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Farm Typologies and Resource Endowment Among Smallholder Farmers In Semi-Arid Region, Nigeria

Nijerya'nın Yarı Kurak Bölgesindeki Küçük Çiftçiler Arasında Çiftlik Tipolojileri ve Kaynak Bağışı

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ÖZ

Nijerya'nın Kuzeybatısı'ndaki yarı kurak araziler, Sahra Altı Afrika'da tahıl ve diğer ekilebilir bitkilerin üretimi için önemli bir pazar oluşturmaktadır. Bu çalışma için, Kuzeybatı Nijerya'nın yarı kurak bölgesinde 168 küçük çiftlik büyüklüğündeki hane arasında birincil verileri kullanarak kesitsel bir anket gerçekleştirildi. Analiz araçları, temel bileşen tahmininin çok değişkenli istatistiksel araçlarının yardımıyla tipoloji oluşturmayı ve 2021 anket verilerinin yardımıyla kümeleme çalışmasını içermektedir. Her üç çiftçi grubu da tarım dışı faaliyetlere farklı derecelerde de olsa önemli ölçüde katılmıştır. Bu çalışma, yalnızca çiftçi haneleri arasındaki çeşitliliği vurgulamakla kalmamış, aynı zamanda yarı kurak arazi sisteminin karmaşıklığını da sergileyerek, sürdürülebilir kuraklık yönetim planları geliştirmek için hedefli teşviklerin gerekliliğini vurgulamıştır. Bu bağlamda, ileri tarım teknolojilerine daha iyi erişim sağlamak ve verimi ve hayvancılığı artırmak için bunların kullanımı konusunda eğitim vermek, geçim kaynaklarını ve genel refahlarını güçlendirmede kilit rol oynayabilir.

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A B S T R A C T

The semi-arid land of the North West of Nigeria is an important niche for cereal and other arable crops production in sub-Saharan Africa. For this study, we conducted a cross-sectional survey among 168 small farm size households in the semi-arid region of North West Nigeria, using primary data. The tools of analysis include constructing typology with the aid of the multivariate statistical tools of principal component estimation and cluster study with the aid of 2021 survey data. All the three farm groups were markedly involved in non-farm activities but at different degrees. This study not only highlighted the diversity among farming households but also showcased the complexity of the semi-arid land system, underscoring the necessity for targeted incentives to develop sustainable dryland management plans. In light of this, granting better access to advanced agricultural technologies and providing training on their utilization to increase yields and livestock production could be key to bolstering their livelihoods and overall well-being.

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1. Introduction

A substantial number (54%) of Africa's population are rural smallholder farmers (FAO, 2014) with Nigeria accounting for over 80% of its farmers falling into this category (Mgbenkai and Mbah 2016). These farmers are the key players of the agricultural sector and the stronghold of the wealth of sub-Saharan African (SSA) nations including Nigeria who are greatly dependent on agriculture (Davis et al., 2017; Altieri, 2009; GoK, 2009; Wiggins 2009; Chamberlin, 2007). This is because, majority of the farming population (about 70%) are pocket-scale farmers operating on farmlands of less than two hectares and locked in a vicious cycle of low margin, which bring about low risk-taking ability and low farm capital outlay. This led to a low yield, low market orientation and low value addition (Nyambo et al., 2019). Remarkably, small-size farms spanning from 0.1 to 5 hectares account for over 85% of Nigeria's total agricultural output (Muricho et al., 2020). Consequently, local production by small size farmers, coupled with partial importations from other nations, meets both the food supply and demand within the country. However, Nigeria, being a developing nation, heavily relies on imports for certain staple foods like wheat, sugar, rice, fish, and finished agricultural products, making it susceptible to outside factors like price variabilities and trade obstacles (WFP, 2016). Despite numerous attempts to halt this movement, boost local demand in food production, and close the demand-supply gap, Nigeria faces quite a lot of predicaments (Oladimeji et al., 2013). Smallholder farmers possess distinctive characteristics, such as small and scattered land holdings, limited productivity, and resource constraints, particularly prevalent in the semi dry areas of Nigeria, where most of these farmers are concentrated (Sabo et al., 2017). Despite these challenges, smallholder farmers remain the primary providers of the country's food consumption.

In Nigeria, small land size farmers typically work on farms ranging from 0.1 to 5.0 hectares, engaging in mixed crop-livestock farming (Sulaiman et al., 2021a), with usually around one to three large ruminants (Sulaiman et al., 2021b). They primarily rely on rudimentary technologies to produce goods for consumption or sale (Sulaiman et al., 2021b; Oladimeji et al., 2018; Bongers et al., 2015; Swai et al., 2014). Family labour plays a crucial role in managing these farms, as the main focus is on subsistence production (Sulaiman et al., 2021a; Oladimeji et al., 2018). Small land size farmers' production activities and decisions form diverse farming systems, characterized by notable variations in biophysical and socio-economic conditions among farming households (Chikowo et al., 2014).

A farming system denotes a comprehensive and interconnected series of activities undertaken by farm households within the confines of their resources and conditions to achieve sustainable enhancement of productivity and net farm income (Cloud Farm Funds, 2019). These activities encompass the choice of crops to cultivate, the utilization of various inputs, the raising of livestock, and the sources of on-farm and off-farm revenue. Smallholder farming systems share specific traits that distinguish them from commercial farming enterprises (Kuivanen et al., 2016). These traits include restricted access to arable land, funds, and agricultural production materials, as well as heightened vulnerability and reduced market participation (Chamberlin, 2008). Nonetheless, according to Chapoto and Bonsu (2013) and Ngeleza et al. (2011), the aggregate- and micro-level frameworks, drivers, and limitations of these systems are influenced by continuous interactions with the indigenous, societal and biophysical factors. This interaction results in diverse farming systems in terms of temporal variations, production consumption decisions, and resource endowment (Mortimore and Adams, 1999). Household resources assumes important position in determining the distribution of inputs and their allocation to various farming endeavors. Additionally, it hinges on the prime decisions and farm goals of the household (Chikowo et al., 2014). Those with abundant resources enjoy leverage to cash reserve and employ appropriate quantities of inorganic and organic manures and other farm inputs compared to less-endowed farming households (Mtambanengwe and Mapfumo, 2005; Tittonell et al., 2005).The diversity in farmers' profile contributes to a complex farming system. Addressing these intricacies requires the categorization of farming households into homogeneous sets using a number of parameters, such as resource availability, farming operations, livelihoods, and farm production challenges (Kobrich et al., 2003). This classification is achieved through the use of a tool called farm typology.

