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Prioritizing Critical Success Factors for Smallholder Maize Farmers in Zambia: A Pathway to Sustainable Food Security and Rural Development

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ABSTRACT

The agricultural sector is pivotal to the economies of most developing countries. In Zambia, the agricultural sector is dominated by smallholder maize farmers who play a key role in ensuring food security, employment, and rural development. Despite receiving a significant share of the agricultural budget, smallholder maize farmers continue to experience low levels of productivity. This necessitates a focused evaluation of the critical success factors (CSFs) that can support and elevate smallholder maize farming outcomes. This study aims to evaluate the CSFs of smallholder maize farming in Zambia using the Fuzzy analytic hierarchy process (Fuzzy AHP). An expert survey was conducted to collect data on the relative importance of each CSF, allowing for a systematic prioritization of the factors influencing smallholder maize farming. The results indicate that knowledge (0.2617), adoption of technology (0.1779), and financial resources (0.1365) have the most significant impact on the success of smallholder maize farming in Zambia. Additionally, the study identified knowledge application (0.1715), conservation agriculture practices (0.0936), knowledge acquisition (0.0901), irrigation (0.0843), and access to loan facilities (0.0793) as the most influential sub-factors. The study offers valuable insights for policymakers and agricultural practitioners, enabling them to focus on the most impactful areas to enhance the performance and sustainability of smallholder maize farming. Prioritizing the CSFs has the potential to drive progress in Zambia's smallholder maize sector, boosting productivity, enhancing food security, and fostering sustainable rural livelihoods, thereby contributing to the broader sustainable development goals such as eradicating poverty, achieving zero hunger, and climate resilience.

1 | Introduction

Agriculture plays a key role in many developing countries, contributing to poverty reduction, hunger elimination, and economic growth, all of which support the sustainable development goals (SDGs) for 2030. Despite concerted efforts in several countries, Africa remains off track to achieve the SDG of zero hunger by 2030 (FAO et al. 2024). Although Sub-Saharan Africa (SSA) is one of the major agricultural regions, nearly one in four people

in the region continues to suffer from undernourishment. In fact, it has been projected that 582 million people in Africa, SSA specifically, will be chronically undernourished in 2030 (FAO et al. 2024). Moreover, millions are likely to be at risk of worsening hunger in the near future as a result of the rippling effects of the war in Ukraine (FAO 2023; Ngwu et al. 2024). These issues highlight the urgent need to enhance the agricultural sector's productivity and resilience to ensure sufficient food security and availability, particularly in the hardest-hit regions of SSA.

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In SSA, smallholder farmers are at the heart of the agricultural sector where they play a dominant role. They are primarily engaged in maize cultivation, which serves as the staple food in most parts of the region (Obunyali et al. 2019; Tshikovhi and van Wyk 2021). Maize is cultivated on over 40 M ha of land in SSA and serves as a staple food for over 200 million people (Cairns et al. 2021; Muchelo and Akpa 2024). Maize has been widely recognized for its caloric value, its role in food security, and its contribution to the income of rural communities (Cairns et al. 2021; Montalbano et al. 2018; Utonga and Kamwela 2024).

In Zambia, maize is a vital crop and staple food that plays a key role in food security and economic development. Smallholder farmers predominantly grow maize, accounting for about 80% of Zambia's maize production (Manda et al. 2018). Maize provides about 50%–90% of the country's caloric requirements (Silva et al. 2023). Moreover, maize production contributes to the agricultural Gross Domestic Product (GDP) and is one of the country's major crop exports (Mulenga et al. 2021).

Despite their importance to food security and economic development, smallholder maize farmers in Zambia have struggled with persistently low productivity levels over the years (Umar 2016; Kayula 2018). Zambia's average annual maize yield is relatively low, ranging from 1.2 MT/ha to 1.5 MT/ha compared with the expected value of 5 MT/ha (Mulenga et al. 2021). The consistent low levels of productivity raise concerns about smallholder maize farmers' potential to contribute to food security and drive economic growth in Zambia. For instance, the Global Hunger Index ranked Zambia as the fifth hungriest country in 2018 (Middelberg et al. 2020). Aligned with the vision 2030 goal of SDG 1 and 2 to end poverty and hunger, Zambia is focused on improving productivity among smallholder maize farmers who are major contributors to the country's staple food supply, contributing more than 80% of maize production (Zambia Statistical Agency 2021).

In a bid to strengthen food security through increased maize productivity, the government has consistently allocated a substantial portion of the agricultural budget to support smallholder maize farmers via Farmer Input Support Programme (FISP) and the Food Reserve Agency (FRA), see Umar (2016); Tambo and Liverpool-Tasie (2024). Previous studies have shown that improving the productivity of smallholder farmers has the potential to reduce poverty, enhance food security, and contribute significantly to the achievement of multiple SDGs (Larson et al. 2020; Louhichi et al. 2020). To optimize the impact of smallholder maize farmers in Zambia, it is essential to identify and prioritize the critical success factors (CSFs) that drive their productivity and sustainability, as doing so will pinpoint key areas for improvement and guide effective resource allocation.

While several studies have identified CSFs in the agricultural context, most of them have focused on categorizing these factors without systematically prioritizing them based on their relative importance, see Tritsch et al. (2021). Additionally, most of the existing research has been conducted in regions outside of SSA, leading to a gap in understanding the unique contextual challenges and priorities of smallholder farmers in this particular

region of Africa. Specifically, there is limited research dedicated to understanding and prioritizing the CSFs for smallholder maize farmers in SSA, despite maize being a key crop for food security, economic development, and rural livelihoods across much of SSA (Badu-Apraku et al. 2017; Obunyali et al. 2019). Without a clear understanding and prioritization of CSFs tailored to smallholder maize farmers in the context of SSA, it is difficult for policymakers and stakeholders to allocate resources effectively.

The purpose of this study is to develop a framework for prioritizing interventions aimed at improving the performance of smallholder maize farmers in SSA, with a specific focus on Zambia. In this study, we apply the Fuzzy AHP approach systematically to analyze the CSFs of smallholder maize farmers based on the opinions of experts in the field. Fuzzy AHP extends the traditional AHP framework by integrating fuzzy set theory, allowing for better handling of uncertainty and vagueness in the decision-making process (Buckley 1985). Fuzzy AHP is particularly useful for handling the uncertainty and subjectivity often associated with expert judgments, ensuring a more accurate prioritization of the CSFs (Zaid et al. 2024). Moreover, there may not be a large number of experts in the field. This shortcoming then limits or even outright excludes some other methodological approaches for the considered analysis, e.g., logit and probit models, which require large data sets (samples of appropriate size and structure) to obtain robust results. The application of Fuzzy AHP is also supported by the fact that our study focuses on prioritizing CSFs, that is, on the hierarchy of their importance.

In this context, the application of Fuzzy AHP is an adequate and usable approach to agricultural decision-making, allowing for more accurate and nuanced prioritization of CSFs under uncertainty, which is often a problem in the small-scale maize farming environment. Especially if the research is conducted using the opinions of several experts in a given field—not on hard data. In addition to implementing Fuzzy AHP, our study further incorporates expert insights to deepen the understanding of the prioritization process and also conducts sensitivity analysis to assess the robustness of our results and findings.

Regarding the above-mentioned facts, the aim of the present study was specified through three sub-objectives: RO1, RO2, and RO3. In relation to the three specified objectives, corresponding research questions were formulated: RQ1, RQ2, and RQ2. The specific research objectives (RO) and their corresponding research questions (RQ) of this study are:

- RO 1: To identify and prioritize CSFs affecting smallholder maize farmers in Zambia using Fuzzy AHP.
- RQ 1: What are the CSFs for smallholder maize farmers in Zambia and what is their prioritization?
- RO 2: To justify the identified prioritization of CSFs for smallholder maize farming in Zambia.
- RQ 2: What are the reasons for the identified prioritization of CSFs for smallholder maize farmers in Zambia?
- RO 3: To assess the stability and reliability of the prioritized CSFs under different conditions using sensitivity analysis.

- RQ 3: What is the sensitivity of CSFs for smallholder maize farming in Zambia under different conditions?

We anticipate that our study contributes to the existing body of knowledge by developing a framework that prioritizes CSFs specifically for smallholder maize farming in the SSA context and specifically Zambia. Our study provides a systematic evaluation approach that enhances understanding of how CSFs can be leveraged to improve maize productivity and food security in Zambia and similar contexts. It offers stakeholders a practical tool for prioritizing resources and support for smallholder maize farmers. Additionally, the study contributes to the literature by demonstrating the applicability of the Fuzzy AHP methodology in prioritizing CSFs within agricultural contexts.

2 | Literature Review

2.1 | Smallholder Maize Farming in Zambia

Maize is the cornerstone of Zambia's agricultural sector, playing an essential role in the nation's food security and economic stability (Chisanga et al. 2022; Ngoma et al. 2021). It is the dominant staple food in Zambia and is widely cultivated by over 80% of smallholder farmers (Chiona et al. 2014; Pelletier et al. 2020). Approximately 85% to 90% of maize produced in Zambia is used

for food, making Zambians some of the largest consumers of maize in Africa (Fusillier et al. 2021).

The crucial role that smallholder maize farmers play in Zambia cannot be overstated. However, they face challenges in their maize production, including limited access to financial resources, impacts of climate change, and technological constraints, among others (Hasimuna et al. 2023; Makondo et al. 2014). Due to the importance attached to maize production, the agricultural budget in Zambia prioritizes smallholder maize farmers through the programs of FISP and FRA aimed at improving the farmers' access to agricultural inputs and market accessibility of their produce, respectively (Umar 2016; Middelberg et al. 2020). As shown in Figure 1, funding for the FRA and FISP has exhibited an upward trend in recent years, reflecting increased investment in these support programs.

