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TYPOLOGY OF SMALL-SCALE FARMERS IN SOUTHERN AFRICA AND IMPLICATIONS FOR POLICY DESIGN

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Abstract

Small-scale farmers play a vital role in providing food for a growing urbanized population and improving food security in Southern Africa. The smallholder farms are highly heterogeneous in terms of types of farming, levels of productivity and commercialization. These heterogeneous groups of smallholder farming systems require different forms of government interventions, depending on the objective and characteristics of each group. The aim of this paper is 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. For this, a cluster analysis is conducted on the basis of a comprehensive survey among 212 small-scale farmers in the Limpopo region in 2019. An unsupervised machine learning approach with Partitioning Around Medoids (PAM) for the subsequent clustering is used. According to the results, the small-scale farmers can be grouped into four clusters. 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 market-oriented farmers. The other two clusters are the semi-subsistence livestock and the crop-oriented farmers that predominantly produce for own consumption and sell their surplus at their farm. According to the results, implications for target-group-specific policies are exemplary derived with regards to the topics of extension services, the adaptation of irrigation technologies and credit access.

Keywords: Machine learning, Partitioning Around Medoids, smallholder, small-scale farming, agricultural policy design, Southern Africa

1. Introduction

In most African countries, the agricultural sector is amongst the most important economic sectors and plays a critical role in contributing to the achievements 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 and ecosystems.

Agriculture in sub-Saharan African countries in general, and South Africa in specific, is still largely dualistic; consisting of a relatively small group of large-scale commercial farmers on one hand and a relatively large group of small-scale, mostly subsistence farmers on the other hand (Aliber et al., 2009). Historically in those countries, policy emphasis was mainly on the development and support of the formal commercial agricultural sector, rather than the numbers and cultivated land of a much larger group of smallholder sector (Modiselle, 2001). However, throughout the past two and a half decades, this has more and more shifted towards also supporting small-scale farmers. For instance, the South African National Development Plan from 2011 put specific emphasizes to “former homeland areas”, so small-scale farmer communities (NPC, 2011).

For creating accurate target-group-oriented policy measures, a crucial pre-requisite is to understand the structure of the addressed group of farmers in a comprehensive and objective way. While a growing body of literature deals with ways to develop small-scale farmers and their management practices, most of them still view this group as largely undifferentiated with limited consideration of contextual factors that produce and exacerbate the unevenness between them (Olofsson, 2019). Therefore, stereotypes such as “smallholder” need

to be deconstructed to allow for a more target-group-oriented policy design, for instance, with regard to technology adoption and access to funding, within this large group of farmers.

Therefore, the overall aim of this study is 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. For this, a cluster analysis is conducted on the basis of a comprehensive survey among small-scale in the Limpopo region from 2019, which comprises a wide range of quantitative variables and "hard facts" about their farms, management practices and socio-demographic data of themselves. An unsupervised machine learning approach with Partitioning Around Medoids (PAM) for the clustering of farmers is used. Compared with the popular k-means clustering method, which can only analyze continual variables, PAM takes into account mixed data (Lesmeister, 2015). From the results, implications for target-group-specific policies are exemplary derived with regards to the topics of extension services, the adaptation of irrigation technologies and credit access.

An overview of existing limited typologies of small-scale farmers and their shortcomings is presented in section 2. Data and methodology are described in Section 3. The descriptive statistics and the PAM clustering results are presented in Section 4 and discussed in Section 5 in relation to policy design. Finally, conclusions are drawn in Section 6.

2. Typologies of smallholder farming systems in sub-Saharan Africa

The definition of smallholders or small-scale farmers varies between countries and agro-ecological zones (Dixon et al., 2004; Pienaar, 2013), as these farmers are heterogeneous and vary significantly depending on farm characteristics including socioeconomic characteristics, resource endowments and agro-ecological dimensions (FAO, 2017a).

