Analyzing Smallholder Farmers Performance

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Farmer Typology, Technical Efficiency, Market participation, Policies and Management Practices

Evidence from Limpopo Region of South Africa

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List of abbreviations and acronyms

%	Percent
BMBF	Bundesministerium für Bildung und Forschung
CASP	Comprehensive Agricultural Support Program
CBO	Community-based Organizations
DAAD	Deutscher Akademischer Austauschdienst
DAFF	Department of Agriculture, Forestry, and Fisheries
DEA	Data Envelopment Analysis
DRDLR	Department of Rural Development and Land Reform
e.g.	Exempli Gratia
ENSO	El Niño-Southern Oscillation
ER	Exclusion Restriction
etc.	Et Cetera
FAO	Food and Agriculture Organization of the United Nations
FONA	Forschung für Nachhaltigkeit
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
IV	Instrumental Variables
kg	Kilogram
LR	Log-Likelihood Ratio
LRAD	Land Redistribution for Agricultural Development
Mafisa	Micro-agricultural Financial Institutions of South Africa
MLE	Maximum Likelihood Estimation
NGOs	Non-Governmental Organizations
OLS	Ordinary Least Square
PAM	Partitioning Around Medoids
PTO	Permission to Occupy
ρ	Rho
R&D	Research and Development
RSA	Republic of South Africa
RTS	Return to Scale
SADC	Southern African Development Community

SALLnet	South African Limpopo Landscapes Network
SDGs	Sustainable Development Goals
SFA	Stochastic Frontier Analysis
SPACES II	Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa II
Std.err.	Standard Error
TE	Technical Efficiency
TLU	Tropical Livestock Unit
Translog	Transcendental Logarithmic
WCDoA	Western Cape Department of Agriculture
WMO	World Meteorological Organization
ZAR	South African Rand

1. General Introduction

Rising population and urbanization significantly influence lifestyles and income growth, and they change food consumption patterns, leading to more demand for food and agricultural products. Sub-Saharan Africa's population is projected to grow to almost double its population by mid-century (UN DESA, 2017).

As the main source of food and livelihood, the agricultural sector is of great importance for most low- and middle-income countries, particularly African countries (Adetutu & Ajayi, 2020). This sector is crucial in stimulating livelihoods and economic growth in rural areas, generating employment, and ensuring food security. However, there are increasing concerns regarding numerous challenges, such as climate variability and other agri-relevant risks that have significant effects on the agricultural sector and food security, resulting in accelerating the gaps between global demand and supply.

Addressing the global and national demand for food and agricultural products requires sustainable development of agricultural production systems and policy reforms to transform agricultural production systems to meet the Sustainable Development Goals (SDGs) of the United Nations Development Program with the main objective of ending hunger and poverty, achieving food and nutrition security, and sustaining natural resources (Kofi & Adams, 2020).

The Republic of South Africa (RSA) has the largest agricultural land on the African continent with approximately 96.34 million hectares of agricultural land in 2020, which corresponded to 79.4% of the total land area in the country (World bank, 2020). Approximately 70% of the RSA population is engaged in agriculture and high proportion of around 94% depend on rainfed agriculture (Sikora et al., 2020).

The agriculture sector in RSA has been coined dualistic by the apartheid policies and still persists under the power of democratic governments, which have been in place since 1994. This dualistic agricultural system consists of, on one hand, a modern and capital-intensive but comparatively small group of large-scale commercial farmers with infrastructure supporting agricultural production and marketing (Hendriks, 2014). And on the other hand, a large group of poorly-developed and resource-limited small-scale farmers who are living primarily in the rural former apartheid homeland areas and rely predominantly on their land and agricultural production to sustain their livelihood (Gwebu & Matthews, 2018). According to the General Household Survey of 2019 in RSA, there are approximately 2.3 million small-scale farmers compared to 40,122 large-scale farmers (STATS SA, 2020). Despite the outnumber of small-scale farmers compared to the large-scale producers, they contribute negligibly to the national food systems (Mathinya et al., 2022). However, they still play a crucial role in local and rural food security. The dualistic agricultural sector in RSA had adverse impacts on the development of small-scale farmers, as historically, South Africa's policies focused primarily on supporting the formal commercial agricultural sector rather than on the much larger group of small-scale farmers (Tshuma, 2014).

However, over the past two and a half decades, the support has shifted towards small-scale farmers, and the RSA government has tried to shorten the dualistic gap by implementing policies to support small-scale agriculture, such as the Comprehensive Agricultural Support Programme (CASP) and Land Redistribution for Agricultural Development (LRAD) (Kepe & Hall, 2016). Regardless of various national and provincial government supports for small-scale farmers to enhance the agricultural sector in recent years, these farmers are still confronted with many constraints (such as limited access to markets, inputs, and credit, as well as restricted property rights and inadequate infrastructural facilities such as transportation and communication) which make them more vulnerable to the diverse agricultural risks and uncertainties (Gwebu & Matthews, 2018; Tshuma, 2014). That results in these farmers performing below their potential production capacities and with low productivity, and food insecurity lag behind that of their large-scale counterparts (Baloyi et al., 2012; Branca & Perelli, 2020). These uncomplimentary trends are exacerbating through devastating drought events particularly for the small-scale farmers that predominantly rely on rainfed agriculture for income (Nelson et al., 2022). RSA has been identified as a climate hotspot as it has been exposed to frequent severe droughts throughout the last decades, which have been exacerbating in recent years following the El Niño event during the 2015/16 cropping season (Hove & Kambanje, 2019). Droughts, which are characterized by prolonged dry periods with unpredictable rainfall, pose a high risk to agricultural production by contributing to other agricultural risks, such as the incidence of invasive pests and diseases (Setimela et al., 2018).

Considering all the challenges mentioned above, in order to overcome the inequalities within the South African society, efficient policies of agricultural development for supporting and stimulating the small-scale farming system in RSA are essential. This is due to the fact that the small-scale farmers constitute the vast majority of farmers in RSA and have the potential to make a significant contribution to rural development and, more generally, food security and poverty reduction in rural areas by providing food for own consumption and a growing urbanized population, and generating employment and income (Cousins, 2013). Therefore, these farmers are the main pillars in transforming Southern Africa's agricultural and food system and the transition to sustainability (Jayne et al., 2019).

To design accurate and effective policy measures, a crucial pre-requisite is to understand the structure and the context of the addressed group of small-scale farmers in a comprehensive and objective way. A growing body of literature focused on enhancing small-scale farmers' performance and management practices. However, most still view this group as holistic without considering the contextual factors contributing to and exacerbating the disparities between them (Olofsson, 2019). Small-scale farmers in general and in particular in RSA are highly diverse and heterogeneous regarding farm characteristics, ranging from socio-economic features to resource endowments and agro-ecological dimensions (FAO, 2017), which result in diverse types of farming, levels of technology adoption, and degree of commercialization (Carelsen et al., 2021; Mądry et al., 2016). Such heterogeneous types, respectively, groups of small-scale farming systems require different forms of government interventions, depending on the objectives and characteristics of each group (Carelsen et al., 2021). Therefore, stereotypes such as "small-scale" need to be deconstructed to enable a more target-group-oriented policy design (Yazdan-Bakhsh & Feil, 2021).

Along with that, another critical aspect in the development of policy design for small-scale farmers, which significantly influences the policy implications, is farmers' risk attitudes and perceptions. Small-scale farmers in developing economies, particularly RSA, have been continually confronted with uncertainties and risks arising from different sources such as climatic, production, market, financial, institutional or political, and human resource risks (Meraner & Finger, 2019). Heterogeneous farmers have diverse perceptions of risks, depending on their main farming goals and typologies. Therefore, to design comprehensive and effective target-group-oriented policy measures with the desired implications in practice, it is fundamental to understand the farmers' risk attitudes and perceptions in addition to their socio-economic and demographic characteristics.

In consideration of the prominent role of these diversified small-scale farmers in the development of the agricultural sector and rural economic growth in RSA, this dissertation tries to investigate the main fundamentals of rural transformation to support designing and implementing efficient and effective policies with the goal of improving agricultural productivity and efficiency levels of farmers, as well as enhancing market orientation to ensure the economic performance of small-scale farmers and food security. In this regard, following an understanding of the structure and context of small-scale farmers in rural communities of RSA, this study investigates the main drivers of the transition within the types of small-scale farmers towards commercialization and more contribution to the national food system. Moreover, considering maize as the most prevalent agricultural crop in the smallholder farming system, this research analyzes the Technical Efficiency (TE) and the main factors affecting the efficiency levels of farmers. Improvement in the efficiency levels of agricultural production is the main component of agricultural productivity growth which plays a vital role in alleviating the issue of food insecurity in developing economies (Asmare et al., 2022). Based on the results, this dissertation suggests possible farm-type-specific risk management options and policy implications to support farmers in improving their livelihoods and resilience to different risks and uncertainties.

This dissertation was derived from a research project titled “SALLnet (South African Limpopo Landscapes Network)” which was a German-South African research collaboration with the framework of the SPACES II (Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa). The SALLnet was an interdisciplinary research project with the main goal of how the resilience of the multi-functional landscapes in southern Africa can be enhanced under the conditions of climate change and different socio-economic developments. The Federal Ministry of Education and Research (BMBF) funded the project within the framework of the strategy "Research for Sustainability" (FONA), and managed by Project Management Agency DLR with additional funding by German Academic Exchange Service (DAAD). SALLnet was a joint project, with the cooperation of six partners, including the Georg-August University of Göttingen (Göttingen, Germany), Senckenberg Nature Research Society (Frankfurt am Main, Germany), University of Bonn (Bonn, Germany), University of Limpopo (Sovenga, SA), University of Witwatersrand (Johannesburg, SA), and University of Venda (Thohoyandou, SA).

1.1. Research objectives and design of study

The purpose of this dissertation within the cooperation project is to achieve the following main objectives:

i. to develop our understanding of different typologies of small-scale farmers in South Africa;

ii. to identify diversification of risk attitudes and perceptions of different sources of risks involved in agricultural production (e.g., climatic, production, financial and market risks) for the selected target- groups of small-scale farmers;

iii. to analyze the main determinants of transition of small-scale farmers from subsistence to market-oriented farming systems;

iv. to investigate technical efficiency of small-scale maize farmers and the potential factors that lead to deviations from the common production frontier, considering the perceived production risks in the region;

v. to recommend possible targeted policy implications that policy makers can use to support small-scale farmers to promote sustainable land use management.

This dissertation comprises three main chapters, each representing one essay focusing on the aforementioned research objectives.

The first essay tries to answer the following questions: *"Which different typologies can be distinguished for the small-scale farmers in RSA, and how do they differ in personal, farm, and resource endowments characteristics?" and "How do the diversified small-scale farmers vary in risk attitude and perceptions of different sources of risks involved in agricultural production?"* (research objectives i, ii, and v). Therefore, it focuses on the typology of small-scale farmers based on a wide range of objective variables regarding their personal, farm, and context characteristics, which support an effective, target-group-specific design and communication of policies. An unsupervised machine learning approach, Partitioning Around Medoids (PAM), was applied to the survey data (212 small-scale farmers in the Limpopo Province). Following the clustering of the small-scale farmers, the risk attitude and perceptions among the selected groups were compared and examined to fine-tune related policy measures and their implications on risk management.

The second essay attempts to answer the question: "*What factors are the drivers of the transition of small-scale farmers from subsistence to the market-oriented farming system?*" (research objectives iii and v). In this regard, it focuses on identifying the main socio-economic factors associated with small-scale farmers' marketing decisions. Commercializing agricultural production through participating in marketing and choosing appropriate marketing channels is a crucial requirement for economic growth and the development of small-scale farmers, especially in rural communities in southern Africa that predominantly rely on agriculture. Considering the sequential process of commercialization (subsistence to semi-subsistence and the market-oriented farming systems), this essay employed the sequential bivariate probit selection model to identify the main determinants of the transitions from subsistence to the market-oriented farming system while controlling for the endogeneity and selectivity problems that may arise due to correlation of unobserved heterogeneity and observed explanatory variables. The results of this analysis can provide valuable insights for policymakers and farming communities on how to facilitate the marketing and economic growth of small-scale farming systems in order to improve food security at the farm and regional levels, provide higher resilience and, thus, viability for farms in the long term in the face of increasing risks and crises.

The third essay attempts to answer the question: *"What is the level of technical efficiency of small-scale maize farmers? Which factors determine the technical efficiency of small-scale maize farmers, and what are the potential factors that lead to deviations from the common production frontier, considering the perceived production risks in the region?"* (research objectives iv and v). It thus focuses on the small-scale farmers' maize production efficiency by explicitly considering current and future perceived production risks in the Limpopo province of RSA. A single-step Stochastic Frontier model considering double heteroscedasticity in both the efficiency and idiosyncratic terms was applied to a cross-sectional farm-level data set from a field survey conducted in 2019. The results of this essay can provide useful insights for policymakers and farming communities on how to increase the food production efficiency of small-scale farming systems and improve food security in the region.

1.2. Study location and data collection

The research was conducted in the Limpopo Province of RSA, located in the northeast of the country, bordering Botswana, Zimbabwe and Mozambique. According to Koeppen-Geiger classification, the climate conditions in Limpopo vary considerably from hot-desert climate (BWh) to hot semi-arid (BSh) and to humid subtropical (Cwa) climate from West to East of the province (Engelbrecht & Engelbrecht, 2016). Compared to other neighboring regions, agriculture in this province is exposed to a relatively higher climatic variability (Hitayezu et al., 2014). Climate variability in this province is characterized by a long dry spell in the winter season along with irregular rainfall patterns in the summer season (October-April), which is regularly influenced by the El Niño-Southern Oscillation (ENSO) phenomenon with drought events during El Niño years (Mosase & Ahiablame, 2018).

Limpopo is one of the least developed provinces in RSA compounded by a high population growth rate and a high share of poverty (Rötter et al., 2021). With a population of 5.8 million people, Limpopo comprises around 10% of the total population of RSA (Statistics South Africa, 2016). A large share of the population (89%) is living in rural areas and farming is their main occupation (Gyekye & Akinboade, 2003; LDARD, 2012).

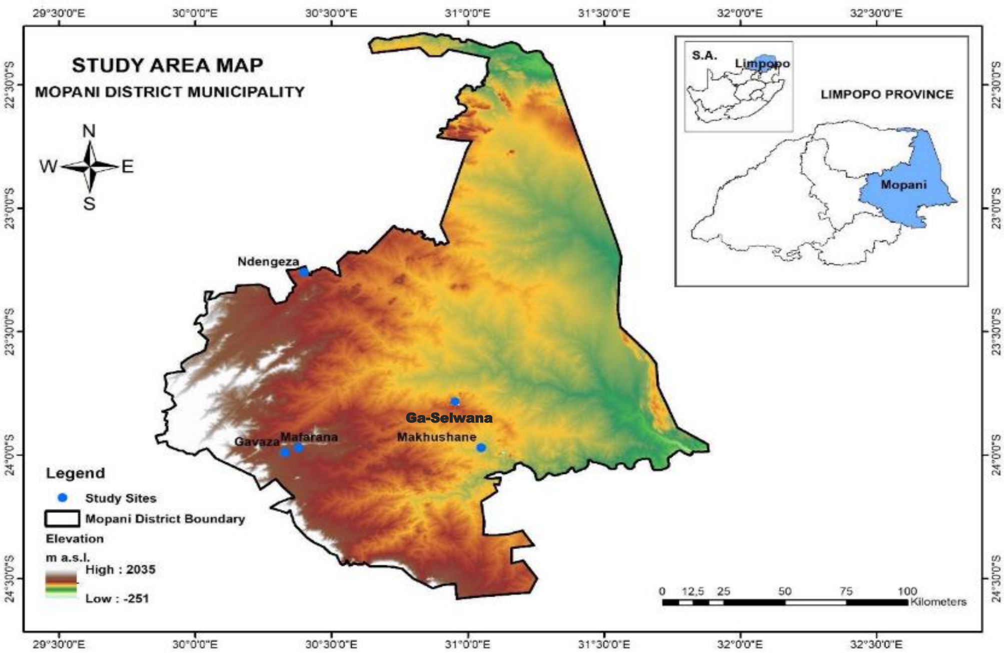

Figure 1.1. Map of research area
(Source: (May, 2019))

Five study sites (villages) were selected in Limpopo Province along a climatic gradient (from sub-humid to semi-arid) with variation in demographic and socio-economic factors. The selected villages are all located in the former-homeland rural area of the Mopani district of Limpopo Province: Mafarana, Gavaza, Ga-Selwana, Makushane, and Ndengeza (Figure 1.1).

Farming systems in the selected areas are mainly small-scale farms with limited resource endowments that produce predominantly for subsistence purposes and just a few are selling their products at markets. Maize (*Zea mays* L.) is the main dietary staple crop that dominates the small-scale farming system, supplemented with legumes such as peanut (*Arachis hypogaea*), Bambara nut (*Vigna subterranea*), cowpea (*Vigna unguiculata*), and some horticultural crops, and plays a vital role in food security and the reduction of malnutrition in these areas.

Using a purposive random sampling procedure, cross-sectional data was collected from 215 small-scale farmers across the five selected villages, of which three had to be excluded due to incomplete information. Consequently, the final data set covered 212 observations, which were distributed among the selected villages as listed in Table 1.1.

Table 1.1. Observations distributed among selected villages

Location	**Household Head gender**		**Number**
	Female	Male	
Ga-Selwana	26	24	50
Gavaza	15	10	25
Mafarana	14	14	28
Makushane	29	25	54
Ndengeza	18	37	55
Total Number of observations	102	110	212

Respondents were the household heads or the people in a position to make decisions on resource allocation for farming activities and their household food security. Permission to access and interview farmers was obtained from tribal authorities of each village and informed prior consent was obtained from all respondents. A pre-test questionnaire was conducted from some random farm households in the selected regions. Subsequently, a structured questionnaire was conducted using 'Sawtooth Software' (SawtoothSoftware 2019) for in-person interviews with the farmers in order to collect information on socio-economic, demographic, farm and household characteristics, as well as input and output data of the agricultural production during the 2018-19 cropping season. Moreover, the information regarding risk attitude and risk perception of different sources of risks were collected from each farmer. The complete questionnaire is available in the Questionnaire section (page 102). To capture the broadest possible diversity, the sample included different sized farms with diverse agricultural activities that had different degrees of market integration and selfprovision. The data collection was carried out after the harvest of the summer cropping season, between April and July 2019.

1.3. Outline of the dissertation

The remainder of this dissertation is structured as follows: Chapter 2 presents the first essay, focusing on the typology of small-scale farmers. Chapter 3 describes the second essay, analyzing the main drivers of the transition of small-scale farmers from subsistence to the market-oriented farming system. Chapter 4 consists of the third essay investigating the technical efficiency of small-scale maize farmers. In Chapter 5, the main findings of the three aforementioned chapters are summarized with some policy implications of the research findings, as well as some limitations of our research.

2. Typologies of South African Small-Scale Farmers and Their Risk Perceptions Using Unsupervised Machine Learning Approach

Small-scale farmers in Southern Africa play a vital role in developing rural economies by providing food for own consumption and a growing urbanized population and, thus, improving rural livelihoods and, more generally, food security in rural areas. These farmers are highly heterogeneous regarding types of farming, levels of technology adoption and degree of commercialization. Such heterogeneous types, respectively groups of small-scale farming systems require different forms of government interventions, depending on the objectives and characteristics of each group. This chapter aims to apply a machine learning approach to analyze the typologies of small-scale farmers in South Africa based on a wide range of objective variables regarding their personal, farm and context characteristics, which support an effective, target-group-specific design and communication of policies. Therefore, a cluster analysis is applied based on a comprehensive survey among 212 small-scale farmers conducted in 2019 in the Limpopo Province. An unsupervised machine learning approach, Partitioning Around Medoids (PAM), is applied to the survey data. Following clustering of the small-scale farmers, the risk attitude and perceptions among the selected groups were compared and examined to fine-tune related policy measures and their implications on risk management[1].

Keywords: *agricultural policy design; farmer typology; machine learning; Partitioning Around Medoids; risk perception; small-scale farming*

This essay is co-authored by Reimund Paul Rötter, Kingsley Kwabena Ayisi, Wayne Twine, Jan-Henning Feil. The contribution of each author are as follows: **Sara Yazdan-Bakhsh:** Conceptualization, Software, Formal analysis, Investigation, Data curation, Writing - Original Draft, Writing - Review and Editing, Visualization; **Reimund Paul Rötter:** Conceptualization, Validation**; Kingsley Kwabena Ayisi:** Conceptualization, Validation, Project administration; **Wayne Twine:** Validation; **Jan-Henning Feil:** Conceptualization, Methodology, Data curation, Validation, Resources, Supervision, Project administration

[1] The earlier version of this chapter was accepted for oral presentation in "*61. Jahrestagung der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V (Gewisola), Humboldt-Universität Berlin*", 22-24 September 2021, (Yazdan-Bakhsh & Feil, 2021)
The advanced version of this chapter is submitted to the "*China Agricultural Economic Review*", and the status is under review after the first revision

2.1. Introduction

In RSA's development policy, the agricultural sector is amongst the most important economic sectors that can play a critical role in contributing to the achievement of the Sustainable Development Goals (SDGs), such as reducing poverty and hunger, attaining food security, and sustaining natural resources (Kofi & Adams, 2020). In this regard, improving the management of existing agricultural systems and, through this, enhancing sustainable land use is a prerequisite to sustaining food supply for a rapidly increasing population in Sub-Saharan Africa.

The agricultural sector in RSA in particular is largely dualistic, consisting of a modern and capital-intensive but comparatively small group of large-scale commercial farmers, as well as a large group of poorly-developed and resource-limited small-scale farmers, predominantly living in the rural former apartheid homeland areas (Aliber & Cousins, 2013; Gwebu & Matthews, 2018). According to the General Household Survey of 2019 in RSA, there are approximately 2.3 million small-scale farmers compared to 40,122 large-scale farmers (Mathinya et al., 2022; STATS SA, 2020). These outnumbering small-scale farmers play a crucial role in developing rural economies by providing food for own consumption and a growing urbanized population, thus, improving rural livelihoods and, more generally, food security in rural areas. Therefore, these small-scale farmers can be seen as the main drivers of achieving the SDG imperatives in RSA (Aliber & Cousins, 2013).

The dualistic characteristic of the agricultural sector in RSA had adverse effect on the development of small-scale farmers (Tshuma, 2014), as historically, policy emphasis was mainly on the development and support of the formal commercial agricultural sector rather than on the much larger group of small-scale farmers (Carelsen et al., 2021; Tshuma, 2014). However, over the past two and a half decades, the support has shifted more toward the small-scale farming sector (Hendriks, 2014; Pienaar, 2013; Vink & Van Rooyen, 2009), and many researchers, policymakers, and civil society organizations in RSA have tried to understand the challenges the small-scale farmers are facing and implement various strategies and policies to enhance the status of small-scale agricultural production.

Currently, in RSA, the Department of Agriculture, Forestry, and Fisheries (DAFF) is mainly responsible for designing the legislation and policies for the agricultural sector at the national level, while Provincial Departments of Agriculture are implementing these policies and legislation at the local level (Carelsen et al., 2021).

Despite various national and provincial government support for small-scale farmers to enhance the agricultural sector in recent years (Cele & Wale, 2018; FAO, 2017; Gwebu & Matthews, 2018), these farmers are still extremely vulnerable to the diverse agricultural risks and perform below their potential production capacities. In addition, they are confronted with several challenges that result in low productivity and, hence, lead to exacerbating the issue of food insecurity and poverty (Hart & Aliber, 2010; Tshuma, 2014). By looking at the literature, two main reasons for the policy ineffectiveness in supporting small-scale farming systems in RSA are discussed:

The first reason might lay in the undifferentiated view and treatment towards these groups of farmers, with little consideration of contextual factors that render and exacerbate the unevenness between them (Olofsson, 2019). However, this disregards the fact that small-scale farmers are highly heterogeneous, for instance, regarding types of farming, levels of technology adoption, and degree of commercialization (Carelsen et al., 2021; Mądry et al., 2016). Therefore, stereotypes such as "small-scale" need to be deconstructed to allow for a more target-group-oriented policy design. These heterogeneous groups of small-scale farmers require different forms of government interventions depending on the objectives and characteristics of each group (Carelsen et al., 2021). Consequently, to design accurate target-group-oriented policy measures, a crucial pre-requisite is to understand the structure of the addressed group of small-scale farmers comprehensively and objectively.

The second reason for ineffective support policies for small-scale farmers might lay in the fact that farmers' risk attitudes and perceptions are largely neglected when it comes to policy design. Small-scale farmers in developing countries and particularly in RSA have constantly been confronted with different sources of risks such as production, market, financial, institutional or political, and human resource risks (Meraner & Finger, 2019). Risk perception has been recognized as an important influence on small-scale farmers' performance and decision-making, such as adoption of different types of practices and new technologies (Bidogeza et al., 2009; Joffre et al., 2019). Heterogeneous farmers have diverse perceptions of risks, depending on their main farming goal and their farming typologies. In order to design comprehensive and effective target-group-oriented policy measures with the desired implications in practice, it is essential to understand the risk perceptions of the various target groups. Many research publications point out the importance of risk perception and risk attitude for understanding farmers' individual risk behavior (Boholm, 1998; Dave et al., 2010; Pennings & Garcia, 2001; Renn, 1998; Van Winsen et al., 2016). Farmers' decision-making on selecting and applying the optimal risk management strategies, among others, results from the interplay of their risk attitude and their perception regarding the sources of the risk (Bidogeza et al., 2009; Meraner & Finger, 2019; Sulewski & Kłoczko-Gajewska, 2014). Therefore, understanding the farmer´s risk behavior, i.e., risk attitude and subjective risk perception of the farmers, is a prerequisite for designing appropriate risk management strategies and, hence, respective policy support programs (Sulewski & Kłoczko-Gajewska, 2014).

Therefore, this chapter aims to analyze the typologies of small-scale farmers in RSA based on a wide range of objective variables regarding their personal, farm, and context characteristics, which support effective, target-group-specific design and communication of policies. In this regard, a cluster analysis is conducted based on a comprehensive survey among small-scale farmers from 2019 in the Limpopo Province. It comprises a wide range of quantitative and qualitative variables about their farms, management practices, and socio-demographic characteristics. For identifying different types of small-scale farmers from this complex data, an unsupervised machine learning approach, that is, Partitioning Around Medoids (PAM) is used. Following this, the risk attitudes and risk perceptions are compared between the identified farmer types for the first time.

This study contributes to the literature by analyzing typologies of small-scale farmers in southern Africa based on a wide range of variables regarding their socio-demographics, their farm structures and their resource management characteristics as well as by linking these typologies with the analysis of their respective risk perceptions. Our respective results could provide a reference for decision makers for a more need-based and target-oriented policy design and communication for small-scale farmers, which is especially important in southern Africa.

The remainder of chapter 2 is organized as follows: **Section 2.2** provides an overview of existing limited typologies of small-scale farmers and their shortcomings in RSA. **Section 2.3** describes the data and methodology. **Section 2.4** presents the PAM clustering results. In **Section 2.5**, the risk attitudes and risk perceptions of the selected groups are compared, and in **Section 2.6** the results are discussed, and finally, conclusions are drawn in **Section 2.7**.

2.2. Typologies of small-scale farming systems in RSA

The definition of smallholders or small-scale farmers varies internationally between countries and agro-ecological zones, as these farmers are heterogeneous and vary significantly depending on farm characteristics including socio-economic characteristics, resource endowments and agro-ecological dimensions (FAO, 2017). The existing literature on classifying small-scale farmers uses diverse conceptual approaches and methods, depending on the purpose of the analysis and the units of investigation (e.g., farm, farmer). Several criteria such as farm size, sources of farming capital and income, labor, market integration, and livelihood diversification can be considered for the classification (Olofsson, 2019). Recent literature revealed that farm size and the objective of production are the two predominant criteria to classify small-scale farmers, although the threshold measures vary across countries and regions (FAO, 2017).

In South African policy and planning documents, there are several definitions and terminologies for small-scale farmers which are inconsistent and differ depending on the context. Table 2.1 provides a brief overview of relevant farmer typologies in research studies and policy documentations in RSA to focus on policy implementations.

The South African Department of Agriculture (DAFF), which is mainly responsible for designing the legislation and policies for the agricultural sector at the national level (Carelsen et al., 2021), in 2013 generally classified the small-scale farmers into the three groups, that is, "Part-time subsistence farmers" for which agriculture contributes merely a small share of their livelihood, "middle of the spectrum smallholders" who mainly rely on agriculture as their main source of livelihood, as well as "commercial smallholders" (DAFF, 2013). These typologies were mainly based on the degree of commercialization, importance of agriculture in a household's livelihood, and the poverty level. In 2015, this department (DAFF, 2015) classified farmers mainly by considering the farmers' land size and their primary purpose of production, while the main differences within and between the farming groups were not apparent. Looking at these typologies, smallholders were mainly referred to as the farm categories between the two extreme groups of subsistence and large-scale commercial farmers, although they were classified into two groups of subsistence and emerging smallholder farmers. In doing so, subsistence smallholder farmers were defined as ones involved in agricultural production only for their own household consumption, while emerging farmers were also considered to be selling their products at a market.

The farm typology according to DRDLR (2009) classified farmers in five different categories based on the land reform projects. In comparison to other policy documents, they considered more criteria such as farmers' aspirations, capabilities and resources.

In addition to the definitions of small-scale farmers from the agricultural policy and planning documents, various researchers and academics attempt to define the small-scale farmers in SA (Aliber et al., 2009; Cousins, 2010; Torero, 2011) as well as provincially, for example for Western Cape (Carelsen et al., 2021).

Based on the literature we screened, none of the existing typologies did consider socio-economic characteristics, risk attitudes, and resource management of the farmers for differentiating among small-scale farmer groups. Based on the insights from the literature review, the existing typologies of (small-scale) farmers are still imprecise and too broad to represent the main characteristics of different groups of farmers, in order to design respective need-based policies to improve their specific situations.

Table 2.1. Classifications of farmers in RSA

Author/ Policy reference	Identified typologies	Criteria
Department of Agriculture, Fisheries, and Forestry (DAFF, 2015)	Subsistence farmers; smallholder farmers; commercial farmers	land size and production orientation
Department of Agriculture, Fisheries, and Forestry (DAFF, 2013)	Part-time smallholder (agriculture contributes only small share of livelihood); middle of the spectrum smallholder (rely on agriculture as the main source of livelihood); commercial smallholders (not obliged to register for VAT or income tax)	Degree of commercialization, importance of agriculture in household's livelihood, poverty level
Department of Rural Development and Land Reform (DRDLR, 2009)	Landless households; commercial-ready subsistence producers; expanding commercial smallholders; well-established black commercial farmers; financially capable, aspirant black commercial farmers	Land size, production orientation, assets
Aliber et al. (2009)	Subsistence; semi-subsistence; emerging commercial farmers (or semi-commercial farmers)	Labor, source of income
Cousins (2010)	Supplementary food producers; Allotment holding wage workers; Worker-peasants; Petty commodity producers; Small-scale capitalist farmers; Capitalists whose main income is not from farming	degree of agriculture contributes to social reproduction or expanded reproduction, degree of hired labor in the agricultural production process
Torero (2011)	Smallholder farmers including Rural world 1; Rural world 2; and Rural world 3	Market level
Carelsen et al. (2021) adapted from Western Cape Department of Agriculture (WCDoA)	Subsistence; smallholder; Commercial farmers	Taxation, production intent, access to resources, labor, and technology level

2.3. Data and methodology

In the following section, we will present the variables used for classification. Afterward, we introduce the methodology for classifying small-scale farming systems and determining the optimal number of clusters.

