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How does the decision to cultivate underutilized crops influence food and nutrition security in rural areas?

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ABSTRACT

The neglect in the cultivation, utilization, and diverse edible indigenous crops (ICs) threatens food-nutrition security (FNS) and rural development. Here, we (i) profiled the socioeconomics, ethnobotanicals and factors influencing the decision to cultivate edible ICs among smallholder farmers and (ii) factors influencing the FNS status of the ICs farmers in rural communities in South Africa using descriptive statistics and Heckman's probit-selection model to evaluate the factors influencing the decision to cultivate ICs and FNS. In the study, the household dietary diversity score (HDDS) was 7.01 and the household's food insecurity access scores (HFIAS) was 4.40. In addition, the food security indicator shows that 40.60 % of the participants were food insecure. Taken together, these metrics shows a significant existence of food and nutrition insecurity among the participants. Additionally, the decisions to cultivate ICs among the participants was driven by the household size, access to seeds, produce market, perceived nutritional benefits of the ICs and proportion of land used for cultivation significantly affects FNS status of the participants. Overall, the cultivation of these ICs is important as their cultivation significantly contributed to the FNS of the rural communities. Policy interventions, targeted at improving the present land tenure pattern, awareness on the value of ICs and incentives for production as a means for stimulating wider acceptance, cultivation, and sustainability in South Africa was recommended.

1. Introduction

Africa is endowed with many plants with nutritional value for mitigating food insecurity but this diverse plants have been largely threatened by negligence, insufficient knowledge and population growth which affects biodiversity [1,2]. Most individuals living in the rural parts of Africa lives below the poverty line [3,4]. In rural South Africa, there is an increasing report of individuals that can barely afford meals which are largely unbalanced diets due to the affordability [5]. Indigenous crops (ICs[1]) have been consumed since ancient times by the indigenous people [6–9]. Presently, ICs play important roles in time of starvation by providing alternative food-nutritional sources for people [1,10].

Generally, ICs are essential for thriving ecosystems, which provide the conditions and processes that support all life [11,12]. Currently, there is a reliance on a few crops that form the basis for agricultural food production. Among the estimated 30,000 plant species that are edible, approximately 7000 have been cultivated for sustenance at some point while about 30 of these plants are feeding the global population [13]. However, it is unclear how the present food system will be able to satisfy the increasing nutritional needs of the projected 9 billion people by 2050 [14].

According to the FAO (2017), sub-Saharan African (SSA) countries depend mainly on imports and face particularly severe FNS issues. Existing studies from southern Africa indicate that ICs have the potential to help in the subsistence of rural communities [15–18]. However, the cultivation and research on ICs remain neglected [18]. The cultivation of ICs is currently characterized by challenges such as limited cultivation, land fragmentation, unsustainable harvesting from the wild, relative decline production and consumption. Particularly, there is limited information owing to the minimal level of research on ICs [19–21].

Therefore, this study contributes to informing national-scale planning to upgrade interventions for enhanced cultivation of ICs. Particularly, rural communities are ideal for evaluating the decision to cultivate

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[1] Indigenous crops (ICs) - grain, fruit and vegetables.

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ICs and FNS. Regrettably, countries with rich indigenous floras still experience high food and nutrition insecurity [22]. It is pertinent to enhance the understanding of the potentials of ICs in the face of FNS. Thus, the current research applied a multi-disciplinary approach on the ethnobotanical survey in recording information pertaining to the cultivation of ICs in rural areas and FNS. Knowledge on the utilization and potential of the ICs remains a subject of a significant research effort. Hence, the findings of this study can aid in the formulation of policies and the selection of strategic investment opportunities that would alleviate the impoverished livelihoods and FNS in rural communities of South Africa.

2. Agro-biodiversity, indigenous crops (ICs) interventions and food-nutrition security (FNS) in South Africa

The South African Agricultural Policy is reticent on ICs [23]. The priorities of the South African national development plan (NDP 2030) was on the improvement of the food system [24]. Similarly, the national food security policy, equally emphasized agri-food production while remaining largely reticent on the cultivation of underutilized plants with the aim of promoting the utilization of nutrient-dense, underutilized native flora [24,25]. The current policy intervention in South Africa reflects a small-scale farmer-inclusive and development-oriented agenda.

However, these interventions have not adequately considered the constraints and opportunities for incorporation into the prevalent commercial food system in the country. These inconsistencies may result from the divergent perspectives of policymakers. The success of past government interventions in supporting agriculture to ensure food security in South Africa may have influenced these divergent perspectives [26]. In recent years, many unimaginable occurrences have affected the FNS in rural communities while they should at least have easy access to food through self-production [27]. These situation has exacerbated for the vulnerable poor as the COVID-19 pandemic shocks and its ripple effects have made food prices unaffordable for the rural poor in South Africa [17].

In the meantime, there is potential in the current discourse for underutilized ICs in the strategic documents [17,23]. On the other hand, literature identifies Apartheid policies, which focused on the production of the popular exotic arable crops, hence limited the emergent outcome on ICs [23,28]. To combat the vicious cycle of food shortage, food price increase, malnutrition, and food insecurity in South Africa, each of these realities must be addressed.