The existing literature on classifying smallholder farmers uses various 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 smallholders, although the threshold measures vary across countries and regions (FAO, 2017a).

In South African policy and planning documents, there are several definitions and terminologies for smallholder farmers which are inconsistent and differ depending on the context. Table 1 provides a brief overview of relevant farmer typologies in research studies and policy documentations in South Africa to focus on policy implementations.

According to the South African agricultural department (DAFF, 2015), farmers are classified mainly by their land size and their primary purpose of production, while the main differences within and between the farming groups are not apparent. Based on that, smallholders are mainly referred to as the farm categories between the two extreme groups of subsistence and large-scale commercial farmers, although they are classified into two groups of subsistence and emerging smallholder farmers, whereas Subsistence smallholder farmers are defined as the ones that involved in agricultural production only for own household consumption, however, emerging farmers selling their products at market.

In the National Planning Council (NDP) documents, the farmers are classified based on the purpose of job opportunities, and livelihood improvement in addition to their farm size. The farm typology according to (DRDLR, 2009) classified farmers in five different categories based on the land reform projects. In compare to other policy documents, they considered more criteria such as farmers' aspirations, capabilities and resources.

Based on the insights gained from literature on smallholder farmer typologies in South African policy documents, none of the classifications considered socioeconomic characteristics and resource endowment management of the farmers in analyzing the diversifications between groups.

Table 1. Farmer Typologies in South Africa

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	Degree of commercialization,

	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)	importance of agriculture in household's livelihood, poverty level
National Planning Council (NPC, 2011)	Subsistence farmers (<0.5 ha); smallholder farmers (0.5–5 ha or >5 ha)	Land size
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

Source: (Olofsson, 2019)

3. Data and Methodology

In the following, the study area and data collection will be presented and afterwards the methodology of the classification of smallholder farming system and determining of the optimal number of clusters are introduced.

3.1 Data collection

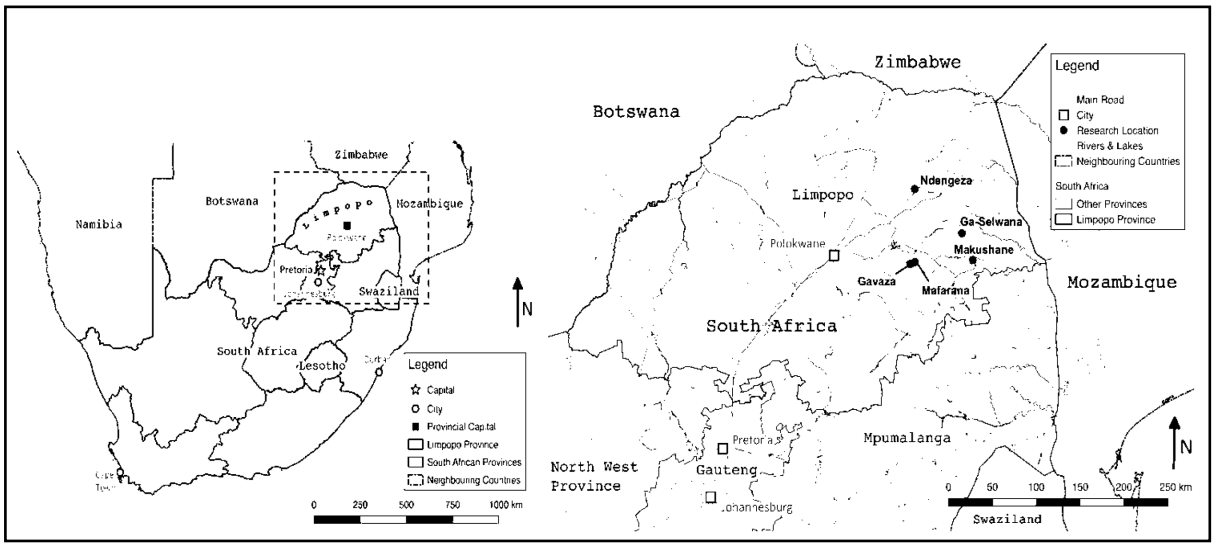
The research was conducted in the Limpopo province of South Africa, located in the north-eastern of the country. Climate variability in this province is characterized by the long dry spell in winter season along with irregular rainfall patterns in the summer season (October-April), which also influenced by the El Nino-induced drought event (Mosase & Ahiablame, 2018).