2.3.1. Variables for classification

The diversity of small-scale farming systems in our study was determined by considering multidimensional criteria consisting of farmer characteristics (e.g., age, education, risk attitude, etc.), farm characteristics (e.g., agricultural production, agricultural income) and resource management (e.g., water sources and irrigation, labor, inputs), as well as external incentives (e.g., agricultural extension services, access to credits, and markets). In contrast to previous literature on small-scale farmer typologies in South African policy documents, the multidimensional criteria of selected variables provide further differentiation and detail in analyzing the diversifications between groups. These numerous variables used in the survey were based on an extensive upstream literature review as well as on numerous expert discussions prior to and during the design of the survey (cf. section 2.2). Table 2.2 presents the descriptive statistics of the selected continuous and categorical variables implemented in the clustering. A total of 34 variables were applied to construct the smallholder farming system classification.

According to this table, a typical farming household in the survey sample has a household head of an advanced age (66 years), who is mainly male. The share of female-headed households was the same as the national general household survey in 2019 with 48.8% (Statistics South Africa, 2019). Risk attitude indicating the farmers' self-assessment regarding risk behavior in farming is on average 4.29 which shows relatively risk-averse characteristics of the farmers.

The average farming system in the survey owns 4.4 ha land, of which 70% is left fallow during winter (dry season). In terms of production systems, the smallholder farming system is mainly characterized by mixed crop-livestock production. Besides maize[2] (Zea mays L.), which is cultivated by almost all the farmers as the staple crop to ensure household food security, the secondary major crops are legumes[3] cultivated by 59% of farmers, fruits[4] with an average of 32%, and vegetables[5] with 15% of the farmers. Livestock consists of cattle, goats, pigs as well as chickens. Cattle provides the main source of livestock income. On average, 41% of agricultural farm income is from crop sales and 25% is from livestock sales. Around 58% of the farmers sale their agricultural produce at their farm and 17% sale at off-farm markets such as retailers, fresh produce markets and livestock auction.

Table 2.2. Descriptive statistics of the variables

Variables	Description	Mean	Std dev.	Min	Max
Farmer characteristics					
age	Age of household head (number of years)	66.45	11.19	33	93
gender	Gender of household head; (1=Male)	0.52	0.50	0	1

[2] Due to its ubiquity, we did not include Maize in our analysis, as all the farmers cultivate this crop as the staple food and not diversified among farmers

[3] Legumes include peanuts, Bambara nuts (Vigna subterranea L.), cowpea

[4] Fruits such as Mango, banana

[5] Vegetables include tomato, onion, cabbage

educ	Years of formal education of household head	4.76	5.04	0	1
Job_offFarm	Off-farm job of the farmer; (1=Yes)	0.22	0.41	0	1
Inc_socio	Social grant income including pension and child grant (in Rand)	26689.8	15308.7	0	69840
Inc_remit	Remittance income (in Rand)	4168.3	12026.5	0	96000
Risk_att	Risk attitude (Likert scale: 1: highly risk averse – 10: highly risk seeking	4.29	2.85	1	10
Farm characteristics					
Farm_area	Total area of the farm (ha)	4.44	6.13	0.25	47
Cult_area	Total area under cultivation (ha)	3.02	3.33	0	22
Winter_fallow_area	Share of fallow area in winter; between 0-1	0.70	0.43	0	1
Nr_winterCrops	Number of crops cultivated in winter	0.25	0.72	0	6
Cr_vegetables	Cultivating vegetables; (1=Yes)	0.15	0.36	0	1
Cr_fruits	Cultivating fruits; (1=Yes)	0.32	0.47	0	1
Cr_legumes	Cultivating legumes; (1=Yes)	0.59	0.49	0	1
SaleValue_cropShare	Share of sale value crops to total value crops cultivated	0.40	0.41	0	1
SaleValue_animShare	Share of sale value animals to total value of animals	0.06	0.13	0	0.83
Animal	Having animal; (1=Yes)	0.58	0.49	0	1
Nr_cattle	Number of cattle	4.6	9.4	0	65
Inc_onFarm	Income of selling crops and animals (Rand)	25137.9	121098	0	1574700
Inc_onFarm_crops	Crop share of total on-farm income	0.41	0.46	0	1
Inc_onFarm_anim	Animal share of total on-farm income	0.25	0.40	0	1
Resource management and external incentives					
OwnTractor	Having tractor; (1=Yes)	0.06	0.23	0	1
Water source					
• Rain-dependent	Dummy; 1= Yes, 0= No	0.34	0.47	0	1
• Tap water	Dummy; 1= Yes, 0= No	0.41	0.49	0	1
• Public dam, lake	Dummy; 1= Yes, 0= No	0.09	0.29	0	1
• Private borehole	Dummy; 1= Yes, 0= No	0.16	0.36	0	1
Irrigation_Time	Hours of Irrigation in year	91.56	310.50	0	2184
Irrigation_Method	Methods of irrigation				
• No Irrigation	Dummy; 1= Yes, 0= No	0.34	0.47	0	1
• Primitive Irrigation method	Dummy; 1= Yes, 0= No	0.49	0.50	0	1
• Advanced Irrigation method	Dummy; 1= Yes, 0= No	0.16	0.36	0	1
PesticideUse	Applying pesticide on farm; (1=Yes)	0.14	0.34	0	1
FertilizerUse	Applying fertilizer on farm; (1=Yes)	0.31	0.46	0	1
Employee_Permanent	Number of hired permanent worker in year (Man-day)	48.50	255.60	0	2484
Employee_Seasonal	Number of hired seasonal worker in year (Man-day)	17.33	59.36	0	540

OnFarmMarket	Selling at farm; (1=Yes)	0.58	0.49	0	1
OffFarmMarket	Selling at market; (1=Yes)	0.17	0.38	0	1
CreditAccess	Access to credits; (1=Yes)	0.10	0.30	0	1
Invest_past5Yrs	Investment in the past 5 years; (1=Yes)	0.37	0.48	0	1
ExtVisits_Yr	Number of visits/supports of Extension services	1.32	4.35	0	52

Social grants including old age and child support grants play an important role on farm household incomes for most smallholders. According to Statistics South Africa (2019), around 59% of the households received grants as their main source of income in Limpopo. Direct agricultural support from government or extension services are mainly in the form of input supplies, mechanization, livestock health services, and providing information and training on farming practices (Xaba & Dlamini, 2015). In RSA, extension services are provided by the Department of Agricultural and Rural Development of the Province through their trained staff. They play an essential role in supporting small-scale farmers in the country and are therefore noted in various studies as one of the main influences on farm performance (Dube & Guveya, 2016; Magingxa et al., 2009; Murugani & Thamaga-Chitja, 2018). We considered the number of visits of the agricultural extension officer during the previous year. In our sample, around 53.3% of the farmers received support from the local extension agents, with an average 1.32 visits in a year. Access to credit from formal financial institutions is a significant limitation for the majority of the South African small-scale farmers who are mostly old aged and have mainly unreliable and low income, undocumented property, and no formal credit history (Murugani & Thamaga-Chitja, 2018; Myeni et al., 2019; von Loeper et al., 2016). Within our sample, only 10% of the respondents have access to formal credit, although 37% of the farmers invested in the last five years, mainly on equipment for irrigation, fences, and machinery. Besides household members as labor on farm, the permanently and seasonally employed labor worked on average 48.5 and 17.33 man-days per year (eight-hour labor days).

The most common source of water is tap water (41%) which is usually only available in the home garden next to their residential building. 34% of the sample is purely rain-dependent, while on average 9% and 16% of farmers have access to public water sources and private boreholes. Hence, 49% of the sample uses primitive irrigation methods (e.g., buckets, farrow).

2.3.2. Methodology

Clustering belongs to the unsupervised learning techniques and allows to identify patterns within the data set to create homogenous groups by considering the similarities of members within a group and dissimilarities between the groups (Graskemper et al., 2021; Morris et al., 2017).

In general, clustering methods are distinguished into hierarchical and non-hierarchical (partitioning) based approaches. One of the most popular clustering methods based on partitioning is the k-mean algorithm (MacQueen, 1967) which applies only for continuous quantitative data types. Conversely, Partitioning Around Medoids (PAM) (Kaufman; & Rousseeuw, 1990) is an appropriate method in analyzing mixed-type data, considering both quantitative and qualitative (e.g., nominal, ordinal, and interval) data (Graskemper, 2021; Lesmeister, 2015). The partitioning methods rely mainly on the initial center of the cluster (Xu & Tian, 2015). Accordingly, k-means consider the mean of the data sets as the center of the cluster, whereas k-medoids consider the median for the selection center of the cluster. Therefore, k-medoids are generally more robust against noise and outliers in comparison to k-means (Xu & Tian, 2015).

PAM is one of the popular methods of k-medoids algorithm (Arunachalam & Kumar, 2018). The appropriate distance metric for PAM clustering which is suitable for mixed data type is Gower dissimilarity matrix (Guarín et al., 2020; Weltin et al., 2017). According to Gower (1971), the dissimilarity measure for a pair of observations (i and j) is defined as a weighted sum of dissimilarities for each variable as follows:

$$d(x_{ik}, x_{jk}) = \frac{\sum_k \delta_{ijk} d_{ijk}}{\sum_k \delta_{ijk}} \tag{2.1}$$

Where d_{ijk} represents the distance between the ith and jth observation considering the kth variable and depends on the type of variables. For discrete variables (e.g., binary variables, categorical nominal variables), it is obtained as: $d_{ijk} = 0$ if $x_{ik} = x_{jk}$, and 1 otherwise. As well for the continuous variables:

$$d_{ijk} = \frac{|x_{ik} - x_{jk}|}{R_k} \tag{2.2}$$

Being the $R_k$is the range of the kth variable. Moreover, for categorical ordinal variables, the corresponding position index r_{ik} in the factor levels are transformed as follows to z_{ik} and treated as numerical variables:

$$z_{ik} = \frac{(r_{ik} - 1)}{max(r_{ik}) - 1} \tag{2.3}$$

The δ_{ijk} is a 0-1 coefficient based on whether the variables are valid (= 1) or else (=0).

The Gower dissimilarity matrix is used as an input for the clustering procedure with PAM, with the main objective of minimize the sum of dissimilarities between all observations and the nearest medoid (Lesmeister, 2015). The analysis was conducted using R statistics software and the Gower dissimilarity matrix was computed using 'dist' or 'daisy' functions from the 'cluster' package (Arunachalam & Kumar, 2018).

2.3.3. Optimal number of clusters

The selection of an optimal number of clusters is the prerequisite for clustering (Lesmeister, 2015). To determine the optimal number of clusters, the Silhouette index or Average Silhouette Width approach is conducted. This method tries to compare the similarity of observations within their assigned cluster to the similarity to all other clusters and measures the quality of the clustering. Based on this method, a high average silhouette width indicates good clustering. The optimal number of clusters (k) is the one that maximizes the average silhouette over a range of possible values for K (Kaufman; & Rousseeuw, 1990).

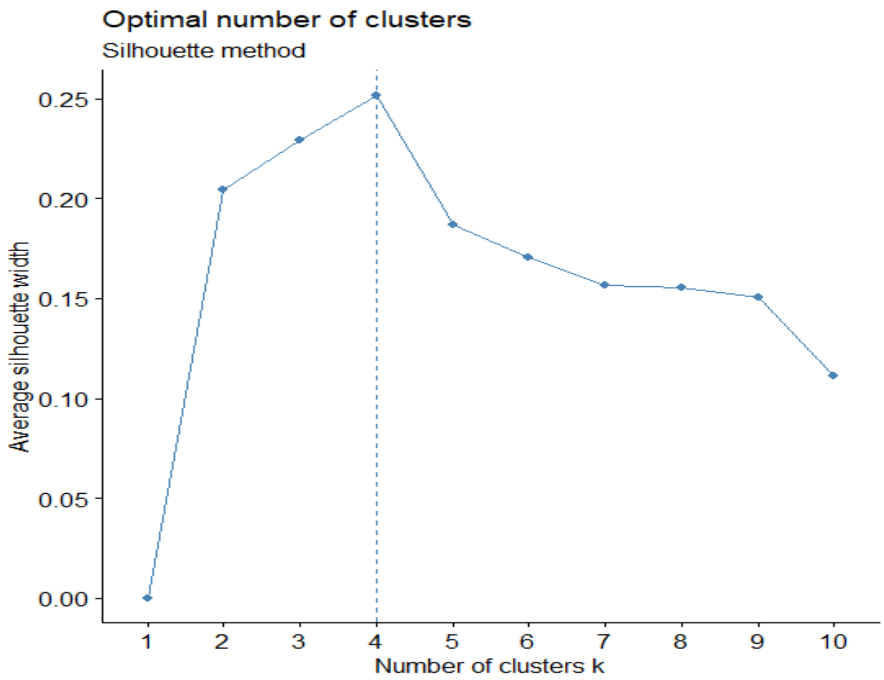

Figure 2.1. Optimal number of clusters based on average Silhouette method

According to Figure 2.1, the appropriate number of clusters is four based on the highest value of silhouette width. In addition, the Elbow method using the within-cluster sum of squares confirmed the optimal number of four clusters for the small-scale farming systems in RSA (Appendix (S. 2.8), Figure 2.3).

As a final step of the analysis, the nonparametric test of Kruskall-Wallis was conducted to evaluate whether there were significant differences in the distributions of the variables across different clusters of farmers. This test is an appropriate approach for mixed-type variables, with a chi-square distribution.

2.4. Results

In the following, the results of clustering and diversifications in characteristics of the farming systems are compared between the four selected clusters.

2.4.1. Defining the clusters

Using the k-medoids clustering method, 212 smallholder farm households were grouped into four clusters of 80, 48, 54, and 30 members. These four groups were specified based on their main criteria of purpose of farming, agricultural activities and resource management. The largest cluster with 37.7% of the farmers represents the group of ***Subsistence-oriented farmers***, while the smallest cluster with 14% of respondents indicates the ***commercial (market)-oriented farmers***. The other two clusters are the ***Semi-subsistence livestock farmers*** as well as the ***crop-oriented farmers*** that predominantly produce for their own consumption and sell their surplus at their farm. This means that the latter two groups can be understood as intermediate groups in their development.

2.4.2. Characterization and comparison of the clusters

Table 2.3. describes the results of each cluster in terms of various characteristics of the farmers which develop the profile of each group. These profile variables relate to farmer, farm, and resource management characteristics. The table presents the mean and standard deviations for continuous variables and the distribution proportion (percentage) for categorical variables for each of the farmer type clusters. The last column shows the results of the Kruskal-Wallis test to evaluate the performance of the variables in the different clusters to be significantly different from each other (p-value).

Additionally, Figure 2.2. illustrates the relative distribution of the variables' expression for the selected four groups.

Table 2.3. Results of Cluster Analysis

Clusters	**Subsistence oriented**	**Semi-subsistence Livestock-oriented**	**Semi-subsistence Crop-oriented**	**Market-oriented**	**Overall significance (Kruskal-Wallis test)**
Number of members	**80**	**48**	**54**	**30**	
Farmer Characteristics					
age	70.7 (10.6)	65.9 (10.7)	64.5 (7.95)	59.6 (14.1)	0.000
gender	0.35	0.77	0.31	0.93	0.000
educ	2.62 (3.58)	5.6 (4.82)	4.50 (4.71)	9.60 (5.80)	0.000
Job_offFarm	0.24	0.19	0.15	0.34	0.229

Inc_socio	26676 (12391)	31670 (18081)	25080 (13421)	21656 (18861)	0.026
Inc_remit	5487 (13471)	4350 (14991)	3080 (7439)	2320 (9057)	0.215
Risk_att	3.5	4.6	4.1	6.10	0.000
Farmer Characteristics					
Farm_area	2.93(2.41)	4.59 (6.20)	2.83 (2.13)	11.1 (11.4)	0.000
Cult_area	2.34 (1.87)	2.83 (3.16)	2.42 (2.06)	6.23 (5.88)	0.009
Winter_fallow_area	0.85 (0.34)	0.63 (0.46)	0.80 (0.38)	0.29(0.39)	0.000
Nr_winterCrops	0.06 (0.37)	0.19 (0.89)	0.07 (0.26)	1.20 (0.96)	0.000
Cr_vegetables	0.01	0.08	0.06	0.80	0.000
Cr_fruits	0.01	0.52	0.72	0.10	0.000
Cr_legumes	0.85	0.33	0.65	0.23	0.000
SaleValue_cropShare	0.05 (0.20)	0.35 (0.38)	0.66 (0.25)	0.91 (0.15)	0.000
SaleValue_animShare	0.01 (0.04)	0.14 (0.12)	0.02 (0.06)	0.15 (0.25)	0.000
Animal	0.44	1.00	0.43	0.60	0.000
Nr_cattle	3.22 (8.97)	8.56 (10.8)	1.41 (3.27)	7.83 (12.5)	0.000
Inc_onFarm	1740 (6335)	13504 (21033)	2860 (4548)	146121 (296717)	0.000
Inc_onFarm_crops	0.03 (0.16)	0.22 (0.35)	0.96 (0.16)	0.77 (0.32)	0.000
Inc_onFarm_anim	0.11 (0.30)	0.68 (0.41)	0.04 (0.16)	0.23 (0.32)	0.000
Resource management and external incentives					
OwnTractor	0.02	0.00	0.02	0.30	0.000
Water source					0.000
• Rain-dependent	0.58	0.27	0.22	0.03	
• Tap water	0.33	0.52	0.61	0.10	
• Public dam, lake	0.03	0.08	0.06	0.37	
• Private borehole	0.07	0.12	0.11	0.50	
Irrigation_Time	0.00 (0.00)	0.00 (0.00)	3.85 (28.3)	640 (581)	
Irrigation_Method					0.000
• No Irrigation	1.00	1.00	0.98	0.20	
• Primitive Irrigation method	0.00	0.00	0.02	0.07	
• Advances Irrigation method	0.00	0.00	0.00	0.73	
PesticideUse	0.05	0.08	0.04	0.63	0.000
FertilizerUse	0.30	0.23	0.20	0.67	0.000
Employee_Permanent	5.82 (36.8)	2.58 (16.6)	0.00 (0.00)	323 (617)	0.000
Employee_Seasonal	9.19 (21.2)	8.48 (18.8)	9.44 (24.4)	67.3 (140)	0.505
OnFarmMarket	0.09	0.94	0.96	0.67	0.000
OffFarmMarket	0.00	0.10	0.09	0.90	0.000
CreditAccess	0.02	0.06	0.06	0.43	0.000
Invest_past5Yrs	0.19	0.27	0.48	0.83	0.000
ExtVisits_Yr	0.78 (1.45)	0.48 (0.68)	0.54 (0.54)	5.50 (10.5)	0.000

*numbers in () is the standard deviations for the numerical variables

Farmer characteristics

The four defined clusters are diverse in terms of the characteristics of the farmers. As shown in Table 2.3., and Figure 2.2., Subsistence-oriented farmers are mainly women with an average age of 71 years old. They are mainly illiterate with an average of 3 years of formal education. Their main sources of income are remittances and social grants (mainly pension). In contrast, a market-oriented farming system is characterized by predominantly male farmers with higher education in comparison to other groups. The share of social grants and remittances are lower in comparison to other groups, as they are comparatively younger and more involved in off-farm jobs.

In terms of perceived risk attitude, subsistence-oriented farmers and semi-subsistence crop-oriented farmers are more risk averse, whereas market-oriented farmers and semi-subsistence livestock-oriented farmers take more risks.

Farm characteristics

Subsistence and semi-subsistence crop-oriented farming have the least land area which is mainly cultivated in summer (wet season) and are almost fallow in dry seasons. Their main focus of cultivation is staple food and legumes for own household consumption. Market-oriented farmers have access to bigger land areas with cultivating in both seasons. They are involved in agricultural diversification with the focus mostly on vegetables and livestock. Their main purpose of cultivation is for marketing.

Semi-subsistence livestock-oriented farmers have the second highest land area but in terms of cultivation are mainly fallow. Their focus is mainly on livestock (predominantly cattle) with a higher share of farming income. Regarding cultivation, fruits and legumes are their second interests.

Resource management characteristics

Taking a closer look at each farming systems regarding resource endowments, market-oriented farmers are comparably more developed than the other groups. Most of the farmers in this group have access to private boreholes and irrigating their farms with drippers and sprinklers. A high share of farmers in this group apply fertilizer and pesticides on their fields and employ permanent and seasonal laborers. These farmers have access to off-farm markets where they can sell most of their products.

With regard to finance access and investment, market-oriented farmers have more possibility to get agricultural credits which results in more investment in the agricultural sector. The other three types of farmers are constrained by financial access, which also affects providing agricultural inputs such as pesticide, fertilizer, water source and hired labor.

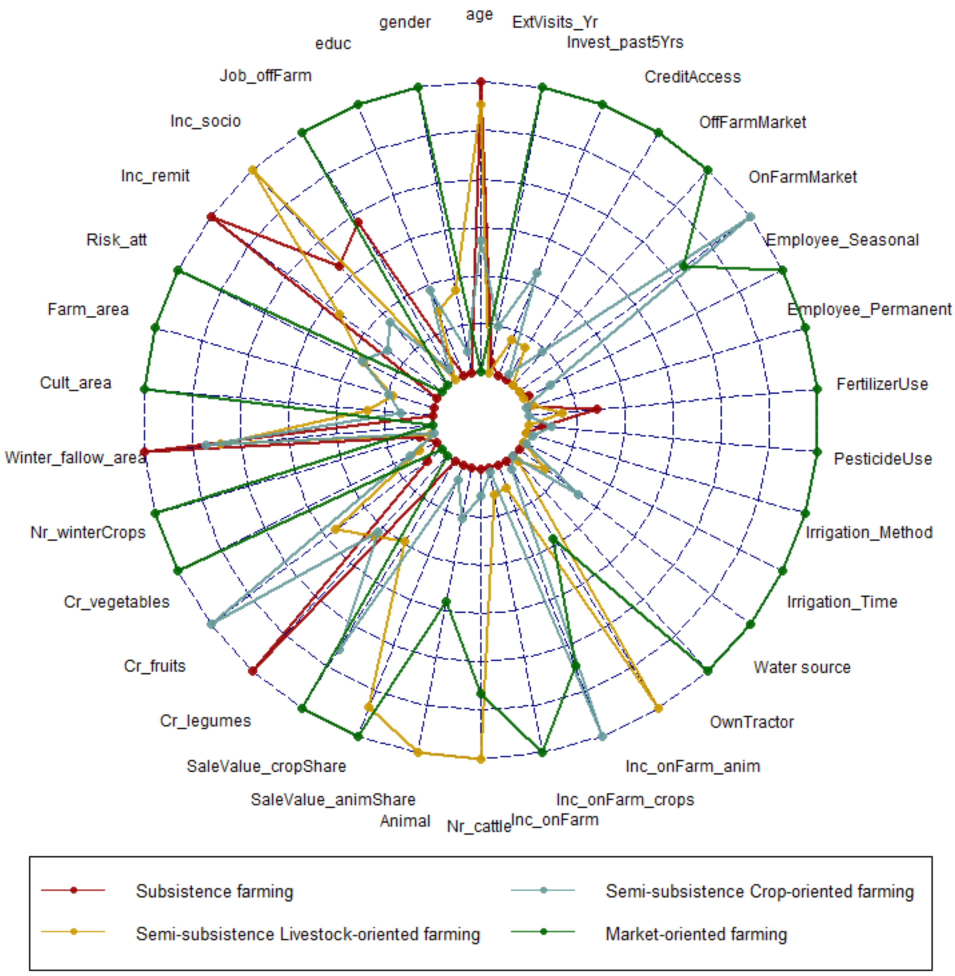

Figure 2.2. PAM results: Characteristics of different farmer groups. Relative distribution of the expression of the variables

2.5. Diversity of risk attitudes and perceptions between small-scale farmers' groups

Farming is inherently a risky business, especially for the small-scale farmers in developing countries like Southern Africa with limited sources of endowments. Farmers are confronted with risks and uncertainties arising from a wide range of sources such as climatic, production, financial and market risks in agricultural production. How farmers respond to these risks and implement appropriate risk management portfolios is complex and varies among farmers depending on the individual's assessment of the risk involved (Boholm, 1998; Dave et al., 2010; Pennings & Garcia, 2001; Renn, 1998; Van Winsen et al., 2016). Therefore, understanding the farmer´s risk attitude and subjective risk perception of the farmers is a prerequisite in policy implications on formulating appropriate risk management strategies (Sulewski & Kłoczko-Gajewska, 2014).

Risk attitude explains the farmers' self-assessment regarding risk-taking behavior and it can vary from unwilling to take risk to highly willing to take risk (Van Winsen et al., 2016). In this regard, the farmers were asked about their willingness to take or avoid risks in making decisions for their farm, scoring on a Likert scale from 1 (highly risk averse) to 10 (highly risk taking). Based on the results, the subsistence small-scale farmers are more risk-averse, while market-oriented small-scale farmers tend to take more risks in their farming (Table 2.4).

According to previous studies (Flaten et al., 2005; Meraner & Finger, 2019; Meuwissen et al., 2001; Van Winsen et al., 2016), risk perception can be considered as the combination of the probability of the occurrence of the risk (uncertain event) and the potential negative consequence of that. In this regard, to investigate the farmers' subjective risk perception, a total of 15 main risk sources, which are grouped into five main risk categories (Musser & Patrick, 2002) were asked from the small-scale farmers in the selected villages. The main sources of risks were collected from the previous literature (Duong et al., 2019; Meraner & Finger, 2019; Van Winsen et al., 2016), as well as interviews with some farmers and extension service consultants during pretesting of the main survey.

Farmers were asked to score the perceived likelihood of occurrence on a five-point Likert scale, from 1 (very unlikely) to 5 (very likely) and the perceived impact (potential damage) from 1 (very low) to 5 (very high) for each selected risk. The perceived risk perception score is calculated by multiplying the two perceived scores for each of the risk sources. Moreover, by taking the mean overall risk scores in each category, we obtained the risk score for each category. Table 2.4. shows the results of the risk attitude and perceived likelihood of the risk sources, perceived impact of the risk and the perceived risk score in the four different types of small-scale farmers.

Table 2.4. Perceived risk attitude and risk perception of different sources

Cluster names	Subsistence oriented			Semi-subsistence Livestock- oriented			Semi-subsistence Crop-oriented			Market-oriented		
Number of members	**80**			**48**			**54**			**30**		
Risk attitude	**3.5**			**4.6**			**4.1**			**6.10**		
	prob[a]	imp[b]	**score**	prob[a]	imp[b]	**score**	prob[a]	imp[b]	**score**	prob[a]	imp[b]	**score**
Climatic risks	2.70	3.46	**10.55**	2.49	3.42	**9.41**	2.59	3.52	**10.18**	2.40	2.47	**6.92**
Drought	3.94	4.64	**18.36**	3.77	4.44	**16.98**	3.80	4.67	**17.93**	3.63	3.40	**13.00**
Flooding	1.98	2.85	**6.11**	1.65	3.13	**5.38**	1.87	3.06	**6.13**	1.67	2.40	**4.43**
Storm/ wind	2.20	2.89	**7.18**	2.06	2.69	**5.88**	2.09	2.83	**6.48**	1.90	1.60	**3.33**
Production risks	2.41	2.64	**7.76**	2.66	2.48	**7.86**	2.31	2.24	**6.63**	2.40	2.20	**6.66**
Pests or diseases	4.18	4.10	**17.59**	3.85	3.77	**14.96**	4.11	4.00	**16.93**	3.83	3.07	**12.40**
Epidemic animal diseases	2.19	2.34	**6.39**	2.29	2.48	**6.48**	1.83	1.69	**3.57**	2.07	1.67	**3.83**
Lack of feed and fodder supply	2.64	2.29	**7.16**	2.85	2.54	**7.98**	1.78	1.85	**4.59**	2.20	1.87	**5.13**
Reduced land availability	2.33	3.26	**7.59**	2.63	1.85	**5.96**	2.63	2.24	**6.24**	2.43	2.27	**7.80**
Theft (crops)	2.24	2.61	**6.94**	2.65	2.13	**6.02**	2.80	2.46	**7.80**	2.20	1.80	**4.97**
Theft (livestock)	1.95	2.49	**6.19**	3.00	3.15	**11.02**	1.76	1.94	**4.76**	1.90	2.07	**5.47**
Theft (equipment)	1.33	1.38	**2.50**	1.33	1.44	**2.60**	1.24	1.50	**2.50**	2.13	2.63	**7.00**
Market and price risks	1.52	1.74	**3.01**	1.96	2.11	**4.65**	1.86	2.06	**4.20**	3.38	2.82	**10.77**
Price volatility on sales markets	1.43	1.24	**2.14**	2.19	2.38	**5.79**	2.07	2.13	**4.94**	4.10	3.57	**15.07**
Price volatility on purchase markets/inputs	1.61	2.25	**3.89**	1.73	1.85	**3.50**	1.65	2.00	**3.46**	2.67	2.07	**6.47**
Financial risks	3.83	2.82	**10.03**	3.67	2.41	**8.50**	3.67	2.56	**8.81**	2.67	2.53	**7.18**
Sudden lack of money for basic requirement	2.78	3.86	**11.46**	2.60	3.08	**9.04**	2.65	3.41	**9.65**	1.87	2.10	**4.50**
Uncertainty of receiving credits	4.88	1.79	**8.60**	4.73	1.73	**7.96**	4.69	1.72	**7.96**	3.47	2.97	**9.87**
Other risks												
Limited availability of qualified (skilled) workforce	1.68	1.95	**3.68**	2.06	1.83	**4.42**	2.30	2.25	**5.72**	2.83	2.97	**8.70**

a. Perceived (probability) likelihood of occurrence of the risk; **b.** Perceived impact (potential damage) of the risk

The results for the perceived likelihood of risk sources indicate that the first five main risk sources for these four groups are as follows:

Subsistence-oriented farmers: 1. Drought, 2. Pests and disease, 3. Sudden lack of money for basic requirement, 4. Uncertainty of receiving credits, and 5. Reduced land availability

Semi-subsistence crop-oriented farming: 1. Drought, 2. Pests and disease, 3. Sudden lack of money for basic requirement, 4. Uncertainty of receiving credits and 5. Theft (crops)

Semi-subsistence livestock-oriented farming: 1. Drought, 2. Pests and disease, 3. Theft (livestock), 4. Sudden lack of money for basic requirement and 5. Lack of feed and fodder supply

Market oriented farmers: 1. Price volatility on sales markets, 2. Drought, 3. Pests and disease, 4. Uncertainty of receiving credits, 5. Limited availability of qualified (skilled) workforce

2.6. Discussion

The results of the clustering indicate that small-scale farmers in Limpopo can be classified into four groups based on their farmer, farm and resource management characteristics. In contrast to the previous agricultural policy documentation in RSA, which grouped small-scale farmers merely into two groups of subsistence farmers on one hand and market-oriented farmers on the other hand (Aliber et al., 2009; DAFF, 2012; Pienaar, 2013), the endogenous result of the present cluster analysis based on PAM and a wide range of variables provides a more comprehensive classification, including livestock and crop oriented semi-subsistence farming.

