SMALLHOLDER DAIRY FARMING CHARACTERISATION, TYPOLOGIES AND DETERMINANTS IN NAKURU AND NYANDARUA COUNTIES, KENYA

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Abstract
Kenya's dairy industry is the largest and one of the most successful in Africa. Private sector dominates the sector and milk production is majorly from small-scale farms. Despite the policies in place for the dairy inefficiencies and inadequacies in production and commercialization that differs from farmer to farmer. This study established the smallholder dairy farming typologies and their underlying determinants. The study obtained data from a cross section survey of farmers in Nyandarua and Nakuru counties of Kenya, where dairy activities are predominant. Data was collected from 380 smallholder dairy farmers identified using stratified random sampling. Data analysis was conducted by Principal Components Analysis and Cluster Analysis. Results of Principal Component Analysis showed that the smallholders' dairy farming differed because of output, land, household assets and infrastructure components. Cluster analysis results indicated three significantly different smallholder dairy farming typologies, i.e., Low resource endowed and lower market oriented, moderate resource endowed and moderate market oriented and high resource endowed and high market oriented. The determinants of smallholder dairy typologies were land factors, years of dairy farming, stock of dairy animals kept, labor engaged, household income, farming assets, dairy output and consumption levels and costs of production. The study recommended policies that would increase access to land through land reform processes, financial accessibility and adequate infrastructure needed by the smallholder dairy farmers.

Key words: Smallholder dairy, principal components analysis, cluster analysis, characterisation, farming typologies, Kenya

1.0 Introduction

The Kenya dairy sector contributes 4% of the national GDP, 14% to the agricultural GDP and 40% to the livestock sector GDP. The sector growth rate is at an average rate of 5 – 7% per year and provides employment directly and indirectly to over 1.2 million citizens (KDB 2015). About 80% of Kenya's total milk production is from small-scale farms (KDB 2013). Over 1.8 million smallholder households own between one to three cows. In aggregate terms, the smallholder sector owns over 80% of the national dairy herd estimated at 4.2 – 6.7 million cattle. Kenya aims at global productivity and competitiveness of her dairy sector through her Dairy Master Plan of 2010. Currently Kenya exports less than 1% of dairy products.

However, there is untapped potential for high exports to many African countries who report shortages in dairy products (Amalie et al., 2015). Smallholder dairy farmers in Kenya undertake their dairy activities using varying, limited production, and marketing resources. Limitations in production and commercialisation explain the persistent subsistence of the smallholder dairy farmers in Kenya and hence their poor economic status. The main limitations in milk production and marketing in Kenya include seasonality and less production, inadequate quantity and quality of animal feed compounded by the limited use of supplement feeds. Inappropriate animal husbandry and farming practices, poor access to breeding, animal health and credit services in addition to the high cost of artificial insemination (AI) service are some of the main limiting factors. Dairy producing areas have poor dairy infrastructure (including roads and electricity), insufficient milk collection and marketing system, poor interaction and priority setting between research, extension and training, and limited farmers' involvement in the output market (SDP, 2005). Improvement in productivity and commercialisation would transform the Kenyan dairy subsector into a net exporter of dairy milk and related products. Much of the milk in Kenya is not processed and is consumed more by the informal sector. Therefore, there is need for promotion of the formal market to fast track exportation of dairy products that are highly value-added (Amalie et al., 2015). Improving smallholder dairy farming has a potential of greatly enhancing the process of economic development in Kenya.

There is need of knowledge particularly on socioeconomic indicators of smallholder dairy farming to inform relevant and specific policies for efficiency and competitiveness of the subsector. Analysis of existing literature reveals an evolving heterogeneity of farmers and hence the subsequent need to adapt policies and communications to the various types of farmers. The inherent farming typology evident calls for the need to formulate varied extension strategies specific to the various groups in a cost-effective manner (Vanclay, 2005; Van Herzele & Van Gossum, 2008). There are different methodologies of identification and characterisation of farming systems in identifying dissimilar farm types. Such typology description would help in formulating distinguished, whole and broad-based extension intervention to address specific needs of the different identified farm typologies. It would also reduce transaction costs in agricultural research and precise extension system targeting agricultural inputs, advisory services. Research and extension recommend that farmers with similar conditions are appropriate for recommendation domain. Recommendation domain is a cluster of farmers whose conditions are alike enough that they are appropriate for the same commendation (Birner & Anderson, 2007). Describing farm typologies would help in rapid dissemination of applicable technology, extension support and development of policy environment adequate for the diversity of smallholder farms. Approach for characterizing smallholder farm types is necessary for technological intervention and policy directive beneficial to the institutional arrangement (Daloğlu et al., 2014).