Limpopo is one of the least developed provinces in South Africa compounded by an acute population growth rate and poverty. With the population of 5.8 million people, Limpopo comprises around 10% of the total population of South Africa (STATS SA, 2016). A large share of the population (89%) living in rural areas and farming is their main occupation (Gyekye & Akinboade, 2003; LDARD, 2012). Five study areas were selected from Limpopo province based on their climatic aridity differences, demography and socioeconomic factors. The selected sites are located in rural areas: Mafarana, Gavaza, Ga-Selwana, Makushane, and Ndengeza (Figure 1). These are situated in the Mopani district of Limpopo province. Farming system in the selected areas are mainly small holder farmers with limited resource endowments.

A structured questionnaire was conducted between April and July 2019 after pretesting 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.

Using a purposive random sampling procedure, data were collected from 215 smallholder farm households across the five selected villages in Limpopo, of which three had to be excluded due to incomplete information. Consequently, the final data set for the following analysis covered 212 observations. To capture the broadest possible diversity, the sample included different sized farms with diverse agricultural activities that had different degrees of market integration and self-provisioning, using snowball sampling in selected villages. Permission to access farmers was obtained from tribal authorities of each village.

Figure 1. Research area map



Source: Own illustration

3.2 Variables for classification

The diversity of smallholder farming systems in our study were 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 studies on smallholder farmer typologies in South African policy documents, the multidimensional criteria of selected variables provide further differentiation and detail in analyzing the diversifications between groups. Table 2 presents the descriptive statistics of the selected continuous and categorical variables. A total of 34 variables were applied to construct the smallholder farming system classification.

3.3 Methodology

Clustering as one of the unsupervised learning techniques, allows identifying patterns within the data set to create homogenous groups by considering the similarities of members within the same groups and dissimilarities between the groups (Graskemper & Feil, 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 et al., 2021; Lesmeister, 2015). These methods are mainly rely on the initial center of the cluster (Xu & Tian, 2015). Accordingly, k-means considers 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 is generally more robust against noise and outliers in compare to k-means (Xu & Tian, 2015).

Partitioning around medoids (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). According to Gower, (1971), the goal of this metric is to minimize sum of dissimilarities between all observations and the nearest medoid (Lesmeister, 2015). The analysis were conducted using R statistics software and Gower dissimilarity matrix was computed using 'dist' or 'daisy' functions in R (Arunachalam & Kumar, 2018).

