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Effects of perceived effectiveness in contract farming on adoption of best crop management practices among sugarcane farmers in Tanzania

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The resilience of agro-processing firms engaged in contract farming (CF) production heavily depends on the quality and quantity of supplies from their linked farmers. Adopting best crop management practices (BCMPs) is crucial to enhancing production and meeting the supply demands of contracting firms. Understanding the factors influencing farmers' decisions is key to successfully implementing strategies that promote BCMP adoption. This study explored the effects of farmers' perceptions of contract farming arrangement (CFA) effectiveness on sugarcane BCMP adoption, using survey data from 400 farmers in Tanzania. The results from both a multivariate probit model (for specific practices) and ordinal regression (for adoption intensity) revealed positive effects. In particular, the perceived effectiveness of pricing and payment systems and produce supply management had a stronger influence on BCMP adoption than resource support and extension service provision. These findings suggest that efforts to improve BCMP adoption among sugarcane contract farmers should not only focus on enhancing production capabilities through input, credit, and technical support packages but also emphasize the creation of robust incentive structures. Ensuring fair pricing, timely payments, and compliance with contract terms—alongside mechanisms to mitigate farmer loss risks—would significantly enhance BCMP adoption rates.

KEYWORDS

contract farming arrangement, perceived effectiveness, best crop management practices, sugarcane, multivariate probit model, principal component analysis

1 Introduction

Tanzania's goal of achieving sugar self-sufficiency by the year 2025 remains far-fetched as the deficit persists. The domestic sugar production volume, at 370,000 tons, is still below the set target of 420,000 tons per annum (Andreoni et al., 2020; Sugar Board of Tanzania, 2022). Ongoing efforts to scale production by expanding processing capacity require a complementary, reliable, and sustainable sugarcane supply, the primary crop used in sugar production (Mabeta and Smutka, 2023). Smallholder farmers (SHFs) operating under contract farming arrangements (CFAs) play a pivotal role in sugarcane production. Nevertheless, lower crop yields and commercial sugar levels continue to threaten the reliability of farmers' supplies to processing firms (Mbua and Atta-Aidoo, 2023).

Improving crop production and the reliability of quality supply for high-value processing crops such as sugarcane requires not only specific technology or practice, such as the use of chemical fertilizer and herbicides in isolation but adherence to best crop management practices (BCMPs) (Otieno et al., 2019; Tukaew et al., 2016). The latter entails adherence to a set of recommended agronomic practices necessary for crop growth and improved yield, ranging from farm preparation and improved inputs use to post-harvesting handling and produce supply to the market (Walia, 2021). Therefore, enhancing smallholder farmers' adoption of BCMPs cannot be overstated among efforts to increase sugarcane production and supply to sugar processing firms.

Institutional factors, including limited access to resources such as inputs, credit, technical support, and markets, pose significant challenges to smallholder farmers' adoption of improved technologies and farm practices in agricultural production (Yirga et al., 2015). Consequently, farmers are motivated to participate in contract farming (CF) production by the opportunity to reduce constraints such as limited access to extension services, improved technologies, input and credit support, and reliable markets and income (Masakure and Henson, 2005). However, simple marketing contracts often leave farmers with limited bargaining power over contract terms and operational arrangements dictated by firms, compounded by inadequate capability support services for farmers (Jia and Bijman, 2013; Ruml and Qaim, 2021). Additionally, opportunistic behavior by firms and weak enforcement of contracts expose smallholder farmers to risks such as supply failures and payment delays due to non-compliance with agreements. The lack of performance incentives or compensation for losses further undermines the returns farmers can expect from the significant investments required for CF production (Bakari, 2018; Sulle et al., 2014; Sulle and Dancer, 2019).

Farmers' opinions and perceptions of CFA operations, including satisfaction with agreement terms and processes, have received significant attention in CF literature (Gutema et al., 2022; Machimu, 2020).

While these perceptions are often associated with farming decisions, such as participation or withdrawal from contract production (Ruml and Qaim, 2021; Vamuloh et al., 2020), the effectiveness of CFAs in addressing production constraints and providing incentives, such as assured market access and reliable payment systems, remains a key driver of the performance improvements observed among sugarcane contract farmers. However, these improvements have primarily been associated with production outcomes such as output levels and the quality of supplied products (Nsindagi and Sesabo, 2017). Therefore, the focus should be on farmers' adoption of improved farm technologies. Specifically, BCMPs are still rarely adopted despite their critical role in enhancing sugarcane yields and boosting commercial sugar production levels (Otieno et al., 2019; Tukaew et al., 2016).

Furthermore, empirical research on decisions regarding the adoption of farm technologies and innovations suggests that, beyond extrinsic factors such as the benefits of the technology relative to its costs and farmer characteristics, intrinsic factors like farmers' perceptions and attitudes toward operations have emerged as significant influences (Korir et al., 2023; Meijer et al., 2015). Addressing gaps in understanding these drivers is essential for developing effective strategies to promote the adoption of BCMPs. However, the question of whether and how farmers' perceptions of production institutional operations—specifically CFAs—affect decisions to upgrade production practices, such as BCMP adoption among contract farmers, remains largely unexplored. To address this gap, this study used survey data from 400 sugarcane contract farmers in Tanzania to empirically investigate the link between farmers' perceptions of CFA operational effectiveness and their adoption of BCMPs.

To address the wide range of farmers' concerns, opinions, and attitudes regarding various CFA operations, principal component analysis (PCA) was employed as an effective method to reduce data dimensionality. PCA classifies large datasets into a few key aspects while retaining relevant information, enabling the extraction and generation of factors that explain farmers' perceptions of CFA (Prasad et al., 2013). Specifically, the PCA results revealed that farmers perceived the effectiveness of CFA operations across four key aspects: price and payments, supply management, resource support, and extension and advisory services.