Farm typology encompasses the study of categorizing and defining non-identical categories of smallholdings, including the resultant system of these types (Landais, 1998). This valuable tool simplifies the comprehension of the vast diversity and variation among smallholder farms, enabling better targeting of approaches for intensifying crop production (Chikowo et al., 2014). Typology facilitates the accurate identification of suitable interventions for each farming system, making it easier to disseminate appropriate practices on a larger scale (Alvarez et al., 2014). The selection of criteria to differentiate farms hangs on the specific objectives of the typology and the information obtainable (Kostrowicki 1997). It is crucial to recognize that agricultural programs and policies designed to tackle the major concern of low productivity among different farm units must take into account these diversities and spatial divergent of smallholdings and agricultural systems (Tittonell et al., 2010).

One way to classify smallholder farms involves examining various aspects of the entire farm unit, such as family size composition, cropping and livestock practices, and their interconnection with the surrounding natural, monetary, and communal contexts (Alvarez et al., 2014). Additional factors utilized in categorizing farms in SSA encompass family structure, the size of the farmland of household, the resources available on the basis of land, animal rearing, and other production inputs, and the human efforts' division between non-/off-agricultural and on-agricultural activities. Furthermore, aspects like capital (including income and availability of finance), willingness to adopt of modern innovations, and investment capability are among the most commonly employed variables in this classification process (Bidogeza et al., 2009; Giller et al., 2011; Kuivanen et al., 2016; Mutoko et al., 2014; Pacini et al., 2014; Sakané et al., 2013; Shepherd and Soule, 1998; Signorelli et al., 2016; Tittonell et al., 2005, 2010; van de Steeg et al., 2010; Kamau et al., 2018).

Several studies (Mburu et al., 2019; Alvarez et al., 2018; Kamau et al., 2018; Kuivanen et al., 2016; Signorelli et al., 2016; Chikowo et al., 2014; Timler et al., 2014; Sakané et al., 2013; Bidogeza et al., 2009; Emtage et al., 2006) have categorized farmers into different groups to define farm units in various parts of Africa, adopting numerous benchmarks within different agro-ecological zones. However, there is a dearth of studies on farming systems in Nigeria. Takeshima and Edeh (2013) utilized cluster analysis to classify farm households and irrigation farms in Nigeria, mainly focusing on the Living Standard Measurement Survey (LSMS) and comparing costs and inputs across different irrigation crops, with little emphasis on the semi-dry areas of Nigeria. Therefore, there is a need to construct a typology to understand the needs of smallholder farmers in Nigeria's semi-dry areas, based on their resources and farming activities. This is in addition to estimating socio-economic and institutional factors determining millet- and sorghum-based farmers in crop farming system using multinomial logistic regression model (MNLR) model. This study's findings are expected to facilitate improved adaptation of agricultural findings to address farm unit predicaments in the semi-dry areas of Nigeria and SSA as a whole, where global warming constitutes an important impediment to crop and livestock production.

2. Research Methodology

Study area and data sources

The research initiative was spearheaded by the Institute for Agricultural Research (IAR) and financially supported by the TETFUND-NRF research fund, and coordinated by Ahmadu Bello University, Zaria. Over the course of three years (2019–2021), this project aimed to bolster Nigeria's socioeconomic development amidst an increasingly globalized and fiercely competitive knowledge-based global economy. Similar to other research funds, its primary objective was to empower small-scale farmers, enabling them to break free from hunger and poverty by adopting sustainable and modern agricultural techniques that enhance nutritional balance, sustainable agricultural production and income security while preserving and enriching the natural resource base (Nigerian National Research Fund, 2009; Kuivanen et al., 2016). Funded primarily by the Nigerian federal government through the TETFUND National Research Fund (NRF) Programme, this initiative was inaugurated in 2009 as a special intervention sanctioned by the Government of the Federal Republic of Nigeria. The overarching purpose of the program was to encourage applied research and innovation among academics in public tertiary educational institutions. Notably, the project remains active and invites proposals from researchers and academicians affiliated with any tertiary institution within Nigeria.

The research took place in the north-western states of Jigawa, Kano, and Katsina in Nigeria. Data was gathered directly from 168 farming households residing across these three states in 2021. To ensure a comprehensive representation, a stratified random sampling approach was adopted to select states, Local Government Areas (LGAs), communities, and sample households. In the initial phase, three states in the North West —Jigawa, Kano, and Katsina—were purposefully chosen based on their predominant millet-based and sorghum-based crop production systems. These states were also selected because their proposals had been approved by NRF for the survey. Subsequently, three Local Government Areas (LGAs) from each state were randomly selected, resulting in a total of nine LGAs (See figure 1). Lastly, at the third stage, two communities from each LGA were randomly selected. These communities were Baguda, Gwarmai (Bebeji); Badume, Saye (Bichi); Damisawa, Kazawa (Minjibir); Zandam, Tsohuwar Gwaram (Gwaram); Kankaran Dagariyo, Hammado (Gumel); Dunari, Dakido (Malam Mador); Gozaki, Unguwar Abdul Masari (Kafur); Dutse Ma (Makara, Garhi), and Zango, Yakubawa (Zango).

The sample size of the respondents was selected from each community based on proportionality factor adopted by Ibrahim (2011) and Adeola (2018), to eliminate bias in the selection of samples. The factor is given as:

$n = Y / L \times T$

Where n = Sample size per selected state, Y =Number of farmers collected from each state ministry by NRF survey team, L = Total number of registered millet and sorghum based farmers in the three states survey, and T = Total sample size. The selected farmers formed the population sample (sample size) used for this study. Finally, 168 farming households were randomly chosen for the interview from the project villages using the probability proportionate to size sampling technique. The population investigated was divided into two strata based on millet-based and sorghum-based farmers and consisted of 75 and 93 farm enterprises, respectively. Ethics committee permission was given by Ahmadu Bello University, Institute for Agricultural Research for the survey application of this study, with dated 21.03.2022.