Despite these efforts, maize productivity among smallholder maize farmers in Zambia has continued to be low (Umar 2016; Middelberg et al. 2020; World Food Programme 2021). Figure 2 illustrates the fluctuating maize yields for smallholder farmers in Zambia, with a general decline observed in most years from 2013/2014 to 2022/2023. Specifically, maize yields decreased from 2.26 MT/ha in 2013/2014 to 1.67 MT/ha in 2022/2023, reflecting a downward trend over the past decade. This overall decline of approximately 26% underscores

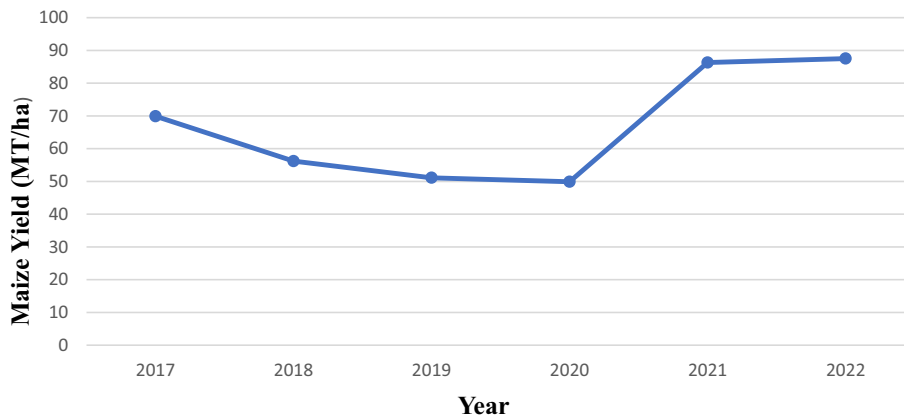


FIGURE 1 | Allocation of agriculture budget towards FISP & FRA in percent (2017–2022). *Source:* Processed by authors.

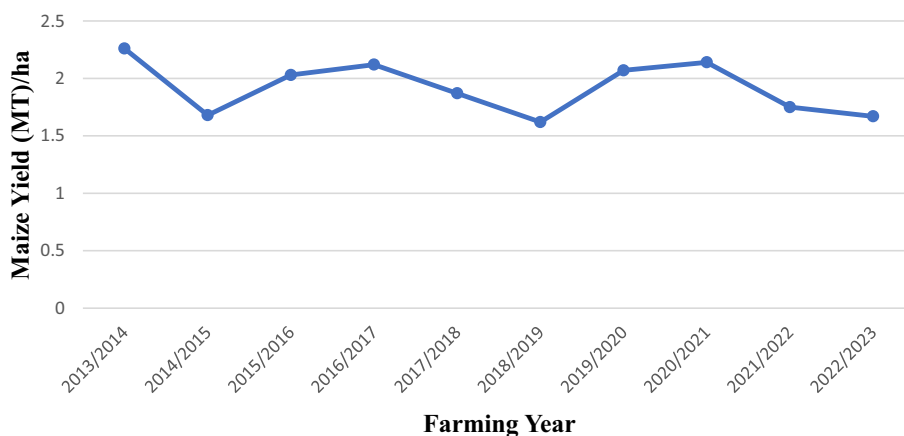


FIGURE 2 | Annual Maize yield trends for smallholder farmers in Zambia, (2013/2014–2022/2023). *Source:* Processed by authors.

persistent challenges in maintaining productivity, emphasizing the need for effective support measures to stabilize and enhance yields.

The low productivity of maize could influence food security negatively (Middelberg 2017). Regrettably, most smallholder maize farmers in Zambia are unable to produce enough food to feed their families and often have little surplus for sale. Increased maize production is crucial to Zambia's economy; thus, enhancing its productivity and efficiency is essential for ensuring food security and reducing poverty (Chiona et al. 2014; Silva et al. 2023). Moreover, Zambia has significant potential to become the breadbasket of the SSA region (Muchelo and Akpa 2024; World Food Programme 2021).

2.2 | CSFs in the Agricultural Context

This literature review examines the CSFs for small farms through the lens of the resource-based view (RBV), highlighting the resources and capabilities that determine small farm success and sustainability. Previous research has identified a range of CSFs, underscoring the importance of both internal resources and external influences in shaping farm performance.

Access to financial resources has been consistently identified as a success factor in the context of smallholder farming (Qing et al. 2021). A study by De Almeida and Zylbersztajn (2017) revealed that access to governmental rural credit programs and other alternative forms of finance was important for Brazilian coffee producers. Financial resources are a critical strategic asset that smallholder farmers can leverage to acquire and deploy other valuable resources, contributing to a sustainable competitive advantage (Middelberg 2017). Agricultural credit provides farmers with the essential capital required to fulfill their financial obligations at each stage of the production cycle (Khanal and Omobitan 2020). However, the challenge remains that many smallholder farmers face limited access to financing due to factors such as inadequate collateral and perceptions of low creditworthiness (Malesu and Syrovátka 2024; Middelberg 2017). The government has been recognized as a key entity that can improve loan access for small farms through the development of rural banking systems (Ngo et al. 2019). Supporting other studies, Garima et al. (2023) identified effective financial management as a key factor for farm success, with agripreneurs in India ranking it among the top factors. While the study effectively ranked the factors, the use of a relatively simple ranking technique limited its ability to fully capture the complexity of prioritizing them.

The adoption of technology is widely acknowledged as a CSF for small farms with studies showing that integrating the latest technological advancements into agricultural practices enhances productivity and efficiency (Adobor 2020; Dendup et al. 2017; Stillitano et al. 2016). From the RBV perspective, technology represents a valuable resource that can provide farmers with a competitive advantage by improving productivity and reducing operational costs (Paoloni et al. 2022; Barney 1991). Garima et al. (2023) revealed that agripreneurs ranked technology highly among the top success factors in India. While

technology is widely recognized as essential, its adoption among smallholder farms, especially in developing countries, may be constrained by limited financial access and a lack of necessary skills (Dendup et al. 2017; Middelberg 2017; Malesu and Syrovátka 2024). The study by Malesu and Syrovátka (2024) identified irrigation and the practice of conservation agriculture (CA) as important technologies for small farming businesses. While past studies emphasize technology adoption as crucial for small farms, it is important to note that regional differences in climate, agricultural practices, and resource availability create diverse needs, making region-specific strategies essential.

Personal characteristics of the farm owner or manager have been linked to success in small farms (Qing et al. 2021). Entrepreneurial characteristics can be regarded as essential capabilities within the RBV, enabling farmers to effectively utilize available resources and create a competitive advantage (Barney 1991). Characteristics such as a positive attitude and a farming background (Smolová et al. 2018); motivation, creativity, and innovation (Sroka et al. 2023) determined the success of smallholder farming. Possessing such characteristics enables owners or farm managers to better cope with the inherent threats of farming and continuously adapt to the highly dynamic environment (Sroka et al. 2023). Other studies have gone further to reveal that motivated and high-quality employees also contribute to success by enhancing productivity (De Almeida and Zylbersztajn 2017; Garima et al. 2023). It can be noted that past studies identify various personal characteristics as essential for small farm success, suggesting that further research is needed to better understand which characteristics are most critical across different contexts.

Another CSF frequently highlighted by scholars is knowledge acquisition. Prior research emphasizes that small farms should actively seek essential knowledge through technical training sessions (Adobor 2020; Ragbir et al. 2014). Technical training in areas such as processing, packaging, and labeling can significantly help grow small farming ventures (Khanal and Mishra 2016). Knowledge is an intangible resource that enables farmers to make informed decisions and adapt to changing conditions, providing a competitive advantage (Barney 1991; Grande et al. 2011). Farmers who lack relevant training experience negative impacts on their performance (Adobor 2020). Along with acquiring knowledge, other studies highlight the importance of applying that knowledge for the success of the small farm (Malesu and Syrovátka 2024).

Networking has been closely linked to the success of farmers, particularly small farming operations. Networking can take various forms such as joining cooperatives or engaging in informal social interactions with peers (Lin et al. 2022). Networking plays a crucial role by providing a platform for knowledge sharing and creating opportunities for farmers (Ghauri et al. 2023; Malesu and Syrovátka 2024). Moreover, participating in networks such as cooperatives allows farmers to access affordable, high-quality inputs, which enhance their performance and improve their chances of survival (Lin et al. 2022).

Several studies have highlighted management practices such as business planning, record keeping, and marketing strategy as essential for small farms. In their study (Garima et al. 2023),

farmers considered timely planning, execution, and control as important factors to ensure the success of smallholder farming. However, to achieve effective planning, small-scale farmers need demand and production information that will enable them to make accurate and well-informed decisions (Raungpaka and Savetpanuvong 2017). Other studies have demonstrated that market orientation is crucial for farming (Dendup et al. 2017). Farmers who maintained formal record keeping were more market-oriented than those who did not (Ragbir et al. 2014).

Previous studies have also recognized government support as a CSF for small farms. Extension services have been hailed as a key component of government support as they serve as a conduit through which technical assistance and advisory services are provided to small-scale farmers (Adobor 2020; Ragbir et al. 2014). Previous studies have demonstrated that farmers significantly increase their production outcomes when they have regular contact with extension services (Kawsar et al. 2013; Kubitza et al. 2024). In addition to extension services, government subsidies are recognized as another essential tool for supporting small farms (Malesu and Syrovátka 2024; Ragbir et al. 2014). While some studies identify subsidies as a CSF for small farms, others argue that subsidies often frequently fail to achieve their intended purpose (Andrews 2021). Research by Malesu and Syrovátka (2024) revealed that while subsidies are important, they can foster dependency rather than improving farmers' productivity and resilience. In light of this, the government should focus on fostering a supportive environment by implementing sound policies, developing infrastructure, and offering various assistance schemes (Dendup et al. 2017).