The impact of these perceptions on the adoption of five sugarcane BCMPs was then analyzed. BCMPs included effective farm preparation, use of improved varieties, chemical fertilizer application, integrated weed management, and pest and disease control measures. To account for potential synergies in the adoption of these practices, a multivariate probit (MVP) regression model was applied, providing a robust framework for the analysis (Abdul-Rahman et al., 2019; Henning and Cardona, 2000; Kurgat et al., 2020).

Furthermore, recognizing the potential benefits of adhering to combined practices on crop yield and produce quality, as highlighted by Aryal et al. (2018), the effects of perceived CFA effectiveness were also analyzed in relation to BCMP adoption intensity. Adoption intensity was measured as the total number of practices adopted and assessed using an ordered probit regression model. The results generally indicated that positive perceptions of CFA effectiveness increased the likelihood of farmers adopting BCMPs across specific practices. Additionally, the analysis revealed varying effect sizes on adoption intensity, demonstrating the nuanced impact of CFA perceptions on the breadth of practice implementation.

These findings suggest that, in addition to enhancing farmers' production capabilities through resource and extension services, regulating and tailoring contract designs to address pricing, payment, and supply management—identified as the least effective aspects of CFAs—would improve BCMP adoption and potentially increase sugarcane production and supply to processing firms in Tanzania. The remainder of this article is structured as follows: The next section briefly describes methods for data collection and the empirical strategy employed. In Section 3, we present and discuss the descriptive and empirical results. Finally, Section 4 concludes and highlights policy implications and the study's limitations.

2 Materials and methods

2.1 Study area and data

This study used farmer survey data collected from the three largest sugarcane "out-grower" schemes in Tanzania—Kilombero, Mtibwa, and Kagera—between July and October 2021 (see Figure 1). The schemes account for 73% of the total sugarcane production in the country (Andreoni et al., 2020; Sugar Board of Tanzania, 2022). The sugarcane production operation is under the "Nucleus and out-grower model," where farmers enter a Cane Supply Agreement (CSA) with a sugar processor firm available within their localities organized in Agricultural Marketing Cooperatives (AMCOs). A sample used for this study was obtained using a mixed-sampling procedure. First, the three schemes were purposively selected as they comprise the country's total population of sugarcane CF farmers. According to the Sugar Board of Tanzania (SBT), there were 7,040 sugarcane out-growers in Tanzania in 2019. Using Yamane's (1967) formula for sample size determination, a minimum sample size of 379 farmers was required from the three schemes. Kilombero, the largest scheme, accounts for over 80% of all sugarcane CF farmers. Thus, a non-proportionate mixed sampling procedure, with a minimum of 100 farmers from each firm, was adopted to ensure sufficient scheme representation in the total sample. At the scheme level, all AMCOs were identified, and the newly established cooperatives with less than two seasons of operating during the survey were excluded because most lacked complete database records of registered member farmers.[1] A total of eight (out of 17), four (out of six), and all available AMCOs (2) were included in Kilombero, Kagera, and Mtibwa schemes, respectively. Simple random sampling was then used to select respondents proportionally from the included AMCO members using farmers' register lists and based on the total share of the number of farmers and farm locations within each scheme.

To survey the local community, researchers obtained approval from relevant Regional and District Local Government Authorities (LGAs) in Tanzania. The ethics principles concerning human rights and participant confidentiality during data collection were also adhered to. Hereby, before participating in the survey, all individual farmers provided informed consent and were informed of their right to withdraw without consequences and that the data collected were solely for research purposes. A total of 174, 105, and 121 sugarcane farmers were interviewed using a structured questionnaire from Kilombero, Kagera, and Mtibwa, respectively, making a total sample of 400 respondents. The survey collected farmers' data on sugarcane production activities, including inputs, BCMPs adopted by farmers, and harvested produce quantities during the year 2020–2021 crop season. Other information collected during the survey included farmers' perceptions and attitudes on various aspects of the CFA operations, including support resources and services, produce supply management, and the remuneration system. The details of the opinion statements on CFA were adopted from recent previous studies on perception evaluation statements in sugarcane production under CF conducted in Ethiopia and Tanzania, respectively (Gutema et al., 2022; Machimu, 2020). Finally, the survey also collected information on farmers' socioeconomic characteristics and sugarcane farming experience.

2.2 The empirical model

A multivariate probit (MVP) model captures one's decision-making process by allowing one to explore determinants of adoption for practices and evaluate the interconnectedness of different practices by assessing their correlations, a phenomenon that univariate multinomial logit and probit models overlook (Kurgat et al., 2020). To describe the MVP model, the adoption of the practices was indicated by a series of binary variables, where each practice was assigned a unique index j taking on the values (1, 2, 3, 4, and 5) for a positive integer. In this case, representing the five understudy BCMPs and letting X denote a set of conditioning variables, the practice chosen by any farmer i was represented by random variables ($BCMP_i$). Therefore, the MVP model was characterized by a set of binary dependent variables ($BCMP_{ij}$) such as the following:

$$BCMP^*_{ij} = \beta_{j'} X_{ij} + u_{ij} \tag{1}$$

and

$$BCMP_{ij} = \begin{cases} 1 \text{ if } BCMP^*_{ij} > 0 \\ 0 \text{ otherwise} \end{cases}, \tag{2}$$

where $\beta_{j'}$ is the corresponding vector of parameters to be estimated, and $BCMP^*_{ij}$ is the latent variable. Equation 2 assumes that a rational farmer has a latent variable, $BCMP^*_{ij}$, which captures the unobserved preferences associated with the j^{th} choice of BCMP practice. This latent variable was assumed to be a linear combination of the factors (X_{ij}) that are observed to be influencing the simultaneous selection of the practices, as well as the unobserved characteristics that are captured by the stochastic error term u_{ij}. In the MVP model, the error terms are assumed to jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity, and the symmetric variance-covariance matrix is given in Equation 3 as follows:

$$\Omega = \begin{bmatrix} 1 & \rho 12 & \rho 13 & \dots & \rho 1j \\ \rho 21 & 1 & \rho 23 & \dots & \rho 2j \\ \rho 31 & \rho 32 & 1 & \dots & \rho 3j \\ . & . & . & . & . \\ . & . & . & . & . \\ \rho k1 & \rho k2 & \rho k3 & \dots & 1 \end{bmatrix} \tag{3}$$

ρ (rho) is the pairwise correlation coefficient between the error terms of any two adoption equations to be estimated in the model. In this model, the sign and significance of the correlation coefficient, ρ, provide evidence of the nature of the relationship between adoption equations. A positive correlation is interpreted as complementarity between practices, while a negative correlation is interpreted as substitutability.