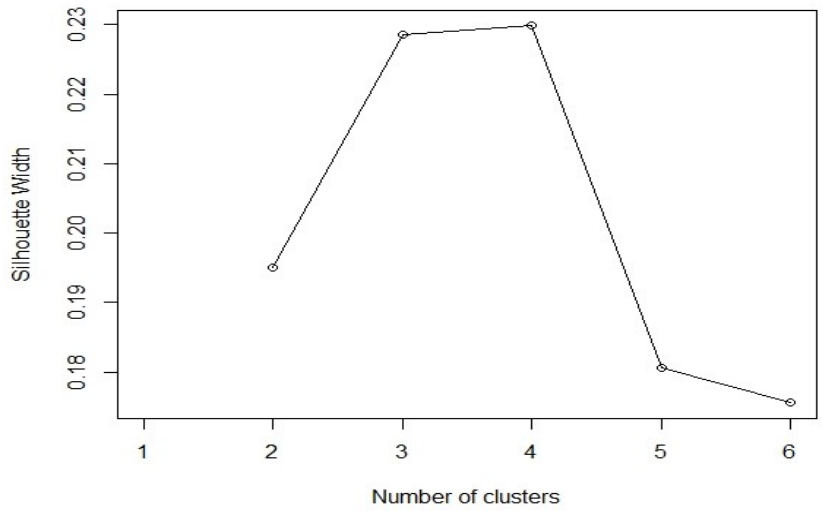
3.4 Optimal number of clusters

The selection of an optimal number of clusters is the prerequisite for clustering (Lesmeister, 2015). To determine the optimal number of clusters, the average silhouette 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 well clustering. The optimal number of clusters (k) is the one that maximize the average silhouette over a range of possible values for K (Kaufman; & Rousseeuw, 1990).

According to figure 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 smallholder farming systems in South Africa.

Figure 2. Optimal number of clusters based on average Silhouette method



4. Results

In the following, after describing the selected variables in the sample, the results of clustering and differences/diversifications in characteristics of the farming systems are compared between the four selected clusters.

4.1 Description of the sample

Several farm household variables such as farm inputs, assets, farm performance, farm management, and socio-economics were used to construct the farm typologies. Table 2. summarizes the descriptive statistics of the variables implemented in the clustering.

It shows the 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 were the same as the national general household survey in 2019 with 48.8% (Statistics South Africa, 2019).

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 system, smallholder farming system is mainly characterized by mixed crop-livestock production. Besides maize[1] (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[2] with 59% of farmers, fruits[3] with an average of 32%, and vegetables[4] with 15% of the farmers. Livestock consists of cattle, goats, pigs as well as chickens. Cattle provide the main source of livestock income. In average, 41% of agricultural income is from crop sales and 25% are from livestock sales.

Social grants including old age and child support grants play an important role on farm household incomes for most of smallholders. According to Statistics South Africa (2019), around 59% of the households received grants as their main sources 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 training. Only 10 % of the respondents have access to formal credits but 37% of the farmers invested in the last five years

[1] 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.

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

[3] Fruits such as Mango, banana

[4] Vegetables include tomato, onion, cabbage

mainly on equipment for irrigation, fences, and machinery. Besides household members as labors on farm, the permanent and seasonal employed labors worked on average 48.5 and 17.33 man-days per year (1 man-day = 8 hours/person).

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 are purely rain-dependent, while in average 9% and 16% of farmers have access to public water sources and private boreholes. Hence, 49% of the sample use primitive irrigation methods (e.g., buckets, farrow)

Table 2. Descriptive statistics of the variables

Variable	Definition	Scale/ measurement	Mean	SD	Min	Max
Farmer						
age	Age	Number of years	66.45	11.19	33	93
gender	Gender	1= male; 0 = female	0.52	0.50	0	1
educ	Education	Number of years	4.76	5.04	0	1
Job_offFarm	Off-farm job of the farmer	1= yes; 0 = no	0.22	0.41	0	1
Inc_socio	Social grant income	In Rand	26689.8	15308.7	0	69840
Inc_remit	Remittence 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						
Farm_area	Total area of the farm	Number of hectares	4.44	6.13	0.25	47
Cult_area	Total area under cultivation		3.02	3.33	0	22
Winter_fallow_area	Share of fallow area in winter	Share: 0 - 1	0.70	0.43	0	1
Nr_winterCrops	Number of crops cultivated in winter	Numbers	0.25	0.72	0	6
Cr_vegetables	Cultivating vegetables	1 = yes; 0 = no	0.15	0.36	0	1
Cr_fruits	Cultivating fruits	1 = yes; 0 = no	0.32	0.47	0	1
Cr_legumes	Cultivating legumes	1 = yes; 0 = no	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 = no	0.58	0.49	0	1
Nr_cattle	Number of cattle	Number	4.6	9.4	0	65
Inc_onFarm	Income of selling crops and animals	In 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 = no	0.06	0.23	0	1
Water source						
➢ Rain-dependent	Depends on rain	1 = yes; 0 = no	0.34	0.47	0	1
➢ Tap water		1 = yes; 0 = no	0.41	0.49	0	1
➢ Public dam, lake		1 = yes; 0 = no	0.09	0.29	0	1
➢ Private borehole		1 = yes; 0 = no	0.16	0.36	0	1
Irrigation_Time	Hours of Irrigation in year	Number of hours	91.56	310.50	0	2184
Irrigation_Method	Methods of irrigation					
➢ No Irrigation		1 = yes; 0 = no	0.34	0.47	0	1
➢ Primitive Irrigation method		1 = yes; 0 = no	0.49	0.50	0	1
➢ Advances Irrigation method		1 = yes; 0 = no	0.16	0.36	0	1