The data collection involved the use of a structured questionnaire and interview schedules during the survey. To safeguard the reliability and validity of the interview schedules, a preliminary test was conducted on thirty (30) randomly selected farm households. The obtained reliability coefficient of 0.82 confirmed the instrument's satisfactory reliability. The survey covered various aspects, including socio-economic and institutional profiles of the farm households, crop production patterns, land holdings, livestock ownership, labor usage, owned assets, major crops, and income sources. This study focuses on utilizing the resulting dataset from the three states to classify these farm households, building on the research by Kuivanen et al. (2016).

Description of Study area

Nigeria's landmass encompasses approximately 932,768 km2 (Ajao et al., 2021). The North-western region covers an expanse of 226,662 square kilometers, which makes up approximately 24.5% of Nigeria's total area (Figure 1; NBS, 2017). This zone is home to around 25% of Nigeria's population, boasting a populace of over 48,942,307 individuals (NBS, 2017). It is subdivided into seven (7) states, namely Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, and Zamfara, each comprising 21 senatorial districts (Bakare, 2015).

To examine the farming system diversity in chosen states, quantitative and qualitative variables related to socio-economic, institutional, and production characteristics of the farming households were examined. These variables included household size, different types of assets and income sources, livestock, labour, and the value of organic and inorganic fertilizers. Multivariate analysis was employed for this purpose (Table 1). The questionnaires were administered using the Open Data Kit (ODK) mobile app by competent enumerators. To facilitate comparison, households' earnings derived from produce harvest, animal products, and other farm assets were converted to adult equivalents, enabling the calculation of average, minimum, maximum, and other descriptive statistics.

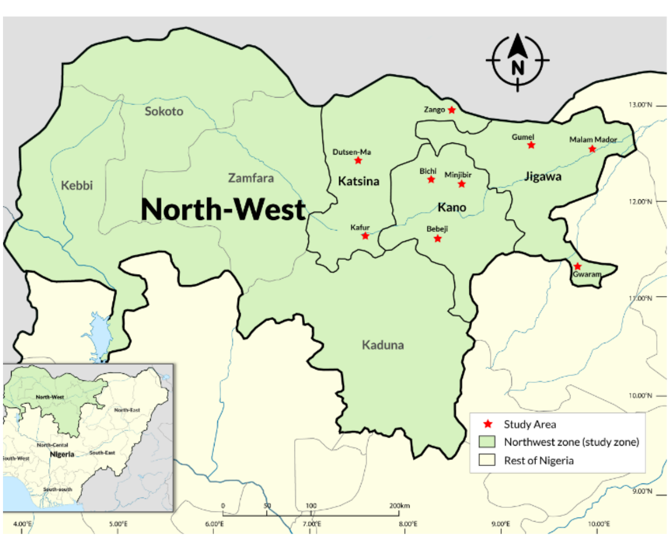

Figure 1: Map of Nigeria showing the study area

Description of variables used for farm typology construction

Table 1: Summary statistics of variables used in construction of typology

Variable	Mean	Std. Dev	Min	Max
HH Size	16	8	1	40
Total HH income	2.14e+6	2.23e+6	145800	1.39e+7
Value of Produ Assets	446,976.4	962,154.9	0	8.0e+6
Value of Farm Asset	101429.3	126707.2	0	676,400
Value of HH Assets	54,946.45	82,995.73	0	517,700
Total Non-Farm Income	359,453.00	502,180.40	0	3e+6
Total Farm Income	699,730.20	1.51e+6	7700	1.24e+7
Value of Livestock	351,186.90	348,628.6	0	2.06e+6
Value of Farm Labour	120,706.20	126,545.80	8,950	857,000
Total Inorg Cost(N)	77,245.27	119,943.80	0	800,000
Total Manure Cost(N)	57,978.75	212,069.80	0	2.25e+6

Source: 2021 survey data analysed. Subsequent Tables and Figures that follow also emanated from survey data except indicated.

Typology construction

Two multivariate analytical methods were applied sequentially to establish a typology of the farm households surveyed. The typology was constructed using Principal Component Analysis (PCA) and Cluster Analysis (CA).. The typology creation process involved two main steps: (i) classified, consolidation clustering using Ward's technique, and (ii) non-hierarchical, partitioning clustering using k-means on the dataset. This two-step approach has been widely used by various researchers in different African countries (Bidogeza et al., 2009; Chavez et al., 2010; Cortez-Arriola et al., 2015; Köbrich et al., 2003; Tittonell et al., 2010; Kuivanen et al. 2016; Signorelli et al. 2016; Kamau et al. 2018; Lopez-Ridaura et al. 2018; Musafiri et al. 2020; Irairoz et al., 2007; Field, 2013). To perform the Principal Component Analysis (PCA), Cluster analysis (CA) and Multinomial regression estimate (MNRE), the researchers utilized STATA (Version 16) with the built-in commands 'pca' and 'cluster', which are readily available in STATA.

It is crucial to mention to ensure the accuracy of the numerical analysis, the data set centred on the 11 variables presented in Table 1 was meticulously examined. This involved considering missing data and detecting possible outliers, in view of PCA's sensitivity to outliers, as noted by Rosenstock et al. (2016) and Musafiri et al. (2020). Box plots were utilized for outlier detection prior to the PCA analysis, following the techniques adopted by Musafiri et al. (2020) and Hair et al. (2010). Outliers that could potentially undermine the multivariate analysis while constraining its generalizability to the broader population were removed from the dataset [see Figure 2]. This approach aligns with the findings of Musafiri et al. (2020), Kuivanen et al. (2016), and Hair et al. (2010). However, certain outliers were included in the analysis as they appeared to form cohesive farm types, as observed in the study by Alvarez et al. (2014). Out of the 168 respondents sampled in the field work, 14 were identified as outliers, leaving 154 households for the subsequent cluster analysis.