[1] The sugarcane out-grower schemes had just undergone a reform process in farmers' organizations, from farmers associations to AMCOs, during the survey duration.

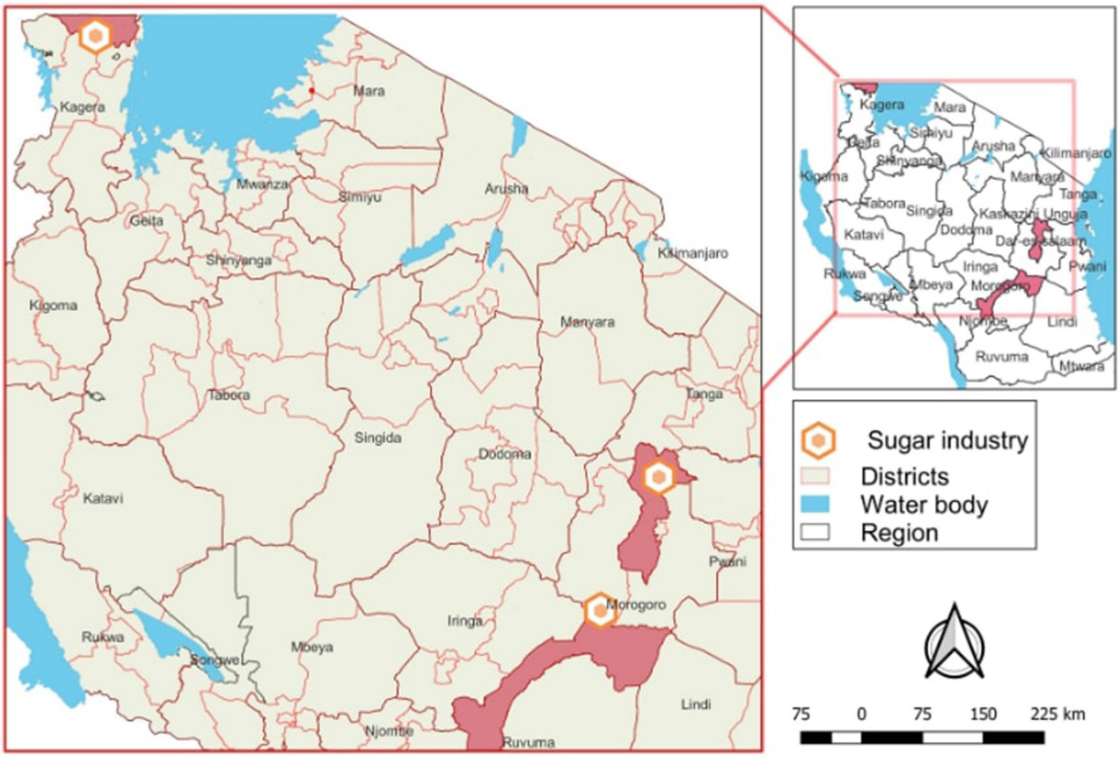

FIGURE 1
Map of the study area showing production schemes.

The MVP solely considers the probability of adopting a specific BCMP without distinguishing between farmers who adopt a single practice and those who combine multiple practices. However, adherence to a combination of crop management practices yields better outcomes than those relying on a single or few practices (Kassie et al., 2015; Walia, 2021). To address this, the second part of our econometric approach further analyzed factors influencing the intensity of BCMP adoption, measured as a count variable representing the number of practices adopted. Unlike the Poisson regression model, which assumes equal event probabilities (Abdul-Rahman et al., 2019), the likelihood of adopting each practice may vary depending on farmers' prior experiences and exposure to the benefits of specific practices. This leads to differentiated probabilities when adopting each practice. Similar to Kpadonou et al. (2017), we treated the number of practices adopted as an ordinal variable for BCMP adoption intensity and employed an ordered probit model (OPM) to estimate its relationship with a set of independent variables.

2.2.1 Dependent variables

Dependent variables used in the MVP model were dummy variables corresponding to applied BCMPs in sugarcane production. The practice selection is based on sugarcane crop husbandry guidelines by the "Sugar Board of Tanzania" (Sugar Board of Tanzania, 2005). Consultations with the sugar processor firm's extension officers further complemented the practice selection process. Five of the BCMPs for sugarcane were thereafter considered for inclusion. The first practice was effective farm preparation, which entailed at least two soil tillages (plowing and harrowing prior to new cane planting) and/or after-harvest ratoon maintenance (farm plots with re-growing sugarcane plant shoots). The second practice was the use of improved sugarcane varieties, *"setts,"* in new cane planting and/or during gap filling. Other practices included the application of chemical fertilizers for boosting soil nutrients, integrated weed management (combined use of herbicide application and mechanical weeding control), and the undertaking of pest and disease control measures. These selected BCMPs are in line with recent existing literature on sugarcane best production practices (Otieno et al., 2019; Prasara and Gheewala, 2016). Other important BCMPs in sugarcane production, such as irrigation, were excluded because the country's majority of smallholder sugarcane production is rainfed. Additionally, producing a harvest, post-harvest handling, and supply to processor firms are undertaken by privately contracted firms by AMCOs in accordance with processor firms' requests. Thus, some of the best sugarcane crop management practices, including timeliness of farm preparation, producing a harvest, and supplying to CF firms, were not within farmers' production operations mandate in this study's context.