Based on our analysis, the subsistence-oriented farming system, with higher proportions of members, consists of farmers who partake in agriculture mainly to provide staple foods for their own household consumption. They prefer to grow mainly legumes on rain-fed land, with low access to inputs and finance. Their primary sources of income are from social grants (including child and pension), borrowing money (and remittance), and off-farm jobs (e.g., working as a daily wage laborer). These farmers are highly dependent on government and extension service support to meet household food security. These farmers are mainly risk averse when applying the least technology and strategy management on their farm. Therefore, they are more vulnerable to drought and pest risks in comparison to other groups of farmers.

Market-oriented farmers have sufficient land and labor resources, as well as access to water and other inputs to diversify production, mainly aiming for selling at markets. They grow vegetables predominantly. Their primary sources of income are selling agricultural products and other off-farm jobs. Hence, comparatively, financial capital is not a constraint for them and some of them have already invested in more advanced irrigation equipment. These farmers are the risk-taking groups of farmers and adopt more technologies at their farm.

Nevertheless, they perceived the price fluctuations for the agricultural products as their main source of risk.

The semi-subsistence crop- as well as livestock-oriented farmers, which can be seen as intermediate groups between the former mentioned groups, have farming as the core activity that supports their livelihood and income. Farmers in the crop-oriented group grow diverse crops such as fruits and legumes and some vegetables for their self-consumption and sell their surplus at the farm gate. The livestock-oriented farmers keep mainly cattle, goats, and sheep and grow some fruits. These farmers are a rather risk-averse groups of farmers.

The results of the risk perception among the selected groups show that climatic risks, specifically drought were perceived as the main risk for all the small-scale farmers, mainly subsistence and semi-subsistence farmers, followed by pests and disease. Market and price risks, as expected, were considered substantial risks for market-oriented farmers. Exposure to theft for crops and livestock is ranked high among semi-subsistence farmers, compared to market-oriented farmers, who are exposed to equipment theft. Moreover, one of the risks that mostly market-oriented farmers face is the limited availability of a skilled workforce. This can be related to the fact that these farmers have larger cultivated land and tend to increase their yield and the quality of their agricultural products to meet the qualification to sell their products at the formal off-farm market channels.

2.7. Concluding remarks

To design and implement support policies for small-scale farmers need-based and target-group specific, it is a prerequisite to understand the structure of the farmers in a comprehensive way by considering a wide range of variables. In this regard, the purpose of this chapter was to develop the typology of the smallholder farmers in the Limpopo province of RSA. Farm level survey data from 212 smallholder farmers in five selected regions of Limpopo was collected in 2019 and analyzed by using the PAM clustering method. According to the results, the smallholder farmers in the sample can be classified into four different groups: subsistence-oriented (N=80), semi-subsistence-livestock oriented (N=48), semi-subsistence-crop oriented (N=54) and market-oriented farmers (N=30). The key factors in the farming system diversity was the farmer characteristics such as education and risk attitude, farm performance such as agricultural production, diversification, market oriented, as well as access to finance.

The classification of small-scale farming systems and the main drivers of diversity provide an entry point for a more need-based and, thus, more effective design of respective support policies. Recent agricultural development policy in RSA concentrates on commercially oriented small-scale farmers rather than subsistence farmers. Our results indicate that the share of subsistence and semi-subsistence farmers are high in comparison to market-oriented farmers and, therefore, require more attention and support from politicians in comparison. Also, knowledge of farmers' risk attitude and perception of different sources of risks is a prerequisite in implementing policies to support effective agricultural risk management for different types of small-scale farmers.

2.8. Appendix

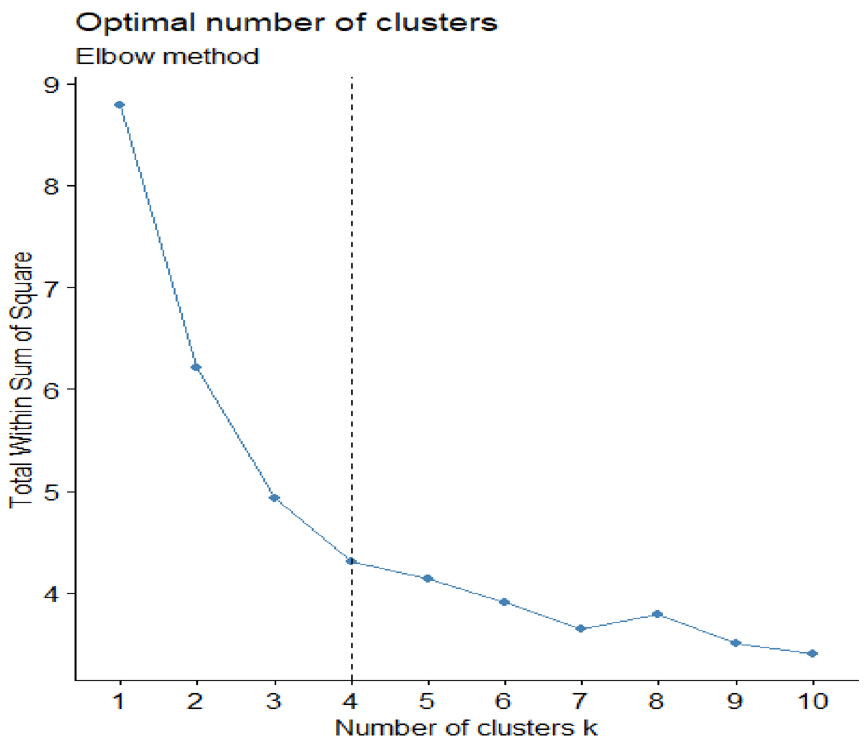

Figure 2.3. Optimal number of clusters according to the Elbow method

3. Agricultural Commercialization of the Small-scale Farm Households in South Africa: Transition from Subsistence to Market-oriented Farming Systems

Commercialization of agricultural production through participating in marketing and choosing appropriate marketing channels is a crucial requirement for economic growth and the development of small-scale farmers, especially in rural communities in southern Africa that predominantly rely on agriculture. Considering a presumptive sequential process of commercialization, we employed the sequential bivariate probit selection model to identify the main determinants of the transitions from subsistence, over semi-subsistence to market-oriented farming systems, while controlling for the endogeneity and selectivity problems that may arise from the correlation of unobserved heterogeneity and observed explanatory variables. A cross-sectional data of 212 farm households was sampled from five villages in the Limpopo Province of South Africa in 2019. The number of market-oriented farmers was relatively low, accounting for only 21% of our sample. The results of this chapter can provide useful insights for policymakers and farming communities on how to facilitate the marketing and economic growth of small-scale farming systems in order to improve food security at farm and regional level, provide higher resilience and thus viability for farms in the long term in the face of increasing risks and crises.

Keywords: *Market-oriented transition, market channels, sequential bivariate probit selection, small-scale farmers*

This essay is co-authored by Bernhard Brümmer, Kingsley Kwabena Ayisi, Jan-Henning Feil. The contribution of each author are as follows: **Sara Yazdan-Bakhsh:** Conceptualization, Software, Formal analysis, Investigation, Data curation, Writing - Original Draft, Writing - Review and Editing, Visualization; **Bernhard Brümmer:** Conceptualization, Methodology, Data curation, Validation; **Kingsley Kwabena Ayisi:** Conceptualization, Validation, Project administration; **Jan-Henning Feil:** Conceptualization, Methodology, Data curation, Validation, Resources, Supervision, Project administration

3.1. Introduction

Rising population and urbanization influence the food systems globally and, in particular, in developing economies such as sub-Saharan Africa (de Bruin et al., 2021). Urban population growth leads to more demand for food and agricultural products, providing a great opportunity for rural transformation to explore markets for farm products. Therefore, agricultural markets play a critical role in economic growth, and promote sustainable development by providing opportunities for the small-scale producers to effectively integrate into the mainstream of national economies (Mahlangu et al., 2020). This can contribute to food security and poverty reduction by generating employment, income, and productivity growth, as well as higher resilience in the face of increasing risks and crises (Hlatshwayo et al., 2022; Timmer, 1988).

The agriculture sector in the RSA is identified by the two contrasted types of commercial and small-scale farmers as a result of separate development policies of the South African government. Commercial farmers have well-established large-scale farms with infrastructure supporting agricultural production and marketing (Hendriks, 2014). These farmers contribute significantly to the agricultural economy, mainly through export. In contrast, small-scale farmers live primarily in rural communities and rely predominantly on their land and agricultural production to sustain their livelihood. According to the General Household Survey of 2019 in RSA, there are approximately 2.3 million small-scale farmers compared to 40,122 large-scale farmers (STATS SA, 2020). Despite the high number of small-scale farmers compared to the large-scale producers, they contribute negligibly to the national food systems (Mathinya et al., 2022). However, they still play a crucial role in local food systems and employment. The dualistic agricultural sector in RSA had adverse impacts on the market access of small-scale farmers, as historically, in RSA, policy emphasis was primarily on the development and support of the formal commercial agricultural sector rather than on the much larger group of small-scale farmers (Modiselle, 2001; Tshuma, 2014). However, over the past two and a half decades, the support has shifted towards small-scale farmers (Pienaar, 2013), and the RSA government has tried to implement policies to improve the capacity of small-scale farmers and agribusinesses, as well as promote commercialization (Ngqangweni et al., 2016).

According to the study of Yazdan-Bakhsh & Feil (2021), small-scale farm households in RSA are heterogeneous and can be classified into three alternative market regimes for their agricultural production. These include subsistence-oriented farmers who are characterized by low productivity that are engaged in farming mainly to maintain their own and household consumption; semi-subsistence/semi-commercial[6] farmers are those who produce primarily for their consumption and sell a proportion of their agricultural products at their farm gate and informal markets; finally, the market-oriented farmers who are characterized by high productivity marketing surplus (Kondo et al., 2019) that sell their agricultural products at the formal off-farm markets to gain profit (Yazdan-Bakhsh & Feil, 2021).

Increased commercialization and market participation of small-scale farmers implies transitioning from subsistence to profitable market-oriented farming to increase rural incomes and enhance economic growth (Amrouk et al., 2013; Pingali & Rosegrant, 1995). According to Pingali & Rosegrant (1995), this transition pathway passes from subsistence toward semi-commercial to commercial stages with different production objectives, input use decisions, and product mix (specialization and diversification) at each transition stage. Subsequently, market participation of small-scale farmers can lead to more specialized production systems while ensuring the efficient use of resources. Therefore, it leads to improved productivity, higher incomes, investments, and access to new opportunities to increase food security and alleviate poverty (Hlatshwayo et al., 2022).

Existing literature discusses several factors affecting the pathway transformation of small-scale farmers towards commercialization and access to lucrative markets (Amrouk et al., 2013; Pingali & Rosegrant, 1995; Yaseen et al., 2018). Based on the research conducted by Amrouk et al. (2013), the transition is influenced by three main components such as farm and farmer characteristics (e.g., available technology, level of education, land size, productive assets), prevailing physical and institutional infrastructure (such as road, communications, market, etc.), and macro and sectorial policies related to price and trade incentives. In addition to these factors, the availability of market channels (outlets) and the farm household's decision to choose an appropriate and efficient market outlet is recognized as essential in contributing to commercialization and generating high returns (Tarekegn et al., 2017). Understanding the main factors influencing this transition of small-scale farm households to market participation and choosing appropriate marketing channels (outlets) are prerequisites for increasing the level of commercialization and improving their livelihood and, therefore, sustainable development and economic growth.

While much has been written about market participation and its impact on rural development, up to date, there is less attention to South African small-scale farmers to investigate the conditions and factors that shape this transformation in rural areas. Therefore, the empirical research is based on data from a survey of small-scale farmers in the Limpopo Province of RSA, one of the least-developed provinces in this country, compounded by a high population growth rate and a high share of poverty (Rötter et al., 2021). A large proportion of the

[6] In this chapter, semi-subsistence and semi-commercial are used interchangeably

population of Limpopo (89%) lives in rural areas, and farming is their principal occupation (Gyekye & Akinboade, 2003; LDARD, 2012). They produce predominantly for subsistence purposes with little surplus production to sell at farm-gate, and some send their output to the formal market centers. Following the study of Pingali & Rosegrant (1995), and considering the sequential process of small-scale commercialization, the chapter is intended to use a method that explains the sequential behavior of these farmers' commercialization while investigating the main determinants associated with their marketing decisions. In particular, it attempts to identify the key socio-economic characteristics that drive subsistence farmers to participate in output markets. Also, conditional on participating in marketing, we investigate the main factors influencing the farmers' decision to choose marketing channels (informal vs. formal and off-farm markets).

The subsequent sections of this chapter are organized as follows: **Section 3.2** briefly reviews the literature on commercialization of small-scale farmers in RSA, **Section 3.3** describes the econometric approach, while **Section 3.4** presents the data description. In **Section 3.5** the empirical results and the discussion are offered, and finally in **Section 3.6** the chapter ends with conclusions.

3.2. Literature on commercialization of small-scale producers in RSA

The literature on the marketing of agricultural products is mainly based on the two assumptions of a simultaneous or a sequential process of farmers' decision-making, depending on the goal of the respective study (Abu et al., 2016; Bellemare & Barrett, 2006).

In this regard, the simultaneous procedure indicates that farm households simultaneously predetermine all the decisions related to market participation, market outlet choices, and market intensity before receiving information regarding these choices. According to Bellemare & Barrett (2006), the simultaneous decision-making process gives the traders market power by making the farmers' demand (supply) inelastic to new market information and the prices, which leads to these farmers becoming more vulnerable to exploitation by the traders. In contrast, in the sequential procedure, the decisions are conducted by the farm households sequentially and after receiving information from the market. It gives the farmers more flexibility over their marketing decisions and to adjust based on the market information. Hence, these farmers are less likely to be vulnerable to trader exploitation (Bellemare & Barrett, 2006).

Besides considering the simultaneous or sequential process of farmers' marketing decisions, there is a substantial number of empirical studies with different econometric approaches, depending on the aims of the study. In the context of analyzing the intensity of marketing, there are three main econometric approaches (one-step, two or three-step). The one-step approach is only focused on the intensity and level of marketing, and the main models include Tobit and truncated regression models. Such studies are Holloway et al. (2001), Martey et al. (2012), and Omiti et al. (2009). However, this model fails to consider the first decision of the farmers to market participation. For the two-stage approach, in the first stage, the households' decision on whether to participate in the market is analyzed (participation stage), and in the second stage, the intensity of participation is determined (intensity decision). The prominent econometric procedures include Heckman sample selection (the studies of Alene et al. (2008), and Boughton et al. (2007)) and double hurdle models (Abu et al., 2014; Holloway et al., 2001; Olwande & Mathenge, 2012; Reyes et al., 2012). The Heckman approach considers the two stages simultaneously and is capable of correcting selectivity bias. However, there have been inquiries regarding the appropriateness of this method for market participation according to the studies of Olwande & Mathenge (2012), Reyes et al. (2012), and Ricker-gilbert et al. (2011). On the other hand, the double hurdle model considers the two stages of participation and intensity as independent and sequential. Some studies apply a three-stage model (e.g., triple hurdle model) by introducing another stage regarding the production decision (e.g., the studies of Burke et al. (2015), Gebremedhin et al. (2018), and Kondo et al. (2019)), or the adoption of improved agricultural technologies (such as Singbo et al. (2021), and Tabe-Ojong et al. (2022)).

In the context of the transition of small-scale farmers from subsistence to market-oriented farming, or the decision of small-scale farmers on market participation and alternative market outlets, the models are mainly based on the principle of random utility (Greene, 2008). In such models, farmers make decisions on choosing among alternatives that maximize their utility. Since the dependent variables in such studies are categorical choices (market participant vs. non-participants, market outlet alternatives choices), the appropriate econometric models are discrete choice models including multivariate, multinomial, conditional and nested, and the sequential logistic or probit models (Maddala, 1986). The multinomial logit/probit model has been used extensively in marketing channel choices studies for the last several decades (K.Mutura et al., 2015; Kariyasa & Dewi, 2011; Musara et al., 2018; Nxumalo et al., 2019). The primary assumption for multinomial logit/probit and nested logit/probit models is that the individuals choose an alternative considering all the choices simultaneously; however, the process of engaging small-scale farmers in the market-oriented farming system can be seen as a sequence of pathways transitions from subsistence to semi-subsistence (decision on participate in marketing or not) and to the market-oriented farming system (decision on choosing the market outlet (at farm-gate or off-farm markets). The pioneering work on sequential decisions is proposed by Mare (1981) for the sequential logit model and Amemiya (1981) for the sequential probit model. These approaches estimate the sequential decision process and identify the main determinants of the outcome at each transition by considering uncorrelated binary choices in each transition. Mare (1981) introduced the sequential logit model for evaluating the education system and educational transition, and it has been extensively used in applied research (e.g., Buis (2017), Shavit & Westerbeek (1998), and Vaid (2004)). However, the sequential logit/probit model of Mare is criticized in some literature (Abowd & Farber, 1982; Poirier, 1980) for the uncorrelation assumption. Additionally, Cameron & Heckman (1998, 2001), and Holm & Jæger (2011) criticized the selection problem on unobserved variables that can lead to bias and inconsistent estimations. Selection on unobserved variables is that, as individuals make transitions, the selection process becomes more selective at higher transitions. This is due to the fact that selection into these groups is often non-random and is based on some observed, and unobserved factors. According to Holm & Jæger (2011), the sequential bivariate probit selection model is an appropriate approach that takes into account the correlation between unobserved variables in each transition. It also allows for controlling selection and endogeneity bias that may occur due to the correlation between unobserved heterogeneity and observed explanatory variables. To the best of our knowledge, there are quite a few literatures on small-scale farmers' decision on market participation and the choices of market outlets in sub-Saharan Africa. Seminal studies include Abu et al. (2016), who investigate the key factors that influence the market decisions (market participation and market choice) of small-scale maize and groundnut farmers in Ghana, assuming simultaneous market decisions, using a bivariate probit model, correcting for endogeneity and selectivity bias. Shete & Garcia (2011) investigated the probability of farmers participation in the agricultural credit market and estimated the parameters that determine agricultural credit market participation in Ethiopia, using bivariate probit model. As well, Ouma et al. (2010) used a bivariate probit model to analyze the banana market participation decisions of buying and selling of the households in central Africa.

3.3. Econometric approach

The process of commercialization and the market-oriented farming system can be seen as a sequence of pathways transitions from subsistence to semi-subsistence/semi-commercial and to the market-oriented farming systems. In this regard, we consider a hypothetical process consisting of three states, representing the pathway development (marketing) transitions of farming systems to commercialization (Figure 3.1). Therefore, for this model, based on our observation from the study region, we assume that all the small-scale farmers in our sample are the subsistent farmers who involve farming to produce food and agricultural products for their household consumption (subsistence farming system). These farmers face two transitions (Figure 3.1): in the first transition (decision on market participation), they make decisions to remain autarkic or willing to sell their agricultural produce (mainly their surplus) at the informal markets (farm-gate) (semi-subsistence/semi-commercial farming system). In the second transition (decision on choosing market channels), from these farmers opting to sell their agricultural products (semi-commercial), some tend to adapt to a market-oriented farmer and sell and send their produce to the formal markets (off-farm market centers) (market-oriented farming system).

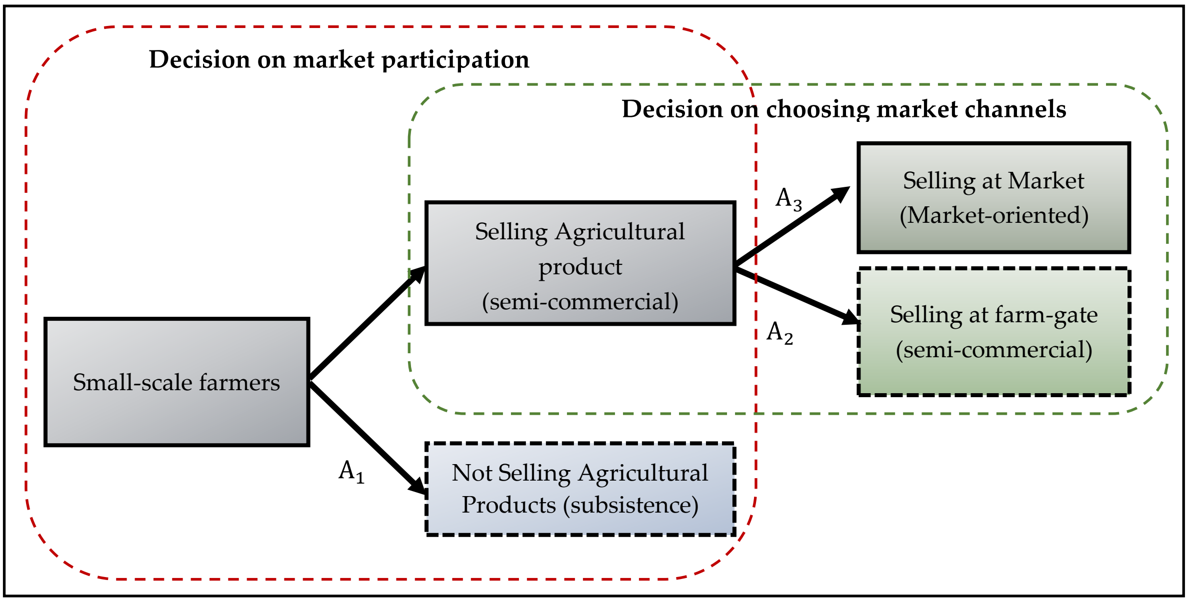

Figure 3.1. Model structure of commercialization process as sequential choice

Source: adjusted from Abu et al. (2016), Buis (2017), and (Yazdan-Bakhsh & Feil, 2021)

This sequential process of commercialization can be analyzed with the sequential bivariate probit selection model, which is an appropriate approach to estimate the probabilities of passing these transitions while identifying the main determinants of the outcome at each transition, as well as considering the endogeneity and selectivity problems. In this regard, two latent stochastic variables p_{1i}^* and p_{2i}^*, representing the propensity that individual *i* passes the first and second transitions are defined as follows:

$$p_{1i}^* = \hat{\beta}_1 x_{1i} + \varepsilon_{1i} \qquad (3.1)$$

$$p_{2i}^* = \hat{\beta}_2 x_{2i} + \varepsilon_{2i} \qquad \text{if} \qquad p_{i1}^* > 0$$

where p_{2i}^* is the conditional probability that person *i* passes the second transition, having made the first transition, and $\hat{\beta}_k$ is the association between explanatory observed variables x_{i} and the probability of passing transition k, while ε_{ik} represents the random error terms that capture the effect of unobserved variables in transition k.

As the propensities are latent variables and not observable, therefore, two binary variables indicating if individuals pass each transition are defined as $p_{ik} = 1$ if $p_{ik}^* > 0$ and 0 otherwise. In order to obtain the bivariate probit selection model (estimating a binary probit regression for each transition), we assume the error terms $(\varepsilon_{1i}, \varepsilon_{2i})$ follow a bivariate normal distribution:

$N\left\{(0,0); \begin{bmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{bmatrix}\right\}$, where ρ_{12} represents the correlation between the unobserved variables in each transition. The probability of passing each transition can be shown as equations (3.2-3.4):

$$\boldsymbol{Prob(A_1)} = \Pr(p_{i1}^* \leq 0|x_{i1}) = Pr(p_{i1}|x_{i1} = 0) = Pr(\varepsilon_{i1} < -\hat{\beta}_1 x_{i1}) = 1 - \Phi(\hat{\beta}_1 x_{i1}) \rightarrow$$

Subsistence farming system (3.2)

$$\boldsymbol{Prob(A_2)} = \Pr((p_{i1}^* > 0|x_{i1}), (p_{i2}^* \leq 0|x_{i2})) = Pr((p_{i1}|x_{i1} = 1), (p_{i2}|x_{i2} = 0)) = Pr(\varepsilon_{i1} > -\hat{\beta}_1 x_{i1}, \varepsilon_{i2} < -\hat{\beta}_2 x_{i2}) = \Phi(\hat{\beta}_1 x_{i1}, -\hat{\beta}_2 x_{i2}, -\rho_{12}) \rightarrow \text{ Semi-subsistence farming system} \quad (3.3)$$

$$\boldsymbol{Prob(A_3)} = \Pr((p_{i1}^* > 0|x_{i1}), (p_{i2}^* > 0|x_{i2})) = Pr((p_{i1}|x_{i1} = 1), (p_{i2}|x_{i2} = 1)) = Pr(\varepsilon_{i1} > -\hat{\beta}_1 x_{i1}, \varepsilon_{i2} > -\hat{\beta}_2 x_{i2}) = \Phi(\hat{\beta}_1 x_{i1}, \hat{\beta}_2 x_{i2}, \rho_{12}) \rightarrow \text{ Market-oriented farming system} \quad (3.4)$$

Considering these probabilities for each outcome, the sequential bivariate probit model allows all the parameters in the two transitions estimated through the Maximum likelihood estimation (MLE) technique. The likelihood function is:

$$L = \prod_{A_3} \Phi(\hat{\beta}_1 x_{i1}, \hat{\beta}_2 x_{i2}, \rho_{12}). \prod_{A_2} \Phi(\hat{\beta}_1 x_{i1}, -\hat{\beta}_2 x_{i2}, -\rho_{12}). \prod_{A_1} \{1 - \Phi(\hat{\beta}_1 x_{i1})\} \quad (3.5)$$

This model estimates the relationship between explanatory variables, the probability of passing each transition, and the effects of each explanatory variable on the outcome. The final outcome in our study is predicting the likelihood of selling agricultural products at the off-farm markets and the effect of explanatory variables (e.g., using modern irrigation) on the final outcome as the marginal effect on the probability of selling at off-farm markets.

To obtain the unbiased and consistent estimates for the coefficients in our model, two empirical issues must be addressed: self-selection and the endogeneity (Heckman, 1978, 1979). The sequential bivariate probit model is capable of solving these two problems.

1) Unobserved heterogeneity and selectivity bias:

The error terms in the two steps are assumed to be independent, identically distributed, and uncorrelated conditional on the explanatory variables and unobserved factors. According to Cameron & Heckman (1998, 2001), the unobserved heterogeneity can lead to biased estimates. For testing the assumption of conditionally uncorrelated errors, we follow Heckman's approach for sample selection bias (Wooldridge, 2010). We test the selectivity bias by considering the rho (ρ) parameter in the model between the error terms. If the estimate of ρ_{12} is statistically significant, we reject the null hypothesis of the conditionally uncorrelated error terms and re-estimate the model and correct the standard errors. If not significant, we do not have a selectivity bias, and therefore, the estimated coefficients are consistent. Respectively, we impose an exclusion restriction (ER) on the dependency ratio variable in the second transition.

2) Endogeneity of an explanatory variable:

The farm households are heterogonous regarding asset ownership, access to market information, and other observable and non-observable factors that can affect the market participation and the market-channel decision, as well as adopting new technologies (e.g., irrigation system). Adopting new technologies (irrigation systems) is likely endogenous, while it has a potential reverse causality between adopting irrigation and commercialization. Adopting a new irrigation system can lead to higher yields and, therefore, more possibility to participate in marketing and gain more income, which may result in adopting new technologies. Thus, the role of unobserved factors can lead to endogeneity issues. In this regard, first we estimate a probit regression of adopting irrigation system on explanatory variables and the potential instrumental variables (IV). The correlation between the residuals from the estimated exogenous explanatory variable and the residuals of our sequential process model provides a valid test for the null hypothesis of exogeneity. If we rejected the null hypothesis, we should include them in the model to correct for endogeneity. We use access to credit and water resources (public and private such as lakes, and boreholes) as two instrumental variables. We believe that these variables are valid instruments, as small-scale farmers with access to credits and the availability of water resources are more likely to invest in modern irrigation technology. Therefore, these two variables indirectly affect our dependent variables in each transition through the adoption of a new irrigation system.

3.4. Data and descriptive statistics

3.4.1. Data collection and farm survey

Data for this study were collected in 2019 from small-scale farmers through a survey in the Limpopo Province of RSA. The description of the study area is explained in section 1.2.

Farmers were interviewed in person using a structured questionnaire. Information on production outputs and inputs, socio-economic and demographic data, farm and household characteristics, as well as the marketing of agricultural products during the 2018-19 cropping season were collected.

Farmers were asked to list and rank the market channels through which they sell their crop and livestock products. The main market outlets they reported for selling their products can be categorized into formal and informal market channels. Informal markets involve decentralized distributions in that the small-scale farmers sell their produce directly to the consumers at the farm gate, roadside stands, or local communities. Mainly in these market channels, the prices are determined by the buyers. In contrast, formal markets such as supermarkets and urban wholesale markets (fresh fruit and vegetable produce markets) are characterized by high-quality produce, food safety standards, volume and consistency in supply. Operations in these markets are regulated by law, and the product prices are determined based on the quality of the products and widely fluctuate according to the market demand and the supply situation. The closest wholesale markets to our selected villages were Pretoria and Johannesburg fresh markets. Each village had a collection spot where the farmers' produce was collected and transferred to these markets.

From 215 household head respondents, three were excluded because of incomplete information. The number of farm households that produced only for household consumption and did not participate in marketing was 71 farmers, and 141 participated in marketing and initially sold some of their farm produce at informal markets. Among farmers who participated in marketing, 44 sent their products to the collection spots to sell in formal markets.