This would then reduce transaction cost in smallholder agriculture through relevant technology. Review of market and state policy framework inadequacies besides the community failures calls for agricultural extension to focus on the demand driven interventions relevant to the needs of all farmers (Birner and Anderson, 2007). Abraham *et al.* (2010) found out that farmers varied in farm characteristics including their training orientation and therefore stakeholders found it hard to influence the farmers' development because of the varied uncommon problems. This study therefore determined smallholder dairy producer typologies and their determinants in Nakuru and Nyandarua counties in Kenya. The study recommendations would guide relevant interventions for the improvement of the dairy sector.

2.0 Material and Methods

2.1 Analytical Model and Procedures

Identification of smallholder dairy farm typologies in this study used two sequential multivariate statistical techniques of Principal Component Analysis (PCA) and Cluster Analysis (CA). Multivariate statistics procedures such as Principal Component Analysis (PCA) and Cluster Analysis (CA) are often used in identifying various household farm typologies and classifications (Andersen et al., 2006; Goswami et al., 2014). Principal Component Analysis was used to reduce the information from the interdependent variables to a smaller set of factors (Bidogeza et al., 2009; Kuivanen et al., 2016). PCA reduces the number of variables by collapsing the information from the inter-reliant variables to a reduced set of variables. Key assumptions in Principal Component Analysis (PCA) is its dependence on the normality of the data used, sampling adequacy and overall factorability of the matrix (Suhr, 2006). The purpose of PCA is to decrease dimension, more precisely, to define the difference in a set of correlated variables in terms of a new set of uncorrelated variables each being a linear combination of the variables (Jolliffe et al., 2016). The Principal Components are less than or equal to the number of original variables. When the number of variables is less than 30, Kaiser's criterion advises that all the factors above an Eigenvalue of one are retained (Field, 2005). PCA uses an orthogonal alteration to transform a set of observations of perhaps correlated variables into a set of values of linearly uncorrelated variables called principal components. This study used the Varimax Matrix method to identify the principal factors using orthogonal rotation as demonstrated by Kaiser (1970) and Gorsuch (1983). This method provides for a mutually exclusive number of highly correlated variables into a factor for easier analysis (Yong & Pearce, 2013).

The study conducted the Kaiser-Meyer-Olkin (KMO) Test to measure sampling adequacy. In addition, the study tested the correlation matrix as an identity matrix using Bartlett's test of sphericity. If Bartlett's Test of Sphericity (BTS) is large and significant and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is greater than 0.6 then factorability is assumed (Yong & Pearce, 2013).

The econometric procedure for a random variable X using Principal Component Analysis provided a matrix of diverse observations from individuals as,

$$X = \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_p \end{pmatrix} \quad \text{..... Equation 1}$$

The population variance-covariance matrix would then be,

$$Var(X) = \Sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} \dots \dots & \sigma_{1p} \\ \sigma_{21} & \sigma_{22} \dots \dots & \sigma_{2p} \\ \vdots & \vdots & \vdots \\ \sigma_{p1} & \sigma_{p2} & \sigma_{pp} \end{pmatrix} \text{.....Equation 2}$$

Then the linear combinations would be,

$$\begin{aligned} Y_1 &= e_{11}X_1 + e_{12}X_2 + \cdots\cdots + e_{1p}X_p \\ Y_1 &= e_{11}X_1 + e_{12}X_2 + \cdots\cdots + e_{1p}X_p \\ &\vdots \\ &\vdots \\ Y_p &= e_{p1}X_1 + e_{p2}X_2 + \cdots\cdots + e_{pp}X_p \end{aligned} \quad \text{..... Equation 3}$$