The recognition of the significance of indigenous crop cultivation, for example, could serve as a springboard for the inclusion of underutilized plants for increase dietary diversity and FNS in the rural communities of the nation [23]. This marginalized rural people have suffered from the vicious cycle of food–nutrition insecurity increased by poor socio-economics resulting from an unsustainable dependence on the commercial farmers and poor structures.

2.1. The theory of planned behaviour (TPB)

According to Boateng, Agyei-Baffour, Boateng, Rockson, Mensah and Edusei [29], the TPB theory reveals the numerous factors that can influence an individual's behaviour and decision regarding an innovation. The theory explains that people's behaviour can be predicted by their intentions, which are influenced by social norms and the level of controls [29–32]. The theory is found on the idea that logical reasoning influences the decisions, choices, and behaviours of individuals, which is governed by three factors: attitudes, subjective standards, and perceived behavioural control. Attitudes are the perceived benefits of an action that are influenced by its outcomes [33,34]. Subjective norms refer to the influence of others' beliefs or the social attitudes of family, acquaintances and community as a whole on the behaviour of individuals [35–37]. The perceived behavioural controls are key influencers of an action or behaviour of individuals, with internal control and external control [29]. Human behaviour and decision-making are influenced by the attitudes and behavioural intentions of individual, which are defined by social norms and discretion [38,39].

2.1.1. Key assumptions of the theory of planned behaviour (TPB)

As indicated by Fishbein and Ajzen [40], TPB upholds the following critical assumptions when attempting to explain the rationale that influences and governs an individual's choices, behaviour, and decision-making (Fig. 1). First, the attitude of a person or perception of an individual's level of desirability has a significant impact on their intentions. This will be influenced by their cognitive and perceptual beliefs regarding the behaviour [41]. Second, subjective norms to which individuals are exposed influence their intentions. Moreover, there is a high likelihood that intentions of an individual are significantly influenced by the degree of approval or otherwise from family and loved ones, as well as the availability of resources [39].

Third, the perceived behavioural of individuals control influences their intentions and subsequent behaviour [42]. This implies people's perception of ability to partake in the aforementioned behaviours. Nevertheless, the application of TPB to the decisions to cultivate ICs reveals that positive attitudes towards the plants, supportive social norms, and a sense of perceived behavioural control contributed to the intention to cultivate the ICs. In addition, it is essential to recognise that other contextual factors, such as land ownership status, the economic importance of the crop, government regulations (e.g. availability of support services and extension training), and the socioeconomic variables of farmers may influence their decision to cultivate or not [43,44].

2.2. Synthesised hypothetical framework

The decision of rural farmers to cultivate ICs may be influenced by socio-cultural, economic and environmental variables. To comprehend the determinants herewith, the theory of planned behaviour, a subset of the theory of reasoned action was utilized [29,31,32]. Fig. 2 is a structural diagram of TPB revealing the relationship between the decision of rural farmers to cultivate ICs and socioeconomic variables. Based on the theory of TPB, three factors influenced the decision of rural farmers to cultivate ICs but socioeconomic factors and land ownership status mainly accounted for their decisions. Within the context of the theory, the status of land ownership, the perceived economic value of the commodity, access to extension training, and access to seeds and incentives can influence the decision to cultivate ICs.

The relationship between demographic variables, decision of rural farmers to cultivate ICs and their FNS could not be adequately supported by the studies ([15,16,31,32]. As depicted in Fig. 2, this study examined the interaction between those who cultivate ICs, their FNS status, and their demographic variables for a theoretical framework. Owning to the objectives of this study, attitudes refer to the perceptions of participants on their moral responsibilities and the anticipated outcomes of cultivating ICs. Subjective norms pertain to the economic value of the crop and the land ownership status of farmers. The decision-making capacity of farmers may be influenced by access to incentives, training, all of which are perceived behavioural controls.

3. Research methodology

3.1. Data and descriptive statistics

The study relied on data collected through a face-to-face interview with 133 participants across 12 rural communities within the districts of the North West Province, South Africa (Fig. 3). As detailed by Omotayo, Ndhlovu, Tshwene and Aremu [31,32], social dynamics, low socio-economic status, high biodiversity and climatic conditions which support the cultivation of ICs with minimal external inputs were the basis for the selection of the rural communities. North West Province is a

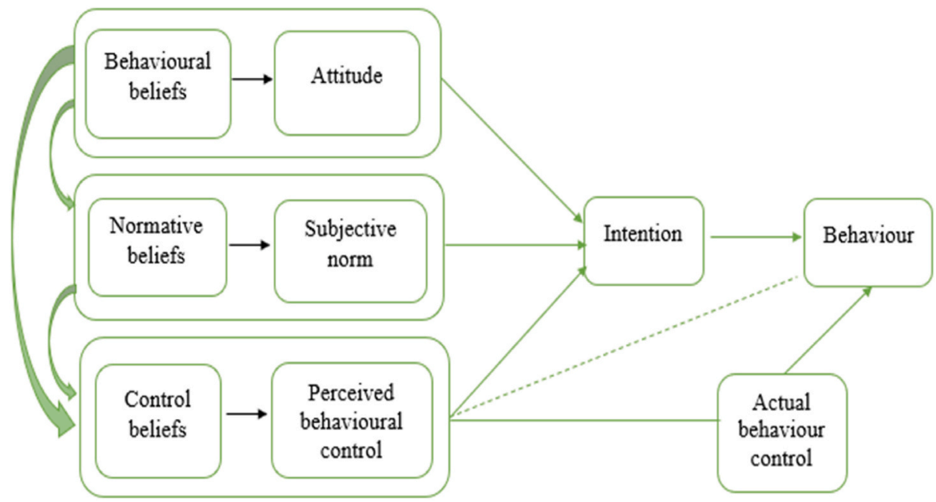

Fig. 1. Conceptual framework of the theory of planned behaviour (TPB).