3.4.2. Household socio-economic, farm and institutional characteristics

Descriptive information on household and farm characteristics for the sample households are displayed in Table 3.1. The choice of explanatory variables affecting the outcomes of our analysis is obtained from extant literature (e.g., Amrouk et al., 2013; Mdlalose, 2016; Musara et al., 2018). With regard to household characteristics, we include the socio-economic characteristics of the households, which can affect the decisions on participating in marketing, as well as the choice of the market channel. These variables include age, gender, education, risk attitude, and off-farm occupation of the household head. Households' dependency ratio indicates the proportion of the number of household members under the age of 15 and above 65 years old to the number of all household members living together. We hypothesize that the dependency ratio influences the farmers' decision to participate in marketing, and a higher dependency ratio is expected to lead to a higher proportion of self-consumption of the products. The data show highly significant differences between the groups. Concerning farm and institutional characteristics, we include the cultivation area, use of modern irrigation technology such as drip irrigation and sprinklers, access to extension services, and farmer organizations. All these variables significantly differ between the groups of subsistence farmers and those who participate in marketing, as well as the farmers selling at informal markets (farm-gate suppliers) and those sent to formal markets (market- center supplier). Farmers that tend to be market- center suppliers have larger cultivated land and modern irrigation technology. The size of land used for crop cultivation among small-scale farmers in the study area varied between 0.25 to 22 ha, with an average of 3 ha being allocated to cultivate crops to complement income and self-consumption.

Farmers in the study region are generally involved in producing various commodities such as livestock, field crops, and horticulture (fruits and vegetables). Grain legumes, including cowpea, peanuts, Bambara groundnut, and beans, are part of the traditional diet of South Africans and hence predominantly produced for own and family consumption. Some farmers have transformed from growing staple crop production to more market-oriented crops such as fruits and vegetables.

Since different types of field crops, fruits, and vegetables are produced, measured in different units, and sold at different prices, the output quantities and incomes are not easily comparable. Also, farmers were not able to report the exact quantity measures for each produced crop and vegetable type. Therefore, the dummies of having legumes and fresh products (fruits and vegetables) are included in the model, as well as crop diversity as a proxy of diversification of crops at the farm (if they have one type crop (=1), two types (=2) or more crops (=3) on their field). Since small-scale farmers are mainly risk averse, diversification of crops can help farmers to be more stabilized in production and earning in the face of risks (Kondo et al., 2019). The amount of livestock owned is calculated based on the tropical livestock unit (TLU) considering the assigned weights: cattle 0.70, pigs 0.20, sheep and donkey 0.1, and poultry 0.01 (Jahnke, 1982). We proxy the transaction cost variables by considering access to market information, owning transport assets, access to extension services, and membership in the farm organizations and cooperation with other farmers. These variables can account for the opportunity costs of producers to spend time searching and accessing information, as well as the time spent organizing transport to convey their agricultural products to off-farm markets (Mabuza et al., 2014). Efficient market information and marketing facilities enable farmers to adjust their production and make planting decisions based on consumer demand. Marketing information is one of the significant constraints of commercialization among small-scale farmers, especially in rural communities. This information consists of product prices, locations of effective demand, the preferred quality of products for buyers, alternative market channels, and how to negotiate with the buyers. Own means of transportation (transportation assets such as motorcycle, bicycle, car, truck, and donkey) is expected to have a positive influence on off-farm marketing, as it facilitates the spatial distribution of products to different markets and from rural to urban areas (Tarekegn et al., 2017).

Small-scale farmers can improve their farming skills mainly by getting support through extension services and farmer organizations. Extension services provide information on farming practices, new technologies, and input applications (Krishnan & Patnam, 2014; Xaba & Dlamini, 2015).

Table 3.1. Household socio-economic, farm and institutional characteristics, by different groups of farmers

	Total sample (N=212)	Subsistence farmers (N=71)	Market participation (N=141)	Farm-gate supplier (N=97)	Market-center supplier (N=44)
Household characteristics					
Household head age (years)	66.45 (11.19)	69.61*** (10.26)	64.86 (11.33)	66.63††† (10.15)	60.98 (12.89)
Household head male (dummy)	0.52 (0.50)	0.44* (0.50)	0.56 (0.50)	0.45††† (0.50)	0.80 (0.41)
Household head education (years)	4.76 (5.04)	2.86*** (3.66)	5.72 (5.37)	4.40††† (4.23)	8.61 (6.44)
Dependency ratio (%)	0.52 (0.26)	0.65*** (0.25)	0.46 (0.24)	0.51††† (0.23)	0.36 (0.25)
Access to credit (dummy)	0.099 (0.30)	0.028*** (0.17)	0.14 (0.34)	0.08††† (0.28)	0.25 (0.44)
Off-farm employment (dummy) head	0.22 (0.41)	0.27 (0.44)	0.19 (0.39)	0.12††† (0.33)	0.34 (0.48)
Own means of transportation (dummy)	0.33 (0.47)	0.18*** (0.39)	0.40 (0.49)	0.27††† (0.44)	0.70 (0.46)
Risk attitude (1-10 scale)	4.29 (2.85)	3.69** (2.48)	4.67 (2.98)	4.21†† (3.08)	5.70 (2.47)
Farm characteristics					
Farm cultivated area (hectare)	3.02 (3.33)	1.96*** (1.55)	3.55 (3.80)	2.59††† (2.40)	5.65 (5.25)
Use of modern irrigation technology (Dummy)	0.22 (0.42)	0.07*** (0.26)	0.30 (0.46)	0.18††† (0.38)	0.57 (0.50)
Fresh production (vegetable and fruits) (dummy)	0.75 (0.43)	0.49*** (0.50)	0.89 (0.32)	0.87 (0.34)	0.93 (0.25)
Legumes production (dummy)	0.59 (0.50)	0.82*** (0.39)	0.43 (0.50)	0.49†† (0.50)	0.30 (0.46)
Livestock owned (TLU)	3.97 (7.04)	1.33*** (4.50)	5.30 (7.70)	4.14††† (6.47)	7.84 (9.48)
Crop diversity	2.46 (0.58)	2.31*** (0.49)	2.54 (0.60)	2.60† (0.55)	2.41 (0.69)
Cooperation with farmers /organization member	0.40 (0.49)	0.24*** (0.43)	0.48 (0.50)	0.42†† (0.50)	0.61 (0.49)
Access to extension services (dummy)	0.69 (0.46)	0.56*** (0.50)	0.76 (0.43)	0.82††† (0.38)	0.61 (0.49)
Market information (dummy)	0.25 (0.43)	0.04*** (0.20)	0.35 (0.48)	0.13††† (0.34)	0.82 (0.39)
Experiencing extreme years (dummy)	0.89 (0.32)	0.97*** (0.17)	0.84 (0.36)	0.94††† (0.24)	0.64 (0.49)

Note: The statistical significance of the differences between the mean values of the different groups are as follows: * Significant at 10% level, ** Significant at 5% level, and *** Significant at 1% level for the difference between market and non-market participation farmers; † Significant at 10% level, †† Significant at 5% level, and ††† Significant at 1% level for the difference between farm-gate suppliers and market center suppliers.

Extension services in RSA are provided by the Department of Agricultural and Rural Development of the Province through their trained staff. They play an essential role in supporting small-scale farmers in the country and are therefore noted in various studies as one of the main influences on farm performance (Dube & Guveya, 2016; Magingxa et al., 2009; Murugani & Thamaga-Chitja, 2018). Around 89% of the farmers received advice and other support (e.g., input supplies, mechanization, etc.) from the local extension agents regarding their crop production activities. Farmer organizations, such as non-governmental organizations (NGOs) and community-based organizations (CBOs), are crucial in improving the commercialization behavior of small-scale farmers by linking small-scale farmers to high-value distant markets through technical and institutional support (Rao et al., 2012), reducing transaction costs, managing uncertainties, and exchanging market information (Yaseen et al., 2018). These organizations increase small-scale farmers' incentives and assertiveness for farming activities and market participation by providing information, credit, appropriate transports, and storage facilities to convey fresh agricultural produce to markets. Of our sampled farmers, around 40% indicated that they were a member of a farmer's organization.

In terms of off-farm occupation, households that deliver their products to the market center are relatively more likely to engage in off-farm work than other households. While this group comprises mostly youth farmers, they are more likely to undertake off-farm activities than older-age farmers. Most of the off-farm activities undertaken by the households in our sample are wage jobs outside the farming activities, particularly renting out agricultural machinery and equipment, holding family shops, working as constructor workers, and teachers.

Access to credit from formal financial institutions is a significant limitation for the majority of the South African small-scale farmers who are mostly old aged and have mainly unreliable and low income, undocumented property, and no formal credit history (Murugani & Thamaga-Chitja, 2018; Myeni et al., 2019; von Loeper et al., 2016). This variable would indirectly affect the decision on market participation and market channel choices and through its effect on the probability of adopting new technologies such as modern irrigation systems and thus include only in the technology adoption equation. As well, access to water sources has a direct effect on adopting modern irrigation systems and, through this, can influence the decision on market participation and market channel choices.

3.5. Results and discussion

The following analysis represents the results of the sequential bivariate probit selection model for small-scale farmers regarding the commercialization transition, testing endogeneity, and selection bias.

3.5.1. Endogeneity and selection bias tests: Unobserved heterogeneity and error correlation across equations

Table 3.2 presents the results of the endogeneity and selection bias tests (correlation between the residuals). For the endogeneity test of irrigation adoption, the two variables of access to credit and water sources affect the likelihood of adopting modern irrigation technology (Table 3.4. in Appendix (S. 3.7)), which validates the choice of these two instruments[7]. Since the correlation between the derived residuals is not statistically significant in any of the transitions, thus, this test fails to reject the null hypothesis of exogeneity of adopting modern irrigation. Therefore, we can exclude the endogeneity part from the model based on Ricker-gilbert et al. (2011). For the selection bias and interaction between transitions (choices of alternatives), the estimates of the correlation between the two residuals from the first and second transition are not statistically significant; thus, we fail to reject the null hypothesis of uncorrelated unobserved variables, which is the indication of no selection bias estimates in the model.

Table 3.2. Endogeneity and selection bias tests

Residual for	Coefficient (robust std. err.)	p-value	Conclusion
First and second transitions	-0.52 (0.55)	0.35	No correlation not rejected
Adoption and first transition	0.04 (0.41)	0.92	Exogeneity not rejected
Adoption and second transition	0.13 (0.64)	0.84	Exogeneity not rejected

3.5.2. Factors affecting the decisions to commercialization

Table 3.3 shows the results of the sequential bivariate probit selection model. The coefficients represent the effect of the explanatory variables on the probability of passing each transition[8].

In order to be easier to interpret, we present the average marginal effects at the mean value of the continuous variables. The results are as follows:

First transition: Subsistence to Semi-Commercial farming

The first transition from subsistence to semi-commercial farming represents the small-scale farmers' decision to participate in marketing their agricultural produce.

From the household characteristics, the dependency ratio had a statistically significant negative relationship with the decision on market participation. The result implies that it is more likely that the household farms with a higher proportion of dependent members (aged under 15 and above 65) tend to remain subsistence and produce mainly for their family members than contribute to selling their produce. This result is in line with the study of

[7] The two selected instrumental variables were not statistically correlated with the first and second transitions.

[8] The probability of passing each transition is presented in Table 3.5. in the Appendix (S. 3.7).

Randela et al. (2008), who found that the dependency ratio negatively affected the market participation of small-scale cotton farmers in RSA. Similarly, the results of Bahta & Bauer (2012) indicated a decrease in the likelihood of food and horticultural crop market participation between small-scale farmers in RSA by increasing the dependency ratio. Off-farm occupation of the household head showed a statistically significant negative relationship with market participation. It reveals that farmers with more profitable off-farm activities and income are less likely to participate in marketing and selling their produce. According to Tabe-Ojong et al. (2018), small-scale farmers that engage in off-farm activities and earning income would want to concentrate more on increasing their off-farm income in order to increase their consumption rather than investing in improving the farm sector; therefore, the production and marketing will decrease. This finding is consistent with the study of Gebremedhin et al. (2018) and Woldeyohanesa et al. (2017) regarding small-scale commercialization in Ethiopia, Alene et al. (2008) and Omiti et al. (2009) in Kenya, and Seng (2016) in Cambodia.

From the institutional factors, extension services, and farmer associations were both statistically highly significant at the 1% probability level and had the expected positive impact on the likelihood of market participation. This can be the result of their role in education and farm training to increase the management capabilities of the farmers and improve farmers' information on production and marketing.

From the farm characteristics, our results suggest that small-scale farmers who cultivate grain legumes were more likely to use them for their household consumption rather than selling them. In general, small-scale farmers grow grain legumes as a food security crop, in rotation with maize, to increase soil fertility and consume them as the staple food and the main source of protein in their diet.

Furthermore, the small-scale farmers with livestock were potentially more likely to participate in marketing by 2%. This implies that the small-scale farmers that diversify their agricultural production with crop and livestock activities tend to maximize their returns and spread the risks across the two enterprises. The results are consistent with the studies of Woldeyohanesa et al. (2017) in Ethiopia, and Kondo et al. (2019) for smallholder cowpea producers in Ghana.

In terms of adopting modern irrigation technology, the coefficient is expectedly positive and significantly related to the transition from subsistence to semi-commercial farming. On average, adopting a modern irrigation system leads to an increase in the likelihood of small-scale farmers participating in marketing by 16%. This implies that farmers with advanced irrigation systems have higher yields and product quality than those without and therefore tend to sell their agricultural produce.

Table 3.3. Average marginal effects on small-scale farmers' transition probabilities

	First transition	*Second transition*	
	Decision on Market Participation (Selling Agricultural products)	*Informal market channel*	*Off-farm formal market channel*
Household characteristics			
Household head age (years)	0.001 (0.003)	-0.001 (0.003)	0.002 (0.002)
Household head male (dummy)	-0.05 (0.06)	-0.05 (0.06)	-0.0002 (0.04)
Household head education (years)	0.01 (0.01)	0.005 (0.007)	0.003 (0.004)
Dependency ratio (%)	-0.26**(0.13)	-	-
Off-farm employment (dummy) head	-0.20***(0.08)	-0.16 (0.08)	-0.01 (0.04)
Risk attitude (Likert scale)	0.01 (0.01)	0.007 (0.01)	0.001 (0.006)
Own means of transportation (dummy)	0.02 (0.07)	-0.08(0.07)	0.12 **(0.05)
Farm characteristics			
Farm cultivated area (hectare)	0.02 (0.01)	0.004(0.01)	0.01**(0.01)
Use of modern irrigation technology (Dummy)	0.16***(0.06)	0.06(0.08)	0.10**(0.05)
Fresh production (vegetable and fruits) (dummy)	0.15 (0.12)	0.03 (0.12)	0.12**(0.06)
Legumes production (dummy)	-0.20**(0.08)	-0.21**(0.08)	0.04 (0.04)
Livestock owned (TLU)	0.02*(0.01)	0.01**(0.01)	-0.001 (0.003)
Crop diversity	0.10 (0.08)	0.15**(0.08)	-0.08**(0.04)
Cooperation with farmers /organization member	0.21***(0.05)	0.11**(0.06)	0.09**(0.04)
Access to extension services (dummy)	0.16***(0.06)	0.20*** (0.06)	-0.08 (0.05)
Market information (dummy)	0.18**(0.07)	-0.23***(0.08)	0.45***(0.08)
Experiencing extreme years (dummy)	-0.20***(0.07)	-0.06 (0.10)	-0.14*(0.08)
Number of observations	212		
Selected	141		
Non-selected	71		
Wald chi2 (16)	63.10		
Prob > chi2	0.00		
Log pseudolikelihood	-103.25		

Notes: Coefficient estimates are shown with Delta-Method standard errors in parentheses for the average marginal effects of the first transition and second transition conditional of passing the first transition, at means of continues variables.

*Significant at the 10% level, **significant at the 5% level, ***significant at the 1% level.

Furthermore, access to market information significantly increases the probability of passing the first transition by 18%. This aligns with the findings of Abu et al. (2016), who argue that access to market information persuaded small-scale farmers to make marketing decisions.

Second Transition: Semi- Commercial farming to Market-oriented farming

Conditional of passing the first transition, the second transition is the decision of the farmers to continue selling their produce at farm-gate and informal or sending them to the off-farm formal markets. According to our results, possession of own means of transportation had a significant positive effect on the decision of farmers to participate in off-farm market channels. Since the small-scale farmers live in remote rural areas, possession of their means of transportation markedly reduces both the transaction cost and marginal cost of movement to distant markets or collection centers. The importance of transportation in conveying fresh agricultural products to distant markets is explained in the study of Mdlalose (2016) for the smallholders in RSA.

Regarding farm characteristics (Table 3.3), cultivated area and the use of modern irrigation technology are statistically highly significant at the 5% probability level on the tendency of farmers to sell their produce at off-farm markets. This can be related to the larger quantities and higher qualities of the agricultural products, which are the main requirements for selling at the off-farm formal markets. The estimated coefficients of livestock ownership and crop diversity show that the farmers mainly tend to use them as diversification strategies and income complements in order to mitigate the potential negative impacts of risks associated with production by selling them at the farm gate. In contrast, market-oriented farmers tend to be somewhat more specialized, particularly in fresh vegetable and fruit production (positive and highly significant). Commercialization and market-oriented farming encourages the specialization of farmers in producing crops that have a comparative advantage (Muamba, 2011), and are compatible with the market demands, particularly for the small-scale farmers in RSA with limited niche markets. Therefore, it leads to ensure the efficient use of resources (Rao et al., 2012), and enhances the productivity growth and higher economic growth of farmers.

One of the main differences between farmers selling their agricultural produce at off-farm marks and their counterparts selling at farm-gate and informal markets is the access to market information, with statistically highly significant at a 1% level of probability. According to the results, small-scale farmers with access to market information have a 45% higher probability of being market-oriented than those without access to market information. This confirms the findings of Tabe-Ojong et al. (2022) on the commercialization of subsistence chickpea producers in Ethiopia, which showed that access to market information significantly influenced the decision of farmers to participate in formal markets.

Being a member of farmer organizations and cooperatives with other farmers significantly enhances small-scale farmers' commercialization and market participation by accessing updated information and market opportunities, and facilitating transportation to markets (farm-gate or off-farm markets). Farmer organizations are trying to connect small-scale farmers in rural areas with distant markets via collection centers in selected villages. Collective action by farmer organizations would promote market-oriented farming by facilitating farmers' bargaining, coordinating, and reducing the uncertainties of farmers' interactions with markets (Bahta & Bauer, 2012). This aligns with previous empirical evidence from the literature that farmer organizations intended to facilitate access to higher-return market channels (Abu et al., 2016; Bachke, 2019; Barrett, 2008).

The significant positive impact of extension agent supports on farm-gate marketing and negative, but not significant effect on selling at market centers indicated that farmers with access to extension services are 20% more likely to sell at farm-gate. While we expected the farmers with access to extension services would be more market-oriented, the results are in line with the finding of Abu et al. (2016) for the small-scale farmers in Ghana, and they indicated the ineffectiveness of extension services in Ghana as the result of this issue. According to previous studies, the small-scale farmers in RSA do not receive adequate assistance from government and extension services on sustainable crop production methods, sufficient information and support for marketing (DAFF, 2018; Hlatshwayo et al., 2022; Xaba & Dlamini, 2015). Therefore, this results in farmers relying mainly on their traditional methods to produce staple crops for their own consumption and selling the surplus at the farm gate and informal markets. Finally, experiencing extreme years such as drought, pests, and disease expectedly has a significant negative effect on both transitions of market participation and selling to the off-farm formal markets. Compared to neighboring regions, agriculture in the Limpopo Province of RSA is exposed to a relatively higher climatic variability (Hitayezu et al., 2014); this province experiences a prolonged dry spell during the winter season and irregular rainfall patterns during the summer season (October-April). This climate variability is often influenced by the El Niño-Southern Oscillation (ENSO) phenomenon (Mosase & Ahiablame, 2018).

3.6. Concluding remarks

The involvement of small-scale farmers in marketing can play a critical role in enhancing food security and reducing poverty by generating income and rural employment. Considering the sequential process of small-scale commercialization (the decision of farm households to sell their agricultural products on output markets profitably), the study employed the sequential bivariate probit selection model while investigating the main determinants influencing farmers' choice of market participation and marketing channels, and thereby help inform policy decisions. A cross-sectional data of 212 farm households were sampled from five villages in the Limpopo Province of RSA in 2019.

The transition of small-scale farmers from subsistence to the high-level market-oriented farming system in rural areas of RSA can lead to substantial changes in the organization of farm production and institutional support. In this regard, the agricultural produce choices could be determined by a comparative advantage of individual farms and compliance with market requirements. This leads to more specialization and increased product quality, which results in the efficient allocation of resources (e.g., capital, land, and labor) and enhances the productivity growth and higher economic growth of farmers. Furthermore, technology adoption is one of the main determinants of transition by influencing the total factor productivity growth and increased production.

Membership in farmers' organization and cooperatives with other farmers are crucial in improving the commercialization behavior of small-scale farmers by reducing transaction costs such as searching for trading partners, obtaining and verifying market information, negotiating, transferring the product (e.g., transport, storage, distance, access to roads and their condition) and communication infrastructure. Agricultural extension services have a considerable contribution to improving the production development of small-scale farmers by imparting knowledge on farming practices, new technologies, as well as enhanced management skills. This allows farmers to improve their production and persuade them to participate in marketing and selling their produce at farm-gate. Yet, there needs to be more support and assistance in facilitating small-scale farmers' economic development by marketing at formal off-farm markets. Appropriate government policies and strategies can simplify the process of the small-scale farmers' transition to market-oriented farming.

Considering the negative relationship between off-farm employment and market participation of small-scale farmers, it is important to address that small-scale farmers tend to integrate into market-oriented agriculture, mainly for the need for income, employment, and food security.

While this study offers insights on factors influencing the transition of sample of small-scale farmers from subsistence to market-oriented farming systems in selected areas in the Limpopo Province of RSA, further research is needed to bolster and broaden the evidence base.

3.7. Appendix

Table 3.4. shows the endogeneity estimates of the adopting modern irrigation system.

Table 3.4. Endogeneity estimates of the adopting modern irrigation technology

	Coefficient (Robust Std. Err.)
Household head age (years)	-0.0004 (0.002)
Household head male (dummy)	0.06 (0.06)
Household head education (years)	0.005 (0.006)
Risk Attitude (Likert scale)	0.02 **(0.008)
Off-farm employment (dummy) head	0.02 (0.07)
Access to credit (dummy)	0.36** (0.17)
Farm cultivated area (hectare)	0.005 (0.008)
Fresh production (vegetable and fruits) (dummy)	0.05 (0.09)
Legumes production (dummy)	0.03 (0.06)
Livestock owned (TLU)	0.0009 (0.003)
Crop diversity	-0.02 (0.07)
Water source	
✓ Rain-dependent	-0.08 (0.07)
✓ Tap water	0.35 **(0.13)
✓ Public and private dam, lake, borehole	0.19* (0.11)
Access to extension services (dummy)	0.006 (0.06)

The probability of passing each transition from our sample is presented in Table 3.5.

Table 3.5. Probability of passing each transition

Transition probabilities	**Coefficient (Delta-method std. err.)**
A_1: *Subsistence farming* $(1 - p_1)$	0.30 (0.03)
Semi-commercial farming system (p_1)	0.66 (0.02)
A_2: *Marketing at farm-gate* $(p_1(1 - p_2))$	0.46 (0.02)
A_3: *Market-oriented farming system* $(p_1 p_2)$	0.22 (0.02)

4. Maize Production Efficiency of Small-Scale Farmers Under Risk: Evidence from South Africa

This chapter investigates small-scale farmers' maize production efficiency in the Limpopo Province of South Africa by explicitly considering multiple current and future perceived production risks in the region. In this regard, a parametric efficiency analysis in the form of a single-step Stochastic Frontier Analysis is applied to cross-sectional survey data collected in 2019 in Limpopo Province, RSA. The model is capable of considering a wide range of variables including production inputs, farm structures and socio-economic/socio-demographic characteristics. Moreover, it empirically investigates the effects of the main production risks on the level and variability of maize production. In this regard, we consider a dual heteroskedastic production frontier by controlling for heteroscedasticity in both error terms, which has not been done in previous studies of efficiency analysis of small-scale maize farmers in RSA. Likewise, the analysis allows us to estimate the sensitivity of the farmer's efficiency level with respect to the change of corresponding factors by calculating the marginal effects. By identifying the determinants of production efficiency, this chapter will offer indications for both small-scale farmers and politicians on how to improve their maize production systems and, by this, help tackling the issues of food insecurity and rural poverty in the region.

Keywords: *Technical efficiency, production risk, single-step Stochastic Frontier Analysis, double heteroscedasticity, small-scale maize farmers*

This essay is co-authored by Bernhard Brümmer, Reimund Paul Rötter, Kingsley Kwabena Ayisi, Wayne Twine, Jan-Henning Feil. The contribution of each author are as follows: **Sara Yazdan-Bakhsh:** Conceptualization, Software, Formal analysis, Investigation, Data curation, Writing - Original Draft, Writing - Review and Editing, Visualization; **Bernhard Brümmer:** Conceptualization, Methodology, Data curation, Validation; **Reimund Paul Rötter:** Conceptualization, Validation**; Kingsley Kwabena Ayisi:** Conceptualization, Validation, Project administration; **Wayne Twine:** Validation; **Jan-Henning Feil:** Conceptualization, Methodology, Data curation, Validation, Resources, Supervision, Project administration

4.1. Introduction

The agricultural sector, as the main source of food and livelihood, is amongst the most important economic sectors in African countries (Kolawole et al., 2014). Yet, it is challenged by the need to provide sufficient food for a teeming population with limited resources available and faced with accelerating climate change (Lachaud et al., 2022). For these reasons, food insecurity remains a serious concern in Sub-Saharan Africa (Kuyah et al., 2021). Southern Africa has been exposed to frequent severe droughts throughout the last decades, which have been exacerbating in recent years following the El Niño event during the 2015/16 cropping season (Hove & Kambanje, 2019). Droughts, which are characterized by prolonged dry periods and irregular precipitation patterns, pose a high risk to agricultural production by contributing to other agricultural risks such as the incidence of invasive pests and diseases (Setimela et al., 2018), as well as the shortage of water resources. Agriculture in the RSA is characterized mainly by a dual structure, comprising a relatively small group of large-scale commercial farms that are well-developed and capital intensive, as well as a high number of poorly-developed and resource-limited small-scale farms, predominantly in the rural former apartheid homeland areas (Gwebu & Matthews, 2018). The small-scale farmers account for around 98% of all farmers in RSA and contribute to 70% of the agricultural production (2.5 million smallholder or household farmers compared to 35000 commercial growers) (Lorna Born et al., 2020).

Maize dominates the RSA food system, being both the vital dietary staple crop and feed grain, and therefore, the most prevalent agricultural crop in the smallholder farming system (Obi & Ayodeji, 2020). The majority of small-scale farmers cultivate maize mainly for subsistence purposes, hence the levels of production and supply of maize are important indications of food security. Over the past century, South African maize production experienced some significant changes (Greyling & Pardey, 2019). Although small-scale farmers played an important role in producing maize in the country, historical trends in maize production among both commercial and small-scale producers in RSA show that the share of small-scale farmers' maize production and maize area has decreased substantially over the years (from 20.6% of the total maize production and 40.6% of total maize area in 1942 to 6.3% of production and 13.0% of the area in 2015) (Greyling & Pardey, 2019). Accordingly, the maize yield gaps between commercial and small-scale maize producers have increased over time in the last 20 years (Figure 4.1. based on data from SAGiS (2022)).

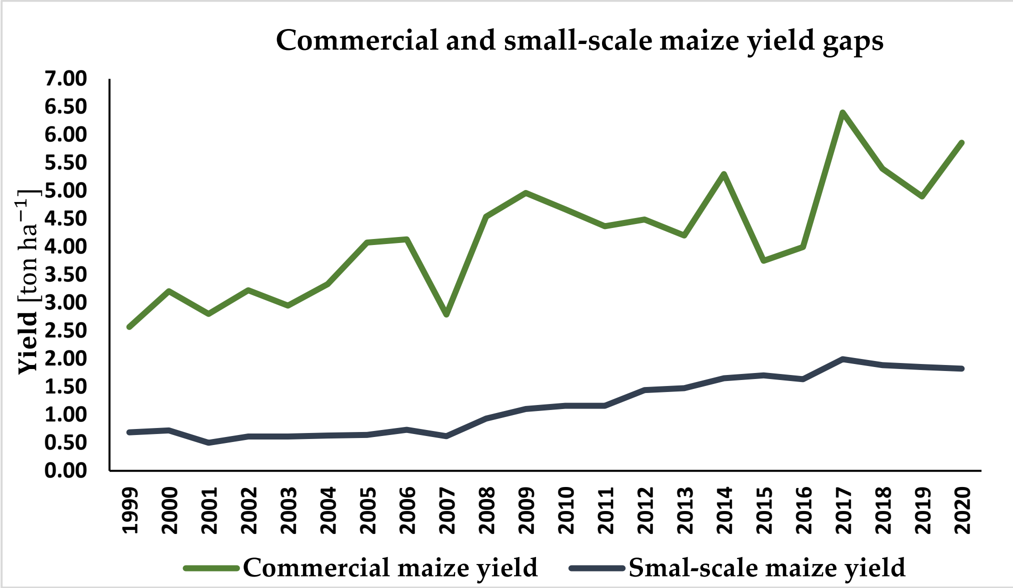

Figure 4.1. Maize yield gaps between commercial and small-scale farmers in the past 20 years

In addition to environmental stresses, agricultural production in general and maize cultivation, in particular, are confronted with several macro and micro-structural constraints in southern Africa (Mpandeli & Maponya, 2014). Some of these constraints are: inefficient policies and extension system supports, limited access to agricultural credit, inadequate infrastructural facilities such as transportation and communication, along with the lack of proper incentives and management practices (Baloyi et al., 2012; Branca & Perelli, 2020; Mpandeli & Maponya, 2014). These constraints have, particularly in recent years, resulted in reduced yields and harvest failures (Hove & Kambanje, 2019), which have aggravated the issue of food insecurity and poverty, especially among smallholder farmers who often practice subsistence farming. Regardless of the governmental support and various strategies implemented to boost the agricultural sector in RSA in recent years, the smallholder maize farmers still perform far below their potential production capacity and with low productivity (Baloyi et al., 2012).

Improving agricultural productivity, and thus crop yields, can generally be achieved by efficient use of available farm resource endowments and adopting technologies, which are mainly associated with the farm characteristics, as well as socio-economic and institutional factors. The concept of technical efficiency (TE) plays a major role in agricultural productivity growth and is widely discussed in the literature (Kofi & Adams, 2020). It provides information on the managerial ability (Bravo-Ureta et al., 2007) of the farmers and their potential to improve output by utilizing existing farm resources and technologies. In addition, it allows for the identification of the main factors affecting the efficiency level of farmers (Kumbhakar et al., 2015). According to various studies in the literature, improvement in the efficiency levels of agricultural production is the main component of agricultural productivity growth which plays a vital role in alleviating the issue of food insecurity in developing economies (Asmare et al., 2022; Kolawole Ogundari, 2014).