These equations can be represented individually as a linear regression that predicts Y_i from X_1, X_2..... X_p, with no intercept while e_{i1}, e_{i2}..... e_{ip} are regression coefficients. Since Y_i is a function of a random data, it is also random. Representation of the population variance would be,

$Var(Y_i) = \sum_{k=1}^{p} \sum_{l=1}^{p} e_{ik} e_{il} \delta_{kl} = e_i' \sum ei$ ..... Equation 4

Y_i and Y_j will have a population covariance represented as,

$Cov(Y_i, Y_j) = \sum_{k=1}^{p} \sum_{l=1}^{p} e_{ik} e_{jl} \delta_{kl} = e_i' \sum ej$ .....Equation 5

Collection of the vector coefficients e_{ij} representation is,

$$e_i = \begin{pmatrix} e_{i1} \\ e_{i2} \\ \vdots \\ e_{ip} \end{pmatrix} \text{.....Equation 6}$$

The First Principal Component, PCA1 (Y_1)

The linear combination of x-variables having maximum variance among all the linear combinations defines the first principal component. The data in this component includes much difference as possible. Considering the constraints that the sum of the squared coefficients is equal to one, the coefficients $\boldsymbol{e}_{11}$, $\boldsymbol{e}_{12}$.....$\boldsymbol{e}_{1p}$ defines the components for the variance maximization. This constraint necessitates the obtaining of unique answer. More correctly, select variables $\boldsymbol{e}_{11}$, $\boldsymbol{e}_{12}$..... $\boldsymbol{e}_{1p}$ that maximizes:

$Var(Y_i) = \sum_{k=1}^{p} \sum_{l=1}^{p} e_{1k} e_{1l} \delta_{kl} = e_1' \sum e1$ ..... Equation 7

The above equation is subject to the constraint defined as;

$e_1'e_1 = \sum_{j=1}^{p} e_{1j}^2 = 1$……Equation 8

The Second Principal Component, PCA2 (Y_2)

The second principal component defines the linear combination of the x-variables accounting for as much of the remaining variation as possible. The constraint of this component is that the correlation between the first and second component is zero. Considering coefficients $\boldsymbol{e}_{21}$, $\boldsymbol{e}_{22}$..... $\boldsymbol{e}_{2p}$ that maximizes the variance of this new component, the expression of variance is:

$Var(Y_i) = \sum_{k=1}^{p}\sum_{l=1}^{p} e_{2k}e_{2l}\delta_{kl} = e_2'\sum e2$…… Equation 9

The above equation is subject to the constraint that the sums of squared coefficients add up to one such that:

$e_2'e_2 = \sum_{j=1}^{p} e_{2j}^2 = 1$…… Equation 10

Additionally another constraint is that the components would be uncorrelated with one another such that:

$Cov(Y_1, Y_2) = \sum_{k=1}^{p}\sum_{l=1}^{p} e_{1k}e_{2l}\delta_{kl} = e_1'\sum e2 = 0$……Equation 11

The subsequent principal components have the same property of linearity and account for the remaining variation. The Principal components also would not correlate with one another. This would be in the same way with each additional component (i.e. i^{th} component).

The i^{th} Principal Component, PCAi (Y_i)

Select coefficients $\boldsymbol{e}_{i1}$, $\boldsymbol{e}_{i2}$..... $\boldsymbol{e}_{ip}$ that maximizes the equation below such that:

$Var(Y_i) = \sum_{k=1}^{p}\sum_{l=1}^{p} e_{ik}e_{il}\delta_{kl} = e_i'\sum ei$……Equation 12

Equation 12 is subject to the constraint that the sums of squared coefficients add up to one. The additional constraint is that the new principal component would be uncorrelated with all the previously defined principal components i.e.