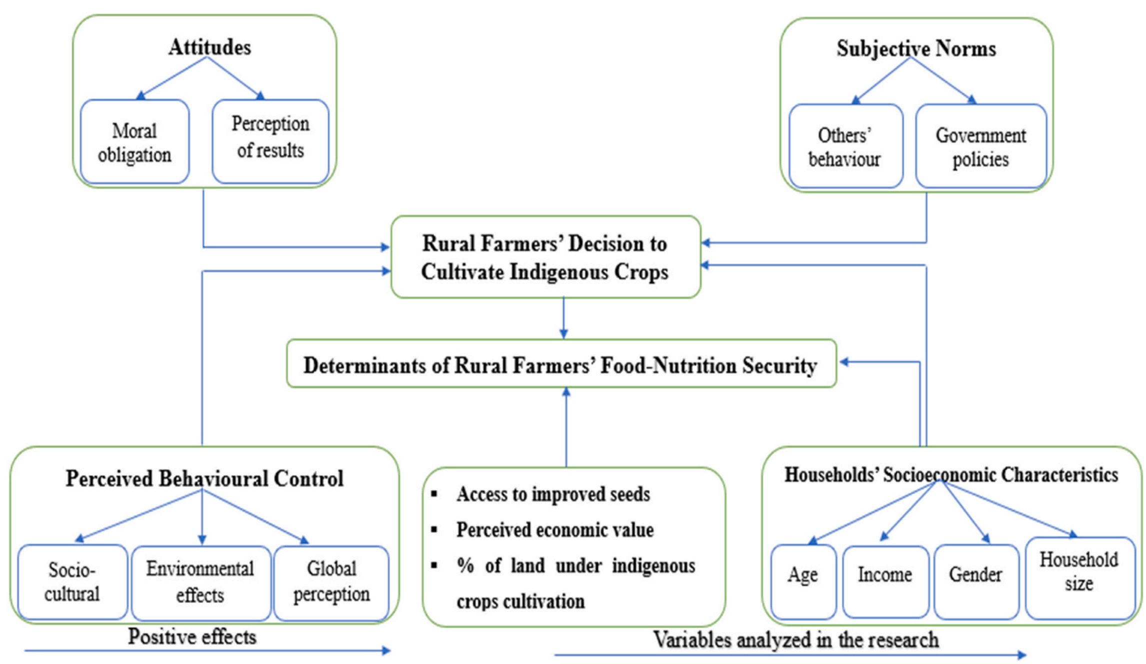

Fig. 2. The hypothetical framework on the decision of farmers to cultivate indigenous crops (ICs).

cultural and historical centre which has great significance to millions of the inhabitants, with an international border with Botswana and provincial boundaries with Free State, Northern Cape, Limpopo and Gauteng [5].

The participants were selected based on their farming experience and length of residence in the community, which indicates adequate understanding of the environment as well as the utilization of natural resources to meet their daily needs. The participants were permanent residents of theselected communities. The interviews were structured and included queries about the cultivation and use of ICs and the FNS of the participants. The data collection tool was designed to capture the following research questions: socioeconomic characteristics of participants, identification of ICs known and/or cultivated, their uses and harvested plant parts, and FNS. The interactions were conducted in the native language of the participants. A well-structured questionnaire and photographs of each plant species (Appendix A, 1–31 indigenous plants containing 7 indigenous grains, 12 indigenous vegetables, and 12 indigenous fruits) were used to collect the required data.

3.2. Indigenous crops (ICs) and food-nutrition security (FNS)

To combat food and nutrition insecurity, food self-sufficiency and the survival of millions of people in South Africa, rural communities needs more involvement in the cultivation of ICs [31,32]. Furthermore, indigenous foods can substantially enhance dietary quality and FNS. Despite this assertion, the consumption of ICs has not increase due to limited research investment, and the unavailability of these foods in modern industrialized and commercialized markets [31,32]. Hence, the consumption of ICs is still linked to poverty and low self-esteem among rural communities in South Africa [31,32].