A substantial number of empirical studies have focused on agricultural productivity and efficiency analysis in Sub-Saharan Africa and specifically in RSA. Seminal studies include (Aye et al., 2018; Lovo, 2011; Mango et al., 2015; Mwalupaso et al., 2019; Pauw et al., 2007; Piesse et al., 1996; Speelman et al., 2008). Depending on the context of the study (e.g., types of production and farms, regions), data sets (e.g., cross-sectional or panel data), as well as methodological approaches (e.g., non-parametric and parametric), these studies vary in assessing productivity, efficiency levels and its corresponding determinants (Ogundari & Brümmer, 2011). For instance, Mwalupaso et al. (2019) used cross-sectional farm household data in maize production from Zambia to analyze the association between mobile phone use and TE. Aye et al. (2018) determined the sources of efficiency (e.g., capital accumulation, social welfare, land quality and research and development (R&D) expenditure) in South African agriculture. Lovo (2011) analyzed the overall TE of small-scale farmers in KwaZulu-Natal province of RSA and revealed the presence of large inefficiencies with an average score of 41%. Kibirige et al. (2016) investigated the TE in small-scale maize production in Eastern Cape province of RSA and revealed an average efficiency score of 44%.

In terms of methodological approaches, the majority of the aforementioned studies implemented non-parametric two-stage Data Envelopment Analysis (DEA) along with ordinary least square estimation (OLS) models (e.g. Aye et al., 2018; Lovo, 2011; Speelman et al., 2008). This approach does not allow the incorporation of random measurement errors and random shocks such as weather shocks and, hence, does not consider production risks. To address this issue, some studies have since then conducted parametric Stochastic Frontier Analysis (SFA) by using a standard two-step approach for estimating the production function and the determinants of efficiency (e.g. Mukete et al., 2016; Obi & Ayodeji, 2020). So far, only few studies that deal with farming in southern Africa have implemented a single-step SFA (e.g. Onu & Echebiri, 2019; Theriault & Serra, 2014). However, these do not address the, for this region very important, branch of small-scale farmers' maize production and the respective potential influence of weather-related risks.

This chapter attempts to fill this research gap by investigating the TE of small-scale maize farmers and the potential factors that lead to deviations from the common production frontier. In this regard, a parametric efficiency analysis in the form of a single-step SFA is applied to cross-sectional survey data collected in 2019 in Limpopo Province, RSA. The model is capable of considering a wide range of variables including production inputs, farm structures and socio-economic/socio-demographic characteristics. Moreover, it empirically investigates the effects of the main production risks on the level and variability of maize production. In this regard, we consider a dual heteroskedastic production frontier by controlling for heteroscedasticity in both error terms, which has not been done in previous studies of efficiency analysis of small-scale maize farmers in RSA. Likewise, the analysis allows us to estimate the sensitivity of the farmer's efficiency level with respect to the change of corresponding factors by calculating the marginal effects. By identifying the determinants of production efficiency, this chapter will offer indications for both small-scale farmers and politicians on how to improve their maize production systems and, by this, help tackling the issues of food insecurity and rural poverty in the region.

The subsequent sections of this chapter are organized as follows: **Section 4.2** briefly reviews the methodology and empirical approach, **Section 4.3** describes the data collection while **Section 4.4** explains the potential explanatory variables in the production frontier and inefficiency, and presents the empirical results and the discussion. The chapter ends with conclusions in **Section 4.5**.

4.2. Empirical approach

Based on the previous literature, there are two main approaches for evaluating productivity and TE: parametric and non-parametric methods. Stochastic Frontier Analysis (SFA) is the main parametric approach based on the econometric techniques, while Data Envelopment Analysis (DEA) is the mathematical-based non-parametric approach. Each of these methods has the advantages and disadvantages that are explained in previous studies including (Battese & Hassan, 1999; Coelli & Perelman, 1999).

The main advantages of SFA compared to DEA, which makes this approach considered to be the best methodology in estimating a firm's productivity and efficiency especially in the agricultural sector, is that the parametric SFA technique allows splitting the impact of random error from the inefficiency effect; hence it is known as the composed error model. This allows an assessment of the stochastic variation of the output which explains the stochastic nature of the agricultural production process (Coelli, 1995). However, the non-parametric DEA approach combines the errors which is known as combination inefficiency (Ali et al., 2019). Furthermore, the SFA approach allows for a flexible functional form and enables the testing of various hypotheses related to the functional form and other attributes of the production function (Rahman & Anik, 2020). This approach not only investigates productivity by comparing the output to several input dimensions included in the model, but it also provides a relative productivity measure by comparing each firm with the best practice firm (Coelli, 1995).

This study employs a SFA approach to investigate the TE and identify the main factors affecting the production efficiency of the small-scale farmers in the selected regions of the Limpopo Province of RSA.

4.2.1. Stochastic Frontier Analysis (SFA)

The SFA model was pioneered by Aigner et al. (1977) and Meeusen & Van Den Broeck (1977) and extended by Greene (2003) to estimate the technical inefficiency. The general form of the stochastic production frontier model is as follows in equation (4.1):

$$Y_i = f(X_i; \beta) + \varepsilon_i \qquad (i = 1, \ldots\ldots, n) \tag{4.1}$$

$$\varepsilon_i = v_i - u_i \tag{4.2}$$

Where Y_i is the logarithm of the output of the ith farm unit, $f(X_i; \beta)$ defines the production technology, X_i is the inputs vector, and β denotes the parameters of the production function. ε_i is a composed error term including two independent components (equation (4.2)): v_i denotes the symmetric random error (idiosyncratic error), which can be attributed to exogenous production shocks such as weather shocks. It also captures measurement errors or unobserved inputs. It is identically and independently distributed with zero mean and variance σ_v^2 $[v_i \sim N(0, \sigma_v^2)]$. The second error component, u_i, is a non-negative error component that is distributed as a one-sided error. It represents the farm-specific technical inefficiency. The distributional assumption of u_i is essential for the model estimation approach (Kumbhakar et al., 2015). We follow the bulk of the literature by assuming a half-normal distribution $N^+(0, \sigma_u^2)$ which is assumed by Aigner et al. (1977) for the one-sided error.

While the primary studies assumed homoscedasticity in both one-sided inefficiency error u_i and two-sided error v_i, Caudill & Ford (1993), Hadri (1999), and Kumbhakar & Lovell (2000) discussed that these assumptions can lead to biased technology and efficiency estimates. The one-sided inefficiency error u_i measures the degree of utilization of the adopted production technologies, as well as the main factors explaining inefficiency by including exogenous variables. Moreover, the heteroscedastic two-sided error v_i in SFA models enhances this concept by incorporating the production risks proposed by Just & Pope (1978), indicating the production uncertainty which affects the producer's decision making on adopting and utilizing new technologies (Battese & Rambaldi, 1997). Ignoring this heteroscedasticity leads to biased estimates of the TE parameters (Kumbhakar et al., 2012).

In this chapter, a single-step SFA model is implemented to estimate simultaneously the stochastic frontier production function and the inefficiency function based on the maximum likelihood estimation (MLE) procedure (equation (4.3)). We consider heteroscedasticity in both

u_i (equation (4.4)) and v_i (equation (4.5)), following the doubly heteroskedastic model of Hadri (1999). This implies that both $\sigma_{v_i}^2$ and $\sigma_{u_i}^2$ are allowed to depend on a set of explanatory variables w_i and z_i respectively.

$$Y_i = f(X_i; \beta) + v_i - u_i \qquad (i = 1, \ldots\ldots, n) \tag{4.3}$$

$$u_i \sim N^+\left(0, \sigma_{u_i}^2(z, \delta')\right) = N^+\left(0, exp(\delta' z_i)\right) \tag{4.4}$$

$$v_i \sim N\left(0, \sigma_{v_i}^2(w, \theta')\right) = N\left(0, exp(\theta' w_i)\right) \tag{4.5}$$

The z variables might comprise farm and farm management characteristics as well as policy variables that are associated with technical inefficiency. The w variables relate to production variability in the stochastic production function framework and capture the effects of these variables on production risk. δ' and θ' are the vectors of unknown parameters. The parameters are estimated by MLE procedure.

Ultimately, the TE level of farmers is estimated with equation (4.6), which ranges between 0 and 1, which 1 indicating a completely technically efficient farmer.

$$TE_i = exp(-u_i) \tag{4.6}$$

4.3. Data collection

Five study sites (villages) were selected in Limpopo Province along a climatic gradient (from sub-humid to semi-arid) with variation in demographic and socio-economic factors. The selected villages are all located in the former-homeland rural area of the Mopani district of Limpopo Province: Mafarana, Gavaza, Ga-Selwana, Makushane, and Ndengeza. The description of the study area and data collection is explained in section 1.2.

Farming systems in the selected areas are mainly small-scale farms with limited resource endowments that produce predominantly for subsistence purposes and just a few are selling their products at markets. Maize is the main dietary staple crop that dominates the small-scale farming system and plays a crucial role in food security and the reduction of malnutrition in these areas. Farmers were interviewed in person using a structured questionnaire (page 102). Information on socio-economic, demographic, farm and household characteristics, as well as input and output data of the agricultural production during the 2018-19 cropping season were collected. From 215 household head respondents, three were excluded because of incomplete information. The total number of households that produced maize during the main cropping season (October to March) 2018/2019 from our sample were 190 farmers, representing 88% of the total sample.

4.4. Results

In the following section, after testing several hypotheses to examine the statistical properties of the SFA model, a brief overview of the main factors that influence the maize productivity and efficiency of the farmers are provided. Furthermore, we present the main findings and discuss the estimation results.

4.4.1. Model specification tests

To investigate the efficacy of the SFA model, before generating and presenting the estimation results, we implemented several tests and hypotheses. At first, to specify an appropriate functional form for the production frontier model, we estimate and compare the transcendental logarithmic (Translog) functional forms with a more restrictive Cobb-Douglas model. We used the log-likelihood ratio (LR) test. The LR test with the null hypothesis of the Cobb-Douglas functional form as a representative of the adequate model is not rejected, implying that a Cobb-Douglas form is the more appropriate production function for our sample (Table 4.1). Correspondingly, the presence of technical inefficiency effects, production variability, as well as the doubly heteroscedasticity in the production function were estimated. The likelihood ratio test with the null hypothesis of no inefficiency component (u_i) is rejected, indicating the inclusion of a one-sided error component (u_i) in the model. This showed that the SFA model is more appropriate relative to the conventional OLS (Table 4.1).

Table 4.1. Hypothesis Tests for Model Specification and Technical Inefficiency Effects

Null Hypothesis (H_0)	df	LR-Test Statistics	Critical Value* (α)	Decision
Cobb-Douglas specification *H_0*: all the β_{ij}s are equal to zero	15	20.00	21.72 (α=0.1)	not reject H_0
No technical inefficiency effects *H_0*: u_i= 0	13	55.07	21.74 (α=0.05)	reject H_0
Homoscedasticity of v_i *H_0*: $\sigma_v^2 = 0$	3	10.87	7.045 (α=0.05)	reject H_0
Joint homoscedasticity of v_i & u_i *H_0*: σ_u^2 & $\sigma_v^2 = 0$	16	60.18	25.69 (α=0.05)	reject H_0

* Source: Table1, Kodde & Palm (1986)

4.4.2. Potential explanatory variables and respective descriptive statistics from the survey

Based on the specification tests in Table 4.1., the SFA equation with Cobb-Douglas production function and doubly heteroscedasticity for our analysis is as follows in equation (4.7):

$$LnY_i = \beta_0 + \sum_{j=1}^{n} \beta_j LnX_{ij} + \sum_{l=1}^{m} \alpha_l D_{il} + v_i(w_{ij}, \theta') - u_i(z_{ij}, \delta') \quad (4.7)$$

Where Y_i is the amount of maize harvested in kilogram in a year, X_i is a vector of observations on inputs, D_l is a vector of observations on dummy variables, as well as dummy controlling for unobserved factors between selected regions. Table 4.2. provides the summary of the statistics of dependent and independent variables included in the estimated SFA model. In this regard, we distinguish between physical inputs that determine the output level and variability of maize via the production function, farm management-related factors that affect their efficiency and risk-related factors that potentially affect their output variability.

The choice of inputs in the production frontier is based on similar studies on RSA and availability and sufficiency of data. Following several studies (Kibirige et al., 2016; Mango et al., 2015; Ndlovu et al., 2014; Obi & Ayodeji, 2020), we considered inputs including area under maize cultivation in ha, the quantity of seeds and fertilizers in kg, pesticide in the number of applications in a year, labor used for maize cultivation in man-days unit, preparation costs (machinery and animal capital) in currency unit (ZAR), and a dummy of irrigation.

Table 4.2. Descriptive statistics (n =190)

Variables	Description	Mean	Std dev.	Min	Max
Variables in the production function					
Maize output	Amount of maize harvest (kg)	81.77	208.44	2.5	1783.4
Land	Land under maize cultivation (ha)	1.97	1.55	0.25	9
Seed	Seed quantity (kg)	21.02	16.40	2	100
Fertilizer	Fertilizer quantity (kg)	41.13	124.71	0	833.33
Pesticide	Application Frequency (in Year)	0.33	0.97	0	4
Labor	Man days	156.13	117.34	14.37	752.31
Preparation costs	Capital flow (Machinery, Donkey, own and renting)	1508.98	1206.86	89.29	8000
Irrigation	Dummy; 1= Yes, 0= No	0.11	0.31	0	1
Factors affecting inefficiency					
Head Age	Years	66.96	11.07	33	93
Head Gender	Gender of household head; (1=Male)	0.48	0.50	0	1
Education level	Years of formal education of household head	4.4	4.9	0	20
Off-farm income	Dummy; 1= Yes, 0= No	0.18	0.39	0	1
Social grants	Dummy; 1= Yes, 0= No Including pension and child grant	0.88	0.33	0	1
Access to credit	Dummy; 1= if the farmer has got cash credit within the last 12 months, 0= Otherwise	0.06	0.24	0	1
Extension service support	Number of visits in year	1.14	3.25	0	30
Organization member	Dummy; 1= Yes, 0= No	0.41	0.49	0	1

Access to market	Dummy; 1= if the farmer sold some of their produced maize, 0= Otherwise	0.20	0.40	0	1
Own Cattle	Dummy; 1= Yes, 0= No	0.37	0.48	0	1
Training in Agriculture	Dummy; 1= Yes, 0= No	0.20	0.40	0	1
Cultivated land	Area (ha)	3.04	3.20	0.25	22
Factors affecting production risk					
Drought_risk only	Perceived only drought risk for harvest failure; Dummy; 1= Yes, 0= No	0.10	0.30	0	1
Pest_risk only	Perceived only pest risk for harvest failure; Dummy; 1= Yes, 0= No	0.06	0.23	0	1
Drought & Pest_risk	Perceived both drought & pest risks for harvest failure; Dummy; 1= Yes, 0= No	0.13	0.34	0	1

According to Table 4.2., land denotes the area under maize cultivation, which varied between 0.25-9.0 ha with an average of 1.97 ha. Labor, including both hired and family members working in maize cultivation, was on average 156 days in the year. All the farmers used family labor for different activities such as preparing land (e.g., weeding), seeding and harvesting. The average amount of seed used for sowing per farm was 21 kg per year. Capital comprised the service flow of main farm assets for preparing land including machinery and draught animal which were owned or rented, considering the ownership costs (depreciation and interest) and the variable costs (e.g., fuel, repairs and maintenance, animal feed) related to maize production. The average quantity of fertilizer applied for maize cultivation per farm was 41.13 kg per year, which were mainly mineral fertilizer (e.g., KAN LAN 321, 234, and 323), as well as livestock manure at the farm. The number of pesticide applications for the total farm during a year is considered as a proxy for the measurement of pesticide quantity[9] . The average frequency of pesticide application was 0.33 (2.5 the average number for the users only) times per year. Most of the farmers in the region did not apply fertilizer and pesticides, as well as irrigation systems. The bulk of the farmers depended on rain-fed agriculture and only 11% applied some kind of irrigation on their cultivated land. As around 69.5% of the selected farmers were not applying fertilizer at their farm, following Battese (1997), a dummy variable for zero values of fertilizer input is included in the model (equal to one if the input variable is equal to zero) to avoid biased inference when log-transforming the inputs with zero values. We also include location dummies in the production frontier to capture regional heterogeneity between the selected villages.

The main factors that influence the TE of the small-scale maize farmers in RSA can be classified as demographic and socio-economic characteristics, farm-specific and institutional factors. Therefore, the explanatory variables z_i include age, gender, and educational level of household

[9] Farmers were not well aware of the applied quantities of pesticides but were able to recall the number of applications.

head, off-farm income, social grants, extension service support, credit access, member of the agricultural organizations, agricultural training, access to markets, owning cattle, and the total cultivated land.

Most previous empirical studies considered age, gender, and educational level as the main factors influencing the farmer's TE (Coelli & Battese, 1996). The typical farming household in the survey sample had a household head of an advanced age (67 years), who was mainly female. The formal education level between these farmers was low with an average of 4 years.

Small-scale farmers can improve their farming skills mainly by getting support through agricultural trainings, extension services and farmer organizations. Training is noted by many studies as a relevant influencing factor and covers a wide range of farm management or marketing-specific education and practical training that a farmer receives (Dube & Guveya, 2016; Murugani & Thamaga-Chitja, 2018). Despite the importance of formal training, the majority of the farmers in our sample learnt through practical experience, working with their parents or on commercial farms. Only 20% of the farmers received some training programs in agriculture regarding production, planning marketing and risk management.

Extension services provide information on farming practices, new technologies and input applications (Krishnan & Patnam, 2014; Xaba & Dlamini, 2015). The quality and focus of the services are key in enhancing efficiency and productivity of the farmers (Ullah, 2016). Extension services in RSA are provided by the Department of Agricultural and Rural Development of the Province through their trained staff. They play an essential role in supporting small-scale farmers in the country and are therefore noted in various studies as one of the main influences on farm performance (Dube & Guveya, 2016; Magingxa et al., 2009; Murugani & Thamaga-Chitja, 2018). We considered the number of visits by the agricultural extension officers in the previous year. Around 53% of the farmers received advice and other support (e.g., input supplies, mechanization, etc.) regarding their crop production activities from the local extension agents, with an average 1.14 visits in a year.

Farmer organizations such as NGOs and CBOs play an important role in the development and support of small-scale farmers through the provision of linkages and technical support (DAFF, 2013). This support consists of knowledge and labor exchanging, sharing farming equipment such as machinery and irrigation systems, as well as seeds and other inputs (Bachke, 2019). These organizations increase farmers' incentives and assertiveness for farming activities, targeting mainly households with vulnerable farmers (Dube & Guveya, 2016; Magingxa et al., 2009; Murugani & Thamaga-Chitja, 2018). From our sampled farmers, around 41% indicated that they were a member of a farmer's organization.

The primary financial resources in the Limpopo Province for small-scale farmers that can have an impact on the TE of farms are on-farm income, credit, social grants, and income from off-farm activities. These financial resources reduce the small-scale farmers' vulnerability, increase their ability to cope with risk, and enhance their adaptive capacity. Furthermore, the financial resources allow farmers to purchase farm inputs and invest in agricultural equipment and new technologies. Social grants including child support and old-age pension grants are some of the main sources of financial support from the government for most small-scale farmers in RSA. Around 88% of the farmers in our sample received social grants. This can be related to the age of the farmers which are mainly older people (average age was 67 years). While farming is the primary occupation in the study area, around 18% of the households relied on off-farm income as their main source of income. Access to credit from formal financial institutions is a significant limitation for the majority of the South African small-scale farmers who are mostly old aged and have mainly unreliable and low income, undocumented property, and no formal credit history (Myeni et al., 2019; von Loeper et al., 2016). From our sampled farmers in the selected villages, only 6% had access to credit for crop production in the past 12 months. The low ratio of farmers with access to credit can be explained by their old age and low education and income levels.

Around 37% of the small-scale maize farmers in the Limpopo region owned cattle. This ratio indicated that the main farming activity in this region was crop production. The low share of livestock ownership can be attributed to the drought and heat stress climatic conditions, lack of capital, and high livestock theft in the region (Musumba et al., 2022; Myeni et al., 2019). Most farmers raised cattle primarily to provide a source of food, extra income, and manure production.

The area of cultivated land reflects the households' endowments, as well as the production diversification on the agricultural production (Lachaud et al., 2022). The size of land used for crop cultivation among small-scale maize farmers in the study area varied between 0.25 to 22 ha with an average of 3 ha, being allocated to other crops to complement income and self-consumption besides maize as the main agricultural livelihood. Small-scale farmers in selected regions produced mainly for their consumption and sold a small amount of harvest surplus at their farms. However, some (~ 20%) had access to markets to sell their products.

Due to the high reliance on rain-fed agriculture, the agricultural system in southern Africa is vulnerable to drought, which has been aggravated by a severe El Niño- induced drought during the 2015/16 season (Epule et al., 2017). Several international organizations such as Food and Agricultural organization of the United Nations (FAO), World Meteorological Organization (WMO), Intergovernmental Panel on Climate Change (IPCC), and Southern African Development Community (SADC) have reported the impact of this intense drought on agricultural productivity and production in southern Africa (Hove & Kambanje, 2019), and particularly on maize production deficits in RSA after 2015 (FAO, 2018a; Setimela et al., 2018). Late-season rainfall and subsequently delayed planting have severely limited crop development, reducing production and planted areas (FAO, 2016). Moreover, due to the consecutive droughts, southern Africa faced serious threats posed by pests, including the spread of fall armyworm on crop production and especially on maize cultivation. This pest devastated grain crops, particularly maize, indicated as a cause of considerable yield loss since 2015 (Bengyella et al., 2021; Day et al., 2017; Sikora et al., 2020). Therefore, in this chapter, we included the dummies of environmental risks on harvest failure/ yield loss to reflect the effect of drought and pests on maize harvest quantity, which were perceived by farmers. Drought and pests were the two key uncertainties that the selected farmers perceived as the main reasons for the maize harvest failure in this year. We included these dummies in both production frontier and production risk to investigate their effects on the level and variability of maize production.

4.4.3. Stochastic frontier estimates of production, technical inefficiency, and the production risk

The maximum likelihood estimation method is implemented to estimate the single-step approach of the SFA model, which considers the stochastic production frontier, technical inefficiency effect and the production risk effects. A half-normal distribution is assumed for estimating the model. As our sample is clustered in five villages, the estimated standard errors are adjusted in clustering, following Abadie et al. (2023). The results indicate the model was significant with a good fit. In the following, the results of the three components of the analysis, as can be seen in Table 4.3, are briefly described.

Table 4.3. Maximum Likelihood Estimates of the Stochastic Frontier Model and Technical Inefficiency Effects Model for Small-Scale Maize Farmers

Stochastic Frontier:			*Technical Inefficiency:*			
Variables	**Coefficient**	**Robust Std. Err.**	**Variables**	**Coefficient**	**Robust Std. Err.**	**Marginal Effects**
Constant	2.96*	1.68	Constant	2.23**	1.06	-
ln_Land	0.38*	0.22	Age (<60)	-1.50**	0.71	-0.44
			Age (>60 & <74)	-0.60*	0.37	-0.18
ln_Seed	0.22***	0.08	Age (>75)	0.25	-	-
ln_Fertilizer	0.19***	0.04	Gender	-0.74***	0.19	-0.22
			Education level	0.09	0.10	0.02
Pesticide	0.31***	0.06	Off-farm income	-0.10	0.68	-0.03
ln_Labor	-0.07	0.09	Social grants	-1.62***	0.60	-0.48

ln_Preparation costs	0.04	0.13
D_Irrigation	0.23**	0.11
D_risk_drought only	-0.71***	0.23
D_risk_pest only	-0.75***	0.27
D_risk_drought & pest	-1.55***	0.30
D_Battese_Fertilizer	0.51***	0.20
Region (base:Gavaza):		
Ga-Selwana	-0.42***	0.11
Mafarana	-0.35***	0.05
Makushaneh	-0.04	0.07
Ndengeza	0.21*	0.13

Access to credit	-3.31*	1.85	-0.98
Extension service support	-0.20*	0.11	-0.06
Organization member	-2.46***	0.69	-0.73
Access to market	-2.41**	1.21	-0.71
Own cattle	-0.82***	0.32	-0.24
Training in agriculture	-2.64**	1.24	-0.78
ln_Cultivated land	1.11*	0.58	0.33
Production Variability (Risk):			
Variables	**Coefficient**	**Robust Std. Err.**	**Marginal Effects**
Constant	-0.82***	0.22	-
D_risk_drought only	0.65	0.47	0.48
D_risk_pest only	0.68	0.56	0.52
D_risk_drought & pest	0.97 ***	0.26	0.80

Number of observations	*190*
Wald chi2 (6)	*161.23*
Prob > chi2	*0.000*
Log (likelihood)	*-244.22*

Note: Standard Errors are adjusted for the five clusters in selected villages; Statistically significant at levels of * 0.1, ** 0.05, and ***0.01

Stochastic Frontier (Production Frontier Function)

The results of the production frontier model indicate the main determinants of the productivity level of the respective small-scale farmers in maize production. Since the output and input variables (except pesticide[10]) in the Cobb-Douglas production frontier model are in

[10] We included pesticide in non-logarithmic form into the production function, because of the better empirical fit in comparison with log-form, due to the extremely large proportion of zero values (87%), also the application of Battese (1997) approach was not consistent because of the biased differences between pesticide users and non-users.

logarithmic form, the estimated coefficients can be directly interpreted as the partial production elasticities. The positive signs of the statistically significant coefficients indicate that the production function is monotonically increasing for all inputs except for labor, although the partial production of labor is not statistically different from zero[11] . Land preparation cost is estimated at 0.04 but is not statistically different from zero, too. The application of pesticide has positive effect on maize production with a value of 0.77[12], followed by maize land (0.38), seed (0.22) and fertilizer (0.19). The statistically significant positive coefficient for the dummy variable on irrigation indicated that small-scale farmers with access to irrigation have higher maize production than under rain-fed conditions. The marginal effect of this variable on maize output was computed according to the approach proposed by Kennedy (1981), as $[\boldsymbol{e}^{\hat{c}-\mathbf{0.5}\hat{V}(\hat{c})} - 1]$ with $\hat{\boldsymbol{c}}$ the estimated coefficient and $\hat{\boldsymbol{V}}(\hat{\boldsymbol{c}})$ the estimated variance of $\hat{\boldsymbol{c}}$. Applying this formula reveals a marginal effect of 0.25 and suggests that applying irrigation resulted in gains in maize output of 25%.

The scale elasticity, which is the sum of the partial production elasticities, is estimated at 0.86 indicating decreasing return to scale (RTS), which this result is consistent with the findings of Baloyi et al. (2012), which investigated the Cobb-Douglas production function for the smallholder maize farmers in Ga-Mothiba region of the Limpopo province of RSA. However, as the vast majority of farmers in our sample do not use any pesticides at all, we also calculate the scale elasticity considering only pesticide users and the RTS is 1.53, indicating the existence of increasing RTS in maize production. This implies that a proportional increase in all available inputs leads to a more than proportional increase in maize production. This is in line with the results of Obi & Ayodeji (2020) who find increasing returns to scale in maize production for smallholder farms in the Eastern Cape province of RSA. This result is also consistent with the findings of Addai & Owusu (2014) for maize production of smallholder farmers in Ghana.

Technical Inefficiency Effects

Table 4.3. also presents the estimates of the technical inefficiency model, indicating the main factors affecting the inefficiency of small-scale maize farmers. Since the dependent variable in the technical inefficiency part of the model is the technical inefficiency itself, a negative sign of a coefficient indicates a positive effect on TE (Kumbhakar et al., 2015). Moreover, the estimated coefficients of the technical inefficiency cannot be directly interpreted from the model, due to

[11] Although the negative (but not significant) coefficient of labor violates the monotonicity condition of productivity, we estimate the model by excluding labor from the model (Appendix (S. 4.6), Tables 4.5-4.7). Based on the results, the estimates in productivity and efficiency, as well as the efficiency scores, remained the same, but we prefer to keep labor in our frontier model, as labor is one of the crucial inputs in estimating the production frontier.

[12] We convert the pesticide application coefficient to elasticity by considering the average of pesticide users (= 2.5), and the elasticity of pesticide application would be 0.10 if considering the average of both pesticide users and non-users (=0.33).

the nonlinear relationship between $E(u_i)$ and each of the explanatory variables. Therefore, the marginal effects are obtained to investigate the magnitude of the exogenous factors on the mean of the inefficiency ($E(u_i)$) (Kumbhakar et al., 2015; Wang, 2002).

For age, household heads under 60 years show better TE scores than the reference group above 75 years. This can be attributed to the various activities involved in the cultivation of maize (e.g., weeding, implementing new techniques and technologies) as well as the risk attitude associated with the age of the farmers. Older farmers are more risk-averse and reluctant to adopt new technologies. This finding is consistent with the studies of Kolawole et al. (2014) and Myeni et al. (2019) who indicate that older farmers often rely on their indigenous knowledge to manage their farms which is becoming more and more an unreliable and unsuitable strategy due to the increasing complexities of farm decisions under climate change with higher variability of weather conditions. The positive effect of male-headed households on TE indicates that male farmers are relatively more efficient than female farmers in maize production. This finding can be explained through the fact that on average, female-headed farmers are older and have less access to education and training, as well facing more difficulties in accessing production resources and markets (Murugani & Thamaga-Chitja, 2018). The educational level shows a negative but non-significant effect on TE. In the literature, educational levels of the farmers show ambiguous results (Mwalupaso et al., 2019; Ullah, 2016). It is mainly expected that education has a positive impact on TE by facilitating knowledge and access to information as well as encouraging adoption of new technologies (Jaime & Salazar, 2011; Mwalupaso et al., 2019). However, as noted by Cele & Wale (2018), farmers with higher education tend to spend less time on farming activities and more time on off-farm jobs. The household heads in our study were mainly female and older generations whose educational levels tend to be much lower than the younger farmers. Besides, the younger farmers with comparatively higher education tend to find occupations in urban areas rather than spending time in the villages and at their farms.

Small-scale farmers with access to credit, government social grants as well as off-farm activities were found to have higher TE compared to those who did not have them. These farmers are more encouraged to engage in agricultural practices investing in their farm operations by purchasing adequate inputs and using or renting machinery and equipment at the right time. Similar results are found by Abdulai & Abdulai (2017) for Zambia and Asmare et al. (2022) for Ethiopia. Access to credit has a significant positive impact on TE, indicating the farmers who have access to credit are technically more efficient than the ones without access to credit. The findings align with research conducted by von Loeper et al. (2016) that highlights the importance of improved credit access from banks on the productivity of smallholder farmer. This enables them to take part in the South African economic agricultural value chains. Access to credit offers farmers the liquidity and financial capital to invest in agricultural equipment and technology (Binam et al., 2004; Myeni et al., 2019).