While there is a considerable amount of research on CSFs for small farms, many studies focus primarily on identifying these factors without assessing their relative importance or their hierarchy. This lack of prioritizing CSFs presents missed opportunities for small farms, which, faced with limited resources, must make strategic decisions on where to allocate their efforts. The study by Garima et al. (2023) is one of the few that ranked several factors contributing to the success of small-scale agripreneurs; however, the approach lacked a more robust and systematic prioritization of the CSFs. Our study addresses this gap by using a structured decision-making tool, Fuzzy AHP, to prioritize the CSFs of small farms according to their relative importance. Moreover, our study focuses on understanding and systematic prioritizing the CSFs of smallholder maize farmers in SSA, specifically in Zambia. These evaluations for Zambia or the SSA region have been under-represented in the existing literature. Identifying and systematic prioritizing of these factors is pivotal for developing targeted strategies that can improve farm productivity, guide resource allocation, and enhance the sustainability of smallholder farming in this region.

In this study, the CSFs have been identified through a comprehensive review of relevant literature on CSFs in the agricultural context with a focus on maize farming in Zambia and refined through validation with relevant industry experts. This approach is consistent with previous studies that have prioritized factors by first identifying them through a review of relevant literature and consulting with industry experts (Mangla et al. 2015; Chisale and Lee 2023; Khan et al. 2019; Ahmad and Qahmash 2020). Using this approach ensured that the identified

CSFs for our study are both context-specific and relevant to smallholder maize farming in Zambia. A total of seventeen factors were identified and grouped into seven main categories. Table 1 displays the 7 main CSFs and their 17 associated sub-factors along with the sources from which each factor was derived.

3 | Involving Fuzzy AHP as a Method in Multi-Criteria Decision-Making

Multi criteria decision making (MCDM) methods are widely used to solve complex decision problems involving multiple, often conflicting criteria. These methods provide a structured approach to evaluating alternatives, integrating expert judgments, and optimizing decision outcomes (Sahoo and Goswami 2023; Šostar and Ristanović 2023). Over the years, researchers have proposed a wide range of MCDM methods including analytic hierarchy process (AHP), analytic network process (ANP), technique for order of preference by similarity to ideal solution (TOPSIS), VlseKriterijumska Optimizacija I Kompromisno (VIKOR), elimination and choice expressing reality (ELECTRE), and multi-attribute utility theory (MAUT), see Guo and Zhao (2017) or Zaid et al. (2024). However, many of these methods rely on precise numerical inputs, which may not fully capture the uncertainty and subjectivity inherent in expert decision-making. For example, while TOPSIS accounts for both positive and negative aspects of criteria, it does not address uncertainty or imprecision in decision data, limiting its applicability in situations with uncertain information (Sahoo and Goswami 2023). ELECTRE, on the other hand, focuses on outranking relationships and is particularly useful for dealing with conflicting criteria but lacks the intuitive pairwise comparison structure of AHP. MAUT has the capability of handling both qualitative and quantitative criteria, facilitating a comprehensive evaluation of alternatives; however, it requires precise quantification of utility functions, which can be challenging and subjective (Sahoo and Goswami 2023).

Compared to other MCDM methods, the AHP technique is widely recognized and successfully applied in complex decision-making problems (Singh and Singh 2021; Getawa Ayalew et al. 2024). It was proposed by Thomas L. Saaty in the 1970s and is designed to solve complex decision-making problems (Mangla et al. 2015). AHP allows complex problems to be decomposed into sub-problems organized in hierarchical levels, with each level representing a set of criteria or attributes for each sub-problem (Chisale and Lee (2023)). Thereafter, pairwise comparisons are made between elements at each level to assess their relative importance or preference (Getawa Ayalew et al. 2024). One of the main advantages of AHP is its ability to handle multiple criteria with relative ease (Zaid et al. 2024). AHP is easier to understand and effectively manages both qualitative and quantitative data (Iftikhar and Siddiqui 2017). Moreover, AHP offers flexibility, intuitive appeal to policymakers, and the ability to produce consistent results (Das et al. 2022). Despite its wide range of applications, the traditional AHP may not fully reflect a style of human thinking (Özdağoğlu and Özdağoğlu 2007). AHP relies heavily on the accuracy and consistency of pairwise comparisons, which can be subjective and prone to individual biases (Sahoo and Goswami 2023; Mangla et al. 2015).

TABLE 1 | CSFs of smallholder maize farmers in Zambia—literature review and industry expert opinion.

CSF	Sub factors	Source
1. Entrepreneurial characteristics	Farming background	Malesu and Syrovátka (2024); Industry expert opinion
	Financial Discipline	Garima et al. (2023); Industry expert opinion
	Motivation	Sroka et al. (2023)
	Resilience	Industry expert opinion
2. Knowledge	Knowledge acquisition	Adobor (2020); Ragbir et al. (2014); Industry expert opinion
	Knowledge application	Malesu and Syrovátka (2024); Industry expert opinion
3. Financial resources	Loan facility	De Almeida and Zylbersztajn (2017); Ngo et al. (2019); Malesu and Syrovátka (2024)
	Village banking	Malesu and Syrovátka (2024); Expert opinion
4. Adoption of technology	Irrigation	Expert opinion
	Conservation agriculture	Malesu and Syrovátka (2024); Industry expert opinion
5. Management factors	Business planning	Garima et al. (2023); Industry experts
	Market planning	Dendup et al. (2017)
	Record keeping	Ragbir et al. (2014); Malesu and Syrovátka (2024)
6. Networking	Cooperatives	Ghuri et al. (2023); Malesu and Syrovátka (2024); Lin et al. (2022); Industry expert opinion
	Informal social networking	Lin et al. (2022)
7. Government support	Extension services	Kawsar et al. (2013); Kubitzka et al. (2024); Malesu and Syrovátka (2024); Industry expert opinion
	Subsidies	Malesu and Syrovátka (2024); Ragbir et al. (2014); Industry expert opinion

Fuzzy AHP was developed as an advanced analytical approach to overcome the limitations of traditional MCDM techniques, particularly AHP (Iftikhar and Siddiqui 2017; Sahoo and Goswami 2023). Fuzzy AHP extends the traditional AHP by incorporating fuzzy numbers to represent the uncertainty in expert judgments. Fuzzy AHP uses fuzzy triangular numbers to represent linguistic variables, facilitating pairwise comparisons between criteria and alternatives (Getawa Ayalew et al. 2024). These fuzzy numbers allow for the representation of imprecise or uncertain preferences, which is often the case in real-world decision-making scenarios (Iftikhar and Siddiqui 2017).

Fuzzy AHP stands out for its ability to quantify subjective judgments, yielding numerical results that are instrumental in decision-making processes (Jacob and Subramoniam 2021; Zaid et al. 2024). Unlike the traditional AHP, the fuzzy-based integrated AHP can deal with vagueness and bias that are associated with human judgment when analyzing the factors (Getawa Ayalew et al. 2024). The fuzzy AHP is able to deal with uncertain information and impreciseness in the evaluation of factors (Akbar et al. 2020; Gupta and Gupta 2023). Therefore, fuzzy AHP enhances the accuracy of results in the decision-making process (Gnanavelbabu and Arunagiri 2018; Oyefusi et al. 2024).

Fuzzy AHP addresses uncertainty by allowing decision-makers to use triangular fuzzy numbers (TFNs) to represent their subjective judgments as illustrated in Table 2. TFN is denoted as a

triplet (a, b, c) , with the fuzzy number's membership function $F(x)$ illustrated in Figure 3 and Equation (1):

$$F(x) = \begin{cases} \frac{x-a}{b-a}, & a \leq x \leq b \\ \frac{c-x}{c-b}, & b \leq x \leq c \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Capitalizing on the strengths of Fuzzy AHP in managing uncertainties and providing reliable results, this study applies the method to prioritize the CSFs of smallholder maize farming in Zambia. Recent studies have highlighted the relevance and versatility of Fuzzy AHP in assessing and ranking success factors in real-world decision-making contexts. For example, Sadeghi (2018) used it to model success factors in high-tech small businesses. Likewise, Amrita et al. (2018) applied Fuzzy AHP to evaluate CSFs for women entrepreneurship, while Kim et al. (2018) utilized the method to analyze success factors for startup companies. Akbar et al. (2020) further employed Fuzzy AHP to assess success factors for the development and operations of practices in software organizations. Therefore, given the proven utility of Fuzzy AHP in various studies, this study adopts it to evaluate the CSFs within the context of smallholder maize farming. Notably, the Fuzzy AHP approach yields reliable results even with smaller sample sizes compared to traditional statistical models such as logit and probit, see Zaid et al. (2024).

TABLE 2 | Fuzzy-AHP versus Saaty's scale.

Linguistic scale	AHP scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important	1	(1,1,1)	(1,1,1)
Equal to moderate important	2	(1,2,3)	($\frac{1}{3}, \frac{1}{2}, 1$)
Moderately important	3	(2,3,4)	($\frac{1}{4}, \frac{1}{3}, \frac{1}{2}$)
Moderate to strong importance	4	(3,4,5)	($\frac{1}{5}, \frac{1}{4}, \frac{1}{3}$)
Strong importance	5	(4,5,6)	($\frac{1}{6}, \frac{1}{5}, \frac{1}{4}$)
Strong to very strong importance	6	(5,6,7)	($\frac{1}{7}, \frac{1}{6}, \frac{1}{5}$)
Very strong important	7	(6,7,8)	($\frac{1}{8}, \frac{1}{7}, \frac{1}{6}$)
Very strong to absolute important	8	(7,8,9)	($\frac{1}{9}, \frac{1}{8}, \frac{1}{7}$)
Absolute important	9	(9,9,9)	($\frac{1}{9}, \frac{1}{9}, \frac{1}{9}$)

Source: Gupta et al. (2023).

4 | Materials and Methods

This study followed a systematic methodological approach as depicted in Figure 5. The details of the specific procedures are explained in the sections below.

4.1 | Study Area

This study was conducted in Zambia, a key maize-producing country in SSA. The country has an estimated 75 million hectares of land with 58% considered suitable for agricultural production. The study was conducted in key maize farming regions in Zambia: Chibombo and Chongwe, both of which are known for their strong agricultural activities. Additionally, Lusaka, the capital, was also included as it is the central hub for policymakers and key agricultural stakeholders who have extensive expertise in maize production.