PesticideUse	Applying pesticide on farm	1 = yes; 0 = no	0.14	0.34	0	1
FertilizerUse	Applying fertilizer on farm	1 = yes; 0 = no	0.31	0.46	0	1
Employee_Permanent	Number of hired permanent worker in year	Man-day numbers of permanents hired worker	48.50	255.60	0	2484
Employee_Seasonal	Number of hired seasonal worker in year	Man-day numbers of seasonal hired worker	17.33	59.36	0	540
OnFarmMarket	Selling at farm	1 = yes; 0 = no	0.58	0.49	0	1
OffFarmMarket	Selling at market	1 = yes; 0 = no	0.17	0.38	0	1
CreditAccess	Access to credits	1 = yes; 0 = no	0.10	0.30	0	1
Invest_past5Yrs	Investment in the past 5 years	1 = yes; 0 = no	0.37	0.48	0	1
ExtVisits_Yr	Number of visits/support of Extension services	Number of visits	1.32	4.35	0	52

4.2 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 their 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 and crop oriented farmers*** that predominantly producing for own consumption and selling their surplus at their farm. This means that the latter two groups can be understood as intermediate groups in their development.

4.3 Characterization and Comparison of the Clusters

Table 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 proportion (percentage) for categorical variables for each of the farmer type clusters. Additionally, figure 2 illustrates the relative distribution of the variables 'expression for the selected four groups.

Table 3. Results of Cluster Analysis

Cluster Names	Subsistence oriented	Semi-subsistence Livestock-oriented	Semi-subsistence Crop-oriented	Market-oriented	Overall significance
Number of members	80	48	54	30	
Farmer Charactersitics					
age	70.7 (10.6)	65.9 (10.7)	64.5 (7.95)	59.6 (14.1)	< 0.001
gender	0.35	0.77	0.31	0.93	< 0.001
educ	2.62 (3.58)	5.6 (4.82)	4.50 (4.71)	9.60 (5.80)	< 0.001
Job_offFarm	0.24	0.19	0.15	0.34	0.147
Inc_socio	26676 (12391)	31670 (18081)	25080 (13421)	21656 (18861)	< 0.001
Inc_remit	5487 (13471)	4350 (14991)	3080 (7439)	2320 (9057)	0.55
Risk_att	3.5	4.6	4.1	6.10	< 0.001
Farmer Charactersitics					
Farm_area	2.93(2.41)	4.59 (6.20)	2.83 (2.13)	11.1 (11.4)	< 0.001
Cult_area	2.34 (1.87)	2.83 (3.16)	2.42 (2.06)	6.23 (5.88)	< 0.001
Winter_fallow_area	0.85 (0.34)	0.63 (0.46)	0.80 (0.38)	0.29(0.39)	< 0.001
Nr_winterCrops	0.06 (0.37)	0.19 (0.89)	0.07 (0.26)	1.20 (0.96)	< 0.001
Cr_vegetables	0.01	0.08	0.06	0.80	< 0.001
Cr_fruits	0.01	0.52	0.72	0.10	< 0.001
Cr_legumes	0.85	0.33	0.65	0.23	< 0.001
SaleValue_cropShare	0.05 (0.20)	0.35 (0.38)	0.66 (0.25)	0.91 (0.15)	< 0.001