$e_1'e_1 = \sum_{j=1}^{p} e_{1j}^2 = 1$…… Equation 13

$Cov(Y_1, Y_i) = \sum_{k=1}^{p}\sum_{l=1}^{p} e_{1k}e_{il}\delta_{kl} = e_1'\sum ei = 0$……Equation 14

$Cov(Y_2, Y_i) = \sum_{k=1}^{p}\sum_{l=1}^{p} e_{2k}e_{il}\delta_{kl} = e_2'\sum ei = 0$……Equation 15

⋮

⋮

$Cov(Y_{i-1}, Y_i) = \sum_{k=1}^{p}\sum_{l=1}^{p} e_{i-1,k}e_{il}\delta_{kl} = e_{i-1}'\sum ei = 0$……Equation 16

All the principal components are therefore uncorrelated with one another.

Upon arriving at the Principal Components, the study then employed cluster analysis. Cluster analysis is a group term for an extensive range of techniques for explaining natural groups or clusters in data sets (Sharma, 1996; Hennig, 2015). The

identified factors from the Principal Component analysis used Euclidean Distance (as a group distance measure) and Ward's technique (as agglomerative clustering) for the Cluster Analysis. The agglomeration schedule provides the sequence of analysis and produce coefficients. The aim of the schedule is to arrive at a suitable number of clusters that best fit the data set. A check of the agglomeration schedule and Scree plot suggested the applicable and reasonable clusters.

Cluster analysis was preferred among other alternatives such as the artificial neural networks, discriminant analysis and logistic regression. This was because there was no prior knowledge of which farmers, what farm characteristics belonged to which group and the number of groups. The cluster categories would be relatively homogeneous within themselves and heterogeneous between each other established on a distinct set of variables (Bidogeza et al., 2009). It is a group term with varied techniques for describing normal groups or clusters in data sets. It computes the likeness between any pair of observations by using a distant coefficient. This would provide the most important way of testing their validity. The aim of cluster validity indices was for prompt selection of the best number of clusters in the data with respect to the prior selected conditions. The study used Hierarchical method and K-means methods to arrive at the number of clusters. The numbers of clusters retained from Ward's method were the starting values in the K-means method to allocate cases into the default number of clusters. Accordingly, the number of clusters retained seemed most realistic and meaningful for the final solution. This study used Pseudo F Index to provide for Hierarchical clustering. The Pseudo F statistic explains the quotient between-cluster variance to within-cluster variance. Large values of Pseudo F indicate strong and differentiated clusters hence greater cluster separation. In addition to CA, identifying the differences in variance between clusters was through a one-way Analysis of Variance (ANOVA) test. The variables identified explained the largest differences between the clusters. The hypotheses tested in this study were that smallholder dairy types do not differ in characteristics; and the socioeconomic factors do not affect the type of smallholder dairy farming decision.

2.2 Study Area and Sampling

This study focused on smallholder dairy farmers in Nyandarua and Nakuru counties, which share common borders with each other (Figure 1). In both counties, agriculture is the main source of household food, raw materials for agro-based industries as well as income. Nyandarua is the leading milk producer while Nakuru is the third largest milk producer in the country. The two counties undertake the highest concentration of dairy activities in the country ranging from production, processing and consumption.