Adoption of the sugarcane BCMPs during the survey was evaluated using farmers' responses to binary (yes/no) questions. That is, whether or not a respective practice was applied in any of the sugarcane farm plots during the 2020/2021 crop production season. Combined BCMP adoption leads to more benefits (e.g., higher yield and quality supply to firms) than few practices (Arslan et al., 2017; Kassie et al., 2015). However, farmers might only adopt some of the practices based on the evaluation of their relative importance or their production operation context. Thus, similar to Aryal et al. (2018), the count number (j) of applied practices was used as a dependent variable that measured the intensity of BCMP adoption.

2.2.2 Explanatory variables

2.2.2.1 Farmers' perception of CFA effectiveness

Smallholder farmers face significant production challenges, including limited access to improved technologies, inputs, and credit, reliable markets for their produce, and stable income sources. Consequently, farmers are motivated to engage in CF, among other things, as a means to address these production constraints and improve market access (Masakure and Henson, 2005). However, smallholder farmers have limited bargaining power over the terms and operational arrangements set by CF firms, which often fail to protect their interests. For instance, resource support packages—such as farm inputs and credit—are often insufficient or inadequate, forcing farmers to rely on internal financing despite their already constrained resources (Jia and Bijman, 2013; Ruml and Qaim, 2021; Mazwi et al., 2019). This lack of adequate support negatively impacts farming practices and the adoption of advanced technologies among CF farmers (Ruml and Qaim, 2020). Furthermore, farmers rely on technical and advisory support from extension experts provided by contract agro-processing firms to gain essential knowledge on best farming practices, technologies, and their applications (Perera et al., 2003). Therefore, farmers' perceptions of being well-informed and adequately equipped through technical and advisory support within CFAs can significantly enhance their confidence and willingness to adopt improved sugarcane production practices.

In addition to farmers' production capability, incentives, including a reliable market and remunerative markets that guarantee farmers produce supplies to buyer firms and assure income, are required to motivate farmers to consistently produce supply (Nsindagi and Sesabo, 2017). Nonetheless, firms' opportunistic behavior and weak contract enforcement expose CF farmers to adverse conditions that jeopardize returns from farm investments, including payment delays, lack of transparency in pricing and quality measurements, and crop losses from supply failures (Bakari, 2018; Sulle et al., 2014; Sulle and Dancer, 2019), as most crop husbandries are associated with complex price schedules that may impede economic rationality regardless of the capability (Gow et al., 2000). Therefore, accounting for farmers' perception of the institutional operation arrangements (including production resources and knowledge support acquisition under CF) and presence incentives through assured supply and fair payments and remunerations are among the parameters of relevance in upgrading CF farmers' performance upgrade domains under CFA, including BCMPs adoption. We thus posit that:

H1: Positive perception of CFA effectiveness (resource support, technical and advisory, supply management, and pricing and payment system) enhances farmers' adoption of BCMPs.

While adherence to all best farming practices is beneficial for enhancing production, farmers are acutely aware that the opportunity costs associated with farm resource use—such as inputs and labor required for practice adoption—must be justified by returns (Grosh, 1994).

Considering the vulnerability of smallholder farmers (SHFs), who have limited control over CFA operations and face potential liabilities from costly BCMP adoption, risks such as crop losses, supply failures, lack of compensation from CF firms, and possible indebtedness due to firms' resource support, their perceptions of incentive-driven aspects of CFA operations play a critical role.

Factors such as fair pricing, timely payments, and assured, reliable produce supply to firms—features that maximize returns—are argued to have a stronger influence on farmers' decisions to upgrade performance and adopt BCMPs than capability-enhancing factors like resource support and technical services. This highlights the importance of designing CFAs that prioritize economic incentives to mitigate risks and encourage greater farmer participation in improved farming practices.

H2: The intensity of BCMP adoption is influenced more by farmers' perceptions of the effectiveness of incentive-generating CFA (including supply management, pricing, and payment systems) than capability-enhancing CFA (including resource support and technical and advisory).

2.2.2.2 Control variables

A wide range of other variables affects the decision to adopt best crop practices. For example, a study investigating the factors affecting the adoption of improved rice technology packages and practices among rice-producing household heads in Ethiopia identified several key determinants. Demographic factors, such as family size, socioeconomic variables like farmland size, and institutional factors, including market distance and access to extension services, significantly impacted adoption decisions. These variables had varying effects on the adoption of different improved rice technology packages (Assaye et al., 2023). Similarly, Rahman and Chima (2015), a study analyzing the factors influencing the adoption of modern technologies—such as high-yield variety (HYV) seeds and fertilizers—across multiple food crops (e.g., rice, yam, and cassava), found that high profit was not the primary motive for adoption. Instead, technology adoption was relatively higher among smallholder farms. Additionally, the study highlighted that farming experience positively correlated with the adoption of HYV seeds, underscoring the importance of experience in decision-making related to technology uptake.

Several other studies on-farm practices and technology adoption highlight various household and socioeconomic characteristics as key determinants of adoption. Factors such as household size, distance to markets, engagement in non-farm activities, and farmers' perceptions of the technology have been consistently identified as influential (Chouhan et al., 2013; Acheampong et al., 2021; Anang et al., 2021; Memon et al., 2021; Ruml and Qaim, 2020; Sennuga et al., 2020; Thuo et al., 2022). Additionally, adoption levels often vary due to agroecological location and institutional-specific factors (Kurgat et al., 2020; Senkondo et al., 2013).