SaleValue_animShare	0.01 (0.04)	0.14 (0.12)	0.02 (0.06)	0.15 (0.25)	< 0.001
Animal	0.44	1.00	0.43	0.60	< 0.001
Nr_cattle	3.22 (8.97)	8.56 (10.8)	1.41 (3.27)	7.83 (12.5)	< 0.001
Inc_onFarm	1740 (6335)	13504 (21033)	2860 (4548)	146121 (296717)	< 0.001
Inc_onFarm_crops	0.03 (0.16)	0.22 (0.35)	0.96 (0.16)	0.77 (0.32)	< 0.001
Inc_onFarm_anim	0.11 (0.30)	0.68 (0.41)	0.04 (0.16)	0.23 (0.32)	< 0.001
Resource management and external incentives					
OwnTractor	0.02	0.00	0.02	0.30	< 0.001
Water source					< 0.001
• 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					< 0.001
• 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	< 0.001
FertilizerUse	0.30	0.23	0.20	0.67	< 0.001
Employee_Permanent	5.82 (36.8)	2.58 (16.6)	0.00 (0.00)	323 (617)	< 0.001
Employee_Seasonal	9.19 (21.2)	8.48 (18.8)	9.44 (24.4)	67.3 (140)	< 0.001
OnFarmMarket	0.09	0.94	0.96	0.67	< 0.001
OffFarmMarket	0.00	0.10	0.09	0.90	< 0.001
CreditAccess	0.02	0.06	0.06	0.43	< 0.001
Invest_past5Yrs	0.19	0.27	0.48	0.83	< 0.001
ExtVisits_Yr	0.78 (1.45)	0.48 (0.68)	0.54 (0.54)	5.50 (10.5)	< 0.001

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

4.4 Farmer characteristics

The four defined clusters are diverse in terms of farmer characteristics. As in figure 2 shows, Subsistence-oriented farmers are mainly women with an average of 71 years old. They are mainly illiterate with an average of 3 years of formal educations. Their main sources of income are remittance and social grants (mainly pension). In contrast, market-oriented farming system is characterized with predominantly male farmers with higher education in compare to other groups. The share of social grants and remittance are lower in compare to other groups, as they are comparatively younger and involve to off farm jobs.

In terms of risk perception, subsistence- oriented farmers and semi-subsistence crop oriented farmers are more risk averse and market-oriented farmers and semi-subsistence livestock oriented farmers taking more risks.

4.5 Farm characteristics

Subsistence and semi-subsistence crop oriented farming have the least land area which mainly cultivate 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 area with cultivating in almost in both seasons. They involve in agricultural diversification with focus mostly on vegetables and livestock. Their main purpose of cultivation is for marketing.

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

4.6 Resource endowment management characteristics

Taking 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. High share of farmers in this group apply fertilizer and pesticide on their fields and employ permanent and seasonal labors. 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 labors.