The decision on the number of principal components (PCs) to retain was based on several benchmarks. First, following Kaiser's criterion, all PCs with an eigenvalue greater than 1.00 were initially retained (Kuivanen et al., 2016; Musafiri et al., 2020; Chavez et al., 2010; Köbrich et al., 2003). To validate this, a second criterion involved selecting the minimum number of components required to account for a cumulative variance of at least 62.6% (see Table 2), in line with the guidelines of Hair et al. (2006), Kuivanen et al. (2016), and Musafiri et al. (2020). The third and final criterion, interpretability, assessed the conceptual relevance of the PCs to the underlying constructs, following the method adopted by Kuivanen et al. (2016). This was achieved by analyzing the strength of associations between variables and the PCs (Hair et al., 2006; Kuivanen et al., 2016; Musafiri et al., 2020; Chessel et al., 2004; Husson et al., 2011). Higher correlation coefficients indicate stronger associations with specific PCs (Kuivanen et al., 2016; Lebart et al., 1995; see correlations in Table 4). In this study, loadings of 0.50 or higher were used as the threshold for interpretation, consistent with the approaches of Irairoz et al. (2007), Kuivanen et al. (2016), Musafiri et al. (2020), and Field (2013).

Table 2: Eigenvalues and percentage variance explained by principal components (PC's) using PCA

Component	Eigenvalue	Proportion of variance (%)	Cumulative variance (%)
Comp1	3.25593	29.6	29.6
Comp2	1.40211	12.8	42.4
Comp3	1.17092	10.6	53.0
Comp4	1.0599	9.6	62.6

Cluster analysis

The PCA involved the creation of a condensed dataset based on the retained principal components (PCs), which was then subjected to CA. As previously mentioned, a two-step process was adopted. First, Ward's method, a hierarchical, agglomerative clustering algorithm, was utilized to determine the number of groups (k). Subsequently, a non-hierarchical, partitioning algorithm known as "partitioning around Medoids" was applied to refine these k-groups (Kuivanen et al., 2016; Musafiri et al., 2020).

Ward's method generated a series of cluster answers, starting with individual observation as a separate cluster and gradually merging related clusters until only one cluster remained (Reynolds et al., 2006; Kuivanen et al., 2016). This agglomerative procedure was illustrated using a Dendrogram (Figure 2). To find the optimal cluster threshold points, an equilibrium was sought between the number of clusters and the contrast between them, aiming to exhaust the possibilities of both within-cluster homogeneity and inter-cluster heterogeneity (Hair et al., 2010). The number of clusters retained from Ward's method served as the initial value for the non-hierarchical algorithm, which aimed to enhance the classification's accuracy by optimizing the distribution of farms among clusters to reduce the total distances between each observation and its cluster center (Kuivanen et al., 2016; Reynolds et al., 2006).

The final set of clusters was characterized by examining their inherent structure, including the mean value of each variable for each cluster. To validate the farm groups, experts with vast experience and well acquainted with indigenous farming systems (Director of ADPs in the respective states supported by IAR staff) was consulted. The multivariate system's patterns, such as within group features and inter-group relationships, were evaluated, and farm types were mapped. Furthermore, the implications of farm type-specific features and blueprints for improvement were considered (Kuivanen et al., 2016). The Calinski–Harabasz index in Table 3 indicated the presence of three (3) clusters as the optimal number of clusters (farm types).

Table 3: The presence of three (3) clusters as the optimal number of clusters (farm types)

Number of clusters	Calinski–Harabasz index
2	141.59
3	178.81
4	152.59
5	148.68
6	145.91
7	140.64
8	138.89
9	137.65
10	136.19
11	135.23
12	135.25
13	135.43
14	135.2
15	136.45

Multinomial Regression Model Analysis

The explicit empirical model specification for estimating socio-economic and institutional factors determining millet and sorghum based farmers in crop and livestock farming system using multinomial logistic regression (MNLR) model were as follows:;

$$\ln Y_{i} = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_n \ln X_{ni} + Ui \quad (1)$$

Y = Output (millet- and sorghum- based crops) of the ith farmers (kg). For millet- and sorghum -based systems, output including groundnut and cowpea were converted to grain equal weight supporting the studies of Oladimeji et al. (2021) and Clark and Haswell (1970). The X_{1i} to X_{ni} were specified in Table 5.

3. Results And Discussion

Characterization Of Farm Groups

Table 2 showed that about 62.6% of the dataset's variability was explained when the PCA was employed to extract the first four PCs. The primary contributor to the variation was the first PC, accounting for around 29.6% of the data's variability. Examining the number of observations within each group, the differentiation of characteristics between groups, as well as the result of the Calinski-Harabasz index, a decision was made to categorize the farm households into three groups. These clusters were defined using variables that accounted for the majority of data variation, as captured by the factor analysis. Consequently, most characteristics varied significantly across each group. Group 1 comprised 129 farm households from the sample, while Group 2 included 34 farm households.The smallest group, Group 3, includes five farm households. Broadly speaking, the groups can be described as follows:

Group 1: Resource constrained, primarily engaged in poultry keeping, and generating minimal income from crop and livestock sales and off-farm activities, with large households, low farm assets, low fertilizer usage, and low household asset value (76.8% of the sampled farms):

The first component (Comp/Group 1) in Table 4 exhibited a strong connection to variables representing household size, value of farm assets, total non-farm income, value of farm labour and total manure input. However, it was weakly correlated with total household income, value of production asset, household asset and livestock resources and inorganic input use. This implies that farming system of this cluster depends largely on household size, an important input in man-hours required for farming. Group 1 could be described as resource-constrained farming households, with a small land area cultivated (1.8 ha), mostly dominated by millet or sorghum-based cropping system. Animal rearing predominantly poultry (83.5%), contributed to earnings from animal product trades and off-farm undertakings, 76.8% of the respondents' farms (Figure 4). Flock size was mainly small ruminant and poultry, generally small, and animal production was skewed towards poultry and, mainly sheep and goats with average possession of 0.8 ± 0.2 cow, 4 ± 0.3 goats, 8 ± 0.7 sheep and 42 ± 1.75 poultry. This cluster represents the largest group, characterized by small farm areas, with approximately 52% and 36% of the land allocated to sorghum-based and millet-based crops, respectively. It is also characterized by high annual family labour hours (Figure 4).

