted that the training services offered by extension workers played a convincing role in encouraging farmers to adopt CA in Choma, Zambia, and Nkayi, Zimbabwe. Although the roles of CA promotion organizations and experts are recognized, they did not have a significant positive influence on emergent farmers' intentions to adopt MCA. However, it's worth noting that while these findings are relevant to the surveyed emergent farmers, Bell and Ruhanen (2016) found that smallholder farmers were more likely to learn from experts than from their peers. In summary, the DTPB effectively demonstrates that the intentions of Zambian emergent farmers to adopt MCA are influenced by various socio-economic factors, the TPB constructs, and their decomposed variables.

4. Conclusions and policy recommendations

This pioneering research, based on the DTPB, provides valuable insights into the intentions of Zambian emergent farmers regarding the adoption of MCA. The findings reveal that the majority of emergent farmers have a positive attitude and strong intentions to practice MCA over the next three years. Importantly, their attitudes, perceived behavioral control, and subjective norms exert positive influences on their intention to embrace MCA.

The study highlights that the primary driver for emergent farmers is the pursuit of food security. Despite their confidence in their ability to practice MCA, their limited financial resources and access to machinery and equipment remain significant barriers. To address these challenges, there is a need for concerted efforts to enhance financial support systems and regulations that promote the acquisition of machinery and implements by emergent farmers. The strong positive correlation between their attitudes and intentions underscores the need to harness this potential. This can be achieved by ensuring the accessibility and affordability of small and medium-scale agricultural machinery and implements through mechanisms like low-interest financial facilities. These findings offer valuable insights for shaping and strengthening policies geared toward medium-scale and emergent farmers.

The study also underscores the significance of emergent farmers' perceptions of MCA as a pathway to achieving food security, a fundamental prerequisite for agricultural commercialization. Technical training, social influence, extension services, and mass media all play pivotal roles in shaping emergent farmers' intentions to adopt MCA. Therefore, optimizing public and private sector interventions can enhance the performance, skills, and knowledge of these farmers. Leveraging subjective norms, including technical training, media influence, social influence, and extension services, can effectively promote sustainable practices like CA. Televised information on CA is more impactful than information from newspapers, magazines, or radio. Practical training through short-term programs, workshops, field days, learning from neighbors, and active extension services can significantly boost the adoption of MCA.

Despite the relatively low adoption of CA in Zambia, this study reveals a high intention among emergent farmers to embrace MCA based on their positive attitudes and the perceived usefulness of this approach. Overall, the research demonstrates that unlocking the perceptions of emergent farmers regarding MCA has revealed the untapped potential for expanded CA adoption through medium and large-scale farmers in Zambia. This, in turn, can contribute to achieving sustainable agricultural productivity and food security, even in the face of the escalating challenges posed by climate change.

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CRediT authorship contribution statement

Conceptualization: Godfrey Omulo, Regina Birner, Karlheinz Köller and Thomas Daum; Methodology: Godfrey Omulo and Thomas Daum; Statistical analysis: Godfrey Omulo; Writing–original draft: Godfrey Omulo; Writing – review and editing: Godfrey Omulo and Thomas Daum; Images and visualization: Godfrey Omulo; Funding acquisition: Regina Birner, Karlheinz Köller, Thomas Daum; Supervision: Regina Birner, Karlheinz Köller and Thomas Daum.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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