4.2 | Expert Survey

The expert survey was conducted to apply the Fuzzy AHP methodology to prioritize CSFs for smallholder maize farmers in Zambia. The process began with the development of the questionnaire and expert sampling, followed by data

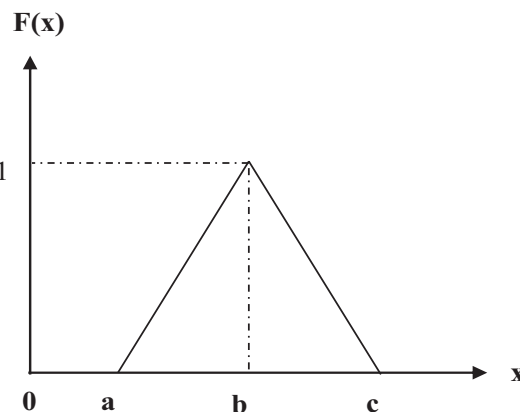


FIGURE 3 | Triangular fuzzy number.

collection, and concluded with the application of the Fuzzy AHP methodology.

4.2.1 | Questionnaire Development and Expert Sampling

We used a questionnaire as the instrument for the expert survey. Based on the established hierarchical structure, a questionnaire was developed to allow experts to conduct pairwise comparisons of the importance or preference of each factor (Chisale and Lee 2023). The questionnaire was divided into two sections: the first collected information on the experts' profiles, while the second comprised a pairwise comparison matrix of all the 7 main factors and 17 subfactors, see Table 1. The questionnaire utilized a nine-point Likert scale comparison matrix as recommended by Saaty (1980). As shown in Table 2, the scale of factors ranged from 1 (*equally important*) to 9 (*absolutely important*). Prior to the main survey, a pilot assessment of the questionnaire was conducted with two experts from an agricultural institution. The feedback received helped enhance the clarity and comprehension of the questionnaire as mentioned in Akbar et al. (2020).

Once the questionnaire was finalized, the next important step was selecting an appropriate sample of participants to ensure the reliability and validity of the findings. The selection process for expert members is a critical aspect of the Fuzzy AHP technique (Getawa Ayalew et al. 2024). Purposive sampling was utilized to select experts who possess substantial knowledge and extensive experience in smallholder maize farming (Belay et al. 2022). The experts were carefully selected based on specific criteria, including professional expertise and experience in smallholder maize farming, policymaking, and direct involvement in smallholder maize farming practices. Consequently, the study engaged a diverse group of experts, including officials from the Ministry of Agriculture, camp extension officers, agricultural research institution experts, NGO representatives in agriculture, academics from agricultural college, smallholder maize farmers, and private sector stakeholders in agriculture. Experts were drawn from both national and regional levels to participate in the survey. This approach allowed for the inclusion of participants who could provide valuable insights into the prioritization of the CSFs.

4.2.2 | Data Collection

The data collection process involved administering the finalized questionnaire to experts through face-to-face interactions. This allowed for real-time clarification of any ambiguities, ensuring that responses were well-informed (Zaid et al. 2024). Consistent with our sampling strategy, experts were identified through a blend of professional networks, institutional affiliations, and recommendations from relevant agricultural organizations. We collected responses from 30 experts who successfully completed the questionnaires. The collected responses underwent manual analysis to identify any incomplete entries; however, no incomplete entries were found. Therefore, all 30 responses collected were included in the final sample for further analysis. It is important to note that previous studies have effectively applied the Fuzzy AHP technique with relatively small sample sizes. For instance, (Sadeghi 2018) used a sample of 18 experts, (Akbar et al. 2020) utilized a sample size of 29 experts, Kukreja and Aggarwal (2021) used a sample of 15 experts, and most recently, Getawa Ayalew et al. (2024) used only 10 experts. Therefore, the utilization of 30 experts in this study can be deemed adequate for obtaining meaningful and reliable insights into the prioritization of the CSFs of smallholder maize farmers in Zambia and also for generalization (Akbar et al. 2020). Moreover, previous studies have indicated that the Fuzzy AHP approach provides sufficient results even for smaller sample sizes compared to more traditional statistical models such as logit and probit; see Zaid et al. (2024).

4.2.3 | Fuzzy AHP Steps

This study employed the Fuzzy AHP steps outlined by Buckley (1985) to determine the relative significance of the factors. We adopted Buckley's approach as it offers greater precision compared to traditional Fuzzy AHP (Abusaeed et al. 2023). The Fuzzy AHP method was carried out as follows:

Step 1: The initial step in the Fuzzy AHP process is to establish the hierarchical structure for the decision criteria. This involves identifying the main criteria and sub-criteria, which should be supported by a theoretical foundation and insights from experts (Ahmad and Qahmash 2020; Chisale and Lee 2023). Following the identification of the CSFs, a hierarchical structure was developed (see Figure 4). The hierarchical structure consists of three levels: *level one* represents the main goal of the Fuzzy AHP, which is to prioritize the CSFs; *level two* comprises the main factors (CSFs); and *level three* consists of the sub-factors.

Step 2: Based on the established hierarchical structure, a questionnaire was developed to allow experts to conduct pairwise comparisons of the importance or preference of each factor (Chisale and Lee 2023). The pairwise judgment matrix for all criteria and sub-criteria was created, with the fuzzy pairwise comparison matrix $\sim D = [\sim a_{ij}]$ constructed as follows:

$$\sim D = \begin{bmatrix} (1, 1, 1) & \sim a_{12} & \cdots & \sim a_{1n} \\ \sim a_{21} & (1, 1, 1) & \ddots & \sim a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \sim a_{n1} & \sim a_{n2} & \cdots & (1, 1, 1) \end{bmatrix} \quad (2)$$

where $\sim a_{ij} * \sim a_{ji} \cong 1$ and $\sim a_{ij} \cong wi/wj; i, j = 1, 2, \dots, n$.

Step 3: This study adopted the geometric mean method, the most common operation used in fuzzy multiple criteria decision-making. Fuzzy Geometric Mean is defined by Equations (3) and (4).

$$FGM l_{ij} = \left(\prod_{k=1}^k l_{ij} \right)^{\frac{1}{k}}; FGM m_{ij} \quad (3)$$

$$= \left(\prod_{k=1}^k m_{ij} \right)^{\frac{1}{k}}; FGM u_{ij} = \left(\prod_{k=1}^k u_{ij} \right)^{\frac{1}{k}}$$

$$\sim r_i = (\sim a_{i1} * \sim a_{i2} * \sim a_{i3} * \dots * \sim a_{in})^{1/n} \quad (4)$$

Step 4: The criterion and sub-criteria fuzzy weights have been calculated by applying Equation (5).

$$\sim w_i = (\sim r_1 * \sim r_2 + \sim r_3 + \dots + \sim r_n)^{-1} \quad (5)$$

Step 5: Defuzzification of the FTN, the center of area (COA) method has been applied in Equation (6).

$$wi = \frac{(u_{wi} - l_{wi})}{3} + \frac{(m_{wi} - l_{wi})}{3} + l_{wi} \quad (6)$$

An example of Defuzzification for factor Farming background (F11) using the formula above (6) is provided below:

$$0.1899 = \frac{(0.21631 - 0.16483)}{3} + \frac{(0.18857 - 0.16483)}{3} + 0.16483$$

Step 6: To normalizing w_i , matrix w_i has been converted into matrix Nw_i by applying Equation (7):

$$Nw_i = \frac{w_i}{\sum_{i=1}^n (w_i)} \quad (7)$$

Normalization of the weight for F11 using the Equation (7) is demonstrated below:

$$0.18869 = \frac{0.1899}{(0.1899 + 0.32286 + 0.24316 + 0.25047)}$$

The computed normalized weight reflects the local weight assigned to a factor. The aim of calculating the local weight was to check the significance of the factors in their specific categories (Akbar et al. 2020). We also calculated the global weight (GW) of each sub-factor to assess their overall impact on smallholder maize farming. The GW, also known as the overall weight of the sub-factor, is obtained by multiplying the weight of each sub-factor by the weight of its corresponding main category (Chisale and Lee 2023). For example, the GW of F11 = local weight of F11 * category weight (F1) as follows:

$$GW(F1) = 0.189 * 0.09811 = 0.0185.$$

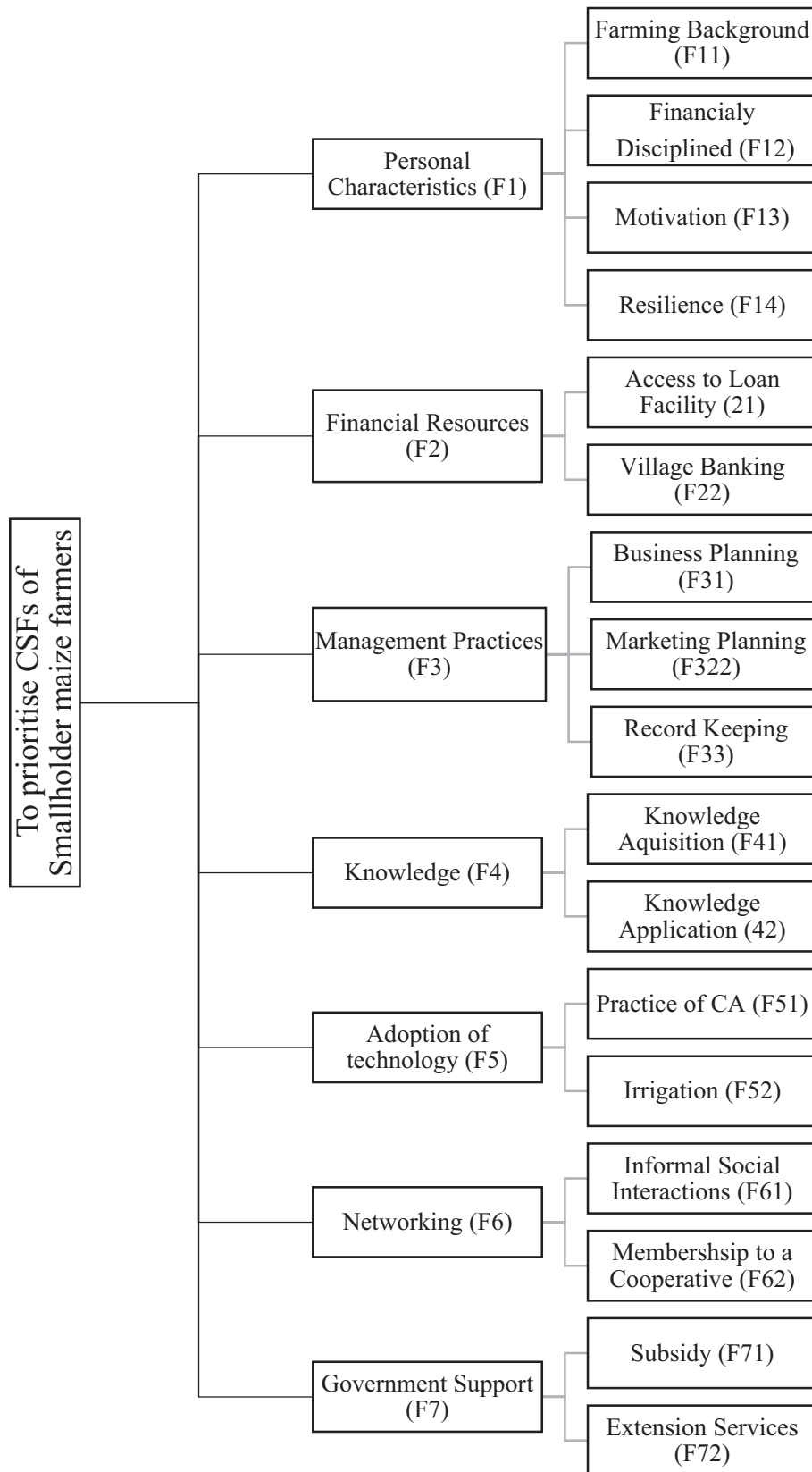


FIGURE 4 | Hierarchical structure for prioritization of CSFs for Smallholder maize farming.

The same approach was used to calculate the local weight and GW of all the other CSFs and their corresponding sub-factors. The detailed results of the fuzzy AHP computations are provided in the [Supporting Information](#).

4.3 | Checking Consistency Ratio

In Fuzzy AHP, pairwise matrices should always be consistent (Chisale and Lee 2023). To calculate the consistency ratio (CR),

the consistency index (CI) must first be computed. The CI and CR are determined as follows:

Calculation of CI for each matrix, as per Equation (8)

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (8)$$

Definition of CR for each matrix, using Equation (9)

$$CR = \frac{CI}{RI} \quad (9)$$

where λ_{\max} is the eigenvalue, n is the number of criteria and RI is the random index value. The standard values of RI for up to 10 criteria as given in Table 3.

In this study, CR of each pairwise comparison matrix was checked. According to Chisale and Lee (2023), the acceptable value of CR was ≤ 0.1 (CR=0 is theoretical ideal).

4.4 | Expert Follow-Up Survey

To complement the Fuzzy AHP findings, expert follow-up discussions were conducted to gain deeper insights into the CSFs and validate the quantitative results. This qualitative phase was designed to explore the underlying reasons behind specific findings that required further explanation (Saunders et al. 2019). For example, unexpected rankings, such as the low prioritization of government support and the lower ranking of subsidies compared to extension services, were explored to understand the reasons behind these outcomes.

4.4.1 | Semi-Structured Interviews and Thematic Analysis Approach

Following the expert survey, we conducted follow-up semi-structured interviews to gain deeper insights into specific results that required further explanation. This qualitative phase was designed to explore the underlying reasons behind unexpected rankings, particularly the low prioritization of government support and the lower ranking of subsidies compared to extension services within the category. The follow-up interviews were conducted with a subset of experts who had previously participated in the ranking survey. This approach ensured that insights were gathered from individuals who were not only knowledgeable about smallholder maize farming but also well-versed in the factors being prioritized in this study (Creswell and Creswell 2018). For this qualitative phase, purposive sampling was used, and selection criteria included prior participation in the survey, a minimum of 10 years of experience, representation across different roles, and willingness and availability to participate.

All the interviews were conducted in person and lasted 25 to 40 min. With the participant's consent, the interviews were recorded and later transcribed. A thematic analysis approach was used to analyze the interview transcripts (Braun and Clarke 2006). Emerging themes were identified and compared with the Fuzzy AHP rankings to assess alignment or discrepancies. Key insights were integrated into the discussion section to provide a richer contextual interpretation of the quantitative findings. In total, 10 interviews were conducted, ensuring sufficient depth and achieving data saturation as no new themes emerged during the analysis (Saunders et al. 2019).

4.5 | Sensitivity Analysis

Following the prioritization of the CSFs using Fuzzy AHP, a sensitivity analysis was conducted to assess the robustness of the rankings under varying conditions (Chisale and Lee 2023). Sensitivity analysis is a technique used to determine how changes in the input values (such as expert judgments) affect the outcomes of the model. In this study, the sensitivity analysis helped verify whether the rankings of the CSFs remained consistent when minor adjustments were made to the expert assessments. With this step, we aimed to verify the reliability and stability of the achieved results and ensure confidence in determining CSF using the Fuzzy AHP approach, in the context of limited quantitative data limiting traditional regression approaches.

In fuzzy AHP, criteria can be categorized into beneficial and non-beneficial categories (Ansaripour et al. 2023; Lakshmi and Kumara 2024). However, in this study, all criteria are considered beneficial and were instead categorized into core beneficial criteria and supporting beneficial criteria. For the sensitivity analysis, several scenarios were determined by assigning equal weights to all criteria, as well as percentage ratios of 80:20, 70:30, and 60:40 for core beneficial criteria and supporting beneficial criteria, respectively. As indicated in Table 4, the weights were then shared equally among the criteria within each category (Figure 5).

5 | Results

This section presents the study's findings, starting with the demographic profile of the participants. This is followed by the expert survey results on factor prioritization, which are integrated with qualitative insights for deeper interpretation. The section concludes with the sensitivity analysis results.

5.1 | Demographic Characteristics of the Respondents

Table 5 presents key demographic details of the study participants. The majority (66.6%) were male, and 73.3% had over

TABLE 3 | Standard values of the random index (RI).

Size of the matrix	1	2	3	4	5	6	7	8	9	10
Random consistency index (RI)	0	0	0.58	0.9	1.12	1.24	1.33	1.41	1.45	1.49

Source: Chisale and Lee (2023).

TABLE 4 | Sensitivity analysis scenarios with different weight distributions for core and supporting beneficial criteria.

Criteria category	Criteria/scenario	Assigned weights			
		Equal	A (80:20)	B (70:30)	C (60:40)
Core beneficial criteria	Financial resources	0.143	0.200	0.175	0.150
	Knowledge	0.143	0.200	0.175	0.150
	Adoption of technology	0.143	0.200	0.175	0.150
	Management factors	0.143	0.200	0.175	0.150
Supporting beneficial criteria	Personal characteristics	0.143	0.067	0.100	0.133
	Networking	0.143	0.067	0.100	0.133
	Government Support	0.143	0.067	0.100	0.133

Source: Created by authors.

11 years of work experience. Full respondent details are available in the [Supporting Information](#).

5.2 | Identification of CSFs-Smallholder Maize Farming

Through a combination of a comprehensive literature review and validation by industry experts, we identified CSFs along with their corresponding sub-factors. The CSFs included nine main factors, namely entrepreneurial characteristics, knowledge, finance resources, adoption of technology, management factors, networking, and government support. Each main factor comprises specific sub-factors such as knowledge acquisition, loan facility, membership to a cooperative, extension service, and subsidy. These factors form the foundation for the prioritization analysis.

5.3 | Prioritization of the CSFs

To determine the relative importance and prioritize the CSFs, we applied the Fuzzy AHP. Figure 6 presents the ranking of the main CSFs based on their assigned weights (see also the radar chart visualization in the [Supporting Information](#)). Among the seven main CSFs, Knowledge emerged as the most influential, receiving the highest weight (26.168%). This was followed by the adoption of technology (17.794%). Financial resources were ranked third (13.647%), followed by management practices (13.638%). Networking was ranked fifth (10.275%), with personal characteristics closely following (9.811%). Government support was ranked last (8.666%).

Follow-up discussions with experts provided contextual explanations for the assigned rankings. Knowledge was identified as the most important CSF, with experts pointing out that having access to relevant information and skills is crucial for farmers to implement best practices and therefore attain success. One respondent explained, “the most important factor is the knowledge that the farmer has, knowledge about CA, knowledge on farm management will contribute to the success of the smallholder maize farmers. Knowledge is key for the farmers” [P6].

Technology was ranked second, with experts emphasizing its significance, particularly since maize is predominantly grown under rain-fed conditions in Zambia. One expert remarked, “we cannot run away from the fact that climate change has brought a lot of change in the farming system. Farmers just need to be on top of things, to accept the change and start to adopt the new techniques. We are currently promoting what is called smart agriculture. We are also promoting conservation farming among others.” [P3].

One of the most surprising outcomes was the ranking of government support last, an unexpected result for which experts provided detailed explanations. Whilst government support was recognized for its importance, experts... highlighted that its effectiveness is often limited by inconsistent implementation and accessibility challenges. One smallholder maize farmer shared, “The government provides inputs through FISP but sometimes it is delayed. As for me I... do not want to depend on FISP because sometimes you find that your name is missing on the... list for FISP.” [P1].

5.4 | Prioritization of Sub Factors

Following the prioritization of the main CSFs, the sub-factors were further assessed to determine their relative significance as illustrated in Figure 7. They were ranked both within their respective categories (local weight) and collectively (GW), providing a comprehensive understanding of their overall importance. Table 6 shows the results of the prioritization of the sub-factors within their respective categories as well as their overall rankings.