The findings for this group also showed that the average household size was 13, and they were characterized by lower education status and low food security. The farming households employed more of family labour, low use of hired labour and non-labour inputs hey had low levels of farm asset endowment, and a large portion of harvest was for subsistence. The level of credit accessed among Group 1 farmers during the last farming seasonwas very low (13.5%) because their social networks and cooperative membership were inactive or unavailable. Land degradation, including soil erosion and desertification, was a common occurrence. The main income resource was off-farm income (50.4%) complemented by both crop output (27%) and livestock product (22.6%) sales. About 35% of these families sowed hybrid millet and sorghum seed for crop production. Total labour hours per year were relatively low (Fig. 4).

Table 4: Loadings of variables for the four principal components (PC's) using PCA: Correlation matrix between the PC's and the variables

Variable	Comp1	Comp2	Comp3	Comp4
Hhousehold size	0.909	0.4326	0.5404	-0.1982
Total household income	0.392	-0.6616	0.2465	-0.2218
Value of product assets	0.3785	0.1972	-0.6918	0.1441
Value farm asset	0.6317	0.1137	-0.5516	0.1667
Value household assets	0.3539	0.723	-0.8564	0.0263
Total non-farm income	0.6841	0.275	-0.0777	-0.4311
Total farm income (output sales)	0.3069	-0.5556	0.7103	-0.1268
Value of livestock	0.2956	0.6743	0.2469	-0.067
Value of farm labour	0.7592	0.0553	0.0297	0.1659
Total inorganic cost	0.3376	-0.7106	-0.6051	0.2403
Total manure cost	0.634	0.2081	0.5081	0.3984

Group 2: Medium resource-endowed with livestock rearing predominantly involving small ruminants such as sheep and goats, practice both millet and sorghum-based cropping systems (20.2% of the sampled farms).

The group is characterized by medium resource-endowed farming households, with animal rearing dominated by poultry and small ruminants. They practice both millet-based and sorghum-based cropping systems. The second component (Comp 2) which depicts Group 2 in Table 4 correlated highly with total household income, value of household assets and livestock and total inorganic cost and moderately with total farm income resulting from sales of crop and livestock. It was less correlated with the household size, value of production assets, farm assets, farm labour and total manure (Table 4). Animal rearing dominated by goats and sheep (46.1%). The flock size showed a relatively small average size 1.6 ± 0.8 cattle, 11 ± 2.1 goats, 17 ± 2.6 sheep and 78 ± 4.3 poultry. Revenue was generated from animal product sales and crop sales by 89.2% of the sampled farms (Figure 4). This was the moderate cluster, characterized by medium-size farm area with mean of 6.9 ha and about 65 and 31% of farm land devoted to sorghum-based and millet-based crops, respectively. It is also characterized by the use of both family and hired labour hours per year. This cluster is distinguished from the Group 1 mainly by its smaller household size (7.3 persons per households) and relatively larger hired labour employed in farm activities and by being fairly market oriented (Figure 4). Group 2 engaged in soil conservation practices but still faces problems with soil erosion. This group can be described as having mid-level endowment.

Group 3: High resource-endowed with livestock rearing dominated by big ruminants (Cattle, donkey and camel), and exotic birds of high price value. They also practice both millet and sorghum-based cropping systems (3.0% of the sampled farms)

The final component (Comp/group 3) displayed a strong correlation with production assets, farm assets, household assets, output sales, organic (manure), and inorganic fertilizer (Table 4). This indicates that group 3 farmers are well-off households with extensive farmland for crop cultivation and sizable herds of cattle, surpassing those of Groups 1 and 2. The findings also revealed that each farmer, on average, reared 13.00 ± 1.50 large ruminants, 28.00 ± 1.98 small ruminants, and 156.00 ± 5.21 poultry animals. The ownership of both large and small ruminants and poultry showed minimal variation, indicating little disparity among farmers in terms of livestock holdings. The average household size was relatively low (5.8 persons per household) in comparison to group 1 (13 persons) and group 2 (7 persons). These farm households in group 3 exhibited higher levels of education, and the household heads were mostly educated. This resulted in significant commercialization of their harvests, a focus on market-oriented practices, and enhanced food security. Group 3 farm households also enjoyed the highest levels of non-farm/off-farm income from non-agricultural employment, agribusiness value chain activities, as well as substantial income from animal rearing and crop production. Besides their purchased farmland, they acquired substantial portions of land from the local community, where they were situated, and possessed the most productive assets. In conclusion, a significant resource endowment gap exists between this cluster and Groups 1 and 2 (Figure 4). Group 3 farmers demonstrate extensive input usage, including improved seeds. Their cropping system mainly revolves around millet- or sorghum-based crops. Moreover, these farming households adopt soil improvement practices such as adding a considerable amount of manure to the soil, implementing cover cropping, crop rotation, and intercropping, particularly with legumes. Group 3 farmers have the highest level of access to credit and the greatest utilization of credit from the previous season. They also maintain a strong level of contact with extension services concerning crop production and input utilization. Active involvement in social networks is another characteristic of this group, with a high membership level in various groups, such as farmer cooperatives, state, and national farmers' associations. Agriculture is highly commercialized in this group, with a greater reliance on the sale of crop products. Approximately two-thirds of all crop products are sold on the market.