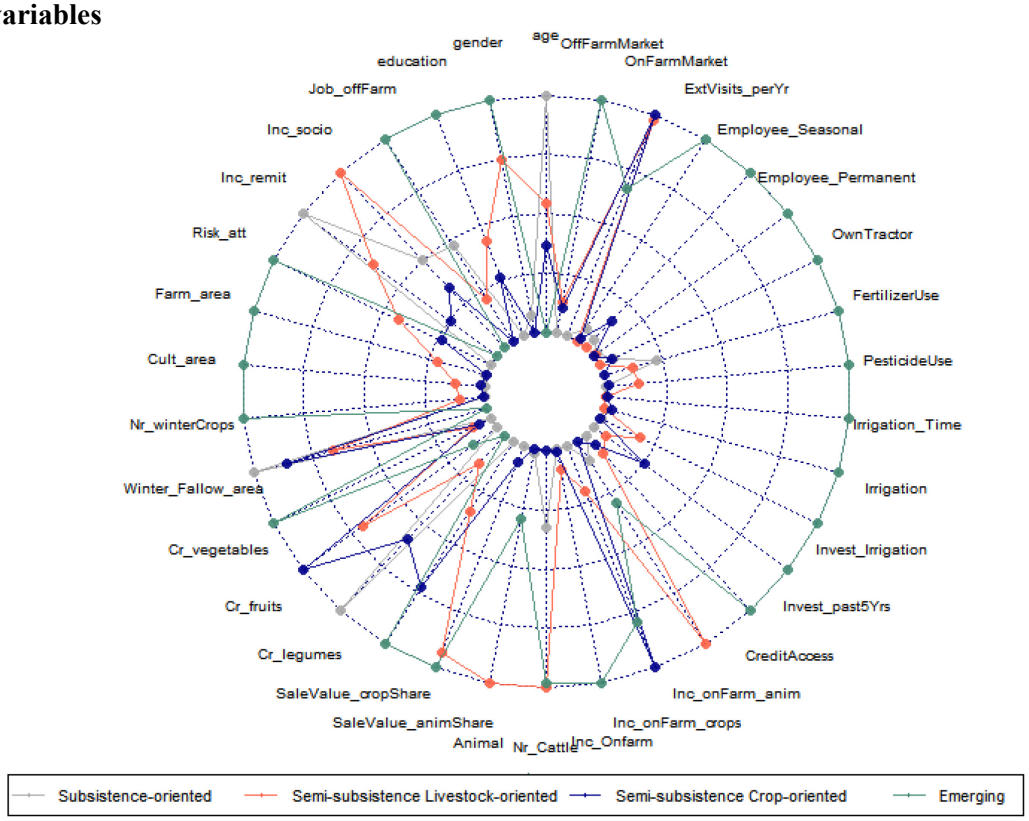
5. Discussion and policy implications

The agricultural sector plays a vital role in the development of rural economies in Southern Africa (NPC, 2011). In recent years, regardless of the government supports and various strategies implemented to improve the agricultural sector in South Africa (Baloyi et al., 2012; Cele & Wale, 2018; FAO, 2017b; Gwebu & Matthews, 2018), the smallholder farmers still confront several challenges that lead to exacerbating the issue of food security and poverty (Baloyi et al., 2012).

One of the main reasons for the ineffective policies of agricultural development for the smallholder farmers in South Africa, is the holistic view to the smallholder farmers and support them in a way to become large-scale commercial oriented farmers, based on the "bigger" is the "better" principle (Aliber et al., 2009; Olofsson, 2019; Pienaar, 2013), regardless the heterogeneity of natural and socioeconomic resources among the farmers (Mądry et al., 2016).

Comprehension about farm type-specific characteristics, their constraints and opportunities is a prerequisite in effectively implementing the policies among smallholder farmers. Hence, adequate strategies and technologies can be developed and adjusted to the specific types of farming systems based on the structure and objectives of these farm households in each type (Aliber et al., 2009; Dunjana et al., 2018; Kraaijvanger et al., 2016; Mądry et al., 2016; Pienaar, 2013).

Figure 2.PAM results: Characteristics of different farmer groups. Relative distribution of the expression of the variables



The results of the clustering according to the previous section 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 documentations in South Africa, 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 involve in agriculture mainly for providing 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 daily wage labor). These farmers are highly dependent on government and extension services support to meet household food security. They mainly sell their agricultural products (typically livestock) as an extra source of income.

Market-oriented farmers have sufficient land and labor resources, as well as water and other inputs to diversify production, which is mostly market-oriented. They grow vegetables predominantly. Their primary sources of income are selling agricultural products and other jobs. Hence, comparatively, financial capital is not a constraint for them and some of them are already invested in more advanced irrigation equipment.