The sub-factors of knowledge acquisition and knowledge application ranked highly overall, with knowledge application taking 1st place and knowledge acquisition 3rd. Within the knowledge category, knowledge application (0.657) was perceived as the more important sub-factor. As one expert explained, “Also for smallholder farmers attending the workshop is one thing but they need to be practical.” [P9]. Another expert emphasized, “we want farmers who learn ... They can learn theoretically from us, but they need to be practical” [P12]. The prominence of knowledge as a CSF aligns with SDG 4 (Quality Education), which advocates for acquiring relevant skills for decent employment and entrepreneurship.

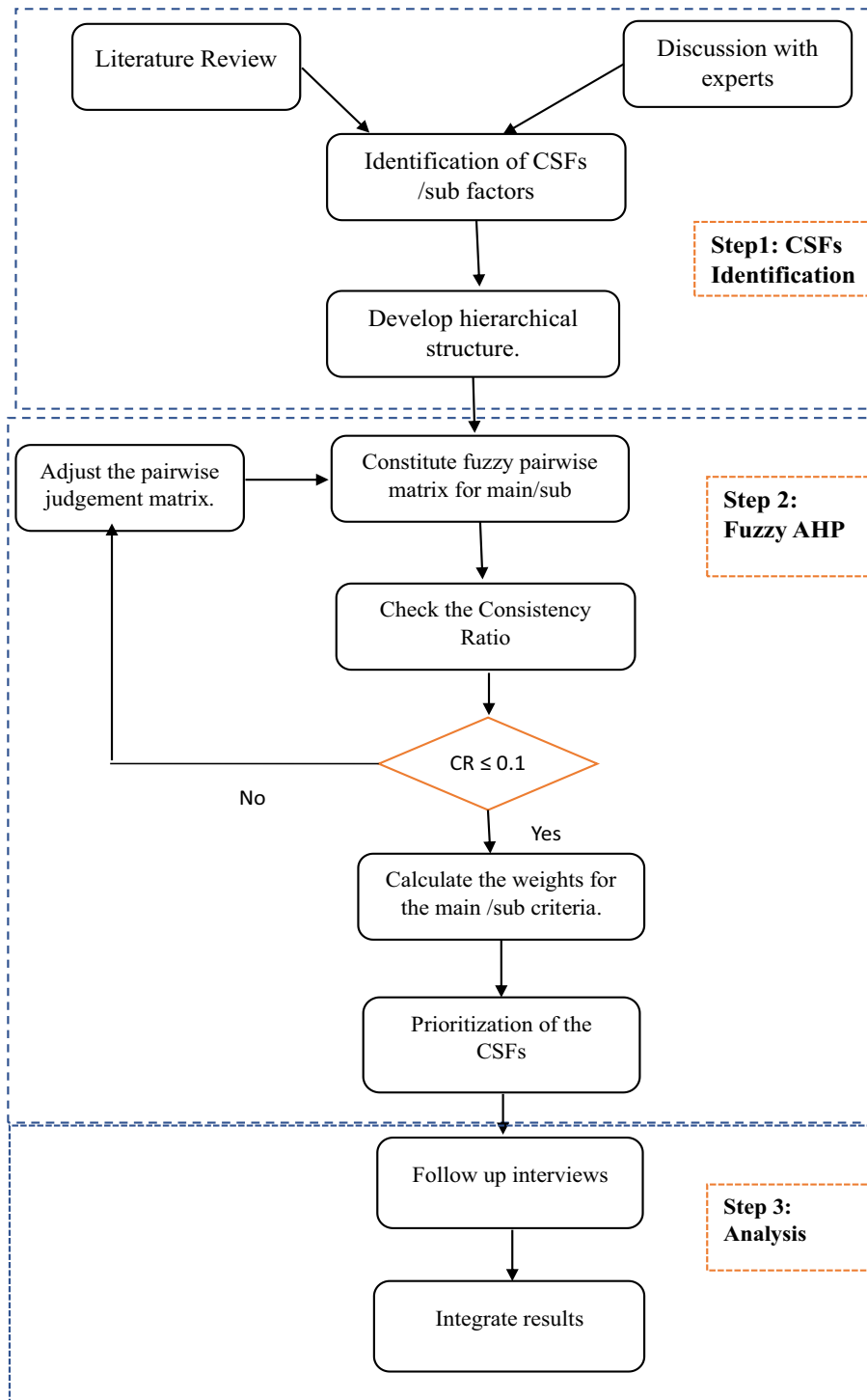


FIGURE 5 | Flow diagram of the research methodology.

Within the adoption of technology category, practice of CA was ranked higher than irrigation with weights of 0.526 and 0.474, respectively as shown in Table 6. In the overall ranking of all sub-factors, CA secured 2nd place, while Irrigation ranked 4th. Insights from expert interviews provided further context to these rankings. Given this challenge, several experts highlighted CA as a more sustainable and cost-effective option, especially for smallholder farmers with limited access to irrigation infrastructure. One of the experts explained, “the practice of CA

is easily attainable by the smallholder maize farmers compared to irrigation” [P3]. This sentiment was echoed by another expert who said that “irrigation is expensive, and most smallholder maize farmers are not able to afford it” [P12]. These qualitative insights suggest that while both technologies are valuable, the higher ranking of CA over irrigation reflects its greater feasibility and accessibility among smallholder farmers, reinforcing the survey finding. The emphasis on technology adoption, especially through CA supports SDG 13 (Climate Action) by

TABLE 5 | Demographic details of the respondent.

	Category	No of respondents	Percentage of the respondents
Gender	Male	20	66.6
	Female	10	33.3
Age	40years	16	53.3
	41–50years	7	23.3
	> 50years	7	23.3
Experience	≤10years	11	36.7
	11–20years	11	36.7
	>20years	5	16.7

fostering climate-resilient farming, and SDG 2 (Zero Hunger) by improving productivity and food security.

Under the financial resources category, access to loans ranked higher than village banking, with weights of (0.581) and (0.419), respectively. This indicated that with access to loan facilities being viewed as more important than informal village banking. In the overall ranking, both sub-factors performed strongly, securing 5th and 8th positions. In the follow-up discussions, almost all respondents underscored the importance of access to loan facilities over informal village banking, while also expressing concerns about the difficulties in obtaining loans from financial institutions. For example, one respondent remarked that “loans from formal institutions are expensive and have high interest rates, thus the smallholder maize farmers cannot afford them” [P9]. Another respondent noted that “village banking is more accommodative and easier to access than formal loans”

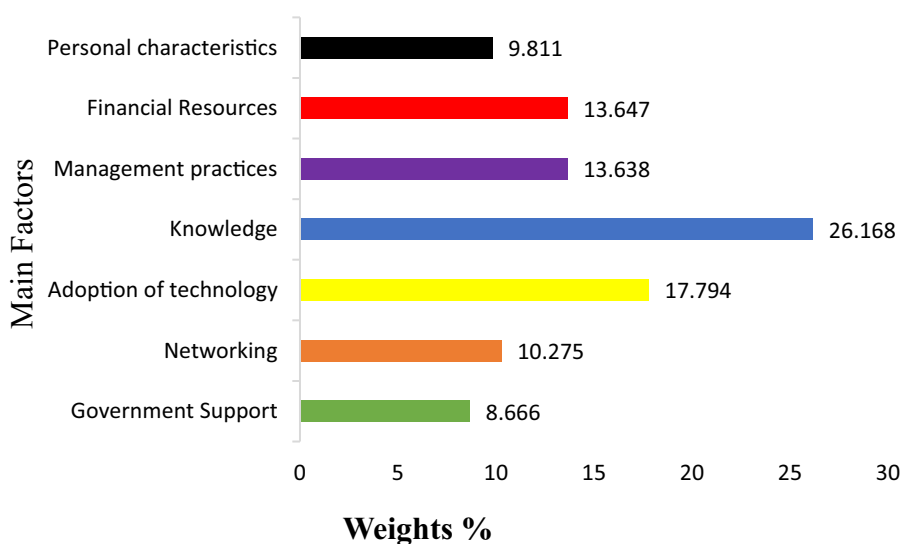


FIGURE 6 | Ranking of main factors.

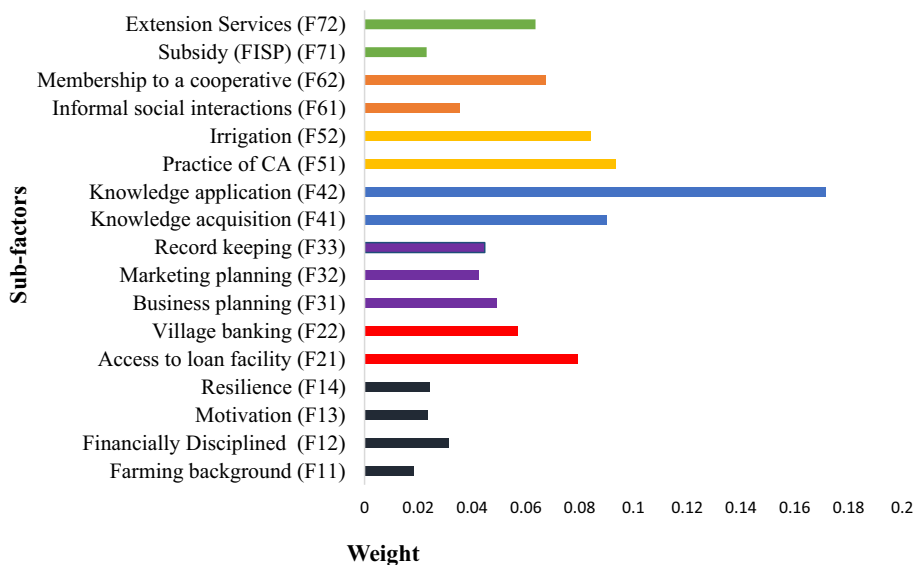


FIGURE 7 | Overall weight (ranking) of the sub factors.