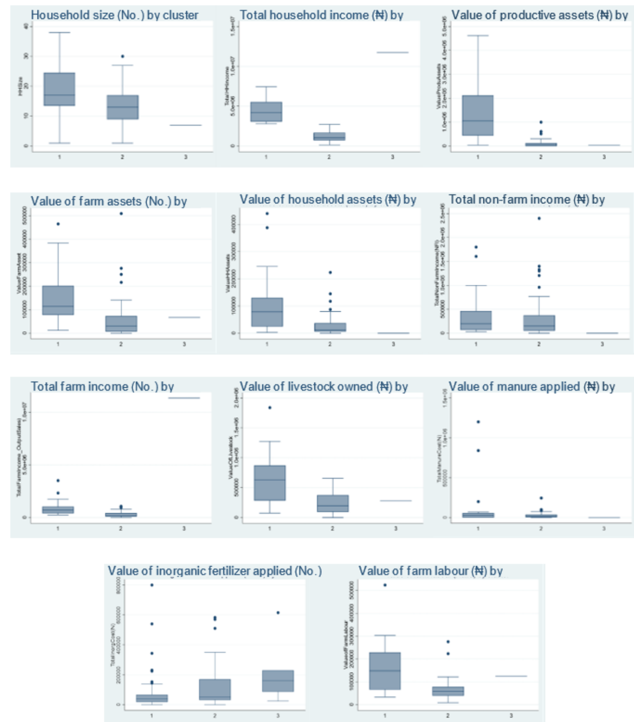

Figure 3: Box plot of variables for the three clusters (farm groups)

Fig. 4: Summary statistics of the three clusters based on variables used in PCA model

Farming system patterns and drivers of variability among farm groups

Farm typology involves categorizing farms into groups based on shared characteristics. These farm types play a crucial role in targeting farm enhancement and providing recommendations. Typically, they are constructed using data from field surveys and past studies on the biophysical and socio-economic aspects of farming systems (refer to Figure 4 and Table 4). The aim is to create farm types that accurately reflect the varying access to resources for managing farms among different households. To achieve this, survey questionnaires are designed to include key variables related to biophysical, socio-economic, and resource endowment aspects of farming households in a specific area. These survey questionnaires should include information about the household head and size, labor availability, main source of income, land use patterns, volumes of crop production sold or bought, usage of agricultural inputs, livestock ownership, production orientation, and owned assets. (Mtambanengwe and Mapfumo, 2005; Tittonell et al., 2005, 2010; Chikowo et al., 2014). A number of findings have demonstrated that the distinct features of farming systems are influenced by site-specific opportunities and limitations, which extend beyond the household level. Factors at the community and regional levels, such as agro-ecology, markets, institutions, traditional land tenure, and inheritance systems, all play a role in shaping the farming systems (Tittonell et al., 2010; Tittonell, 2014; Yaro, 2010). The variation across farm types significantly impacts how farmers cope with and adapt to agricultural shocks, such as price fluctuations, crop failure, drought, pests, diseases, and challenges like declining soil fertility, climate change, and land scarcity. Additionally, it affects their ability and interest in capitalizing on potential opportunities for sustainable farm intensification (Chamberlin, 2007; Yaro, 2010; Kuivanen et al., 2016). This section delves into the determinants and implications of farming system diversity concerning the variables used in cluster analysis. It explores the distinctive features of identified farm types within the study area.

Household size

The data presented in Figure 4 indicates that Group 1 farming households had a higher average number of individuals per household compared to both Group 2 and Group 3. The size and composition of these farming households varied depending on the status, occupation, wealth, and age of the household head, as referenced by Aruwayo et al. (2019), Ngeleza et al. (2011), and Oppong (1967). This disparity can be attributed to the labour-intensive nature of Group 1, which faces resource constraints. Consequently, households with more members are likely to possess a sufficient labour force for agricultural activities. Moreover, having multiple working members in these households is associated with a higher level of well-being under constant conditions. The household size, therefore, significantly impacts the availability of farm labour, influences the food and nutritional requirements, and often affects poverty and food security within the household. In the study area, where subsistence farming is prevalent, as identified by cluster analysis, household size plays a crucial role in determining the labour supply for farming activities (Inoni and Oyaide, 2007). Notably, our analysis also revealed that Group 2 farming households tended to have larger families compared to Group 3 (Figure 4).

Income sources

In the semi-arid agro-ecological zone of northwest Nigeria, agricultural production often faces challenges due to unpredictable precipitation and seasonal farming activities. As a result, rural farming households find it necessary to diversify their livelihoods (Sulaiman et al., 2021a & b). These households derive income from various sources, including on-farm activities (such as crop and livestock income), off-farm activities (related to agriculture), and non-farm activities (unrelated to agriculture) (Oladimeji et al., 2015; Ellis, 1998). The study shows that the rural economy extends beyond agriculture and encompasses a wide range of income-generating activities, both on-farm and non-farm, which contribute to people's livelihoods. Among farming households, those in Group 3, who are well-endowed, excel in generating income from both on-farm and non-farm activities, whereas Group 1 and Group 2 households tend to lean more towards non-farm activities (Figure 4). Surprisingly, despite expectations that Group 1 income would primarily come from on-farm activities, insecurity in the region has significantly reduced farming activities among these groups, as their farms remain vulnerable. While earnings from on-farm activities plays a significant role in influencing other livelihood strategies adopted by household heads, many farming groups heavily rely on off/non-farm income sources, particularly due to insecurity forcing them to seek opportunities in nearby urban areas (Figure 4). This is evident in the considerable share of off/non-agricultural earning for high resource-endowed farming households (Group 3), as well as medium and low-endowed farmers (Group 2 and 3). Studies on rural livelihood strategies suggest that wealthier farmers are more likely to engage in non-farm work (Owusu et al., 2011), and as their earnings increase, they tend to invest more in non-agricultural activities (Oladimeji et al., 2015; Frelat et al., 2016). According to field appraisal data, sources of off-farm income in the case study area include casual wage labor on other farms, artisanal work (e.g., carpentry), and processing agricultural inputs and outputs, while non-farm earning sources encompass trading, paid non-farm work, and transport services. Results indicate that the bulk of Group 1 farmers are associated with motorcycle transport services, artisanal work, and local market trading of various kinds. Consequently, they are limited to low-paid activities in the off-farm sector, often working as hired or casual laborers on the farms of more affluent neighbors (Ellis, 1998). Moreover, many Group 1 and 2 farmers receive remittances, which serve as additional income resulting from rural-urban migration. Insecurity and banditry in the study area contribute to a higher prevalence of migrant households within Group 1 and 2.