There is evidence from studies conducted in South Africa that indigenous foods are consumed by many households, particularly in areas where they are readily available, hence reducing food and nutrition insecurity and promoting dietary diversity. Indigenous grain species (Appendix A, number 1–7) generate protein rich edible seeds and starch. Indigenous plants with tender leaves, stems, and branches are among the indigenous vegetables that can be used for food preparation see

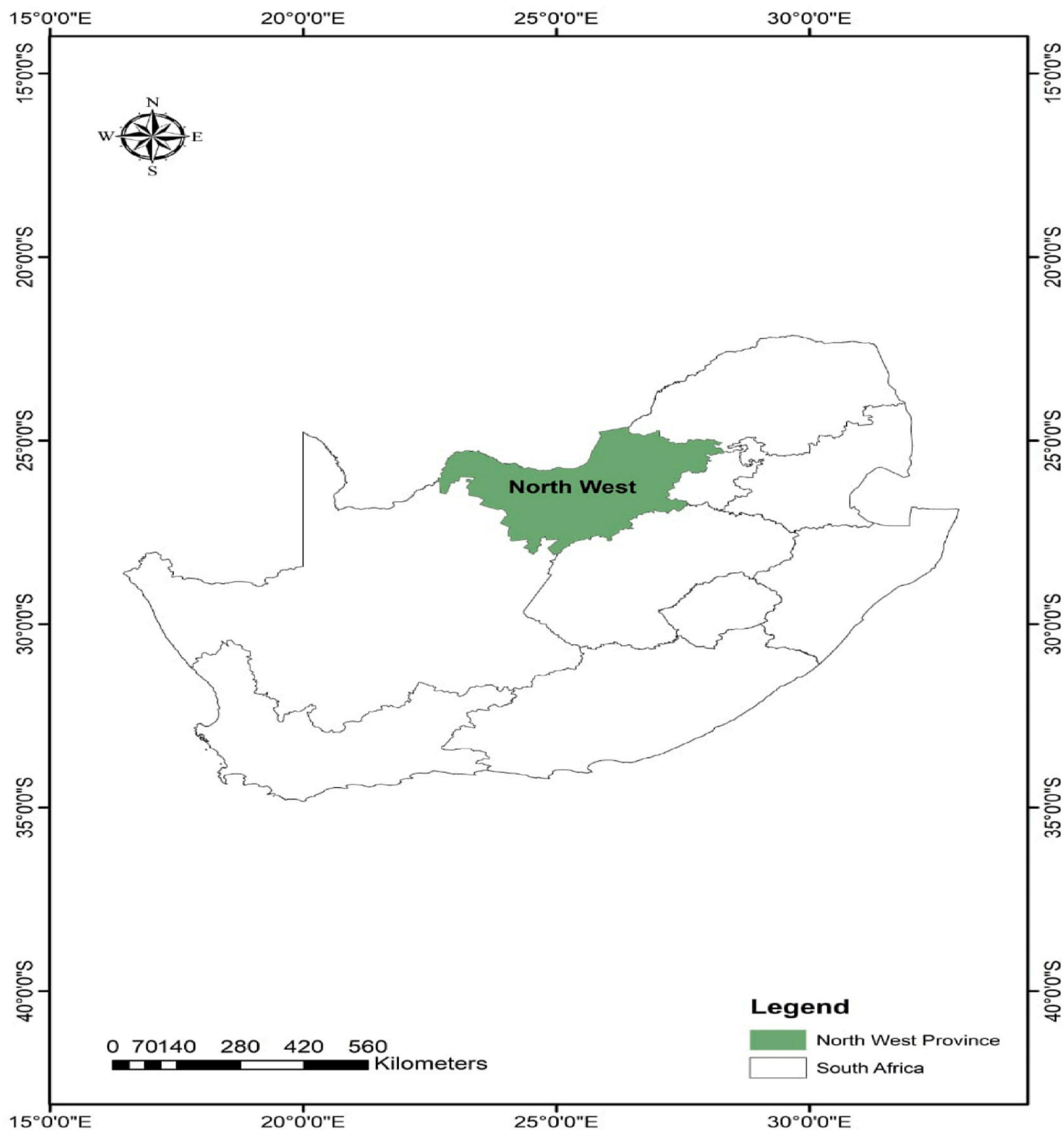

Fig. 3. Geographical location of the North West Province, South Africa.

(Appendix A, number 8–19). While Indigenous fruit crops are fleshy, seed-associated structures that are edible and delectable when uncooked. Marula, Transvaal red milk wood and Kei apple, are a few examples of these fruits (Appendix A, number 19–31).

3.3. Food-nutrition security (FNS) metrics

The FNS was encapsulated with four measures owning to its multidimensional nature. First, we utilized agricultural income as higher farm income have a higher probability of improving FNS [45,46] because it ensures that communities have access to food for consumption. The capacity of people to access food is contingent on the level of food production and the availability for purchase on the market [47]. Consequently, farm income is a key indicator of food accessibility, particularly if farmers are able to make sufficient income and buy from markets to increase their food intake [46]. Accordingly, the household food insecurity access score (HFIAS) was the second metric we utilized. This index quantifies and summarizes various behavioural and psychological dimensions on a scale [48,49].

Household(s) with no reported food insecurity receives a minimum score of 0 (better food access) while a food-insecure counterpart with a high number of eating less foods or skipping due to inadequate access to food receives a maximum score of 27 [48]. Another indicator employed herewith (third indicator) is the household dietary diversity score (HDDS) following the study of [50], the household's consumption within a 7 days period were classified into 12 food categories. It is useful as a measure of dietary quality at the household level. Subjective FNS measures (such as HDDS and HFIAS) are by no means a minor indicator of FNS. The World Food Programme (WFP), the Food and Agriculture Organization (FAO), and the United States Agency for International Development (USAID) have previously used these measurements alongside other metrics in a number of developing countries [49].