The coefficient of extension services is statistically significant, implying that extension services are associated with higher TE. This indicates that farmers in our sample benefit from imparting knowledge on farming practices, new technologies, as well as enhanced management skills. The results are consistent with the findings of the studies by Ogundari (2014), and Tenaye (2020). The coefficient of agricultural training is estimated to be statistically significant and negative. This suggests that receiving training on agronomical practices contributes to improving the TE of the small-scale maize farmers. This result is consistent with the study of Kibirige et al. (2016), indicating the positive impact of agricultural training on efficiency of smallholder maize production in Eastern Cape province of RSA. The size of total cultivated land has a negative and significant effect on TE. It is no surprise that farmers with larger available cultivated land tend to specialize on cultivating crops that are more profitable and market-oriented as well as more resistant to the environment, rather than just engaging in maize production. Moreover, due to the labor constraints in the study area, farmers with larger farm sizes are facing the challenge of timeliness in ploughing, seeding and weeding activities, leading to an efficiency reducing effect on maize production. This result is consistent with Coelli & Battese (1996) and Mwalupaso et al. (2019), indicating that farmers with small land sizes tend to allocate their scarce resources more efficiently. Farmers who own cattle are technically more efficient than those not owning cattle. This can be related to the availability of animal manure in the field which is an important and cheap source of organic fertilizer for soil fertility improvement. A similar result is also revealed in the study by Mango et al. (2015), indicating the positive effect of cattle ownership on the TE of smallholder maize production in Zimbabwe.

The estimated values for the marginal effects of the exogenous variables on the mean of the inefficiency for small-scale maize farmers indicated the magnitude of changes in all these factors on reduction in technical inefficiency. This implies that the TE of farmers who got credit is on average 98% higher compared to those who did not, followed by farmers having or not training in agricultural practices (78%), organization member (73%), market access (71%), social grants (48%), and owning cattle (24%). These effects indicate the importance of different factors on farmers' performance.

Production Risks

Drought and pests were the two critical risks that the selected farmers perceived as the main reasons for the maize harvest failure in recent years, particularly since the 2015/2016 El Niño. The estimated results of these factors in both production frontier and idiosyncratic error imply that drought and pests have significant adverse effects on maize production level and variability. Likewise, the estimated marginal effects of these binary variables of agricultural risks show that maize production has decreased by 52% with only drought condition, 54% with only pest incidence, and 80% with both drought and pests' conditions[13] . Moreover, the yield variability in maize production has increased by 48% with only drought conditions, 52% with only pest incidence, and 80% with both drought and pests compared to conditions without these agricultural risks. The changes in the level and variability of the maize yields because of drought and pest risks exacerbate the food insecurity in the region. The intense and frequent droughts in southern Africa in the last decades and their effect on the incidence of pests, which led to the high possibility of ramifications on maize yields, have been discussed in various recent literature (Bengyella et al., 2021; Day et al., 2017; FAO, 2018b).

Technical Efficiency Scores

Following the estimation of the production frontier and technical inefficiency model as well as identifying the main determinants of technical inefficiency, we investigated the TE scores of the small-scale maize farmers at both farm and regional levels (Table 4.4). The results reveal that the mean estimated TE for all the farmers is 0.66, indicating that, on average, the small-scale maize farmers produce 66% of the potential output with the given input levels and current technology. The mean scores are relatively similar across the selected villages. Individual efficiency levels range from 0.06 to 0.99 and vary due to farm-specific characteristics (e.g., financial and agricultural supports, management practices, production specialization etc.).

Table 4.4. Estimated Technical Efficiency (TE) in the Pooled Sample and in Individual Study Villages

TE Scores	Obs.	Mean	Std. Dev.	Min	Max
Pooled (all villages)	**190**	**0.66**	**0.25**	**0.06**	**0.99**
Gavaza	24	0.76	0.16	0.41	0.98
Ga-Selwana	44	0.67	0.26	0.06	0.99
Mafarana	27	0.79	0.11	0.52	0.98
Makushane	49	0.56	0.26	0.07	0.96
Ndengeza	46	0.63	0.27	0.10	0.98

4.5. Concluding remarks

In southern Africa, agricultural production, and in particular maize cultivation, is confronted with several macro and micro-structural constraints and challenges, resulting in yield reduction and harvest failures in recent decades. This exacerbates the lack of food security and

[13] The marginal effect of these variables on maize output was computed according to the approach proposed by Kennedy (1981), as $[e^{\hat{c}-0.5\hat{V}(\hat{c})} - 1]$ where $\hat{c}$ is the estimated coefficient and $\hat{V}(\hat{c})$ the estimated variance of $\hat{c}$.

the issue of poverty, especially among small-scale farmers, who often practice subsistence farming. Improving agricultural productivity plays a vital role in alleviating poverty. In this regard, the current study investigated the TE of small-scale maize farmers in the Limpopo province of RSA. Farm-level survey data from 190 small-scale maize farmers in five selected villages of Limpopo was collected in 2019. The empirical analysis was carried out by implementing a single-step SFA model to estimate the TE levels of small-scale maize farmers.

The results show that irrigation and pesticide application had the highest positive effects on maize productivity in our sample of small-scale farms. This indicates the importance of these factors in comparison to other inputs. Especially since the last decade, severe drought conditions in RSA have led to the incidence of invasive pests and diseases, posing a considerable risk to agricultural production. Furthermore, our analysis shows that TE levels vary considerably across farmers and selected regions. On average, the TE of small-scale maize farmers in selected regions is around 0.66. This indicates that there is an opportunity to considerably improve maize production through a better usage of current available inputs and technology. The results of the efficiency analysis also show that in the selected sample, age, credit access, social grants, being a member of an agricultural organization, owning cattle, and extension agent support have considerable effects on the efficiency of small-scale farmers. Our findings suggest some policy implications to support the small-scale maize farmers in RSA to increase their productivity and farm-level technical efficiency, which leads to food security and poverty reduction.

4.6. Appendix

Table 4.5 shows the estimates of stochastic production frontier, technical inefficiency effect and the production risk effects by excluding labor from the production frontier.

Table 4.5. Maximum Likelihood Estimates of the Stochastic Frontier Model and Technical Inefficiency Effects Model for Small-scale Maize Farmers (Excluding Labor)

Stochastic Frontier:			*Technical Inefficiency:*			
Variables	**Coefficient**	**Robust Std. Err.**	**Variables**	**Coefficient**	**Robust Std. Err.**	**Marginal Effects**
Constant	2.81*	1.57	Constant	2.27**	1.11	-
ln_Land	0.35*	0.20	Age (<60)	-1.55**	0.68	-0.46
			Age (>60 & <74)	-0.55	0.43	-0.16
ln_Seed	0.21***	0.09	Age (>75)	0.25	-	-
ln_Fertilizer	0.17***	0.05	Gender	-0.77***	0.14	-0.23
			Education level	0.09	0.10	0.03
Pesticide	0.31***	0.06	Off-farm income	-0.08	0.66	-0.02
ln_Preparation costs	0.02	0.16	Social grants	-1.64***	0.60	-0.48
D_Irrigation	0.21*	0.12	Access to credit	-3.30*	1.88	-0.97
D_risk_drought only	-0.69***	0.24	Extension service support	-0.20*	0.11	-0.05
			Organization member	-2.54***	0.61	-0.75
D_risk_pest only	-0.74***	0.26	Access to market	-2.80***	0.92	-0.82
D_risk_drought & pest	-1.51***	0.35	Own cattle	-0.75**	0.37	-0.22
			Training in agriculture	-2.50**	1.24	-0.74
D_Battese_Fertilizer	0.46*	0.27	ln_Cultivated land	1.05*	0.63	0.31
			Production Variability (Risk):			

Region (base:Gavaza):			**Variables**	**Coefficient**	**Robust Std. Err.**	**Marginal Effects**
Ga-Selwana	-0.40***	0.09	Constant	-0.81***	0.24	-
Mafarana	-0.36***	0.05	D_risk_drought only	0.62	0.57	0.45
Makushaneh	-0.03	0.06	D_risk_pest only	0.70	0.49	0.54
Ndengeza	0.23**	0.11	D_risk_drought & pest	0.94 ***	0.30	0.77

Number of	*190*
observations	*158.44*
Wald chi2 (6)	*0.000*
Prob > chi2	*-244.46*
Log (likelihood)	

Note: Standard Errors are adjusted for the five clusters in selected villages; Statistically significant at levels of * 0.1, ** 0.05, and ***0.01

Table 4.6 shows the log-likelihood ratio (LR) test between the two model (with and without labor in production frontier).

Table 4.6. Hypothesis Tests for Model with and without Labor in the Production Frontier

Null Hypothesis (H0)	**df**	**LR-Test Statistics**	**Critical Value* (α)**	**Decision**
Inclusion of labor H_0: β_i for labor equal to zero	1	0.48	1.64 *(α=0.1)*	Not reject H_0

* Source: Table1, Kodde and Palm (1986)

Table 4.7 shows the estimated TE for all sample, excluding labor in the model.

Table 4.7. Estimated TE in the Pooled Sample

TE Scores	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Pooled (all villages)	190	0.67	0.25	0.06	0.99

5. General Discussion

Small-scale farmers constitute the vast majority of farmers in RSA and have the potential to significantly contribute to rural development and, more generally, food security and poverty reduction by providing food for own consumption and a growing urbanized population, generating employment and income. Therefore, these farmers are the potential elements in transforming Southern Africa's agricultural and food system and the transition to sustainability.

Considering the prominent role of small-scale farmers in the development of the agricultural sector and rural economic growth in RSA, the present dissertation aimed to conduct a comprehensive assessment of the agricultural production and economic performance of small-scale farmers in the Limpopo Province of RSA. One of the targets of the overall project, the dissertation was embedded in, was the investigation of the effects of present and future agri-relevant risks on the production activities and the economic performance of different farm types in the Limpopo region. On the basis of this, some policy implications and farm-type-specific risk management options were developed and assessed regarding their effectiveness under different socio-economic and socio-demographic characteristics, land use management, and policy scenarios. The research was conducted in the Limpopo province, one of the least developed provinces in RSA, compounded by an acute population growth rate and poverty. A large share of the population lives in rural areas and relies on agriculture as the main source of income and livelihood. The analysis was based on a structured questionnaire conducted in 2019 in-person interviews with the farmers in order to collect information on socio-economic, demographic, farm, and household characteristics, as well as input and output data of the agricultural production during the 2018-19 cropping season. This dissertation was comprised of three main chapters, each of them representing one essay focusing on the following concrete research objectives and questions:

1st Essay: **Typologies of South African Small-Scale Farmers and Their Risk Perceptions Using Unsupervised Machine Learning Approach**

***Objective i*:** to develop our understanding of different typologies of small-scale farmers in South Africa

Objective ii: to identify diversification of risk attitudes and perceptions of different sources of risks involved in agricultural production (e.g., climatic, production, financial and market risks) for the selected target- groups of small-scale farmers

Q_{11}: *Which different typologies can be distinguished for the small-scale farmers in RSA and how do they differ in personal, farm and resource endowments characteristics?*

***Q$_{12}$:** How do the diversified small-scale farmers vary in risk attitude and perceptions of different sources of risks involved in agricultural production?*

2nd Essay: **Agricultural Commercialization of the Small-scale Farm Households in South Africa: Transition from Subsistence to Market-oriented Farming Systems**

Objective iii: to analyze the main determinants of transition of small-scale farmers from subsistence to market-oriented farming system

***Q$_{21}$:** What factors are the drivers of the transition of small-scale farmers from subsistence to the market-oriented farming system?*

3rd Essay: **Maize Production Efficiency of Small-Scale Farmers Under Risk: Evidence from South Africa**

Objective iv: to investigate technical efficiency of small-scale maize farmers and the potential factors that lead to deviations from the common production frontier, considering the perceived production risks in the region

***Q$_{31}$:** What is the level of technical efficiency of small-scale maize farmers?*

***Q$_{32}$:** Which factors determine the technical efficiency of small-scale maize farmers?*

***Q$_{33}$:** What are the potential factors that lead to deviations from the common production frontier, considering the perceived production risks in the region?*

5.1. Summary and discussion of the results

Small-scale farmers, in general, and particularly in RSA, are highly heterogeneous regarding farm characteristics, ranging from socio-economic features to resource endowments and agro-ecological dimensions (FAO, 2017), as well as farmer characteristics such as risk attitude and their perceptions from different sources of risks, which result in diverse types of farming, levels of technology adoption, and degree of commercialization. Such heterogeneous types of small-scale farming systems require different forms of government interventions, depending on the objectives and characteristics of each group. The insights from previous research studies (Aliber et al., 2009; Carelsen et al., 2021; Cousins, 2010; Torero, 2011) and South African agricultural policy and planning documents (DAFF, 2013, 2015; DRDLR, 2009) showed that the existing typologies of (small-scale) farmers are still imprecise and too broad to represent the main characteristics of different groups of farmers, in order to design respective need-based policies to improve their specific situations. In this regard, to understand the structure of small-scale farmers comprehensively and objectively, the ***first essay*** of this dissertation focused on the typology of small-scale farmers based on a wide range of objective variables regarding their personal, farm and context characteristics, which support an effective, target-group-specific design and communication of policies. An unsupervised machine learning approach, PAM, was applied to the survey data (212 small-scale farmers in the Limpopo Province). The results showed that small-scale farmers can be classified into four different groups: subsistence-oriented, semi-subsistence-livestock-oriented, semi-subsistence-crop-oriented, and market-oriented farmers. The key factors in the farming system diversity were the farmer characteristics such as education and risk attitude; farm performance such as farm area, agricultural production, diversification, access to water, and irrigation system; as well as extension services and access to finance. The dominant farm type, accounting for 37.7% of the farmers, was the subsistence-oriented farmers, characterized by the most risk-averse farmers, cultivating mainly staple food and grain legumes for own household consumption. With 14% of respondents, market-oriented farmers were rather risk-taking farmers; they have access to larger land areas involving more agricultural diversification with a high share of marketing, focusing primarily on vegetables and livestock. The other two clusters were the semi-subsistence livestock- and the crop-oriented farmers that predominantly produce for their consumption and sell the surplus at their farms. In this respect, farmers in the crop-oriented group grow diverse crops such as fruits, legumes, and some vegetables and livestock-oriented farmers keep mainly cattle, goats, and sheep and grow some fruits for their self-consumption and sell their surplus at their farms. In contrast to the previous agricultural policy documentation in RSA, which grouped small-scale farmers merely into two groups of subsistence farmers on the one hand and market-oriented farmers on the other hand (Aliber et al., 2009; DAFF, 2012; Pienaar, 2013), the endogenous result of the present cluster analysis based on PAM and a wide range of variables provides a more comprehensive classification, including livestock and crop oriented semi-subsistence farming (objective i, Q_{11}).

In **the first essay**, following the clustering of the respective small-scale farmers, the risk perceptions among the selected groups were compared and examined to fine-tune related policy measures and their implications on risk management (objective ii, Q_{12}). A total of 15 main risk sources were asked from the farmers regarding the perceived likelihood of occurrence and the perceived impact (potential damage) for each selected risk. The results showed that heterogeneous farmers have diverse perceptions of risks, depending on their main farming goal and typologies. Consequently, climatic risks, specifically drought, were perceived as the main risk for all the small-scale farmers, mainly subsistence and semi-subsistence farmers, followed by pests and disease. Market and price risks, as expected, were considered substantial risks for market-oriented farmers. Exposure to theft for crops and livestock is ranked high among semi-subsistence farmers, compared to market-oriented farmers, who are exposed to equipment theft. Moreover, one of the risks that mostly market-oriented farmers face is the limited availability of a skilled workforce. This can be related to the fact that these farmers involve more hired permanent and seasonal workforce than family labor in comparison to other types of farmers for their agricultural activities and require more knowledge and skilled workforce as they have larger cultivated land and tend to adopt more technologies, increase their yield and the quality of their agricultural products to meet the qualification to sell their products at the formal off-farm market channels. The scarcity of skilled workforce in rural areas can result from inefficient agricultural education and training, as well as the rural-urban migration (Sikora et al., 2020). The main aim of this essay was to identify and understand the diversity among small-scale farmers comprehensively and clearly in the Limpopo province by considering multidimensional criteria. This is an important step towards agricultural development and rural transformation. These typologies provide essential ammunition to support reforming and designing respective policies and formulating appropriate risk management strategies based on the needs of each target group of small-scale farmers, depending on their specific objectives and characteristics.

Following an understanding of the structure and context of small-scale farmers in rural communities of RSA, **the second essay** investigated the main drivers of the transition within the types of small-scale farmers towards commercialization and more contribution to local and national food systems (objective iii, Q_{21}). Commercialization of agricultural production through participating in marketing and choosing appropriate marketing channels is a crucial requirement for economic growth and the development of small-scale farmers, especially in rural communities in southern Africa that predominantly rely on agriculture. According to our questionnaire, the main market outlets that the small-scale farmers in our study reported for selling their products can be categorized into formal and informal market channels. Informal markets involve decentralized distributions in that the small-scale farmers sell their produce directly to the consumers at the farm gate, roadside stands, or local communities. In contrast, formal markets such as supermarkets and urban wholesale markets (fresh fruit and vegetable produce markets) are characterized by high-quality produce, food safety standards, volume, and consistency in supply. The closest wholesale markets to our selected villages were Pretoria and Johannesburg fresh markets. Each village had a collection spot where the farmers' produce was collected and transferred to these markets.

Considering the sequential process of commercialization (subsistence to semi-subsistence/ semi-commercial and the market-oriented farming systems), this essay employed the sequential bivariate probit selection model to identify the main determinants of the transitions from subsistence to the market-oriented farming system while controlling for the endogeneity and selectivity problems that may arise due to correlation of unobserved heterogeneity and observed explanatory variables. In this regard, the main socio-economic factors associated with small-scale farmers' marketing decisions were identified. The findings of this essay showed that the household farms with a higher proportion of dependent members (aged under 15 and above 65) tend to remain subsistence and produce mainly for their family members than contribute to selling their produce. This finding aligns with the study of Randela et al. (2008) and Bahta & Bauer (2012) regarding the associations between the dependency ratio and the market participation of small-scale farmers in RSA. Moreover, the farmers with off-farm occupations and income are less likely to participate in marketing and selling their produce. According to Tabe-Ojong et al. (2018), small-scale farmers that engage in off-farm activities and earning income would want to concentrate more on increasing their off-farm income in order to increase their consumption rather than investing in improving the farm sector; therefore, the production and marketing will decrease. This finding is consistent with the study of Gebremedhin et al. (2018) and Woldeyohanesa et al. (2017) regarding small-scale commercialization in Ethiopia, Alene et al. (2008) and Omiti et al. (2009) in Kenya, and Seng (2016) in Cambodia. Regarding farming activities and agricultural products, the farmers who cultivate grain legumes were more likely to use them for their household consumption rather than selling them. In general, small-scale farmers grow grain legumes as a food security crop, in rotation with maize, to increase soil fertility and consume them as the staple food and the main source of protein in their diet. In contrast, farmers cultivating fresh products (vegetables and fruits) tend to sell at off-farm markets, and those owning livestock sell at informal markets and their farm-gate. Diversification of crops and livestock is an important strategy that small-scale farmers adopt as income complements in order to spread the potential negative impacts of risks associated with production across the two enterprises. The results are consistent with the studies of Woldeyohanesa et al. (2017) in Ethiopia and Kondo et al. (2019) in Ghana. Notwithstanding that, market-oriented farmers tend to be relatively more specialized and expand production particularly in fresh vegetable and fruit production (positive and highly significant). This can be due to the limited availability and access to lucrative and diversified markets for small-scale farmers in rural areas, as well as the expansion of the fresh products markets in RSA. Therefore, these farmers tend to specialize in producing crops that are compatible with the market demands (e.g., fresh vegetables and fruit). The transition of small-scale farmers from subsistence to the high-level market-oriented farming system in rural areas of RSA can lead to substantial changes in the organization of farm production and institutional support. In this regard, the agricultural produce choices could be determined by a comparative advantage of individual farms and compliance with market requirements. This leads to more specialization and increased product quality, which results in the efficient allocation of resources (e.g., capital, land, and labor) and enhances the productivity growth and higher economic growth of farmers. The findings are consistent with the study of Tadesse Sibhatu (2016). Furthermore, technology adoption is one of the main determinants of transition by influencing the total factor productivity growth and increased production.

The results emphasize the importance of transport asset ownership, farmer organizations and cooperatives with other farmers, and market information as the main drivers of the transition to market-oriented farming. The importance of transportation in conveying fresh agricultural products to distant markets is explained in the study of Mdlalose (2016) for the smallholders in RSA. Membership in farmers' organization and cooperatives with other farmers play an essential role in improving the commercialization of small-scale farmers by reducing transaction costs such as the cost of searching for trading partners, obtaining and verifying market information, bargaining, transferring the product (e.g., transport, storage, distance, access to roads and their condition) and communication infrastructure. This is consistent with previous empirical evidence from the literature that farmer organizations intended to facilitate access to higher-return market channels (Abu et al., 2016; Bachke, 2019; Barrett, 2008). Access to market information significantly influenced the decision of farmers to participate in formal markets. This confirms the findings of Tabe-Ojong et al. (2022) on the commercialization of subsistence chickpea producers in Ethiopia. Agricultural extension services can contribute considerably to improving small-scale farmers' production development by imparting knowledge on farming practices, new technologies, as well as enhanced management skills. This allows farmers to improve their production and persuade them to participate in marketing and selling their produce at farm-gate. Yet, there needs to be more support and assistance in facilitating small-scale farmers' economic development by marketing at formal off-farm markets. According to previous studies, the small-scale farmers in RSA do not receive adequate assistance from government and extension services on sustainable crop production methods, sufficient information and support for marketing (DAFF, 2018; Hlatshwayo et al., 2022; Xaba & Dlamini, 2015). Therefore, these farmers rely mainly on their traditional methods to produce staple crops for their own consumption and selling the surplus at the farm gate and informal markets. Appropriate government policies and strategies can simplify the process of the small-scale farmers' transition to market-oriented farming.

The third essay focused on the small-scale farmers' maize production efficiency by explicitly considering current and future perceived production risks in the Limpopo province of RSA. We focused on maize as it is the vital dietary staple crop and feed grain and the most prevalent agricultural crop in the smallholder farming system. The majority of small-scale farmers cultivate maize mainly for subsistence purposes; hence the production and supply levels of maize are important indications of food security. A single-step Stochastic Frontier model considering double heteroscedasticity in both the efficiency and idiosyncratic terms was applied to a cross-sectional farm-level data set from a field survey in the selected regions. The results revealed that the level of technical efficiency of the investigated sample of small-scale maize farmers varied over a wide range between 0.06 and 0.99, with a mean value of 0.66, indicating that, on average, the small-scale maize farmers produce 66% of the potential output with the given input levels and current technology (objective iv, Q_{31}). Our estimates highlighted the significant effects of the main agricultural risks, that is, drought and pests, on the level and variability of maize production of the investigated sample. The intense and frequent droughts in southern Africa in the last decades and their effect on the incidence of pests, which led to the high possibility of ramifications on maize yields, have been discussed in various recent literature (Bengyella et al., 2021; Day et al., 2017; FAO, 2018b). Furthermore, our findings underline the significant effect of irrigation on maize productivity (objective iv, Q_{33}), which is consistent with the study of Akpalu et al. (2011). At the same time, credit access, social grants, being a member of an agricultural organization, extension agent support, access to agricultural markets, and owning cattle had significantly positive impacts on technical efficiency (objective iv, Q_{32}). Our findings are in line with the previous studies (Myeni et al., 2019; Kolawole Ogundari, 2014; Tenaye, 2020; von Loeper et al., 2016). The results of this essay can provide useful insights for policymakers and farming communities on how to increase the food production efficiency of small-scale farming systems and improve food security in the region.

5.2. Policy recommendations

The results of the three essays in this dissertation provide policymakers and farm households insights into the main underlying factors that influence the performance of small-scale farmers in order to develop some risk management options considering different farm types. These insights can be used to reform and adjust current policies and to create new initiatives to stimulate farmers.

In this regard, we discuss the respective implications for a need-based policy design at the example of the following potential interventions:

Providing incentives to encourage the young generation to join farm activities: Current evidence from the study area and our sample has indicated that the vast majority of small-scale farmers in the study region have an advanced age and were assessed as relatively risk-averse. Hence, they might lack the mental flexibility required for a more efficient management of their farm operations. Many young potential successors would rather avoid participating in farming and instead tend to attain education and leave the rural communities to find off-farm occupations to earn income. The lack of interest of young people and hence the declining number of young workforces working in the agricultural sector in rural areas would negatively influence the future sustainability of this sector. In this respect, rural development policies and programs should give priority to targeting the youth's engagement in the agricultural sector by providing more targeted support to ensure a sustainable future for small-scale farming through training programs and workshops on farming and marketing practices. Also, promoting entrepreneurship and innovations to generate profit and income, as well as improving infrastructure, investment, technologies, and market incentives to encourage more young generations to participate in farming.

Improving extension services support: The results indicated that extension services play a critical role in enhancing the efficiency and productivity of small-scale farmers in RSA. Nevertheless, access to extension agents (officers) and distribution of their support among different farm types of small-scale farmers are not equivalent and skewed to particular farming groups, especially market-oriented farmers. Previous studies indicated the low ratio of extension officers to farmers, poor quality of formal education, and lack of appropriate practical training as the main constraints of extension services (Aliber et al., 2009; Dunjana et al., 2018). Therefore, it is recommended to recruit and train more extension officers with diverse skills in various agricultural professions and facilitate their accessibility to small-scale farmers in rural areas. The effectiveness of support from the extension agents for the heterogenous groups of small-scale farmers can be improved by providing support depending on the specific farm types and needs by designated skilled extension officers (Aliber et al., 2009). In this regard, one of the main strategies to enhance extension services for small-scale farmers is strengthening the network among extension service providers such as the government of RSA, NGOs, CBOs, and private sectors. Promoting collaboration and sharing knowledge between these organizations as well as improving communication with farmers and involving them in designing and evaluating the extension programs, ensures the effectiveness and efficiency of the extension services support for the small-scale farmers. Furthermore, considering the importance of extension services in achieving agricultural development goals and improving food security in rural areas, it is essential to advocate policy programs and allocate adequate financial resources to provide infrastructure for the extension services in order to achieve knowledge and skills regarding agronomy practices (e.g., types of fertilizers and pesticides, drought resistance seed varieties, etc.), efficient use of inputs and appropriate skills in farm business management (e.g., irrigation systems, the timing of applying inputs and using technologies, etc.), as well as marketing (e.g., market information, transportation and access to local markets).

Improving water supply and irrigation schemes: Sub-Saharan Africa is exposed to severe drought conditions in recent years, which are exacerbated after the El Nino event during the 2015/16 cropping season (Hove & Kambanje, 2019). The drought-induced condition, which is attributed to prolonged dry periods and irregular precipitation patterns, poses high risks in the agricultural sector (Setimela et al., 2018). The results of our research (chapter. 4) indicated and highlighted drought and pests as crucial agricultural risks that significantly affect the level and variability of maize production. Access to water and irrigation systems plays an important role in reducing the risk of crop failure and developing small-scale farming systems. The results of our study also revealed the significant positive impact of irrigation on maize production (chapter. 4), as well as irrigation as one of the main determinants of the transition of small-scale farmers to market-oriented farming (chapter. 2 and 3). In this regard, it is necessary to create conditions to maintain and restore water supply and irrigation infrastructure based on the specific characteristics of the group targeting farm types. According to previous studies, water and soil conservation technologies, irrigation and rainwater harvesting are the main approaches to water supply for small- scale farmers (Baiphethi & Jacobs, 2009; Denison & Wotshela, 2009). The main goal for soil conservation is to reduce soil erosion while providing additional capacity for soil-water storage. Applying irrigation systems depend on some factors including farm size, diversification of the agricultural production (e.g., vegetables, field crops), financial situations and market-oriented farms. Having access to irrigation systems has some limitations in terms of costs and maintenance which is not affordable for the low-income small-scale farmers. Therefore, household-based rainwater harvesting techniques can be an appropriate and reasonable (low implementation costs) approach to access to water for subsistence-oriented farming, which plays a vital role in reducing the risk of crop failure (Baiphethi & Jacobs, 2009). Denison & Wotshela (2009) presented a classification system for rainwater harvesting and catchment systems utilizing in RSA. Therefore, it is essential that national and local governments and authorities ensure access to water to all farming communities, including small-scale farmers. Thus, it is crucial to invest and provide infrastructure to promote sustainable water use and establish new technologies for rainwater harvesting and irrigation systems.

Facilitating access to agricultural credit and financial support: The results of our study revealed the critical role of access to credit in adopting modern irrigation systems and, therefore, indirectly in marketing farm products (chapter. 3), as well as its impact on the efficiency of small-scale maize farmers (chapter. 4). Limited access to credit is one of the major constraints of small-scale farmers in Southern Africa in adopting agricultural technologies and making agricultural financial decisions. Previous studies investigated the principal factors of agricultural credit constraints from two aspects of supply and demand. Accordingly, limited availability of credit sources and high costs of borrowing are the main constraints to the supply-side factors. However, risk-averse attitude and financial illiteracy of borrowers, as well as high transaction costs are the main constraints on the demand-side (Balana et al., 2020). Improving credit access requires considering these two factors. The main funding institutions for the agricultural sector in RSA are CASP and Micro-agricultural Financial Institutions of South Africa (Mafisa) (DAFF, 2015). Their main focus currently is to support market-oriented farmers who have some property rights and income to adopt new technologies. Subsistence and semi-subsistence farmers get financial assistance mainly through social grants (pension and child grants) from the government. These grants typically serve as a safety net for the rural poor farmers which reduces socio-economic distress. Holding a communal land title, a so-called Permission to Occupy (PTO), and lack of capital assets among most of the small-scale farmers are not considered as collateral by financial institutions. Moreover, engagement in low-paying off-farm jobs and remittance of subsistence and semi-subsistence farmers are the main constraints to getting credits from the institutions (Murugani & Thamaga-Chitja, 2018). Therefore, it is crucial for the government to facilitate the accessibility of credit and financial services for small-scale farmers, in order to reduce their financial risks associated with the production process. A partnership and cooperation between government, farmer organizations (e.g., department of agriculture and rural development, NGOs, CBOs) and the formal financial institutions and banks can provide strategies to improve the financing and credit knowledge of the farmers and enable them to get affordable credit, insurance, and certified inputs. Furthermore, updating land reforms and recording land holdings (PTO) would accelerate the process of getting credit from formal financial institutions and banks by considering it as collateral. In addition, banks and financial institutions should focus on enhancing their effectivity by investing in knowledge and the system's infrastructure. Besides financial support, these farmers can get technical and physical support from a variety of institutions such as independent research organizations, local and district municipalities, government departments, universities, and NGOs (Aliber et al., 2009). Cooperation between small-scale farmers of the villages (which in RSA barely exists in communities in comparison to other sub-Saharan Africa) is a prerequisite in transferring information and knowledge, as well as obtaining public support and collective credit.