Assets

Livestock rearing represents a vital asset for farming households due to its sizeable population and its capacity to generate livelihoods for rural communities. It serves as a renewable resource that can be sustained for future development (Oladimeji, 2017; Adefalu et al., 2013). The significance of livestock rearing lies in its ability to support people's livelihoods, mitigate protein shortages, fulfill domestic responsibilities, and acquire necessary inputs for farming activities. Above all, it plays a crucial role in safeguarding against food insecurity and alleviating poverty in SSA (Oladimeji et al., 2017a & b; Adefalu et al., 2013). Moreover, livestock remains deeply intertwined with the social fabric, serving as a form of insurance and a means of saving resources (Otte and Chilonda, 2002).

Livestock present in the study area encompasses a variety of animals such as cattle, donkeys, camels, sheep, goats, pigs, and poultry. Additionally, to a lesser extent, there are pigs, snails, and artisanal fisheries. Among these, cattle and donkeys hold the highest value, typically being inherited and rarely sold, except during pilgrimages to Mecca or for fulfilling social obligations like bride price, stock alliances, and stock patronages. They also serve as a means of protection against disasters, droughts, epidemics, and raids. The investigation indicated that Group 3 farmers possessed the largest number of livestock in all categories (Figure 4G), with the most substantial cattle herds, followed by Group 2 and Group 1, respectively. According to existing literature, it is customary for farmers to gradually expand their livestock herds during favorable agricultural seasons when earnings from crop sales can be reinvested into acquiring more animals (Tittonell, 2014). Aside from being regarded as a form of insurance and savings, the extensive cattle and donkey herds owned by farming households in groups 2 and 3 contribute to the production of organic fertilizer (manure). This aspect provides these farmers with an advantage in terms of agronomic practices, potentially leading to enhanced soil fertility, increased crop productivity, and a source of income for pastoralists (Sulaiman et al., 2021; Chikowo et al., 2014). According to Winrock (1992) in Adefalu et al. (2013), when considering non-monetized contributions like draught power and manure, which emphasize the importance of livestock or integrated crop-livestock farming systems in Nigeria, the contribution of livestock to the agricultural GDP would surge by 50 percent, raising the livestock component of agricultural GDP to approximately 35 percent.

Poultry is raised by all three groups of farmers and serve as a fast source of protein for households due to their high reproductive rate, short gestation period, and rapid generation interval, unlike cattle and other ruminants that are not suitable for quick, short-term population growth (Okubanjo and Adeneye, 1993; Rahji et al., 2010). Moreover, poultry farming is financially viable for smallholders as it requires minimal factors of production, including land, labor, and capital, to maintain a flock. Unlike pork, which faces restrictions due to religious principles, there are almost no restrictions hindering the consumption of poultry meat or eggs (Rahji et al., 2010). Therefore, poultry production is acknowledged as one of the fastest ways to increase protein supply in the short term within the study area. Consequently, meeting animal protein demands from domestic sources necessitates intensifying the production of meat and eggs, particularly from prolific animals like poultry. Furthermore, these products can be sold to fulfil immediate cash obligations such as bill payments and family needs.

Land ownership of the farming households

The result in Figure 4K describes the distribution of farmers according to land ownership. The study showed that group 3 farmers have a mean of 20 hectares compared to group 2 (with about 8 hectares) and group 1 with less than 2 hectares. Most of the group 1 farmers owned their farmlands through inheritance and communal heritage while groups 2 and 3 lease or purchase most of their farmland. Group 1 farmers who acquired the farmlands through inheritance and at no cost—in the study area—enjoyed implicit savings in land cost but the sizes of their farmlands are small and fragmented. This implies that group 1 farmers operate at subsistence level and will are unlikely to benefit significantly and commercialization of agriculture.

Socio-Economic and Institutional Factors Influencing Farmers' Involvement in Millet- and Sorghum- Based Farming System

Socio-economic factors influencing farmers' involvement in millet- and sorghum- based farming systems are depicted in Table 5 using the multinomial logistic regression (MNLR) model.

Farming household head gender, with negative coefficients, negatively predicted whether a farmer belonged to millet-cowpea ($\beta = -0.145$, $P < 0.10$) millet-groundnut ($\beta = -0.121$, $P > 0.05$), sorghum-cowpea ($\beta = -0.0003$, $P > 0.01$) and sorghum-groundnut ($\beta = 0.293$, $P > 0.10$) (Table 5). This implies that female-headed households were more likely to belong to this farm typology than households headed by their male counterparts. According to Musafiri et al. (2020) and Mugwe et al. (2009), most of the land in the study area is owned by males who also make most of the decisions including access to extension services making them more knowledgeable than their female counterparts (Ortiz-Gonzalo et al., 2017). Furthermore, participation in farmer groups positively influenced and predicted whether farmer practiced millet-cowpea ($\beta = 0.365$, $P < 0.05$) millet-groundnut ($\beta = 0.002$, $P > 0.10$), sorghum-cowpea ($\beta = 0.143$, $P > 0.05$) and sorghum-groundnut ($\beta = 0.002$, $P > 0.05$). This might be because farmers who belonged to agricultural groups were more likely to adopt any of these crop-based systems, in line with study of Musafiri et al. (2020).

According to the results, household size was positive ($\beta =$

0.376, P > 0.05) for only millet-groundnut farmers. This implies that each additional household member increases the probability of engaging in millet groundnut production. This clearly demonstrates that larger households can provide sufficient labour to cultivate the cropping system. especially if a reasonable number of members are active and involved in farm labour. The findings are comparable to the study by Fisher et al. (2015), which asserted that household size determines the combination of crop adoption processes, as larger household have greater capacity to relax the labour constraints required for crop combination, *ceteris paribus*.