To address these complexities, factors likely to influence the adoption of BCMPs were included in the analysis to minimize potential omission bias when estimating the effects of farmers' perceptions of CFA operational effectiveness. Variables controlled for in the model included farmer characteristics such as age, gender, and sugarcane farming experience, as well as household size, distance to the market, engagement in non-farm income activities, perceptions of the practice's significance in production output, and scheme-specific indicators. All analyses were conducted using STATA 14 software.

3 Results and discussion

3.1 Descriptive results

3.1.1 Farmers characteristics

Table 1 presents a description of surveyed farmer characteristics and explanatory variables included in the empirical models estimating BCMP adoption. The majority of the sugarcane farmers (83%) were men, averaging 51 and 9 years of farming experience. The average sugarcane farm size operated by farmers was 11.13 acres, and farmers had an annual income of Tanzanian shillings (TZS) 9,909,744 (≈USD 3,670). Approximately 48% of farmers engaged in non-farm income-generating activities (including small businesses and employment). On average, the farmer's household had six family members, and the distance from the farms to the processing firm plant was 15 kilometers. Farmers' perceptions of the importance of BCMPs in sugarcane production were rated at a mean of 3.32 out of 4, indicating a high level of awareness.

3.1.2 Principal components of farmers' perceptions of CFA effectiveness

During the survey, 14 statements were developed to assess farmers' various features of contract arrangements and compliance with stipulated agreements. These statements were designed to evaluate the effectiveness of CF in addressing farmers' production constraints and resolving market failures, among other challenges (Gutema et al., 2022; Machimu, 2020). Farmers' responses were measured using a 4-point Likert scale, ranging from "strongly disagree" to "strongly agree," to eliminate the ambiguity of a neutral response. A descriptive summary of the score rating for the farmers' perception of CFA effectiveness is presented in Supplementary Table S1. The validity of PCA was assessed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, with a value exceeding the preferred threshold of 0.6 (Kaiser, 1974). The overall KMO value for the sample was 0.78, indicating an acceptable merit level. Similar to the methodology of Prasad et al. (2013), components with eigenvalues of at least one were retained. An orthogonal varimax rotation was also applied to the component loadings, producing uncorrelated factor scores to facilitate interpretation. Moreover, Consistent with Prasad et al. (2013), only statements related to farmers' perceptions of CFA operations with factor loadings above 0.5 were retained and used to compose perception indices.

Table 2 further describes the four components identified through PCA and highlights farmers' perceptions of key dimensions of CFA effectiveness. The cumulative variance explained by these components, with eigenvalues above 1, was 75%. Following the methodology of Prasad et al. (2013), we grouped and reported statements with factor loadings > 0.5.

The first component, labeled "*Price and payment,*" had strong loadings on four statements, including the fairness of the pricing system in addressing rising production costs, payment installment allotments, and adherence to agreed payment schedules. This component accounted for the largest share of the total variation (26.6.4%).

The second component, named "*Supply management,*" had high loadings on three statements, including the timeliness of produce harvesting and delivery to firms, fairness in crop measurement, and emergency harvesting in cases of natural shocks (e.g., fire outbreaks or floods) to minimize crop losses. This component reflects the effectiveness of logistics for crop harvesting and delivery to firms as per agreements, reducing loss risks and ensuring stable farm incomes. It contributed 19.9% to the total variations.

The third component factor, named "*Resource support,*" composed two statements of farm input resource support availability and affordability compared to other sources and contributed 16.8% of the total variations. This explained the extent to which production resource constraints are minimized and improved access to production factors to facilitate the farm production process. Lastly, the fourth factor included two correlated statements on the availability of information on production innovations within CF and the usefulness of advisory service on-farm practices, including managing threats in sugarcane production, including drought, diseases, and pest outbreaks. This factor was named "*Extension and Advisory*" and formed 11.7% of the total variation. The estimated latent variables for each of the four individual perception CFA components indices (with a mean of zero and a standard deviation of one) were used as independent variables to assess CFA effectiveness effects in the BCMP adoption regression.

3.1.3 Adoption of sugarcane BCMPs

Table 3 presents adoption rates for the five-understudy sugarcane BCMPs during the 2020/2021 production season. Fertilizer was used by 63% of surveyed farmers across study schemes, followed by adequate farm preparation adopted by 61%. This is similar to Chouhan et al. (2013), who found that 62% of sugarcane farmers applied recommended field preparation practices in India. Integrated weed management practices were adopted by 50% of farmers. Pest and disease control measures were adopted by approximately one-third (33.5%) of farmers, and lastly, improved sugarcane varieties were the least adopted practice at 20%. The BCMP adoption rates also varied across the three study schemes. Chemical fertilizer use was highest in the Kilombero scheme (above 96%) and lowest in the Mtibwa scheme (below 20%). Effective farm preparations and integrated weed management practices were relatively higher in the Kagera scheme, at 88 and 76%, respectively, while Kilombero and Mtibwa farmers demonstrated comparable rates at ∼50 and 40%. Pest and disease control measures were adopted by ∼41% of farmers in both the Kilombero and Mtibwa schemes and only 10% in Kagera. Improved sugarcane varieties were the practice that was adopted the least across all schemes. As shown in Kurgat et al. (2020), variation

TABLE 1 Descriptive statistics.

Variables	Description	Mean	Std. dev.
Farmer characteristics			
Farm size	Farmer's total sugarcane production area (acres)	11.13	24.96
Annual Income	Farmer's annual income ("000"000 TZS)	9.91	22.90
Distance	Distance from farm to processing firm (Km)	15.41	8.72
Age	Age of farmer in years	50.95	13.83
Gender	1 if a farmer is male, 0 otherwise	0.83	0.38
Household size	Number of members in farmers' households	5.84	2.48
Farming experience	Number of years in sugarcane farming	12.57	9.86
Non-farm income activities	1 if the farmer engaged in non-farm income activities, 0 otherwise	0.49	0.50
Perception on BCMPs	Perceived importance of BCMP adoption on production (1–4 rating scale)	3.32	0.92
Scheme			
Kilombero	1 if Kilombero, 0 otherwise	0.44	0.49
Mtibwa	1 if Mtibwa, 0 otherwise	0.30	0.46
Kagera	1 if Kagera, 0 otherwise	0.26	0.44

in specific BCMPs could be attributed to different agroecological conditions that vary across regions in Tanzania.