Improving market infrastructure: Market participation of small-scale farmers and their integration into local and national agricultural markets can be a viable strategy for achieving sustainable development goals. The transition from subsistence to market-oriented farming of small-scale farmers involves a structural transformation of the agricultural sector, such as enhancing technical efficiency, increasing farm productivity and specialization in higher-value crops with high quality and low transaction costs, and extending information. Therefore, adequate support services and institutions are needed for agricultural insurance, financial institutions and credit access, modern technology, and qualified labor, among others, to enhance the productivity and resilience of farmers in the long term in the face of increasing risks and crises. Farmers' organizations can play an essential role in developing the infrastructure for the commercialization of small-scale farmers by reducing transaction costs such as the cost of searching for trading partners, obtaining and verifying market information, bargaining, transferring the product (e.g., transport, storage, distance, access to roads and their condition) and communication infrastructure. Extension services can also considerably contribute to improving the production development of small-scale farmers by imparting knowledge on farming practices, new technologies, and enhanced management skills. Yet, there needs to be more support and assistance in facilitating small-scale farmers' economic development by marketing at formal off-farm markets. Appropriate government policies and strategies can simplify the process of the small-scale farmers' transition to market-oriented farming.

Risk management strategies: Agricultural enterprise has always been at risk from different sources such as production risk, market risk, financial risk, institutional or political risk, and human resource risk. Small-scale farmers in developing countries and particularly RSA are not exempt from these agricultural risks and are more vulnerable in responding to them. Agricultural risk management can play a crucial role in reducing uncertainty and increasing the farmers' resilience and efficiency. The farmers' management response to risks depend on their socio-economic characteristics and their perception of risks. Therefore, it is essential to take into consideration the farmers' socio-economic characteristics and risk perceptions to make comprehensive risk management strategies and implementation plans in order to limit the impact of agricultural risks. Moreover, it is necessary to investigate and identify the implementation barriers of management strategies (such as lack of information and knowledge about risks, lack of capital, limited government and institutional supports, etc.) in order to reduce these barriers by providing improved strategies. To achieve this, the government can play a vital role in adopting holistic risk management approaches. Extension services can assist farmers in recognizing the sources of their risks and problems and thus improve their management skills to make better farm management decisions. Also, increased investment in R&D is essential to enable small-scale farmers to tackle agricultural risks through access to improved seeds resistant to drought and disease, new fertilizers, equipment and machinery for harvest, and other production methods.

5.3. Outlook to further research needs

The present research contributes to the current debate on transforming agricultural production into a more sustainable system and developing a small-scale farming system to improve the region's livelihoods and food security. The results of this dissertation were achieved using comprehensive approaches at multiple scales to address the research questions. The results provide guidance for future research and data collection to bolster and broaden the comprehensive understanding of the results.

It should be stressed that our analyses in this dissertation have some limitations, which are mainly related to the availability of data and the nature of the data used. The main limitation of this research pertains to conducting the survey, that although we designed a structured and comprehensive questionnaire, collecting detailed information from the small-scale farmers in the rural areas of RSA was challenging in terms of questions regarding quantities of crop harvest and inputs used (e.g. irrigation, pesticide, etc.) as these farmers did not have written records about their farming performance and relied primarily on their memories. Additionally, the units of measurement varied from farmer to farmer (e.g., amount of inputs and harvest). Besides, due to the COVID-19 pandemic and the corresponding travel and social restrictions, supplementary data collection had to be cancelled. This has affected subsequently on the integration and incorporation of new empirical data and insights into models. Therefore, additional data collection with more detailed information regarding measurements are needed for future research to evaluate small-scale farming performance empirically more accurately.

Our research was based on the cross-sectional data set. Therefore, spatial and panel data seems very revealing to understand unobserved heterogeneity and behavioral changes, covering more extended periods, incorporating diverse agricultural communities, along with larger sample sizes.

The results of this dissertation show a comprehensible typology of small-scale farmers with four representative farm types that capture the main aspects of the heterogeneity. Recognition of the diversity of these farmers allows substantial room for discussion on the target group policies and strategy management, considering the specific constraints and circumstances of each farm type. Furthermore, the specific farm types can be a starting point for further research to define appropriate agent types and accordingly simulate a regionalized farm-level economic decision-making model considering all the interlinkages between different production options, farm resources, farmer characteristics, and household objectives, as well as the interactions between farms (Berger, 2001). Likewise, regarding the main factors that influence the transition of small-scale farmers from subsistence to market-oriented farmers, an agent-based market model can be future research to analyze the long-term market entry, growth, shrinkage, exit, and land-use decisions of heterogeneous farms in a competitive environment, considering various types of agri-relevant risks (Feil & Musshoff, 2018). Besides, considering the aforementioned risk-management strategies, further research is needed to investigate the effects of selected risk-management options for different land use management and policy scenarios by integrating them into the production program of the farms.

6. Summary

Sub-Saharan Africa's population is projected to grow to almost double its population by mid-century, leading to more demand for food and agricultural products. As the main source of food and livelihood, the agricultural sector is amongst the most important economic sectors in African countries. Yet, it is challenged by the need to provide sufficient food for a teeming population with limited resources and faced with accelerating climate change. Addressing the demand for food and agricultural products requires sustainable development of agricultural production systems and policy reforms to transform agricultural production systems to meet the SDGs of the United Nations Development Program with the main objective of ending poverty and hunger, attaining food and nutrition security, and sustaining natural resources.

Small-scale farmers constitute the vast majority of farmers in RSA and have the potential to significantly contribute to rural development and, more generally, food security and poverty reduction in rural areas by providing food for own consumption and a growing urbanized population, generating employment and income. Therefore, these farmers are the potential elements in transforming Southern Africa's agricultural and food system and the transition to sustainability. Despite various national and provincial government supports for small-scale farmers in RSA to enhance the agricultural sector in recent decades, these farmers are still vulnerable to diverse agricultural risks and perform below their potential production capacities with low productivity. In this respect, considering the prominent role of small-scale farmers in the development of the agricultural sector and rural economic growth in RSA, this dissertation aimed to investigate the main fundamentals of rural transformation to support designing and implementing efficient and effective policies to improve agricultural productivity and efficiency levels of farmers, as well as enhancing market orientation to ensure the economic performance of small-scale farmers and food security. Small-scale farmers, in general, and particularly in RSA, are highly heterogeneous regarding farm characteristics, ranging from socio-economic features to resource endowments and agro-ecological dimensions, as well as farmer characteristics such as risk attitude and their perceptions from different sources of risks, which result in diverse types of farming, levels of technology adoption, and degree of commercialization. Such heterogeneous types of small-scale farming systems require different forms of government interventions, depending on the objectives and characteristics of each group. To design accurate and effective policy measures, a crucial pre-requisite is understanding the structure and context of these heterogenous small-scale farmers comprehensively. In this regard, ***the first essay*** focused on the typology of small-scale farmers based on a wide range of variables regarding their personal, farm, and context characteristics, which support an effective, target-group-specific design and communication of policies. An unsupervised machine learning approach, PAM, was applied to the survey data. According to

the results, the small-scale farmers were classified into four different groups: subsistence-oriented, semi-subsistence-livestock-oriented, semi-subsistence-crop-oriented, and market-oriented farmers. The key factors in the farming system diversity were the farmer characteristics such as education and risk attitude, farm performance such as agricultural production, diversification, market-oriented, as well as access to finance. Moreover, these heterogeneous farmers had diverse perceptions of risks depending on their main farming goals and typologies. Accordingly, climatic risks were perceived as the primary source of risk for subsistence-oriented and semi-subsistence farmers. In contrast, market and price risks were considered substantial for market-oriented farmers. Following an understanding of the structure and context of small-scale farmers in rural communities of RSA, ***the second essay*** investigated the main drivers of the transition within the types of small-scale farmers towards commercialization and more contribution to local and national food system. In this regard, the sequential bivariate probit selection model was employed to identify the main determinants of the transitions from subsistence to the market-oriented farming system while controlling for the endogeneity and selectivity problems that may arise due to correlation of unobserved heterogeneity and observed explanatory variables. The results emphasize the importance of adopting new technologies (e.g., drip irrigation system), transport asset ownership, farmer organizations and cooperatives with other farmers, and market information as the main drivers of the transition to market-oriented farming.

Considering maize as the most prevalent agricultural crop in the smallholder farming system, this dissertation's ***third essay*** focused on the small-scale farmers' maize production efficiency by explicitly considering current and future perceived production risks. A single-step SFA considering double heteroscedasticity in both the efficiency and idiosyncratic terms was applied. The results highlighted the significant effects of drought and pests on the level and variability of maize production. Furthermore, our findings underlined the importance of irrigation on maize productivity. At the same time, credit access, social grants, being a member of an agricultural organization, extension agent support, access to agricultural markets, and owning cattle positively impacted TE. Finally, the results of the three essays in this dissertation provided policymakers and farm households insights into the main underlying factors that influence the performance of small-scale farmers in order to develop some risk management options considering different farm types. These insights can be used to reform and adjust current policies and to create new initiatives to stimulate farmers

The research was conducted in the Limpopo province, one of the least developed provinces in RSA, compounded by an acute population growth rate and poverty. A large share of the population live in rural areas and farming is their main occupation. Five study areas were selected from this province based on their climatic aridity differences, demography and socioeconomic factors. A structured questionnaire was conducted between April and July 2019

in selected villages to interview in person with the farm household heads or the persons responsible for farm management. The purpose of the survey was to collect information on socioeconomic, demographic, farm and household characteristic as well as information on resource endowment and agricultural activities during 2018-19 crop seasons. Moreover, the information regarding risk attitude and risk perception of different sources of risks were collected from each farmer. Using a purposive random sampling procedure, data was collected from 212 small-scale farm households across the five selected villages in Limpopo.

7. Zusammenfassung

Die Bevölkerung der afrikanischen Länder südlich der Sahara wird sich den Prognosen zufolge bis Mitte des Jahrhunderts fast verdoppeln, was zu einer höheren Nachfrage nach Lebensmitteln und landwirtschaftlichen Erzeugnissen führt. Als Hauptnahrungs- und Lebensunterhaltsquelle gehört der Agrarsektor zu den wichtigsten Wirtschaftssektoren in den afrikanischen Ländern. Er steht jedoch vor der Herausforderung, eine wachsende Bevölkerung mit begrenzten Ressourcen und angesichts des sich beschleunigenden Klimawandels mit ausreichend Nahrungsmitteln zu versorgen. Die Deckung der Nachfrage nach Lebensmitteln und landwirtschaftlichen Erzeugnissen erfordert eine nachhaltige Entwicklung der landwirtschaftlichen Produktionssysteme und politische Reformen, um die landwirtschaftlichen Produktionssysteme so umzugestalten, dass sie den SDGs des Entwicklungsprogramms der Vereinten Nationen entsprechen, deren Hauptziel die Beendigung von Armut und Hunger, die Erreichung von Nahrungsmittel- und Ernährungssicherheit und die Erhaltung der natürlichen Ressourcen ist.

Kleinbauern stellen die überwiegende Mehrheit der Landwirte in der RSA dar und haben das Potenzial, erheblich zur ländlichen Entwicklung und generell zur Ernährungssicherheit und Armutsbekämpfung in ländlichen Gebieten beizutragen, indem sie Nahrungsmittel für den Eigenbedarf und eine wachsende städtische Bevölkerung bereitstellen sowie Arbeitsplätze und Einkommen schaffen. Daher sind diese Landwirte die potenziellen Akteure bei der Umgestaltung des Agrar- und Ernährungssystems des südlichen Afrikas und beim Übergang zur Nachhaltigkeit. Trotz verschiedener staatlicher und provinzieller Unterstützungsmaßnahmen für Kleinbauern in der RSA zur Förderung des Agrarsektors in den letzten Jahrzehnten sind diese Landwirte nach wie vor verschiedenen landwirtschaftlichen Risiken ausgesetzt und arbeiten unter ihren potenziellen Produktionskapazitäten mit geringer Produktivität. In dieser Hinsicht und in Anbetracht der herausragenden Rolle der Kleinbauern bei der Entwicklung des Agrarsektors und des ländlichen Wirtschaftswachstums in der RSA zielte diese Dissertation darauf ab, die wichtigsten Grundlagen der ländlichen Transformation zu untersuchen, um die Entwicklung und Umsetzung effizienter und effektiver politischer Maßnahmen zur Verbesserung der landwirtschaftlichen Produktivität und des Leistungsniveaus der Landwirte zu unterstützen und die Marktorientierung zu verbessern, um die wirtschaftliche Leistungsfähigkeit der Kleinbauern und die Ernährungssicherheit zu gewährleisten. Kleinbauern im Allgemeinen und in der RSA im Besonderen sind sehr heterogen, was die Merkmale ihrer Betriebe angeht, die von sozioökonomischen Merkmalen über die Ressourcenausstattung bis hin zu agrarökologischen Dimensionen reichen, sowie Merkmale der Landwirte, wie z. B. ihre Risikoeinstellung und ihre Wahrnehmung verschiedener Risikoquellen, die zu unterschiedlichen Arten der Landwirtschaft, dem Grad der Technologieanwendung und dem Grad der Kommerzialisierung führen. Solche heterogenen Gruppen von kleinbäuerlichen Systemen erfordern je nach den Zielen und Merkmalen der einzelnen Gruppen unterschiedliche Formen staatlicher Interventionen. Eine entscheidende Voraussetzung für die Entwicklung präziser und wirksamer politischer Maßnahmen ist ein umfassendes Verständnis der Struktur und des Kontextes dieser heterogenen Kleinbauern. In dieser Hinsicht konzentrierte sich der erste Aufsatz auf die Typologie von Kleinbauern auf der Grundlage einer breiten Palette von Variablen in Bezug auf ihre persönlichen, betrieblichen und kontextbezogenen Merkmale, die eine effektive, zielgruppenspezifische Gestaltung und Kommunikation von Maßnahmen unterstützen. Auf die Umfragedaten wurde ein unüberwachtes maschinelles Lernverfahren (unsupervised machine learning), PAM, angewandt. Den Ergebnissen zufolge wurden die Kleinbauern in vier verschiedene Gruppen eingeteilt: subsistenzorientierte, Semi-Subsistenz-Viehhaltung, semi-subsistenz-pflanzenorientiert und marktorientierte Landwirte. Die Hauptfaktoren für die Vielfalt des landwirtschaftlichen Systems waren die Merkmale der Landwirte wie Bildung und Risikoeinstellung, die Leistung des Betriebs wie landwirtschaftliche Produktion, Diversifizierung, Marktorientierung sowie der Zugang zu Finanzmitteln. Darüber hinaus hatten diese heterogenen Landwirte eine unterschiedliche Risikowahrnehmung, abhängig von ihren wichtigsten landwirtschaftlichen Zielen und Typologien. Folglich wurden klimatische Risiken als Hauptrisikoquelle für subsistenzorientierte und Semi-Subsistenzlandwirte angesehen. Im Gegensatz dazu wurden die Markt- und Preisrisiken von den marktorientierten Landwirten als wesentlich angesehen. Nach dem Verständnis der Struktur und des Kontextes der Kleinbauern in den ländlichen Gemeinden der RSA untersuchte der zweite Aufsatz die wichtigsten Triebkräfte für den Übergang der verschiedenen Arten von Kleinbauern zur Kommerzialisierung und zu einem größeren Beitrag zum lokalen und nationalen Lebensmittelsystem. In diesem Zusammenhang wurde das sequentielle bivariate Probit-Auswahlmodell verwendet, um die wichtigsten Determinanten für den Übergang von der Subsistenzwirtschaft zum marktorientierten Landwirtschaftssystem zu ermitteln und gleichzeitig die Endogenitäts und Selektivitätsprobleme zu kontrollieren, die durch die Korrelation von unbeobachteter Heterogenität und beobachteten erklärenden Variablen entstehen können. Die Ergebnisse unterstreichen die Bedeutung der Einführung neuer Technologien (z. B. Tropfbewässerungssysteme), des Besitzes von Transportmitteln, von Bauernorganisationen und Genossenschaften mit anderen Landwirten sowie von Marktinformationen als Hauptfaktoren für den Übergang zu einer marktorientierten Landwirtschaft. Der dritte Aufsatz dieser Dissertation betrachtet Mais als die am weitesten verbreitete landwirtschaftliche Kulturpflanze im kleinbäuerlichen Landwirtschaftssystem und konzentriert sich auf die Effizienz der Maisproduktion von Kleinbauern unter expliziter

Berücksichtigung aktueller und zukünftiger wahrgenommener Produktionsrisiken. Es wurde eine einstufige SFA unter Berücksichtigung von doppelter Heteroskedastizität sowohl bei der Effizienz als auch bei den idiosynkratischen Termen angewandt. Die Ergebnisse verdeutlichen die signifikanten Auswirkungen von Dürre und Schädlingen auf das Niveau und die Variabilität der Maiserzeugung. Außerdem unterstrichen unsere Ergebnisse die Bedeutung der Bewässerung für die Maisproduktivität. Gleichzeitig wirkten sich der Zugang zu Krediten, soziale Zuschüsse, die Mitgliedschaft in einer landwirtschaftlichen Organisation, die Unterstützung durch Berater, der Zugang zu Agrarmärkten und der Besitz von Vieh positiv auf die TE aus. Schließlich haben die Ergebnisse der drei Aufsätze in dieser Dissertation den politischen Entscheidungsträgern und den landwirtschaftlichen Haushalten Einblicke in die wichtigsten Faktoren gegeben, die die Leistung von Kleinbauern beeinflussen, um einige Optionen für das Risikomanagement unter Berücksichtigung verschiedener Betriebstypen zu entwickeln. Diese Erkenntnisse können zur Reform und Anpassung der derzeitigen Politik und zur Entwicklung neuer Initiativen zur Förderung der Landwirte genutzt werden.

Die Studie wurde in der Provinz Limpopo durchgeführt, einer der am wenigsten entwickelten Provinzen der RSA, die durch ein starkes Bevölkerungswachstum und Armut gekennzeichnet ist. Ein großer Teil der Bevölkerung lebt in ländlichen Gebieten und ist hauptsächlich in der Landwirtschaft tätig. Aus dieser Provinz wurden fünf Untersuchungsgebiete ausgewählt, die sich durch klimatische Trockenheit, Demografie und sozioökonomische Faktoren unterscheiden. Mit einem strukturierten Fragebogen wurden zwischen April und Juli 2019 in ausgewählten Dörfern die Haushaltsvorstände der Bauernhöfe bzw. die für die Bewirtschaftung der Höfe zuständigen Personen persönlich befragt. Der Zweck der Erhebung bestand darin, Informationen über sozioökonomische, demografische, betriebs- und haushaltsspezifische Merkmale sowie Informationen über die Ressourcenausstattung und die landwirtschaftlichen Tätigkeiten in den Erntesaisons 2018-19 zu sammeln. Darüber hinaus wurden von jedem Landwirt Informationen über die Risikoeinstellung und die Risikowahrnehmung in Bezug auf verschiedene Risikoquellen gesammelt. Mithilfe eines gezielten Zufallsstichprobenverfahrens wurden Daten von 212 kleinbäuerlichen Haushalten in den fünf ausgewählten Dörfern in Limpopo gesammelt.

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Questionnaire

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Questionnaire ID: …………… Date of interview: ……/ ….. / 2019

Name of the interviewer: ....

Agricultural risk management survey in the province of Limpopo

(SALLnet project)

Dear Participant

Thank you for contributing in our data collection. The purpose of this survey is to investigate agri-relevant risks, their effects on farms and potential risk management options for the future. Your time and inputs are much appreciated.

Your name will never be published and all information and their identities remain strictly confidential.

If you have any questions or concerns, please contact:

Sara.yazdan-bakhsh@uni-goettingen.de

Sincerely

SALLnet team

Name of the respondent: .... **Phone number:** ....

Location of the survey:

Village: □Ndengeza □Makushane □Mafarana □Ga-Selwana □Gavaza

Section: ....

GPS position of the farm: Latitude (N): .... Longitude (E): ....

Role of the respondent: □Head: (□Male □Female) □Husband/wife □Other(specify): ....

Residence status: □Migrant (Since when: ....) □Autochthon

Ethnic group: □Pedi □Venda □Tsonga □Ndebele □ Other(specify): ...

1 Farm unit information

1.1 Your **farm unit** consists of: □Home garden □ Field → how many fields? ………………..

1.2 How much land do you **currently** have in total? [*Hectares, Acres, Square meters, Morgen, Other:* ....] Home garden ……………… + Field(s) …………….

1.3 Were there changes of the **size** of your total land in the past 5 years? □No change □Increased □Decreased

1.4 If change: How much? ………. [*Hectares, Acres, Square meters, Morgen, Other:* ....]

1.5 Please indicate the **ownership of the farm unit/land:** □Privately owned □land given by village chief □leased from government for an agreed amount of money→ Rent you paid for renting in ………..ZAR/(month/year) □leased from other farmers for an agreed amount of money→ Rent you paid for renting in ………..ZAR/(month/year) □other (specify):……

1.5.1 If ***Privately owned OR land given by village chief***, do you have a land title for your stand including home garden (e.g. PTO)? □Yes □No

1.5.2 If ***Privately owned OR land given by village chief***, do you have a land title for your Field(s) (e.g. PTO)? □Yes □No

1.6 How do you manage this farm? □individually (just you and your family) □Jointly (in cooperation with other farmers/families) → How many people? ....

1.7 How many years have you managed this farm?

1.8 Since when has your family been cultivating this farm unit/land? …………………..

1.9 Do you think the farm will stay in your family in future? □Yes □No

1.9.1 **If yes**, who will manage the farm? □Son □Daughter □Niece/Nephew □Brother □Other (Specify)

1.9.2 How old is he/she? ....

1.9.3 When [did]/will he/she take over the farm? ....

1.10 Please indicate your **main** farming activity: □Crops □Livestock □Mixed

1.11 What is the main objective of production? □Self-consumption □Market sales □ Self-consumption and selling the surplus □other (specify): ………

If ***selling:***

1.12 Which of your products do you sell?

□Seeds (Specify): …………..

□Cereals (Specify): …………..

□Vegetables (Specify): …………..

□Livestock (Specify): …………..

□Processed products (Specify): …………..

□other (specify): …………..

1.13 Which of the following marketing channel do you usually use for selling your products? □On-farm market □Roadside stand □Pick-your-own □Local market □Middlemen □other (specify)

1.13.1 The reasons of choosing this marketing channel: □Stable and reliable outlet □Higher Prices □Price stability □Closer (distance) □Lack of transportation to other markets □Lack of alternatives/ access to the other markets □Other (specify)

1.13.2 How do you organize the transport of goods to the selling points? □Own transport □Hired vehicles (individual) □Hired vehicles (group) □Public transport □Buyers transport □Foot/animals

1.14 Please state the major problems regarding *<u>the local market</u>*?

Problems	
Insufficient production	□
Insufficient market places	□
Lack of transport	□
High cost of transportation	□
Long distance from farms to markets	□
Poor market infrastructure (roads, storage facilities)	□
Lack of market information	□
Lack of credit facilities	□
Competition in the market	□

Damages due to disease and pest	□
Others (specify):	□

1.15 How is the **price set** during the sales process? It depends on…..

□Price of other local farmers □Selling market □Production costs □Transaction costs □Decisions of buyers □Advice of the extension officer

1.16 Please provide information on the accessibility of the following ***infrastructures:***

1.16.1 Electricity:

□ **Home:** □Power generator □Solar energy □Public electricity supply □None

□**Farm:** □Power generator □Solar energy □Public electricity supply □None

1.16.2 ***Telecommunication:*** □Smart phone □Cell phone □Internet connection □None

1.16.3 ***Mobility:*** □Car □Tractor □Motor bike □Bicycle □Animal carriage □None

1.17 Do you have cooperation with another farmer or group of farmers on: □ Output (crop or livestock production) □Labor □Machinery and equipment □Other (specify)……………….. □None

2 <u>Home garden information</u>

2.1 How much is the acreage of your home garden? .... [*Hectares, Acres, Square meters, Morgen*]

2.1.1 What are the major crops in the home garden?

□**Summer season:** …………………………………..

□**Winter season:** ....

2.2 How do you cultivate your home garden? □Mono-cropping □Intercropping (cultivation of different types of crops in a specific pattern) □Mixed cropping (cultivation of different types of crops without any specific pattern)

2.2.1 Specify the crops in each cultivation type in the home garden?

Mono-cropping: ....…..

Mixed (inter)-cropping: ....

2.3 Do you practice Crop rotation (Cultivation of *different types of crops on the same land in different years or seasons*) on your home garden? □Yes □No

2.3.1 If ***Yes***, Specify the type of crops in rotation? ....
....

2.4 At any point in time in this year, did you leave the home garden ***fallow (not cultivating)***?

2.4.1 Area of the fallow land …………….. ha

2.4.2 For how long ……………………..months/ years

2.4.3 What are the reasons? □Poor soil fertility □Lack of water □Wildlife problems □Lack of agricultural equipment □Lack of labor □Lack of inputs (except water and labor) □Fence problem □other (specify)

2.5 What is the average topography of the home garden? □Flat □Slight (5-10%) □Steep (10-25%) □Very steep (25%) □Instable/up and down

2.6 How is the soil quality in the home garden? □Good □Middle □Poor

2.7 What is the **source of water supply** in your home garden? (Multiple answers are possible)

□Rain-water □On-farm ground water (e.g. borehole, well,…) □On-farm surface water (ponds and dams) □On-farm governmental water (e.g. tap water) □Off-farm communal ground water (e.g. borehole, well,…) □Off-farm surface water from lakes, rivers, or watercourses and dams □Off-farm water from common water-supply networks (Bulk water, water tanker) □Other sources:.

2.7.1 If ***ground water (e.g. borehole, well,…),*** how much is the depth of this?

2.7.1.1 Does it have sufficient water at the moment? □Yes □No

2.7.2 If ***rain-water,*** do you have tank(s) for collecting water for **irrigating** your home garden? □Yes □No

2.7.3 If ***Yes***, how many tanks?

2.7.4 If ***Yes***, how much is the volume capacity per each tank?

2.7.5 Which **method of irrigation** do you use on your home garden? □Furrow, basin irrigation □ Buckets, watering cans □Sprinkler □Drip irrigation □Other (specify): ……………….

2.7.5.1 How often you irrigate your home garden?

□ **Summer season:** Days per week: ………………Hours per day: ………………

□ **Winter season:** Days per week: ………………Hours per day: ………………

2.7.5.2 How much of the home garden **total area** is under irrigation? □All □None □Partly, just some crops (specify) …………………………..

2.7.5.3 Do you have sufficient water for irrigating your home garden? □Always □Mostly □Variable □Rarely

2.7.6 Do you have a **water pump** in your home garden? □Yes □No

2.7.6.1 If **yes**, how does it work? □Electricity □Power Generator

2.7.6.2 How much was the total cost (e.g. electricity, fuel, etc.) for water pump your home garden in this year?

2.7.6.3 How many days and how many hours per day in average did you irrigate your home garden in this agricultural year?

2.7.6.4 How much water did you pump to the home garden this year?

2.8 Do you have **water pipes** in your home garden? □Yes □No

2.8.1 If ***Yes***, how much are the width and length of the water pipe?

2.8.2 How is the water demand for **maize** production in your home garden? □Purely rain-fed □Watering 2-3 times during season □Watering every week/every 2 weeks □Watering several times a week

2.9 Please determine the main problems in obtaining water for irrigation on the home garden? (Multiple answers are possible) □Distance to water source □water shortages □lack of financial resources □low quality of water □lack of fuel, electricity, etc. □other (specify)

2.10 What do you predominantly use for the land preparation of the home garden? □Hired tractor □Own tractor □Draft animal □Hand □Other (Specify)

2.10.1 If ***draft animal***, which animal? □Donkey □Cattle □Other (Specify)

2.11 Do you have **Fences** around your home garden? □Yes [□Private □Communal] □No

2.11.1 If ***yes,*** □ In a good condition □**Not** in a good condition

3 Field information (for each field under cultivation by the farm unit)

Field 1 and Field 2:

3.1 Since when do you have this field? ....

3.2 How much is the acreage of this Field? .... [*Hectares, Acres, Square meters, Morgen, Other*…...........]

3.3 How much is the **average distance** from your house to this field? .... (km)

3.4 How much time do you need to get from your house to this field? .... (minutes)

3.5 What is the main means of transportation from your house to this field? □Walk □Bicycle □Public transport □Motorbike □Individual car □Animal □Other (specify) ....

3.6 What are the major crops on this field?

□**Summer season:** ………………………………...

□**Winter season:** ....

3.6.1 How do you cultivate on this field? □Mono-cropping □Intercropping (cultivation of different types of crops in a specific pattern) □Mixed cropping (cultivation of different types of crops without any specific pattern)

3.6.2 Specify the crops in each cultivation type in this field?

Mono-cropping: ....…...

Mixed (inter)-cropping: ....

....

3.6.3 Do you practice Crop rotation (Cultivation of *different types of crops on the same land in different years or seasons*) on this field? □Yes □No

3.6.4 If ***Yes***, Specify the type of crops in rotation? ....

....

3.7 At any point in time in this year, did you leave this field ***fallow (not cultivating)***?

3.7.1 Area of the fallow land …………. ha

3.7.2 For how long ………………… .months/ years

3.7.3 What are the reasons? □Poor soil fertility □Lack of water □Wildlife problems □Lack of agricultural equipment □Lack of labor □Lack of inputs (except water and labor) □Fence problem □other (specify)

3.8 What is the average topography of this field? □Flat □Slight (5-10%) □Steep (10-25%) □Very steep (25%) □Instable/up and down

3.9 How is the soil quality in this field? □Good □Middle □Poor

3.10 What is the **source of water supply** in this field? (Multiple answers are possible)

□Rain-water □On-farm ground water (e.g. borehole, well, …) □On-farm surface water (ponds and dams) □On-farm governmental water (e.g. tap water) □Off-farm communal ground water (e.g. borehole, well,…) □Off-farm surface water from lakes, rivers, or watercourses and dams □Off-farm water from common water-supply networks (Bulk water, water tanker) □Other sources: ……………….

3.10.1 If ***ground water (e.g. borehole, well, …),*** how much is the depth of this?

3.10.1.1 Does it have sufficient water at the moment? □Yes □No

3.10.2 If ***rain-water,*** do you have tank(s) for collecting water in this field? □Yes □No

3.10.3 If ***Yes***, how many tanks?

3.10.4 If ***Yes***, how much is the volume capacity per each tank?

3.10.5 If ***Not rain-water,*** which method of irrigation do you use on this field? □Furrow, basin irrigation □ Buckets, watering cans □Sprinkler □Drip irrigation □Other (specify): ……………….

3.10.5.1 How often you irrigate this field?

□ **Summer season:** Days per week: ………………………. Hours per day: ……………………….
□ **Winter season:** Days per week: ………………………. Hours per day: ……………………….