The fourth metric is the Foster-Greer and Thorbecke (FGT) which highlights the food security status. Herewith, the food security line is the 2/3 of the mean per capita household food expenditure (MPCHFE) and classified as food secure or food insecure. Households whose MPCHFE is above the line was food secure while those below was food insecure. Similar to previous studies [51,52], the FGT measures are mathematically derived as:

$$P_{\propto} = \frac{1}{N}\left(\frac{z - y_i}{z}\right)^{\propto} 1(y_i \leq z) \tag{1}$$

Where $1(y_i \leq z)$ mean that food insecurity gap does not exist for households with mean per capita expenditure above the food security line. α = FGT food insecurity index which takes values 0, 1, 2, for P_0 = food insecurity headcount; P_1 = food insecurity depth and P_2 = food insecurity severity respectively. It is also the elasticity of individual's food insecurity with respect to the normalized gap $(z - y_i)$ such that a 1 % increase in the insecurity gap of a food insecure individual leads to an α percent increase in the food insecurity level of individuals.

n = total number of households
z = food security line
q = households below the food security line
y_i = households' per-capita monthly food expenditure with individual i^{th} lives.

3.4. Heckman probit model of factors influencing the cultivation of indigenous plants

Decision to cultivate ICs and food-nutrition security of households are two-stage process. The first stage is whether the participants decide that they will cultivate ICs or not, and the second stage is whether the participants are food secured depending on the first stage. Because the second stage is a sub-sample of the first stage, it is likely that our second stage sub-sample is non-random and different from those who did not cultivate ICs creating sample selection bias. Therefore, we used the well-known maximum likelihood Heckman's two-step procedure [53–55] to correct for this selectivity bias. Heckman's sample selection model assumes that there exists an underlying relationship which consists of. The latent equation is given by:

$$y_j{}^* = x_j\beta + u_ij \tag{2}$$

Such that we observe only the binary outcome given by the probit model as:

$$y_j{}^{\text{probit}} = (y_j{}^* > 0) \tag{3}$$

The dependent variable is observed only if the observation j is presented in the selection equation:

$$y_j{}^{\text{select}} = (Z_j\ \beta + u_2\ j > 0)\ (\quad 4)$$

$$u_1 \sim N\ (0, 1),$$

$$u_2 \sim N\ (0, 1)$$

$$\text{corr}\ (u_1, u_2) = p$$

Where, x is a k-vector of explanatory variables which include different factors hypothesized to affect adaptation and z is an m vector of explanatory variables which include different factors hypothesized to affect perception; u_1 and u_2 are error terms. The first stage of the Heckman's sample selection model is the analysis of the determinant to cultivate ICs by the rural farmer's equation (3).

The second stage, which is the outcome model (equation (2)), represents the intelligent decision to cultivate ICs or not based on the conditional first stage. Based on literature [29], the application of standard probit model techniques to equation (1) may yield biased results. To address these skewed results, the Heckman selectivity probit model is commonly used to compensate for the selection bias that has been generated. Consequently, the Heckman probit provides consistent and asymptotically efficient estimates for all parameters in such models [56]. Consequently, the Heckman probit selection model was used to analyze the adoption of ICs by the participants.

4. Results and discussion

4.1. Descriptive statistics

The average age of the participants was 46.91 years, making them primarily adolescents (Table 1). The participants are principally youths capable of catering for the livelihood of their families, making these households less susceptible to FNS and poverty in the present and future. The age of household heads is also conducive to agriculture, as they are still youthful and able to cultivate ICs for enhanced rural development [17,57]. Other variables of interest include the gender, marital status, educational attainment, extension advisory service and training, economic value of ICs, household access to market, welfare, and access to incentives, while the average size of a household was approximately four individuals.

Table 1
Variables description and descriptive statistics.

Independent variables	Description	Mean	Std. Dev.	Min (Max)
Socio-economic and livelihood assets				
Age	Number of years (Continuous)	46.909	11.847	20 (77)
Gender	Dummy,1 male, 0 otherwise	0.4285	0.4967	0 (1)
Marital status	1 if married, 0 if otherwise	0.4586	0.500	0 (1)
Educational attainment	1 if educated, otherwise	0.6662	0.4952	0 (1)
Household size	Number of household member (Continuous)	3.8796	1.4618	1 (10)
Extension, advisory service and training	Dummy, 1 if yes, 0 if otherwise	0.1278	0.3351	0 (1)
Membership of a cooperative society	Dummy, 1 if yes, 0 if otherwise	0.9323	0.2521	0 (1)
Land ownership	Dummy, 1 if yes, 0 if otherwise	0.8796	0.3265	0 (1)
Does indigenous plants have economic value	Dummy, 1 if yes, 0 if otherwise	0.7894	0.4092	0 (1)
Access to produce market	Dummy, 1 if yes, 0 if otherwise	0.8270	0.3796	0 (1)
Willingness of households to pay for ICs	Dummy, 1 if yes, 0 if otherwise	0.9323	0.2521	0 (1)
Total expenditure of households	South African Rands (Continuous)	595.797	655.4492	90 (6000)
Financial return from ICs cultivation	South African Rands (Continuous)	175.1955	165.7492	100 (1500)
Perceived nutritional benefits	Dummy, 1 if yes, 0 if otherwise	0.5606	0.4982	0 (1)
Access to seed and incentive	Dummy, 1 if yes, 0 if otherwise	0.7593	0.4290	0 (1)
Physical assets of households	Dummy, 1 if yes, 0 if otherwise	0.9609	0.98469	0 (1)
% of land used for the cultivation of ICs	% of land utilized for indigenous crops (Continuous)	37.00	9.077	0 (1)
Food and nutrition security indicators				
Households farm income	Total value in South African Rands (Continuous)	7499.5	11134.85	1000 (71,550)
Household Food Insecurity Access Score (HFIAS)	A food secure individual score 0, absolutely food insecure has a score of 27	4.40	4.22	0 (27)
Household Dietary Diversity Score (HDDS)	Number of consumption within the 12 food categories in the past 7 days	7.01	2.03	0 (12)