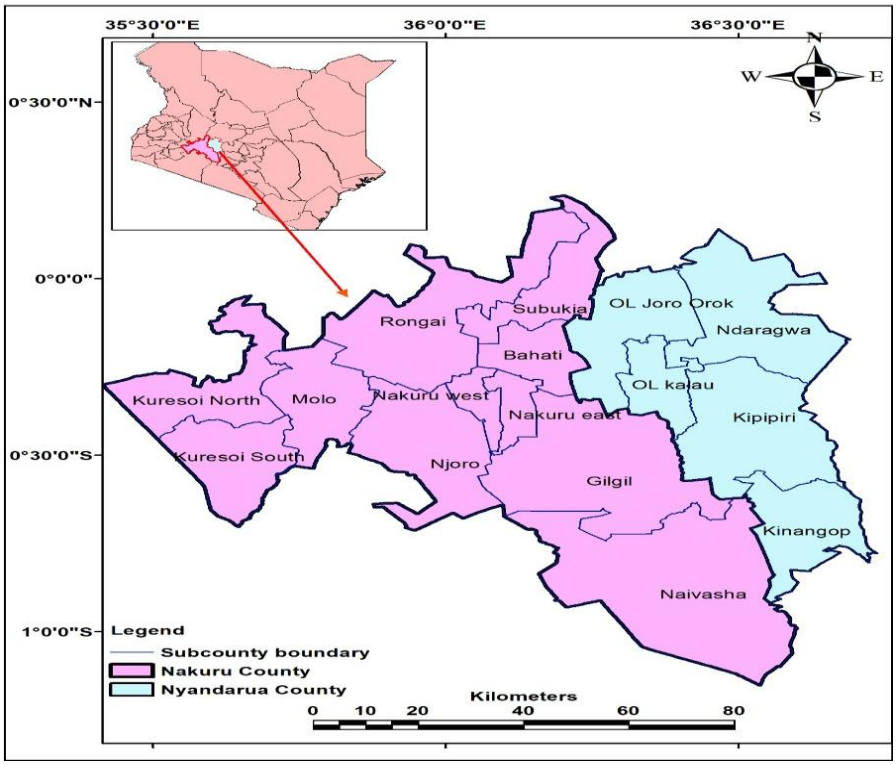

Figure 1: Map of Nakuru and Nyandaru Counties

The study used cross sectional survey approach and multi- stage sampling procedure in selecting the sample of smallholder dairy households to provide data for the study. Purposively, the study identified Nyandarua and Nakuru counties because of their large number of smallholder dairy producers. The administrative sub - counties of the two counties formed strata for sampling. Three sub – counties were purposively selected from each county for inclusion in the study due to their unique characteristics mainly their geographical location, milk production levels, and diversity of dairy activities and their high extent of small-scale dairy production. These were Bahati, Rongai and Molo from Nakuru County and North Kinangop, West Kinangop and South Kinangop from Nyandarua County. The survey tools used to provide data for analysis were pretested structured questionnaires and eight Focus Group Discussions each comprising of at least six individuals. Finally, the study used simple random sampling to select 380 milk-producing households.

3.0 Results and Discussion

3.1 Socioeconomic Characteristics of Smallholder Dairy Farmers

Table 1 presents the socioeconomic characteristics of smallholder dairy farmers. The results showed that on overall, 83.6 percent of households were male-headed while female-headed households were 16.4 percent.

Table 1: Characteristics of Household Heads and Income Sources (%)

Characteristic	Category	Nakuru	Nyandarua	Chi-Sq	Overall
Gender of head	Male	83.7	83.6	0.022	83.6
	Female	16.3	16.4	0.022	16.4
Education level of the head	Primary	47.5	39.3	1.667*	43.4
	Secondary	38.6	50.2	-2.36**	44.4
	Tertiary	13.4	10.4	0.903	11.9
	University	0.5	0.0	0.998	0.2
Where the household head resides	Within homestead	95.0	94.5	0.235	94.8
	Town/other village	5.0	5.5	-0.469	5.2
Employment status of the head	Otherwise	92.1	87.0	1.649*	89.6
	Employed	7.9	13.0	-1.649*	10.4
Occupation of the household head	Farming	86.1	76.0	2.703***	81.1
	Non farming	4.0	1.5	1.521	2.7
	Farming and non-farming	9.9	22.5	-3.449***	16.2
Main source of family income	Farming	81.1	78.1	0.6400	79.6
	Non farming	1.0	0.5	0.5740	0.7
	Farming and non-farming	17.9	21.4	-0.9016	19.7

Source: Calculations by author based on the 2017 survey data. ***p<0.01, **p<0.05, *p<0.1