3.10.5.2 How much of the **total area** of this field is under irrigation? □All □None □Partly, just some crops (specify) ……………………….

3.10.5.3 Do you have sufficient water for irrigating this field? □Always □Mostly □Variable □Rarely

3.11Do you have a **water pump** in this field? □Yes □No

3.11.1 If **yes**, how does it work? □Electricity □Power Generator

3.11.2 How much was the total cost (e.g. electricity, fuel, etc.) for water pump this field in this year?

3.11.3 How many days and how many hours per day in average did you irrigate this field in this agricultural year?

3.11.4 How much water did you pump to the field?

3.12 Do you have **water pipes** in this field? □Yes □No

3.12.1 If ***Yes***, how much are the width and length of the water pipe?

3.12.2 How is the water demand for **maize** production on this field? □Purely rain-fed □Watering 2-3 times during season □Watering every week/every 2 weeks □Watering several times a week

3.13 Please determine the main problems in obtaining water for irrigation on this Field? (Multiple answers are possible) □Distance to water source □water shortages □lack of financial resources□low quality of water □lack of fuel, electricity, etc. □other (specify)

3.14 What do you predominantly use for the land preparation of this Field? □Hired tractor □Own tractor □Draft animal □Hand □Other (Specify)

3.14.1 If ***draft animal***, which animal? □Donkey □Cattle □Other (Specify)

3.15 Do you have **Fences** around this field? □Yes [□Private □Communal] □No

If ***yes,*** □ In a good condition □**Not** in a good condition

4 Crop related information for Crop 1: Maize

Please provide information for ***Maize***:

4.1 Please determine the sowing and harvesting period for Maize **in this agricultural year**

	Month		Month(s)
Planting period:		Harvesting period:	

4.2 Have you changed the sowing time recently? □Yes □No

4.2.1 If ***Yes,***

□Earlier, by …………… weeks □Delayed, by ……………weeks

4.3 Which varieties of Maize are you planting? □Local variety (Specify) …………… □Hybrid maize (Specify) …………… □GMO maize (Specify) …………… □Other (Specify) ……………

4.4 From where do you get your maize seeds? □Extension service/Government □University □Own farm □Relatives □Local shops □Other (Specify) …………….

4.5 How much maize seed did you **plant** in this agricultural year? ………………..

4.5.1 How much maize seed did you **buy** in this agricultural year? ………………..

4.5.2 How much did you **pay** for the Maize seeds in this agricultural year?

4.6 How much area of your farm is under cultivation of maize?

Home garden: ……… [Hectares, acres, square meters, Morgen, Other……]

Fields: ………. [Hectares, acres, square meters, Morgen, Other……]

4.7 How much area of this crop is under irrigation? [ha or %] **Home garden:** ……… **Fields:** …….

4.8 Do you have sufficient water for irrigating this crop?

Home garden: □Always □Mostly □ Variable □Not enough

Fields: □Always □ Mostly □ Variable □Not enough

4.9 Please determine the following information for **Maize:**

4.9.1 **Planting method:** □Row by hand □Broadcasting by hand □Row by planter

4.9.2 **Weed control**: □Chemical □Biological □By hand/mechanical □None

4.9.2.1 **Fertilization:** □Chemical □ Manure (specify) …………… □Compost □None

4.9.2.2 Amount: ……………

4.9.2.3 Frequency of use: …………… When: …………………

4.9.2.4 How much has the use of fertilizer changed over the past 5 years? □Increased, by …………… □Decreased, by ……………… □None (why?) ……………………………………

4.9.2.5 Impact on production: □Poor □Fair □Good □Very good

4.9.2.6 How much did you **buy** fertilizer in this agricultural year?

4.9.2.7 How much did you **pay** for fertilizer in this agricultural year?

4.10 How has the pest prevalence changed over the past 5 years for Maize? □Increased □Decreased □Stable

4.10.1 Which pest? ……………………………………

4.10.2 Since when? …………………………..

4.10.3 **Pesticide:** □Chemical (specify)………. □Biological (specify)……. □None

4.10.4 Amount:

4.10.5 Frequency of use:

4.10.6 How much has the use of pesticides changed over the past 5 years for Maize? □Increased, by ………… □Decreased, by ………… □None (why?) …………

4.10.7 Impact on production? □Poor □Fair □Good □Very good

4.10.8 How much did you **buy** pesticide in this agricultural year?

4.10.9 How much did you **pay** for pesticide in this agricultural year?

4.11 How has the plant disease prevalence changed over the past 5 years? □Increased □Decreased □Stable

4.11.1 Which diseases? ………………………………..

4.11.2 Since when? …………………………

4.12 How is the Maize production/harvest at the moment?

Home garden: □ Crop failed □Not harvested yet □Harvesting currently □Finished harvesting

Fields: □ Crop failed □Not harvested yet □Harvesting currently □Finished harvesting

4.12.1 If ***crop failed***, what is/are the main reason(s)?

Home garden: □Water shortage □Labor shortage □Input shortage (except water and labor) □Poor soil fertility □Pest and disease □Other (specify)

Fields: □Water shortage □Labor shortage □Input shortage (except water and labor) □Poor soil fertility □Pest and disease □Other (specify)

4.13 If ***harvested***, how much quantity of **Maize** is harvested from your land **this year?** ……… [*units in total*]

Units: *1: Kg, 2: Container, specify size, 3: Bag, specify size, 4: Pick-up truck (Bakkie), 5: Piece/Number, 8: Other, specify…..*

4.13.1 How much of your Maize harvest do you bring to the grinding mills? □All □part □None

4.13.2 Amount: ………….

4.13.3 How much of that is sold at market (% or quantity) ……………….

4.13.3.1 How much was the **average price** you received per selling unit **this year** [ZAR] ………

4.13.3.2 How much was the **average price** you received per selling unit in the **past 5 years** [ZAR] ……………….

4.14 If ***Not harvested***, how much quantity of **Maize** do you **estimate** to harvest from your land **this year?** ……… [*units in total*]

4.15 How much quantity of **Maize** was harvested from your land **last year?** ……… [*units in total*]

4.15.1 How much of your Maize harvest did you bring to the grinding mills **last year**? □All □Half □None

4.15.2 Amount: ………….

4.15.3 How much of that was sold at market **last year** (% or quantity) ……………….

4.15.3.1 How much was the **average price** you received per selling unit **last year** [ZAR] ………

4.16 Which post-harvest practice(s) do you use? □Cleaning /Washing □Drying □Grading □Packing □Other (specify) □None

4.16.1 Do you receive a higher price because of this practice? □Yes □No

4.16.2 How much more for 1 unit of this crop did you receive?

4.17 Do you produce any part of this crop as fodder for livestock? □Yes □No

4.17.1 If ***Yes***, **which part** of crop and **how much** do you produce as fodder: □Residues …………… □Consumable crop………………

4.17.2 What is the purpose of producing fodder? □Only for selling □Partial selling and partial for own livestock □Only for own livestock

Adverse events on Maize production and management

4.18 How much quantity of **Maize** would be harvested in a **normal, average year**? …… [*units in total*]

4.18.1 How has the yield of this crop changed over the past 5 years? □Decline □Increase □Variable □No change

4.19 Did you observe extreme years with negative effects on ***Maize*** production **during the past 5 years**? □Yes □No

4.19.1 If ***Yes***:

When?		**Due to which events/shocks:**	**How much did you harvest due to these shocks**
□	**2018**		
□	**2017**		
□	**2016**		
□	**2015**		
□	**2014**		
□	Other years:		
1: Drought, **2:** Heavy rain/Flood**, 3:** Wind/ Storm, **4:** Pests, **5:** Diseases, **6:** Theft			

4.20 Do you have insurance for the production damage of this crop? □Yes □No

5 Crop 2 & Crop 3: .... [Please specify your second and third main crops]

Please provide information for ***this crop***:

5.1 Please determine the Sowing and harvesting period for this crop in this agricultural year

	Month		Month(s)
Planting period:		Harvesting period:	

5.2 Have you changed the sowing time recently? □Yes □No

5.2.1 If ***Yes,***

□Earlier, by …………… weeks □Delayed, by ……………weeks

5.3 From where do you get the seeds for this crop? □Extension service/Government □University □Own farm □Relatives □Local shops □Other (Specify) …………….

5.4 How much of this crop's seeds did you **plant** in this agricultural year? ………………..

5.4.1 How much of this crop's seeds did you **buy** in this agricultural year? ………………..

5.4.2 How much did you **pay** for the seeds of this crop in this agricultural year? ………………..

5.5 How much area of your farm is under cultivation of this crop?

Home garden: ……… [Hectares, acres, square meters, Morgen, Other……]

Fields: ……. [Hectares, acres, square meters, Morgen, Other……]

5.6 How much area of this crop is under irrigation? [ha or %] ……………….

5.6.1 Do you have sufficient water for irrigating this crop? □Always □Mostly □ Variable □Not enough

5.6.2 How is the production/harvesting of this crop this year? □ Crop failed □Not harvested yet □Harvesting currently □Finished harvesting

5.6.3 If ***crop failed***, what is the main reason? □Water shortage □Labor shortage □Input shortage (except water and labor) □Poor soil fertility □Pest and disease □Other (specify)

5.7 If ***harvested***, how much quantity of **this crop** is harvested from your land **this year?** ……… [*units in total*]

Units: *1: Kg, 2: Container, specify size, 3: Bag, specify size, 4: Pick-up truck (Bakkie), 5: Piece/Number, 8: Other, specify …..*

5.7.1 How much of that is sold at market (% or quantity) ……………….

5.8 How much was the **average price** you received per selling unit in this **agricultural year** [ZAR] …

5.9 How much was the **average price** you received per selling unit in the **past 5 years** [ZAR] ………….

5.10 If ***Not harvested***, how much quantity of **this crop** do you **estimate** to harvest from your land **this year?** ……… [*units in total*]

5.11 How much quantity of **this crop** was harvested from your land **last year?** ……… [*units in total*]

5.11.1 How much of that was sold at market (% or quantity) ……………….

5.12 How much was the **average price** you received per selling unit in the **last agricultural year** [ZAR]

5.13 Which post-harvest practice did you use? □Cleaning /Washing □Drying □Grading □Packing □Other (specify) □None

5.13.1 Did you receive a higher price because of this practice? □Yes □No

5.13.2 How much more for 1 unit of this crop did you receive?

5.14 Do you produce any part of this crop as **fodder** for livestock? □Yes □No

5.14.1 If ***yes***, **which part** of crop and **how much** do you produce as fodder: □Residues …………… □Consumable crop………………

5.14.2 What is the purpose of producing fodder? □Only for selling □Partial selling and partial for own livestock □Only for own livestock

5.15 Have you observed any pest/ disease for this crop in this year? □Yes □No

5.16 How has the pest/disease prevalence for this crop changed over the past 5 years? □Increased □Decreased □Stable

5.16.1 Which pest/disease? ……………………………………

5.16.2 Since when? …………………………..

5.17 Do you have insurance for the production damage of this crop? □Yes □No

5.18 If the indicated crop is a ***perennial crop and orchards,*** please provide following extra information:

5.18.1 Total number of trees: ……………….

5.18.2 Average age of trees (years): ……………….

5.18.3 How much was the **average price** of the plant establishment per ha? [ZAR] ………………

6 Livestock related information: Cattle

6.1 Number of animals on farm ………….

6.2 Number of animals you bought in the last 12 months ……………. → The cost per animal purchase

6.3 Determine the type of cattle [indicate breeds if possible] □Beef cattle □Dairy cattle

6.3.1 Please indicate the information regarding the number and average live weight of the herd structure?

Number of adult males……………

Number of adult females …………….

Number of calves …………….

Number of heifers …………….

6.4 What is the purpose of keeping the animal? (Multiple answers are possible):

□Own consumption □Security □Sale of animal and its products □Other (specify)

If ***Sale of animal*** →

6.4.1 Number of animals sold (lived or slaughtered) in the last 12 months ………………

6.4.2 How much was the **average price** you received per selling animal in the **last agricultural year** [ZAR]

6.4.3 How much was the **average price** you received per selling animal in the **past 5 years** [ZAR]

6.5 What is the feeding regime of the animal? (Multiple answers are possible)

□Grazing □Crop residues , grain, supplements □Other (specify)

6.6 Please indicate the feed base of the animal? □Grass only □80%Grass + 20%Crop residues □60%Grass + 20%Crop residues + 20%Supplements □50%Grass + 50%Supplements

6.7 How much is the constraint percentage of feed (grass pasture included):

□0 □30% □50% □60% □75% □100%

If ***grazing*** →

6.8 Where do they graze? (Please specify the area size)

□On farm unit □Planted pastures □Rangeland □Other (Specify)

6.8.1 When Grazing: □Summer only □Year round

6.8.2 Period of feed deficit: □Winter □Spring□Autumn □Summer

6.8.3 Period of feed availability: □Winter □Spring□Autumn □Summer

6.8.4 Please indicate the supplementary feeding/strategy and the month where these are prominent:

□Hay □Grass silage □Crop residues from farmland □Mineral supplements

6.8.5 How much was the average price you paid for buying **feed and supplements** in the last agricultural year [ZAR] ………………

6.8.6 How much was the average price you paid for the **other expenses related to animals** (except feed) in the last agricultural year [ZAR]? ………………

6.9 Do you have feed storage for use in the winter period? □Yes □No

6.10 Have you experienced of weight loss of the animals? □Yes □No

6.10.1 If yes → Indicate period where weight loss was prominent: …………………

6.11 Number of animals lost in the last year…………………

6.11.1 What is/are the main reason(s) of losing this animal? □Feed shortages □Theft □Scarcity of grazing land □Cost of supplements □Water shortage □Diseases □Other (specify):

6.11.2 How often do you lose animals because of **feed shortages**? □Often (each year) □Not often (once in the past 3-4 years) □Not at all

6.12 What is the main constraint to sustain your production? □Availability of grazing land/ lack of pasture □Cost of supplements □Access to water □Access to market □Diseases □Nutritional values of feed □Lack of cash flow □ Limited land and infrastructure □Other (specify):

6.13 Please provide following extra information for ***Animal products***

6.13.1 Which products do you have? And the quantity produced (Litres, kg, ...)

□Meat………………. □Milk ……………. □Other (Specify): ………….

6.13.2 The quantity sold (Litres, kg, ...):

□Meat………………. □Milk ……………. □Other (Specify): ………….

6.13.3 How much was the **average price** you received per selling unit in the **last agricultural year** [ZAR]

6.13.4 How much was the **average price** you received per selling unit in the **past 5 years** [ZAR]

7 Animal 2 and Animal 3: .... [Please specify your second and third main animal]

Please provide following information for ***this animal type***

7.1 Number of animals on farm ………….

7.2 Number of animals bought in the last 12 months → The cost per animal purchase

7.3 What is the purpose of keeping the animal? (Multiple answers are possible):

□Own consumption □Security □Sale of animal and its products □Other (specify)

If ***Sale of animal*** →

7.3.1 Number of animals sold (lived or slaughtered) in the last 12 months ………………

7.3.2 How much was the **average price** you received per animal in the **last agricultural year** [ZAR]

7.3.3 How much was the **average price** you received per animal in the **past 5 years** [ZAR]

7.4 What is the feeding regime of the animal? (Multiple answers are possible)

□Grass □Crop residues, grain, supplements □Other (specify)

7.5 How much was the average price you paid for buying **feed and supplements** in the last agricultural year [ZAR] ………………

7.6 How much was the average price you paid for the **other expenses related to animals** (except feed) in the last agricultural year [ZAR]? ………………

7.7 Number of animals lost last year…………………

7.7.1 What is/are the main reason(s) of losing this animal? □Feed shortages □Theft □Scarcity of grazing land □Cost of supplements □Water shortage □Diseases □Other (specify):

7.8 Please provide following extra information for ***Animal products***

7.8.1 Which products and the quantity produced (Litres, kg, ...) …………………

7.8.2 Quantity sold (Litres, kg, ...) …………………

7.8.3 How much was the **average price** you received per unit in the **last agricultural year** [ZAR]

7.8.4 How much was the **average price** you received per unit in the **past 5 years** [ZAR]

8 Future potential agricultural activities

8.1 Do you have any actual plan to cultivate **new crops in future** (in 5 years)? □Yes □No

8.1.1 Which crops?

8.1.2 How much area are you planning to cultivate new crops? [ha, acres, sq. meters, …]:

8.1.3 What are the reasons for production these crops? □HH consumption □Use for livestock feed □ Sale at Market □Other (specify)

8.2 Do you have any actual plan to keep more **livestock in future** (in 5 years)? □Yes □No

8.2.1 Which livestock?

8.2.2 What are the reasons to keep these livestock? □HH consumption □ Sale at Market □Other (specify)

9 Socio-economic characteristics

Please provide information on ***agricultural extension services***:

Agricultural extension *refers to the provision of agricultural advice and information to crop and livestock producers.*

9.1 In which of the following services did you receive/use support from extension officer for your farming activities **in this year**? □Access to inputs (including machinery and agricultural equipment) □Marketing and market information □Credit access □Cultivation □Livestock keeping □Pesticide application □Fertilizer application □Other (please specify) ………… □None

9.2 How has their performance of providing information changed over the past 5 years? □Improved □Worsened □No change

9.2.1 What is the frequency of visits by extension officer during one year? □Once □Daily □3-4 a week □Weekly □Fortnight □Monthly □Irregular (please state frequency) ……………

9.2.2 How satisfied are you with these services? □Very unsatisfied□Unsatisfied □Satisfied □Very satisfied □Does not apply

9.2.2.1 If ***not satisfied,*** why?

9.3 Which information and decision supports **do you expect** from the extension officer to provide for your farming activities? □Access to inputs (including machinery and agricultural equipment) □Marketing and market information □Credit access □Cultivation □Livestock keeping □Pesticide application □Fertilizer application □Other (please specify) ………… □None

9.4 Please provide information on ***agricultural training:***

9.4.1 Did you have any specific training about farming practices? □Yes □No

9.4.1.1 **If yes**, what specific training did you have? □Crop production □Livestock production □Marketing □Financial management □Risk management □Others (specify): …………

9.4.1.2 **If yes**, was it related to any crop/livestock in particular? □Yes □No

9.4.1.3 **If yes**, which crops/livestock? ....

9.4.1.4 **If yes**, who provided the training? □Government □Academic institutions □Privates □NGOs □Neighbors □Other (specify): ……….

9.4.2 Which training do you think you **need** for your farm? □Crop production □Livestock production □Marketing □Financial management □Risk management □Others (specify): …………

9.5 Which kind of information do you get from ***public media*** ***(e.g. TV, radio, …)***? □Market information □Information on technology/practices □Information on crop management □Weather forecast □Other (Specify)

9.6 Which of the following organizations/groups are you a member? □Farmer associations □Political parties □Credit/Saving groups □Other (Specify) □None

9.6.1 What type of benefits and services do you receive? □Credit □Market information □Information on technology/practices □Access to input □Group marketing □Solidarity/support □Other (Specify)

10 Credit access & investment

10.1 Did you purchase any of the following assets for your farm unit **during the past 5 years** on: (Multiple answers are possible)

		Amount [units]	Did you buy: 1: individually or family 2: jointly with other farmers	Invest volume [ZAR]
	Land			
	Machinery (e.g. motor vehicles, tractors and other transport)			
	Irrigation systems			
	Agricultural equipment (e.g. harrow, seeding machine, etc.,)			
	Non-residential buildings			
	Fences			
	Other assets (specify)			

10.1.1 If ***purchased assets:*** Do you rent out any assets? □Yes □No

10.1.1.1 If ***Yes,*** Which ones? □Land □Machinery (e.g. tractors) □Irrigation systems □Agricultural equipment (e.g. harrow, seeding machine, etc.,) □ Non-residential buildings

10.1.1.2 If ***rent out Land Or buildings:*** How much do you receive per month?

10.1.1.3 If ***rent out Machinery Or Agricultural equipment Or Irrigation systems:*** How many days did you rent out this year?

10.1.1.4 How much did you receive for renting per day?

10.1.1.5 How much was the total cost for maintenance and use of this asset in this agricultural year (repair, fuel, ...)?

10.1.2 If ***not purchased:*** Do you rent any assets? □Yes □No

10.1.2.1 If ***Yes,*** Which ones? □Land □Machinery (e.g. tractors) □Irrigation systems □Agricultural equipment (e.g. harrow, seeding machine, etc.,) □ Non-residential buildings

10.1.2.2 If ***rent Land Or buildings:*** How much do you pay per month?

10.1.2.3 If ***rent Machinery Or Agricultural equipment Or Irrigation systems:*** How many days did you rent this year?

10.1.2.4 How much did you pay for renting per day?

10.1.2.5 From whom? □other farmers □extension services □Other (Specify)

10.1.3 If **Not purchased**→ what was the main reason?

10.2 Do you have plans for investing/purchasing in your farm unit **in the next 5 years**? □Yes □No

10.2.1 If **Yes** → In which objects do you plan to invest over the next 5 years?

□Land → How much acreage?

□Machinery (e.g. tractors) □Irrigation systems □Agricultural equipment (e.g. harrow, seeding machine, etc.,) □Buildings □Fences □Other assets (specify)

10.3 What actions have you taken for this investment? □Saved money □Additional work/job □Take loan/credits □Cut-back spending □Nothing

10.4 Please provide information on **credit accessibility** <u>in the past 5 years</u>

10.4.1 Did you ***have access*** to credits? □Yes □No

10.4.2 Did you ***request*** any credits in the past 5 years? □Yes □No

10.4.2.1 If ***Yes***, did you ***get*** the credits in the past 5 years? □Yes □No

10.4.2.2 How much money have you taken (ZAR)?

10.4.2.3 Indicate the ***sources of credits***: □Commercial banks □Land and agricultural bank □Agricultural cooperatives □Friends/relatives □Private money lenders □Government agencies □NGOs □Input supplier □other (specify)

10.4.3 ***Reasons*** for requesting credits: □Purchasing crop and livestock inputs □Purchasing farm machinery □Purchasing agricultural equipment □Constructing farm buildings □Purchasing land □Non-agricultural activities (e.g. Food consumption, Payment of bills, Social activities) □other (specify)

10.4.4 Type of **collateral** for credits: □Land □other assets (specify)

10.4.5 Interest paid on loans and money borrowed (in %)

10.4.6 When did you get the credit/ loan (year)?

10.4.7 How long is the repayment period of credits (in month)

10.4.8 How much money do you have to pay per repayment time (ZAR)

10.5 If **not getting credits:** Please determine the reason(s) for not getting any credits: □Not required or necessary □Can easily obtain from friends or family □Lack of information □High rate of interest □No land title to pledge to get credit □Not having job □Long loan processing period □Negative loans history □Unfavorable policy, legal and regulatory framework □Not affording to pay back

11 Governmental support

11.1 Have you received any kinds of governmental support in the past 5 years? □Yes □no

11.2Which kind of agriculture related assistance have you received from government?

□Seeds □Fertilizer □Pesticide □Tractor □Agricultural equipment □Food □Money □Other (specify)

12 Risk assessment

12.1 How do you assess the possibility (frequency) of occurrence and the potential damage (negative impact) of the following **shocks**?

	Possibility of occurrence (1= "never" to 5= "very often")					Potential damage (1= "very low" to 5= "very high")				
Climatic/weather risks	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Droughts										
Flooding										
Storm/ wind										
Production risks	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Pests or diseases										
Epidemic animal diseases										
Lack of feed and fodder supply										
Reduced land availability										
Theft (crops)										
Theft (livestock)										
Theft (equipment)										
Market and price risks	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Price volatility on sales markets										
Price volatility on purchase markets/inputs										
Political risks	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Uncertain rights of land use										
Tax increase										
Financial risks	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Sudden lack of money for basic requirement										
Uncertainty of receiving credits										
Other risks	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Limited availability of qualified (skilled) workforce										

12.2 **How do you see yourself**: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please tick a box on the scale, where the value 0 means: 'not at all willing to take risks' and the value 10 means: 'very willing to take risks'.

If you are not sure about the consequences of something (e.g. spending money for something), are you willing to do it? This can either cause profits or losses in the future. It is unsure. Or do you prefer only doing things, for which you are fully sure about the consequences?

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

13 General household information

13.1 How many people does your family **comprise**? ………..

13.1.1 How many of them **stay permanently** in your house (including you)? ………..

13.1.2 How many of them are **below 15** years old? ………..

13.1.3 How many of them are **above 65** years old? ………..

13.2 For each of the people, who **live permanently in your house** and who are **above 15 years old**, we need some information to be able to better estimate the labor input on your farm:

HH member ID	**Relationship to HH head [a]**	**Gender** 1: Male 2: Female	**Age/ Year of birth**	**Marital status [b]**	**Years of formal education**	**Highest degree obtained [c]**	**Main occupation [d]**	**Participation in farm work** 1: Yes 0: No	**Years of farming experience**	**Off-farm occupation** 1: Yes 0: No	**Working hours per day at farm**	**Working days per cropping season at farm**
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

[a]: 1: Head, 2: Husband/wife, 3: Child, 4: Parent, 5: Grandchild, 6: Siblings, 7: Grandparents, 8: Sister/brother-in-law, 9: Parent-in-law, 10: Children-in-law, 11: Stepchildren, 12: Migrant, 13: Others (please specify)

[b]: 1: Never married, 2: Partner, 3: Married, 4: Divorced/Separated, 5: Widowed

[c]: 0: Illiterate, 1: Literate but not FORMAL schooling, 2: Primary school, 3: High school, 4: University or higher

[d]: 1: Farming on own farm, 2: Permanent labor on another farm, 3: Casual labor on another farm, 4: Off-farm own business, 5: Paid/ Salaried employment (private or public), 6: Student/ school, 7: Unemployed, 8: Unable to work, 9: Others (please specify)

13.3 How many of the household members contributing to the ***household income***?

13.4 Number of employees **who are received salaries and wages** for the last pay period:

Employee category	**Number**	**Working hours per day**	**Working days per cropping season**	**Salaries and wages (ZAR)**
Male employees				
Female employees				

13.5 Do you have sufficient workforce for your farm? □Yes □No

13.6 If No, what is/ are the main reason(s) for not hiring more? □Too expensive □No qualified workers available □Other (specify):

13.7 What are the sources of your household's income?

Sources of income	**ZAR**	**Unit**
Income from sales of agricultural production		Per season
Income from off-farm occupations (head)		Per month
Income from agricultural equipment rental		Per season
Pensions		Per month
Remittances (Money from relatives)		Per month
Income from Government and NGO's assistance (child grant)		Per month
Other sources:		

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Declarations

1. I, hereby, declare that this Ph.D. dissertation has not been presented to any other examining body either in its present or a similar form.

Furthermore, I also affirm that I have not applied for a Ph.D. at any other higher school of education.

Göttingen, ...

....

(Signature)

....

(Name in block capitals)

2. I, hereby, solemnly declare that this dissertation was undertaken independently and without any unauthorized aid.

Göttingen, ...

....

(Signature)

....

(Name in block capitals)

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Ph.D. Candidate in Agricultural Economics and Rural Development **2018–2023**

Chair of Agricultural and Food Business Management

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Doctoral dissertation: "Analyzing Smallholder Farmers Performance- Farmer Typology, Technical Efficiency, Market participation, Policies and Management Practices: Evidence from Limpopo region of South Africa", embedded in the BMBF funded joint research project SPACES 2 – SALLnet

Master of Science (M.Sc.) in Agricultural Economics **2013 –2017**

Institute of Agricultural Sciences in the Tropics

University of Hohenheim, Stuttgart, Germany

Title of M.Sc. thesis: Farm-level modeling of the adoption of new crops under climate change; a case study for the "Kraichgau" (South west of Germany)

Master of Science (M.Sc.) in Agricultural Economics **2008 –2012**

Ferdowsi university of Mashhad, Mashhad, Iran

Focus: Agricultural policy and Rural Development

Title of M.Sc. thesis: Identification of factors influencing the production capacity of food and beverage industries, and devise appropriate strategies to improve their status (A case study for "Khorasan-Razavi" Province in Iran)

Bachelor of Science (B.Sc.) in Agricultural Economics **2004 –2008**

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WORK-EXPERIENCE

Research Associate **2018 – 2022**

Chair of Agricultural and Food Business Management
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SALLnet Project: South African Limpopo Landscapes Network

- ✓ Project management (field work preparation, initiated collaboration with farmers, extension services, agricultural organizations in South Africa, arranging meetings, organizing team working, survey design and implementation (online and on field), data collection, data management and analysis, modelling and policy recommendations
- ✓ Travelled to South Africa and stayed for three months for collecting data
- ✓ Writing reports and paper, presenting the results to farmers, conferences and seminars (internal seminars, doctoral seminars)
- ✓ Supervised master students for master thesis

Student Research Assistant **2014 –2017**

Hohenheim University, Stuttgart, Germany

DFG Project FOR1695: Agricultural Landscapes under Global Climate Change - Processes and Feedbacks on a Regional Scale in Baden Würtemberg with MPMAS (Mathematical programming with multi agent system software)

- ✓ Assisting in the modelling and analyzing farmers response to climate change within the DFG Project FOR1695
- ✓ Data analysis and modelling
- ✓ Development of cost-benefit (gross margin) model

Research Assistant **2012 –2013**

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Support as interviewer, design and analysis of modelling and programming in following researches:

- ✓ “Devise Appropriate Strategies for the Institute of Parks and Green lands of Mashhad Municipality, considering the Implementation of Targeted Subsidies Law”, under supervision of Prof. Dr. Naser Shahnoushi Foroushani
- ✓ “Training the Human Resources at the Ferdowsi University of Mashhad, in order to Match to the Country's Long-Term Business Environment”, under supervision of Prof. Dr. Naser Shahnoushi Foroushani
- ✓ “Analysis of the Effective Bicycle Transport Infrastructure to Integrate Bicycle Transport into Short-Distance Passenger Transport system” (Case Study of Mashhad), under supervision of Dr. Leili Abolhasani

PUBLICATIONS

2023 Typologies of South African small-scale farmers and their risk perceptions: an unsupervised machine learning approach. China Agricultural Economic Review, first revision, under review

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2012 Economic Evaluation of Sugar Industry from the Perspective of Macroeconomic Management. The Thirty-Fourth Annual Congress of Iranian sugar factories, Mashhad, Iran, May 2012

2011 SWOT – ANP Analysis of Food & Beverage Processing Industries in Khorasan-Razavi, Iran. present as poster in 21st Annual IFAMA World Forum and Symposium, Frankfurt, Germany, June 2011.

2010 Estimation of Willingness to Pay for Air Quality Improvements (Case study: Mashhad, Iran), accepted to present in the 5th IRDO international conference, Maribor, Slovenia.

2010 Drought Risk Management for Sustainable Use of Agricultural Water Resources in Golestan Province, Iran (Case of Gonbad-e-Kavous County), accepted to present in the 5th IRDO international conference, Maribor, Slovenia.

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Place, Date Signature