TABLE 6 | The overall ranking of the 17 sub-factors as well as ranking within the category.

Main factors	Code	Weight	Sub-factor	Code	Local weight	Global weight	Rank
Personal characteristics	F1	0.09811	Farming background	F11	0.189	0.0185	17
			Financially disciplined	F12	0.321	0.0315	13
			Motivation	F13	0.242	0.0237	15
			Resilience	F14	0.249	0.0244	14
Financial resources	F2	0.13647	Access to loan facility	F21	0.581	0.0793	5
			Village banking	F22	0.419	0.0571	8
Management practices	F3	0.13638	Business planning	F31	0.36	0.0491	9
			Marketing planning	F32	0.312	0.0425	11
			Record keeping	F33	0.328	0.0447	10
Knowledge	F4	0.26168	Knowledge acquisition	F41	0.344	0.0901	3
			Knowledge application	F42	0.656	0.1715	1
Adoption of technology	F5	0.17794	Practice of CA	F51	0.526	0.0936	2
			Irrigation	F52	0.474	0.0843	4
Networking	F6	0.10275	Informal social interactions	F61	0.345	0.0355	12
			Membership to a cooperative	F62	0.655	0.0673	6
Government support	F7	0.08666	Subsidy (FISP)	F71	0.266	0.0231	16
			Extension services	F72	0.734	0.0636	7

[P24], whilst the other one explained that “you see, village banking is more practical for the smallholder maize farmers and requires no collateral” [P29]. One expert however pointed out the limitation of village banking stating that, “even though village banking is easier, it has limitations in terms of the amount of funds one can get” [P22].

The networking sub-factors, membership to a cooperative and informal social interaction, ranked 6th and 12th, respectively, reflecting a significant gap in their perceived importance. Within their category, membership to a cooperative (0.655) was considered more critical than informal social interactions (0.345). Experts attributed this disparity to the structured benefits offered by cooperatives. One respondent explained that “cooperatives provide more activities and trainings for its members” [P6] another mentioned that “smallholder maize farmers benefit from the vast experience of others in the cooperatives and obtain knowledge” [P1]. On the contrary one respondent provided a different view that “cooperatives operated for the purpose of FISP only and were thus irrelevant during most of the periods” [P15].

In the management category, the sub-factors were ranked in the following order as follows: business planning (0.36), record keeping (0.328), and market planning (0.312). On the overall ranking, business planning was placed 9th, followed by record keeping in 10th, and market planning in 11th. Among the three sub-factors, business planning was considered the most significant. Experts underscored its importance with one expert remarking, “a successful farmers before the rain season must sit down and plan. You must plan. How are you doing to work? How do you intend

to achieve, identify like five areas where you intend to achieve and at the end of the program, evaluate yourself” [P6].

The entrepreneurial factors sub-factors ranked the lowest among all sub-factors. In order of significance, the sub-factors were financial discipline (0.321), resilience (0.249), motivation (0.242), and farming background (0.189). In the overall ranking, these sub-factors were ranked 13th, 14th, 15th, and 17th, respectively. Experts considered financial discipline to be more significant than the other sub-factors, with one expert stating, “successful farmers are financially disciplined” [P12], while another explained “they are able to save money to buy seeds and fertilizers” [P9].

Within this category, subsidies were ranked even lower than extension services with a weight of 0.0231, highlighting potential gaps in the perceived effectiveness of government interventions in supporting smallholder maize farmers in Zambia. Follow-up interviews provided further insights into this unexpected finding. Many of the experts interviewed agreed that while subsidies were intended to boost maize productivity, they often fell short of their intended purpose. One expert pointed out, “Not all smallholder maize farmers receive the subsidies,” [P3] indicating significant gaps in access. Another expert emphasized, “Some of the individuals who receive subsidies are not genuine farmers” [P12]. Yet another expert explained that “the problem with FISP is that it is normally delivered late and also it makes the smallholder maize farmers become too dependent on the government” [P6]. Conversely, the experts regarded extension services as more beneficial for smallholder maize farmers,

explaining that these services provided essential information that significantly aided their farming practices. Clearly, despite its low ranking, government support through extension services and subsidies plays a crucial role in advancing several SDGs, including SDG 1 (no poverty), SDG 2 (zero hunger), SDG 4 (quality education), and SDG 13 (climate action).

5.5 | Sensitivity Analysis Results

Based on the sensitivity analysis results in Figure 8 below, we can conclude that the original results are generally stable and, in this way, also robust. Many factors, such as F11, F12, and F13, maintain consistent rankings across all sensitivity scenarios (80:20, 70:30, and 60:40), indicating that their importance is stable regardless of the weight distribution between core and supporting beneficial criteria. This consistency suggests that these factors are not highly sensitive to changes in the weight allocation, supporting the robustness of the original rankings. Even for factors with moderate shifts in ranking, such as F21 and F41, the changes are minimal (e.g., F21 from 14 to 11; F41 from 8 to 5), implying that the overall decision-making process remains relatively unaffected by varying the weight between core and supporting criteria.

Although some factors like F71 and F72 exhibit more noticeable shifts under certain scenarios, the overall rankings do not drastically change. These findings also indicate that the original obtained results provide a reliable foundation for decision-making, and the conclusions drawn from the analysis are not easily swayed by different weight distributions.

From the perspective of these conclusions, we can perceive the results achieved by Fuzzy AHP as robust, offering stability and consistency even when using different weight distribution scenarios. The original results according to Fuzzy AHP therefore provide a relatively reliable basis for decision-making and are not greatly affected by different scenarios for weight distribution.

6 | Discussion

The evaluation of the CSFs reveals compelling insights into the dynamics that influence the success of smallholder maize farming in the SSA country of Zambia. Results show that knowledge,

adoption of technology, and financial resources are the three most influential factors driving productivity and overall success. Other contributing factors, such as networking, government support, management practices, and entrepreneurial characteristics, also play a vital role in strengthening smallholder farmers' resilience and sustainability. These findings align with previous research emphasizing the impact of these factors on agricultural success. Moreover, these factors have the potential to contribute to the achievement of several SDGs including SDG 1 (no poverty), SDG 2 (zero hunger), SDG 4 (quality education), SDG 8 (decent work and economic growth), and SDG 13 (climate action).

In the context of smallholder maize farming, knowledge emerged as the most influential CSF, with both its subfactors of knowledge acquisition and application ranking as top factors overall among all the subfactors. These findings are consistent with previous studies that highlight the importance of knowledge in enhancing agricultural outcomes (Lin et al. 2022; Ngo et al. 2019). Access to relevant knowledge and the ability to effectively apply it are critical for improving farming practices, increasing productivity, and ensuring sustainability (Malesu and Syrovátka 2024). Studies have shown that well-informed farmers are more likely to adopt improved farming practices, leading to better yields and greater resilience against climate challenges (Khanal and Mishra 2016; Ragbir et al. 2014). Therefore, it is important to develop and scale up farmer education programs that focus on practical, hands-on training and the application of modern agricultural knowledge is important. By emphasizing the critical role of agricultural education and technical training, the study aligns with SDG 4's objective of providing educational opportunities that equip individuals such as smallholder maize farmers with the skills essential for building human capital.

Adoption of technology ranked second, with its subfactors of CA and irrigation scoring high in the overall rankings of all subfactors, highlighting the impact of modern agricultural practices on maize productivity. The prioritization of CA over irrigation reflects the reality of maize cultivation in Zambia, where smallholder maize farmers often lack access to irrigation infrastructure. CA practices are essential for maize production, which is largely rain-fed in Zambia and much of SSA (Obunyali et al. 2019). The benefits of CA, such as enhancing productivity, improving resilience, and mitigating climate change, have been well documented (Arslan et al. 2015; Kurgat et al. 2020). The practice of CA reduces the vulnerability of

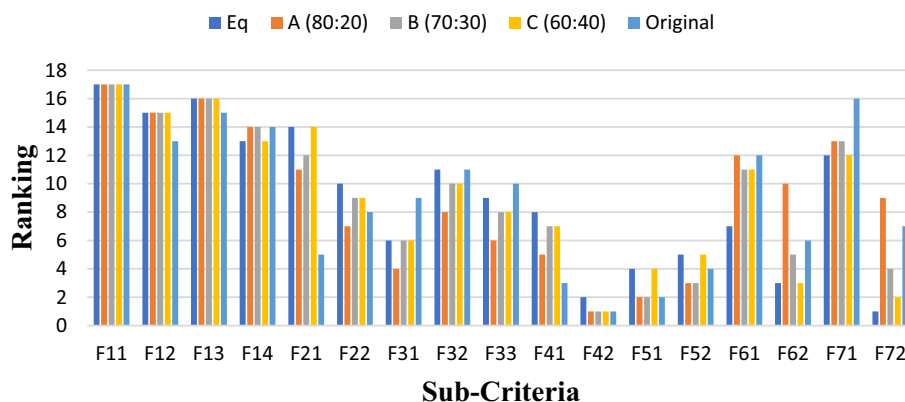


FIGURE 8 | Criteria rankings under different weight distribution scenarios (80:20, 70:30, 60:40) and original rankings.

maize production to climate change, thus enhancing food security and incomes for smallholder maize farmers in Zambia.

While irrigation remains an important subfactor, its lower ranking over CA suggests that smallholder maize farmers view CA as more immediately applicable and beneficial under current conditions. Our finding is consistent with Musika Development Initiative (2020) who revealed that only a mere 4% of smallholder maize farmers in Zambia used irrigation techniques, primarily due to the lack of affordability associated with these systems. Smallholder maize farmers require financial support from stakeholders to adopt technologies like irrigation and CA, as the associated adoption costs can be a significant barrier to their implementation (Agamile et al. 2021).