Food security status	**Frequency**	**Percentage**
Food insecure	54	40.60
Food secure	79	59.40
Total	**133**	**100**

Accordingly, instead of examining the level of education of the household head, this study utilized the average level of education among a given household. Households having higher score had superior human capital, as opposed to those with a lower score. Numerous literature on the synergy between education and agricultural outcomes [58–61] have demonstrated that there is a correlation between educational attainment and agricultural productivity. In addition, educated households are more likely to have employment opportunities, enhanced livelihoods, and resistance to food and nutrition insecurity.

Similarly, improved access to quality education could assist rural dwellers to secure remunerative employment, thereby increasing their income and FNS [62,63]. Included variables are capable of predicting whether or not households will cultivate ICs for FNS and enhanced livelihood. With the financial capital comprised of the average income of households (R11,134.85), the greater the amount received as income, gifts or the greater the number of individuals (networks) on whom s(he) can rely during shocks, the lower its susceptibility to food-nutrition insecurity, all things being equal.

In addition, natural capital through land ownership was incorporated into the model because households with ICs-cultivated land are more likely to convert farm produce into income, thereby increasing access to food more than landless individuals. On the other hand, ownership of physical capital was included because it was anticipated to have a positive impact on the cultivation of ICs and the future FNS status of the households [64]. This is due to the fact that tangible capital procession can serve as collateral, when confronted with idiosyncratic shocks [62].

Similarly, the social capital variables especially the membership in societal groups (cooperative societies) strengthens social networks. These networks play a role when one is confronted with adversity, and those who are well-connected have greater job opportunities. Therefore, households participating in social groups are likely to be less vulnerable, as they may gain access to trainings on the cultivation of ICs for household FNS via the societies. Similarly, the reported HDDS of 7.01 (ranging from 0 to 12) for the participants and HFIAS of 4.40 (ranging from 0 to 27) for the previous week indicate a significant level of food and nutrition insecurity. An increase in the HDDS indicates an improvement in the dietary quality and nutrition security of the household, while a decrease in the HFIAS indicates an improvement in access to food among the participants [50].

This is corroborated by the food security outcomes among the participants, which further summarize household groupings based on food security categories. Following the guidelines by (Boedecter et al., 2014 [3]). Approximately 40.60 % of participants were food insecure, while 59.40 % were food secure. Inferable from the findings is that food insecurity significantly exists in the rural communities. This is consistent with previous findings that approximately 26 % of the African population lacks access to food [28] and confirms the claims of existing literature ([27]; FAO, 2017).

4.2. Determination of decision to cultivate ICs in rural communities of South Africa

Despite the fact that approximately 95 % of participants claimed to be familiar with ICs in the study area, only 69.2 % were aware of the nutritional benefits of ICs. It is possible that farmers who had knowledge of ICs and cultivated (or did not cultivate) share certain characteristics that aid in a better comprehension of the reasons underlying their decision, as captured by the Heckman probit model. The Heckman selection model provides estimates that are consistent and asymptotically efficient for all model parameters.

Several factors influence decisions of participants to cultivate ICs (Table 2). Clearly, household size, extension services, access to improved seed and market substantially increase the likelihood that farmers will choose to cultivate the ICs. In contrast, the age of the household head, marital status, membership in a cooperative society of the farmers are positively correlated with the decision to cultivate ICs, but do not significantly explain the observed selection decision. Apparently, the coefficient of the household size of producers was positive (0.625) and influenced the decision to cultivate ICs significantly ($p < 0.01$). This indicates that the size of the household has a significant impact on the likelihood of ICs cultivation in the household, which likely influences the FNS of the participants in the study area. The incorporation of ICs in the daily diet of households had the potential to increase their food security [57,61].

Table 2
Heckman probit sample selection model-decision to cultivate indigenous crops.

Variables	Coefficient	Standard Error
Age	0.0155	0.0146
Gender	−0.162	0.337
Marital Status	0.197	0.356
Household size	0.625[a]	0.188
Extension visits	1.105[b]	0.598
Household farm income	−7.77e-05	5.04e-05
Cooperative society	0.195	0.764
Perceived economic value	0.402	0.496
Access to improved seed	1.185[b]	0.667
Access to produce market	1.661[a]	0.662
Perceived nutritional benefits	0.135[a]	0.048
Constant	−0.7132	0.123

Note.
**$p < 0.05$.
[a] $p < 0.01$.
[b] $p < 0.1$.