The intensity of BCMP adoption ranged from zero to five practices, with the majority of farmers (>94%) adopting at least one of the five under-study practices (Table 4). Nearly 55% of farmers adopted one to two practices, 35% adopted three to four practices, and only ∼4% adopted all five practices, with slight differences across the schemes. These figures indicate the need to upscale BCMP adoption to increase farmers' sugarcane production and supply to processing firms to increase domestic sugar production.

3.2 Econometric results

3.2.1 Interdependence of sugarcane BCMP adoption

Results of the multivariate probit (MVP) model estimated using the simulated maximum likelihood technique are reported in Table 5. Panel A shows the overall goodness of fit of the model was statistically significant [Wald χ^2 (70) = 336.39, p = 0.000], justifying that the explanatory variables jointly explain predicted variables. The results of pairwise correlations in Table 5 (panel B) show a considerable relationship between error terms of the BCMP components. The significant likelihood ratio test [χ^2 (10) = 32.20, p = 0.000] suggests the BCMPs are not mutually exclusive (i.e., the adoption of one practice is conditional on the adoption of others). This authenticates MVP over individual probit models to account for existing interrelationships among the BCMPs.

Overall, the positive signs and significance of correlation coefficients are consistent with agronomic recommendations (Walia, 2021), which suggest that farmers make a judicious combination of practices in sugarcane production. Adopting improved varieties correlated with adequate farm preparation, integrated weed management, and pest and disease control practices. The use of chemical fertilizer is also positively associated with integrated weed management adoption. Similar observations were made by Henning and Cardona (2000) when assessing the adoption of best sugarcane management practices among Louisiana producers in the USA.

3.2.2 Determinants of BCMP adoption

Coefficient estimates from MVP regression showing the effects of farmers' CFA perception on BCMP adoption are presented in Table 5 (see details in Supplementary Table S2). The probability of chemical fertilizer adoption increases by 65% when farmers' perception score on resource support increases by a unit, with all other factors remaining constant. This shows farmers' assurance of resolving resource constraints to afford high-cost input purchases through obtaining input on credits within CF at affordable prices to help improve adoption. Ruml and Qaim (2020) also found that the resource provision contract design enhances chemical fertilizer use in oil palm production in Ghana. Possible reasons for limited resource support's effect on the adoption of other practices could be limited packages of support services to specific inputs such as fertilizers. It can also be explained by the fact that chemical fertilizer is considered a key BCMP in sugarcane production. Thus, resource support offered to sugarcane farmers within CF is mostly utilized for fertilizer purchase, hence improving adoption and no other practices.

Positive perception of extension service and advisory services within CF increased the probability of farmers adopting three of the five under study BCMPs, specifically efficient farm preparation, use of improved sugarcane varieties, and chemical fertilizer by 26, 30, and 45%, respectively. This shows that contract farmers highly rely on agro-processing firms for technical advice and advice to boost the adoption of good farming practices and information on necessary improved farm technologies. Similarly, Henning and Cardona (2000) found that technical assistance programs

TABLE 2 Varimax-rotated factor loadings matrix of perception on CFA effectiveness.

CFA effectiveness statements	Rotated components			
	Pricing and payments	Supply management	Resource support	Extension and advisory
Timely payment as stipulated in the agreement	0.836	0.062	0.015	−0.247
Price changes reflect cost increments	0.762	0.083	−0.339	0.423
Payment waiting time is too long	−0.743	0.009	−0.064	0.120
The sugarcane pricing system is suitable	0.675	0.062	0.015	0.247
Service charges costs are fairly estimated	0.471	0.324	0.144	−0.002
Crop harvest and supply delivery are timely	−0.089	0.804	0.032	0.187
Preferential harvest exists for emergency sugarcane	0.060	0.604	−0.134	−0.019
Fair produce supply measurements	0.199	0.584	−0.134	0.019
Inputs and credit support are accessible	−0.223	−0.074	0.740	0.423
Inputs and credit support within CF are affordable compared to other sources	−0.207	0.279	0.580	0.234
Inputs and credit support are timely delivered	−0.058	0.089	−0.523	−0.096
Extension services from CF firm are accessible	0.134	−0.320	0.298	0.841
Expert advice on crop threats and resolving solutions is useful	0.229	−0.061	0.025	0.637
Farmers receive information on emerging innovations	0.029	−0.064	0.236	0.440
Eigenvalues	3.001	2.162	2.003	1.518
Variance explained (%)	0.266	0.199	0.168	0.117
Cumulative variance explained (%)	0.266	0.456	0.624	0.750
Cronbach's alpha	0.931	0.737	0.670	0.756

Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy = 0.787. Source: Survey Data (2021).

TABLE 3 Sugarcane BCMP adoption rate.

BCMP	Description	Adoption rate (%)			
		Total	Kilombero	Mtibwa	Kagera
Effective farm preparation	At least two soil tillage (plowing and harrowing) before planting and/or post-harvest ratoon plots maintenance[a]	61.25	49.43	54.55	88.57
Improved varieties	Use of improved sugarcane varieties during planting and gap-filling	20.50	31.03	14.05	10.48
Chemical fertilizer	Application of chemical fertilizer	63.25	96.55	18.18	60.00
Integrated weed management	Both mechanical and herbicide application weed control	50.25	41.38	40.50	76.19
Pest and disease control	Undertaking pest and disease control measures	33.50	41.95	41.32	10.48

Source: Survey Data (2021).
[a]Farm field maintenance after-harvest (e.g., trash management, gap filling, and mulching of ratoon crop farm plots).

played an important role in promoting BMPs in Louisiana sugarcane production.