The low adoption of technologies like CA is not unique to Zambia, as studies from other SSA countries, including Tanzania, Ethiopia, Ghana, and Kenya reveal similarly low uptake (Kurgat et al. 2020; Kifle et al. 2022, Atta-Aidoo et al. 2022; Kangogo et al. 2021). Comparable trends are also observed in Asian countries such as Bangladesh (Tama et al. 2021). Enhancing access to affordable irrigation technologies can further complement CA practices, providing smallholder maize farmers with additional resilience against climate variability, and this can ultimately improve food security and rural development in Zambia and other similar contexts. The adoption of the above-mentioned technologies deeply resonates with SDG 1 (no poverty), SDG 2 (zero hunger), and SDG 13 (climate action) by fostering sustainable farming, enhancing food security, and mitigating climate change impacts (Mpala and Simatele 2024).

The results further indicate that financial resources were ranked third and thus demonstrate significant influence within the framework. This is consistent with past studies, which have recognized the availability of financial resources as a key factor for smallholder farmers (De Almeida and Zylbersztajn 2017; Garima et al. 2023; Ngo et al. 2019). Research on small farms in the USA revealed that credit-constrained farmers experienced significantly lower financial performance compared to those with adequate access to credit (Khanal and Omobitan 2020). This underscores the significance of access to financial resources in driving agricultural success across different contexts. Access to financial resources is cardinal for farm operations as it helps to obtain optimum combinations of inputs (Khanal and Omobitan 2020). In the financial resources category, access to loan facilities was ranked higher than informal village banking. This could be because access to formal financial services provides smallholder farmers with larger-scale financial solutions capable of meeting their operations requirements.

Unfortunately, in Zambia, smallholder maize farmers continue to face significant barriers to accessing credit from formal institutions due to limited collateral, high interest rates, and underdeveloped financial institutions. For instance, Zambian Financial Sector Deepening Limited (2021) reported that only 8% of credit extended to the agricultural sector was allocated to small and medium-scale farmers in 2017. This underscores the financial constraints faced by these farmers. Accessibility to

credit facilities is a significant challenge for smallholder maize farmers, not only in Zambia but also in countries like Zimbabwe, Malawi, and Kenya, where similar barriers exist (Cherotich et al. 2019; Mpala and Simatele 2024).

While village banking may be important, its lower ranking suggests that its benefits may be more supplementary, providing localized, community-based financial support rather than serving as a primary financial resource. Therefore, strengthening financial inclusion efforts, such as creating more accessible, smallholder farmer-friendly loan programs, is essential for empowering smallholder maize farmers and boosting agricultural productivity in Zambia and SSA at large. Improving smallholder maize farmers' access to finance can drive long-term sustainability and contribute significantly to achieving broader SDGs.

Our findings agree with past studies that have ranked management practices among the top factors (Amrita et al. 2018). Business planning, which emerged as the most influential subfactor within its category, encompasses goal setting and resource allocation activities that are necessary to optimize operations, adapt to seasons, and enhance farm performance. Our findings support the work of (Garima et al. 2023) who highlighted that timely planning and effective management of critical inputs and resources are key to maximizing profits for small agripreneurs. The fair overall ranking of record keeping underscores its pivotal role in smallholder maize farming. According to (Ragbir et al. 2014), farmers who maintain records demonstrate greater market orientation, utilize technology more proficiently, and adopt modern agricultural practices. Therefore, the practice of record keeping is instrumental in enhancing the performance of smallholder maize farming in Zambia.

Networking received a moderate ranking of 5th position among the main factors. The higher ranking of cooperative membership over informal social interactions within the networking category suggests that formalized networks provide more significant benefits to smallholder maize farmers than informal social connections in Zambia. This result reflects trends in SSA and across developing countries, where formalized networks like cooperatives have proven to provide smallholder farmers with greater benefits, including collective bargaining, resource sharing, and improved market access (Akinola et al. 2023; Blekking et al. 2021; Ghauri et al. 2023; Vermeire et al. 2023). Due to the significant impact of cooperative membership, it is important for policymakers and development agencies to focus on strengthening and expanding these formalized networks (Ma et al. 2022).

In contrast to other studies that place government support among the top CSFs for small holdings (Amrita et al. 2018; Sadeghi 2018), our results revealed a surprising outcome: government support was ranked last among the main factors. Notably, extension services ranked significantly higher than subsidies in the overall ranking of subfactors, reflecting a wide variation in the performance of these two subfactors. This disparity highlights the varied effectiveness of different aspects of government support towards smallholder maize farming in Zambia. Extension services have been known to be instrumental in providing valuable support, including training and advisory services, which can help smallholder farmers improve their practice and stay informed about new technologies and thus

enhance their productivity (Adobor 2020; Kawsar et al. 2013; Ragbir et al. 2014; Ullah et al. 2024).

On the other hand, the lower ranking of subsidies both within its category and overall ranking was quite surprising, given that previous studies have demonstrated their role in supporting and improving agricultural productivity and profitability (Malimi 2023; Stillitano et al. 2016). A possible explanation for this outcome could be growing concerns about the effectiveness of subsidies in promoting sustainable agricultural development, potentially due to issues such as dependency, late delivery, misuse, or poor targeting (Malesu and Syrovátka 2024; Pelletier et al. 2020; Smale et al. 2014; Tambo and Liverpool-Tasie 2024).

The higher ranking of extension services over subsidies in Zambia reflects a growing recognition across SSA of the critical role that technical support plays in enhancing smallholder farm productivity (Branca et al. 2022; Malimi 2023). It is notable that while funding for extension services has remained consistently low over the past years in Zambia, funding for subsidies has been on the rise (Mulenga et al. 2021), suggesting a misalignment in resource allocation that may impact long-term agricultural development and sustainability.

Although government support ranked lower as a CSF, it remains a critical enabler of smallholder maize farming in Zambia and is essential for advancing SDG 1 (no poverty) and SDG 2 (zero hunger) through its agricultural initiative programs (Masiya et al. 2024). The lower ranking of subsidies highlights the need for more targeted interventions to enhance economic growth and food security in rural areas. The consistent underfunding of extension services in Zambia mirrors a broader pattern across the SSA (Malimi 2023; Marandure et al. 2020) where countries continue to prioritize short-term agricultural subsidies, often at the expense of long-term capacity-building investments (Mason et al. 2013). Based on our findings, we echo past studies that highlight the need to scale down subsidy expenditure and adopt a more balanced approach, prioritizing more impactful areas like extension services among others, which have demonstrated a significantly greater influence on agricultural productivity. Strengthening policy coordination, improving subsidy distribution, and investing in extension services are key to boosting maize productivity and consequently alleviating poverty among smallholder maize farmers.

7 | Conclusion

This study aimed to prioritize the CSFs influencing small farming businesses in Zambia. Using the fuzzy AHP approach, the research evaluated key factors shaping agricultural success. Data was collected through an expert survey involving 30 purposively selected experts from the agricultural sector. Additionally, follow-up discussions with 10 experts from the initial sample provided deeper insights into the survey findings. To further validate the robustness of the results, a sensitivity analysis was conducted to assess the stability of the CSF rankings under varying conditions.

Based on a comprehensive literature review and expert validation, the study identified seven key CSFs and 17 corresponding sub-factors. The Fuzzy AHP findings highlight knowledge,

technology adoption, and financial resources as the most influential factors for smallholder maize farming in Zambia. Furthermore, among the sub-factors, knowledge application and acquisition were ranked highest, followed by the practice of CA, access to loans, irrigation, and extension services. A surprising finding in this study was that government support ranked the lowest among the CSFs, with subsidies positioned second last and extension services being regarded as more important in supporting smallholder farmers. Based on the sensitivity analysis, the original findings remain generally robust, reinforcing the reliability of the CSF rankings. The results of this study demonstrate a strong alignment with the broader objectives of the SDGs, particularly in fostering poverty reduction (SDG 1), food security (SDG 2), climate resilience (SDG 13), and economic growth (SDG 8).

The study presents valuable managerial and policy implications to support smallholder maize farming and policymakers in boosting agricultural productivity and sustainability. From a managerial perspective, smallholder farmers and/or managers should focus on enhancing their knowledge and skills by participating in relevant training programs. Given the significant role of knowledge acquisition in enhancing agricultural productivity, investing in capacity-building initiatives is critical for enhancing resilience and fostering sustainable farming practices. Furthermore, adopting modern technologies such as conservation farming and irrigation can help mitigate the impacts of climate change and enhance productivity. Small farm businesses should also consider joining networks and collaborating with extension services to access expert advice and opportunities.

In terms of policy, the study highlights the need for more effective government interventions to strengthen agricultural support mechanisms, particularly in areas of extension services, financial inclusion, and subsidies. Policymakers should focus on improving the accessibility of financial resources for smallholder maize farmers, such as facilitating affordable credit and incentivizing investment in rural infrastructure. While subsidies were identified as an important factor, their distribution and effectiveness should be revisited to ensure that they are reaching the farmers who need them most. Additionally, policies should aim to create a more supportive environment for the adoption of technology, with a particular emphasis on fostering knowledge transfer and practical skills. By aligning agricultural policies with SDGs, government can create an enabling environment that supports long-term agricultural productivity, poverty reduction, and climate resilience.

8 | Limitations and Future Research

Despite the beneficial results and conclusions of this study, it is necessary to acknowledge its inherent limitations. One of them is that this study relies on expert opinions, which may be biased or inaccurate. Although efforts were made to involve a diverse group of experts, the results may have influenced individual perspectives and experiences—the subjectivity of expert opinions cannot be eliminated. In addition, the study was conducted exclusively in the agricultural-economic context of Zambia, which may affect the full applicability of the achieved results and conclusions to other regions in Africa or in the world. It should also

be noted that this study did not work with other possible data layers, such as primary data from the survey or secondary data from other studies or statistical offices and institutions. Using these layers of data will allow further research to yield more generally applicable results. In this regard, our future research in CSFs will be supplemented. At the level of quantitative analyses, it will then be possible to work with statistical induction and test the formulated hypotheses.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.