The total household income from all activities positively predicted all cropping-based groups that include millet - cowpea (β= 0.907, P <0.01) millet - groundnut (β= 0.165, P > 0.01), sorghum - cowpea (β= 0.327, P > 0.01) and sorghum - groundnut (β= 0.625, P > 0.01) (Table 5). This signifies that farmers with a high proportion of total income from agricultural and non-agricultural activities were more likely to engage in all forms of these farm typologies. Also the value of farm production assets for all the crop-based typology namely: millet-cowpea (β= 0.814, P <0.10) millet-groundnut (β= 0.705, P > 0.05), sorghum-cowpea (β= 0.921, P > 0.05), sorghum-groundnut (β= 0.654, P > 0.05) as well as total farm income for all the crop-based typology that also include millet-cowpea (β= 0.276, P <0.05), millet-groundnut (β= 0.184, P > 0.01), sorghum-cowpea (β= 0.312, P > 0.10), and sorghum-groundnut (β= 0.007, P > 0.05). Many studies on income from different sources including off-farm income reported a positive impact on the adoption of crop combination technologies. According to Bidogeza et al. (2009), income is an important strategy for solving credit constraints faced by rural households in many developing countries.

The value of farm labour negatively influenced both millet- and sorghum- based cropping system such as millet-cowpea (β= -0.421, P <0.05) millet-groundnut (β= 0.187, P > 0.10), sorghum-cowpea (β= -0.005, P > 0.05) and sorghum-groundnut (β= -0.118, P > 0.05) and the value of purchased inorganic inputs was also negatively related to crop combination, millet and cowpea (β= -0.542, P > 0.10) millet groundnut (β= -0.338, P > 0.10), sorghum cowpea (β= -0.004, P > 0.10) but sorghum - groundnut was not statistically significant. The cost of adopting agricultural technology is also a critical factor for technology adoption. As the study done by (Makokha et al., 2001), on determinants of fertilizer and manure use in maize production in Kiambu county, Kenya; reported high cost of labor and other inputs, unavailability of demanded packages and untimely delivery were the main constraints to fertilizer adoption.

Table 5: Socio-economic factors determining belonging to millet- and sorghum- based farming entrepreneurs

Variable	Millet based cropping		Sorghum based cropping	
	Millet-Cowpea	Millet-Groundnut	Sorghum-Cowpea	Sorghum-Groundnut
	β	β	β	β
Constant	0.007**	0.213*	0.006***	0.105*
Sex (dummy)	-0.145*	-0.121**	-0.0003***	-0.293*
LevelEducation (years)	0.317	0.083	0.005	0.092
FarmersGroup (dummy)	0.365**	0.002*	0.143***	0.002**
HHSize (Number)	-0.653	-0.376**	-0.518	-0.319
Total HHincome	0.907***	0.165 ***	0.327***	0.675***
ValueProduAssets	0.814*	0.706**	0.921**	0.654***
ValueFarmAsset	0.276	0.187	0.543	0.206
ValueHHAssets	0.321	0.007	0.431	0.228
TotalNonFarmIncome	-0.005	0.003	0.115	-0.225
TotalFarmIncome	0.276*	0.184***	0.312*	0.007**
ValueLivestock	-0.117	-0.237	-0.006	0.004
ValueFarmLabour	-0.421**	-0.187*	-0.005**	-0.118***
TotalInorgCost	-0.542*	-0.338*	-0.004*	-0.009
TotalManureCost	0.115	0.421	0.165	0.276

Source: 2021 survey data analysed; all values, incomes and costs are measured in ₦; Note ***; ** and * denote statistically significant 1, 5, & 10 %, respectively; β= coefficient

4. Discussion and Conclusions

The development of the household typology marks a key stage in capturing fundamental characteristics that distinguish semi-arid farm households, their agricultural production patterns, and ways of life. This typology establishes a connection between household diversity and the varied semi-arid systems utilized for agriculture. By doing so, it simplifies the range of land uses. Consequently, the typology facilitates decision-making and strategies within farmer-based systems. Notably, it characterizes and simplifies the variations in smallholder farming activities among semi-arid farmers in North West Nigeria. The research identifies three distinct farming groups based on several criteria, including family structure, assets, household income, livestock, and crop-based production systems (millet or sorghum based). Remarkably, these three groups bear resemblance to typology studies in Africa, unrelated to semi-arid regions (e.g., Signorelli et al., 2016; Shepherd and Soule, 1998; Mtambanengwe and Mapfumo, 2005). This similarity highlights the limited diversity in farming activities within Nigeria's semi-arid regions. This study establishes an empirical foundation for categorizing smallholder semi-arid farms into groups exhibiting similar production patterns. The proposed typology and its relationship to existing semi-arid cluster groups hold significance in understanding resource utilization decisions among semi-arid smallholder households, as advocated by Valbuena et al. (2008) and Sakané et al. (2013). Employing the typology approach can shed light on the factors driving smallholder households to utilize the semi-dry region for agricultural purposes. By defining various household types and their diverse livelihood strategies, it enhances our comprehension of the heterogeneous rural livelihoods reliant on small semi-arid land. Through this understanding, we gain insights into the vulnerability of smallholder livelihoods to changes and the adaptive mechanisms employed by people to cope with such changes. Moreover, the typology acknowledges the diversity among rural households in an area, signifying that adaptation options vary significantly among them.

The approach yields deeper insights into the classifications and production strategies of semi-arid farmers. Categorizing smallholder households based on production structures enables a more precise grouping of households according to their behaviours, decisions, values, attitudes, and goals (Sakané et al., 2013). Typologies offer valuable opportunities to identify diverse land use patterns, farmers' production strategies, and the variety of decision-making processes. The typology analysis revealed that a significant majority (76.8%) of the sampled farms faced resource constraints, with a predominant focus on poultry keeping, limited income from crop and livestock sales, and involvement in off-farm activities. This group represents the most vulnerable category and, therefore, should be prioritized in development efforts. Improving the productive capacity and economic resources available to Group 1 requires considerable attention. The potential for less-endowed farmers (Group 1) to intensify crop production is limited, and they may obtain short-term relief through off-farm income opportunities within their communities. Providing enhanced access to advanced agricultural technologies and training on their effective utilization can bolster yields and livestock production. Additionally, facilitating better access to education can contribute to the improvement of their human resources and the utilization of available resources. All three groups face severe soil erosion issues to varying degrees, necessitating interventions aimed at enhancing soil quality that will benefit all of them.

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