Access to enhanced seeds and a produce market positively and significantly influenced the decision to cultivate ICs. This indicates a positive association between access to enhanced seeds/market and the decision to cultivate ICs. It also implies that households with access to enhanced seeds and markets are more likely to cultivate ICs. In general, household size, accessibility to planting materials/market, and contact with extension advisory services have a significant impact the decision-making of households regarding the cultivation of ICs.

4.3. The determinants of food and nutrition security (FNS) of the rural farmers in South Africa

The inverse Mill's ratio (Lambda) for the food security status of the participants was significant (0.981), indicating that a sample selection bias would have resulted if the food security status of the participants had been estimated without considering the decision to cultivate ICs

Table 3
Heckman Probit Sample Selection model – Determinants of food-nutrition security.

Variables	Coefficient	Robust Std. Error
Age	0.0684[b]	0.030
Gender	0.732	0.536
Marital status	−0.889[c]	0.462
Household size	−1.733[a]	0.483
Extension visits	2.617[a]	0.961
Household farm income	3.05e-05	6.91e-05
Cooperative society	−0.480	0.908
Perceived economic value	1.526[c]	0.892
Access to improved seeds	2.540[c]	1.298
Access to produce market	0.241	0.282
% of land under indigenous crops cultivation	0.804[b]	0.372
Constant	−1.992	0.123
Inverse Mills Ratio		
Lambda	0.981[a]	0.002
Rho	0.993[a]	0.023
Observations	133 in total. 64 selected.	

Note.
[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.1$.

(Table 3). The Heckman selection model enables us to use information from ICs farmers to enhance estimates of the regression model's parameters. At 1 % level, the coefficient of the inverse Mill's ratio/Lambda is significant. The significance of Mill's ratio reveals the existence of selection bias and the efficacy of implementing Heckman two-stage models because of their capacity to address the selection problem. The positive sign of Lambda indicates a positive correlation between the error elements in the adoption decision model and selection equations.

Similar to the first stage result, household size and access to improved seeds and the produce market substantially influenced the decision of farmers to cultivate ICs in the study area, as indicated by the predicted signs. Moreover, at 5 % level of significance, the age of the household head positively and substantially influenced the food security status of ICs farmers. This indicates that the likelihood that a household is food secure increases with the age of the household heads. Consequently, older people are more likely to have more agricultural experience with ICs cultivation and greater output, which increases the likelihood that their families will be food secure. This result is consistent with previous findings [23,32]. In contrast, older households may face the challenge of declining productivity and efficiency, thereby decreasing their likelihood of food security [15]. In addition, the result indicated a negative relationship between household size and food security, which was statistically significant at 1 % probability level. The negative sign indicates that the likelihood of FNS decreases as family size increases.

At 1 % significance level, it was determined that the perceived economic value and access to enhanced seeds significantly and positively influenced the food security status of the farmers. At 5 % level, the proportion of land used to cultivate ICs had a significant impact on the food security of the participants. This indicates that the observation is consistent with previous research indicating that the inclusion of ICs in the diet could help to reduce FNS and strengthen the food system [9,27,52]. This is consistent with the contention of many authors [19,57,62], that mainstreaming and integration of ICs for food security could be used to leverage their incorporation in the dietary diversity among the previously disadvantaged population in rural communities of South Africa.

5. Conclusion and policy implications

The increased vulnerability in agriculture over the medium to long term poses risk to farming and food production unless steps are taken to strengthen the resilience of production systems and adapt the coping mechanism to recognise the cultivation of ICs. In addition, the study revealed that financial, social, natural capital, tangible assets, and human capital assets contribute to the FNS of rural households in South Africa. Particularly, the household dietary diversity scores (HDDS) of 7.01 and the household food insecurity access score (HFIAS) of 4.40 indicate a high prevalence of food and nutrition insecurity among the rural communities. The decision of farmers to cultivate ICs was influenced by household size, seed availability, produce market and perceived nutritional benefits. Similarly, the age of the participant, the size of the household, and the proportion of land used for the cultivation of ICs have a significant impact on their food security. Therefore, the cultivation of ICs is essential for the FNS of rural households in South Africa. Based on the data from this study, we advocate for the stimulation of cultivating ICs for food supply, economic prosperity, enhanced quality of life, and sustainability. Consequently, policy initiatives that seek to improve the current land tenure pattern and incentives for the cultivation of ICs will increase their acceptance and improve the livelihoods among rural households and FNS.

Ethical approval

The survey was conducted with the informed consent of the participants following a thorough explanation of the purpose and scope of the research. The study was approved (NWU-01243-19-S9) by the Faculty of Natural and Agricultural Sciences Research Ethics Committee (FNAS-REC), North-West University, South Africa.

CRediT authorship contribution statement

Abiodun Olusola Omotayo: Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Adeyemi Oladapo Aremu:** Supervision, Resources, Methodology, Conceptualization.