Positive perception of supply management factor effectiveness within CFA significantly enhanced the probability of effective farm preparation by 41.7% and integrated weed management by 50%, with all other factors remaining constant. Furthermore, the probability of adopting chemical fertilizer increases by 106%, and farmers' perception score on the effectiveness of produce supply management operations in the CFA increases by a unit, with all other factors remaining constant. As posited earlier, this could be because farmers are assured of a reliable market for the produce as crop loss risks from crop delays in harvesting and losses are minimized. Hereby, the likelihood of returns from invested practices costs increases, motivating farmers to adopt BCMPs. Minot and Ronchi (2014) also showed that farmers' investment in improved crop practices and technology in CF is impaired by income loss threats from harvest failures and crop losses without compensation from firms.

The likelihood of BCMP adoption was observed to increase in the majority of practices understudy (four out of five) when farmers favorably perceived the pricing and payment system within CFA to be effective. It improved the probability of adopting pest and disease control measures (44%), effective farm preparation (62.4%), integrated weed management (74.1%), and fertilizer use by 125%. Chisanga et al. (2014) and Gutema et al. (2022) also argued that delayed farmers' payment, a major challenge in contract sugarcane

TABLE 4 Intensity of BCMP adoption in sugarcane production.

No. of practices	Percent of adopting farmers			
	Total $N = 400$	Kilombero $N = 174$	Mtibwa $N = 121$	Kagera $N = 105$
0	5.75	1.15	14.88	2.86
1	18.50	20.11	26.45	6.67
2	36.50	31.61	40.50	40.00
3	24.00	20.69	12.40	42.86
4	11.00	17.24	4.96	7.62
5	4.25	9.20	0.83	0.00
Total	100.00	100.00	100.00	100.00

Source: Survey Data (2021).

production in Kenya, Ethiopia, and Uganda, leads to farmers' low adoption of farming technology like the application of manual weeding and fertilizer use.

The results of the control factors influencing BCMP adoption are presented in Supplementary Table S1. The coefficients for scheme variable dummies significantly differed from zero in most BCMP equations, especially between the geographically distinct Kilombero and Kagera schemes, compared to the more geographically proximate Kilombero and Mtibwa schemes. This highlights the role of agro-climatic variations (Kurgat et al., 2020) and scheme-specific factors in influencing BCMP adoption (see text footnote1). Notably, significantly higher adoption rates for fertilizers and improved sugarcane varieties were observed in Kilombero, suggesting that incentives and bonuses encourage farmers to upgrade their production practices (Nsindagi and Sesabo, 2017). The Kilombero scheme employs a quality-based pricing system tied to commercial sugar content levels, unlike the fixed pricing systems in Mtibwa and Kagera. Furthermore, the price offered per ton of sugarcane in Kilombero (96,000 TZS) is considerably higher than in Mtibwa and Kagera (72,000 TZS).

The relatively lower price levels in Mtibwa and Kagera, which do not adequately reflect production costs, were identified as a barrier to fertilizer usage in the Mtibwa scheme (Bakari, 2018). Finally, consistent with prior studies on the adoption of sugarcane crop management practices (Chouhan et al., 2013; Memon et al., 2021; Thuo et al., 2022), farmer characteristics, including age, income level, farm size, household size, and distance to markets, were found to significantly influence the adoption of the various sugarcane BCMPs examined in this study.

3.2.3 Determinants of BCMP adoption intensity

In the previous section, we investigated factors influencing farmers' adoption of a particular BCMP, considering that decision may be potentially correlated with adopting one or more other practices. However, the MVP analysis does not allow one to understand the factors that drive farmers' joint adoption of several of these practices. Evidence shows that joint adoption of crop management provides more significant benefits in terms of improved yield and better produce quality than in isolation (Aryal et al., 2018). Therefore, we further assessed the influence of farmers' perception of CPA on the intensity of adoption of sugarcane BCMPs, defined as the total number of practices adopted.

Table 6 (column 1) summarizes the estimated coefficients from the ordered probit model (OPM) analysis (see details in Supplementary Table S3). Consistent with the hypotheses and aligned with the MVP estimation results, all coefficients for farmers' perceptions of CFA effectiveness components were found to significantly and positively influence BCMP adoption intensity, albeit with varying magnitudes. The marginal effects of the independent variables on each outcome of the dependent variable, as reported in Table 6 (columns 2–6), reveal two notable trends. For $j \leq 2$ (columns 2 and 3), the effects are inconsistent with the coefficients, particularly regarding their signs, which are opposite to the ones reported in the OPM analysis. However, for $j \geq 3$ (columns 4–6), the marginal effects agree with the coefficients in both signs and significance. Similar findings were reported by Kpadonou et al. (2017), suggesting that the characteristics of farmers who adopt a few BCMPs may differ from those adopting many practices. These results suggest that a positive perception of CFA effectiveness not only increases the likelihood of adopting a greater number of BCMP practices but also reduces the likelihood of partial or inconsistent adoption within the CF operation setting. Specifically, adoption intensity for farmers adopting three or more practices (columns 4–6) increased by 8.1–12% and 5.8–8.7%, driven by positive perceptions of the price and payment system and supply management components of the CFA, respectively.

These results imply that a positive perception of CFA effectiveness increases the probability of adopting a greater number of BCMP practices and reduces the likelihood of partial or inconsistent adoption within the CF operation setting.

Specifically, adoption intensity for farmers adopting three or more practices (columns 4–6) increased by 8.1–12% and 5.8–8.7%, driven by positive perceptions of the price and payment systems and supply management components of the CFA, respectively.

In contrast, farmers' perceptions of extension and advisory services and resource support contributed more modestly to adoption intensity, with increases ranging from 1.9 to 2.3% and 3.4 to 5.0%, respectively. These findings align closely with the study's second hypothesis, highlighting that the influence of positive perceptions is not uniform across CFA components.