The semi-subsistence crop- as well as livestock-oriented farmers, which can be seen as intermediate groups between the former mentioned groups, farming is 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.

According to the literature and our results, heterogeneous groups of small-scale faming systems require different forms of government interventions, depending on the objective and characteristics of each group. In particular, we investigate the three main interventions as the priorities, based on the results of the four types of smallholder farming system:

1. **Extension services support:** The results indicated that access to extension services and distribution of their support among different farm-types of smallholders are not the same and skewed to particular farming groups, especially the market-oriented farmers (Table 3). Previous studies indicated the low ratio of numbers of extension officers to the numbers of the farmers and poor quality of formal education, and lack of appropriate practical training are the main constraints of extension services (Aliber et al., 2009; Dunjana et al., 2018). Improving the effectiveness of extension supports can be reached by providing various forms of support to specific farm types by designated skilled extension officers (Aliber et al., 2009). Subsistence farmers can get support (e.g., technical supports, initial provision of inputs, capacity building and motivation (Aliber et al., 2009)) with the aim of increasing livelihood sources and to improve food security (Pienaar, 2013). The supports related to semi-structured crop (/livestock)-oriented farming systems should be aimed at involving in specialized crop (/livestock) species, production diversification and transfer information. Moreover, the market-oriented farmers require knowledgeable extension officers regarding crop-livestock diversification systems with high technologies and with the target of expanding production and access to markets.
2. **Water supply and irrigation schemes among the four types of farming system:** 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). Access to water and irrigation systems plays an important role in developing small-scale farming systems. However, the share of irrigated land for smallholders is still very small to the country's overall farmland. According to the study of (Aliber et al., 2009), one solution to expand access to irrigation is to redistribute land reforms to allocate more irrigated farmland to smallholders. Moreover, 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, soil conservation, irrigation and rainwater harvesting are the main approaches to water supply for smallholders. More details can be found in (Aliber et al., 2009). The main goal for soil conservation is to reduce the soil erosions 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 smallholder groups. 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 South Africa.
3. **Credits and financial supports**: Limited access to credits 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 as the main constraints of the supply-side factors. However, risk-averse attitude and financial illiteracy of borrowers, as well as high transaction costs are the main constraints of the demand-side (Balana et al., 2020). Improving credit access requires considering these two factors.

   The main funding institutions for the agricultural sector in South Africa are the Comprehensive Agricultural Support Program (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 reduce socioeconomic distress. Holding communal land title, a so-called Permission to Occupy (PTO), and lack of capital assets among most of the smallholder 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 of getting credits from the institutions (Murugani & Thamaga-Chitja, 2018). Besides financial supports, these farmers can get technical and physical supports from a variety of institutions such as independent research organizations, local and district municipalities, government departments, universities, and NGOs (Aliber et al., 2009).

6. Summary

To design and implement agricultural policies effectively to support smallholder farmers, 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 the paper was to develop the typology of the smallholder farmers in the Limpopo province of South Africa. A farm level survey data from 212 smallholder farmers in five selected regions of Limpopo were collected in 2019 and analyzed by using 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 of 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 the farming systems and the main drivers of diversities provide an entry point to analyze the current policy implications and develop the strategies based on the specific characteristics of each farm type. Current agricultural development policy in South Africa concentrate excessively on commercial oriented smallholder farmers rather than subsistence farmers (Aliber et al., 2009). Our results indicated that the share of subsistence and semi-subsistence farmers are high in compare to market-oriented farmers and require more attention and support.

A clear limitation of the study is that although the clustering on the basis of hard facts and quantitative data generally represents a solid fundament, deeper explanations of reasons and motives are missing. Another limitation lays in the fact that, although the investigated sample is relatively large, it still deviates in some variables from other existing surveys of South African small-scale farmers. Here, representativeness could be further improved in future surveys.

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