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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Abbreviations

COVID-19	Coronavirus Disease
FAO	Food and Agriculture Organization
FGT	Foster-Greer and Thorbecke
FNS	Food and Nutrition Security
HDDS	Household Dietary Diversity Score
HFIAS	Household's Food Insecurity Access Scores
ICs	Indigenous Crops
TPB	Theory of Planned Behaviour
MPCHFE	Mean Per Capita Household Food Expenditure
NDP	National Development Plan
UNIDO	United Nations Industrial Development Organization
WFP	World Food Programme
USAID	United States Agency for International Development

Appendix A. Indigenous crops (ICs) cultivated by the rural farming households (Botanical names were verified using the World flora online (http://www.worldfloraonline.org/)

	Scientific name & Family	$Vernacular/local names
	Indigenous grains	
1	*Cajanus cajan* (L.) Millsp. **Fabaceae**	Pigeon bean (E); Dinawa (Ts)
2	*Pennisetum glaucum* (L.) R.Br. **Poaceae**	Pearl millet (E); Nyalothi, Ntweka, Amabele (Z); Muvhoho (V); Babala, Manna (Ts)
3	*Sorghum bicolor* (L.) Moench **Poaceae**	Sorghum (E); Graansorghum (A); Mabele (Ts); Amabele (Z)
4	*Tylosema esculentum* (Burch.) A.Schreib. **Fabaceae**	Marama bean (E)
5	*Vigna subterranean* (L.) Verdc. **Fabaceae**	Bambara groundnut (E)
6	*Vigna radiata* (L.) R.Wilczek **Fabaceae**	Mung bean (E)
7	*Vigna unguiculata(L.)Walp.* **Fabaceae**	Cowpea (E)
	Indigenous vegetables	
8	*Amaranthus* sp **Amaranthaceae**	Thepe (Ts); Amaranthus (E); Infino (Z)
9	*Bidens pilosa* L. **Asteraceae**	Mokolonyane (Ts); Blackjack (E); gewone knapsekêrel (A); Uqadolo (Z)
10	*Brassica juncea* (L.) Czern. **Brassicaceae**	Ethiopian Mustard (E)
11	*Corchorus olitorius* L **Malvaceae**	Jew's mallow, wild jute (E); Wildejute (A); Thelele, (NS); Delele, Gushe (T)
12	*Cleome gynandra* L **Cleomaceae**	Lerotho (Ts); Cat's whiskers (E); Oorpeultjie (A)
13	*Chenopodium album* L **Amaranthaceae**	Fat hen (E)
14	*Colocasia esculenta* (L.) Schott **Araceae**	Amadumbe, Amadombi, Mufhongwe (Z)
15	*Cucurbita pepo* L **Cucurbitaceae**	Pumpkin (E); Lephutsi (Ts)
16	*Manihot esculenta* Crantz **Euphorbiaceae**	Muthupula (Ts); Ntsumbula (Tso); Umdumbula Othobola (Z)
17	*Lagenaria siceraria* (Mol.) Standl. **Cucurbitaceae**	Bottle gourd (E); Kalbas (A); Moraka (Ns); Segwana (Ts); Iselwa (X, Z)
18	*Tetragonia decumbens* Mill. **Aizoaceae**	Dune spinach (E); Duinespinasie (A)
19	*Annona senegalensis* Pers. **Annonaceae**	African Custard-apple (E); Custard Apple (E), Isiphofu (Z); Mokamanawe (Ts)
Indigenous fruits		
20	*Diospyros simii* (Kuntze) De Winter. **Ebenaceae**	Climbing Star-apple (E); Kraaibessie (A)
21	*Dovyalis caffra* (Hook.f. & Harv.) Sim **Salicaceae**	Kei-apple (E); Kei-appel (A); Motlhono (NS); Umqokolo (Z)
22	*Diospyros lycioides* Desf. **Ebenaceae**	Monkey plum (E); bloubos (A); Lethanyu (T); Monkga-nku (S)
23	*Dovyalis zeyheri* (Sond.) Warb. **Salicaceae**	Wild apricot (E); Wilde-appelkoos (A); umNyazuma (Z); umQokokolo (X); Morethema (NS)
24	*Carissa macrocarpa* (Eckl.) A.DC. **Apocynaceae**	Natal plum, big num-num (E); grootnoem-noem (A); Amatungulu (Z)
25	*Citrus* sp. **Rutaceae**	Lemon (E)
26	*Mimusops zeyheri* Sond **Sapotaceae**	Transvaal red milkwood (E); Moepel (A); Mmupudu (NS); umpushane (Z); Nhlantswa (T)
27	*Parinari curatellifolia* Planch. Ex Benth. **Chrysobalanaceae**	Bosappel (A); Mmola (NS); Mbulwa (Tso); Mobola (Ts); Muvhula (V)
28	*Persea americana* Mill. **Lauraceae**	Avocado (E)
29	*Sclerocarya birrea* (A.Rich.) Hochst. **Anacardiaceae**	Marula (E); Morula (NS); Mufula (V); ukanyi (Tso)
30	*Strychnos spinose* **Loganiaceae**	Corky-bark Monkey-orange (E); Kurkbasklapper (A); Morapa (NS)
31	*Vangueria infausta* Burch. **Rubiaceae**	Chirinda wild-medlar, (E); Bosmispel, Blinkblaarmispel (A); Mobilo (Ts)

$Vernacular/local names: A = Afrikaans, E = English, Z = Zulu, NS=Northern Sotho, Ts = Setswana, Tso = Xitsonga, X = Xhosa, S=Sotho.

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