The observed increases in BCMP adoption intensity were consistently higher for positive perceptions of price and payment systems and supply management effectiveness compared to perceptions of extension and advisory services and resource support. This disparity underscores the critical role of economic and logistical factors in driving higher adoption intensity among sugarcane farmers.

TABLE 5 Estimated multivariate probit model for determinants of BCMP adoption.

Variables	Improved varieties	Chemical fertilizer	Pest and disease control	Integrated weed management	Effective farm preparation
(A) Dependent variables: BCMPs					
Resource support	0.002	0.649**	0.233	0.263	0.230
	(0.268)	(0.319)	(0.232)	(0.230)	(0.227)
Supply management	0.190	1.059***	0.001	0.500**	0.417*
	(0.280)	(0.308)	(0.257)	(0.240)	(0.242)
Pricing and payments	0.229	1.253***	0.440**	0.741***	0.624***
	(0.239)	(0.274)	(0.207)	(0.202)	(0.203)
Extension and advisory	0.309*	0.449**	0.182	0.173	0.258*
	0.162	(0.192)	0.148	0.146	0.154
Farmer characteristics	Yes	Yes	Yes	Yes	Yes
Scheme	Yes	Yes	Yes	Yes	Yes
Constant	1.135	−4.514***	−0.353	0.680	1.690
	(1.340)	(1.524)	(1.229)	(1.198)	(1.275)
Wald $\chi 2$ (70)	338.26***				
N	400				
(B) Correlation matrix (*rho)*					
Effective farm preparation	0.262***	0.103	0.086	0.035	1
	(0.094)	(0.104)	(0.085)	(0.082)	
Integrated weed management	0.219***	0.226**	0.089	1	
	(0.090)	(0.099)	(0.085)		
Pest and disease control	0.352***	0.064	1		
	(0.099)	(0.103)			
Chemical fertilizer	0.012	1			
	(0.114)				
Improved varieties	1				

***$P < 0.01$; **$P < 0.05$; *$P < 0.1$ significance level. Robust standard errors (in brackets).
Likelihood ratio test: Fertilizer pest and disease control = effective farm preparation fertilizer = integrated weed management fertilizer = improved varieties fertilizer = effective farm preparation pest and disease control = integrated weed management pest and disease control = improved varieties pest and disease control = integrated weed management effective farm preparation = improved varieties effective farm preparation = improved varieties integrated weed management = 0 $\chi 2(10) = 32.20$***.

4 Conclusion

Efforts to achieve Tanzania's goal of sugar self-sufficiency require a substantial increase in domestic sugarcane production, a fundamental crop in sugar processing. While smallholder contract farmers contribute significantly to production and supply, crop yield levels remain low, and produce quality is hampered by suboptimal farming practices and limited adoption of improved technologies. Adopting BCMPs is essential for enhancing sugarcane yields and ensuring a consistent supply of high-quality raw materials for processing.

In explaining farmers' decision-making processes regarding the adoption of farming practices, understanding the factors influencing adoption decisions by smallholders is essential for effective promotion strategies. Given the vulnerability of smallholder farmers due to resource constraints and limited bargaining power over CF operation terms set by firms, this study highlights the role of farmer perceptions of institutional operations as salient intrinsic factors influencing the adoption of BCMPs. Specifically, we showed that a positive perception of the effectiveness of pricing and payment systems, as well as produce supply management, has a greater impact on the intensity of BCMP adoption than resource support and the provision of extension services to farmers. Thus, policy strategies should focus not only on capacity-enhancing support but also on ensuring farmers' access to comprehensive input packages and extension services in CF production. Additionally, regulating contract agreements to include fair and rewarding payment systems that reflect production efforts and costs, alongside robust contract enforcement to minimize farmers' risks of loss, could significantly boost BCMP adoption in sugarcane production.

TABLE 6 Estimated coefficients of the ordered probit model and marginal effects on BCMP adoption intensities outcomes.

Variables	(1) OPM	(2) $\frac{dy}{dx}$(j=1)	(3) $\frac{dy}{dx}$(j=2)	(4) $\frac{dy}{dx}$(j=3)	(5) $\frac{dy}{dx}$(j=4)	(6) $\frac{dy}{dx}$(j=5)
Resource support	0.404**	−0.068**	−0.027*	0.050**	0.050**	0.034*
	(0.196)	(0.033)	(0.016)	(0.025)	(0.025)	(0.018)
Supply management	0.694***	−0.117***	−0.048***	0.087***	0.085***	0.058***
	(0.186)	(0.031)	(0.018)	(0.025)	(0.025)	(0.019)
Pricing and payments	0.971***	−0.163***	−0.067***	0.121***	0.119***	0.081***
	(0.158)	(0.028)	(0.019)	(0.023)	(0.023)	(0.019)
Advisory and technical services	0.424***	−0.070***	−0.029***	0.052***	0.051***	0.035***
	(0.118)	(0.032)	(0.010)	(0.015)	(0.016)	(0.011)
Farmer characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Scheme	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2(34)	136.37***					
Pseudo R^2	0.19					
Log pseudo-likelihood	−569.01					

***$P < 0.01$; **$P < 0.05$; *$P < 0.1$ significance level. Robust standard errors (in brackets).

It is important to note that the estimated models in this study are pooled, assuming unobserved heterogeneity is uncorrelated with the explanatory variables. Controlling for potential heterogeneity—such as variability in farmers' perceptions of CFAs and their practice adoption—could refine the results presented here and is suggested for further studies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The research survey was approved by the Tanzania Commission for Science and Technology (COSTECH) and Local Government Authorities (LGAs). The participants farmers provided their written consent to participate in this study.

Author contributions

IDP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing, Visualization. MO: Conceptualization, Formal analysis, Methodology, Validation, Visualization, Writing – review & editing. JH: Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1442301/full#supplementary-material

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