Results also showed that the majority of household heads (87.8 percent) had either primary or secondary education with only 12.1 percent achieving post-secondary education level. Nyandarua County had significantly (P < 0.05) higher proportions of households whose heads had secondary education as their highest level of education compared to Nakuru County at 50.2 and 38.6 percent respectively. In contrast, Nakuru County had significantly (P < 0.1) higher numbers of heads with primary education as the highest level of education compared to Nyandarua at 47.5 and 39.3 percent respectively. The majority of household heads (89.6 percent) were not engaged in formal employment. Additionally, Nyandarua County had significantly (P < 0.1) higher proportions of household heads in formal employment compared to Nakuru at 13.0 and 7.9 percent respectively. Similarly, 81.1 percent of household heads were involved exclusively in farming as their primary occupation while 16.2 percent combined both farming and non-farming activities as their primary occupation. Nakuru County had significantly (P < 0.01) higher proportions of households whose heads exclusively relied on farming as their primary

occupation at 86.1 percent compared to 70.0 percent in Nyandarua. Overall, 79.6 percent of the households relied on farming as the main source of family income while 19.7 percent relied on both farming and non-farming activities for income. The majority of heads (94.8 percent) also resided within their homesteads. Table 2 provides the T-test results used to identify the differences between various socioeconomic characteristics of smallholder dairy farmers in Nakuru and Nyandarua counties. The results showed that household heads and spouses in Nyandarua County were significantly (P < 0.01) younger with the mean ages of 48 and 44 years respectively compared to 56 and 52 years respectively in Nakuru.

Table 2: Household Characteristics and Land Ownership Status

Characteristic	**Nakuru**	**Nyandarua**	**t-test**	**Overall**
Age of head	56.2	48.0	6.55***	52.1
Age of spouse	51.9	43.5	6.39***	47.7
Number of household members	6.0	5.0	1.92*	5.0
Number of children in school	2.0	2.0	0.47	2.0
Days in a month the head is available	28.0	28.0	-0.95	28.0
Distance in Kilometers				
Distance to nearest market	4.5	3.6	3.06***	4.0
Distance to nearest tarmac road	2.7	4.5	-3.79***	3.6
Distance to nearest extension service provider	4.7	5.0	-1.01	4.9
Land Ownership				
Total acres owned	2.8	2.6	0.54	2.7
Total acres rented in	0.4	0.6	-2.40**	0.5
Total acres rented out	0.2	0.1	1.34	0.1
Total acres communally owned	0.2	0.1	1.23	0.1
Total land accessed	3.6	3.4	0.55	3.5

Source: Calculations by author based on the 2017 survey data. ***p<0.01, **p<0.05, *p<0.1

Nakuru County had significantly (P < 0.1) larger households compared to Nyandarua with mean household sizes of 6 household members. Households in Nyandarua County were significantly closer to markets with a mean distance to the nearest market being 3.6 km compared to 4.5 km in Nakuru. Households in Nakuru County were significantly (P < 0.01) closer to tarmac roads compared to those in Nyandarua County with a mean distance of 2.7 km and 4.5 km respectively.

Access to land is also an important component in dairy production and even though there was no significant difference in total land accessed, owned, rented out and land communally owned, households in Nyadarua County rented-in significantly (P <0.05) more land compared to those in Nakuru County at 0.6 and 0.4 acres respectively. Table 3 presents the T-test results used to identify the differences between various sources of

income and expenditures of smallholder dairy farmers in Nakuru and Nyandarua counties.

Table 3: Average monthly household incomes and expenditures in KSh

	Nakuru	Nyandarua	t-test	Overall
Major Income source				
Employment income	18,448	14,002	0.878	6,942
Profit from businesses	6,850	13,483	-3.08***	8,990
Dairy enterprise	6,839	12,565	-4.91***	10,044
Sale of other farm produce	17,656	30,561	-2.86***	23,977
Sale of livestock and other assets	23,086	59,717	-3.22***	37,488
Compost manure	5,125	1,000	0.546	4,300
Land rented out	3,000	1,067	1.124	22,109
Major Expenditure				
Livestock feeds	5,283	13,014	-4.718***	9,465
Veterinary services	2,933	2,482	1.139	2,694
Farming labor	7,096	10,580	-1.575	8,938
School fees	50,682	43,574	0.928	47,005
Household Food	4,288	4,871	-0.830	4,589
Household clothing	6,205	3,532	6.285***	4,749
Household health	2,107	667	5.889***	1,371
Household transport and fuel	1,707	1,266	2.479**	1,498
Gifts and weddings	1,293	780	2.603**	1,038

Source: Calculations by author based on the 2017 survey data. ***p<0.01, **p<0.05, *p<0.1
1 $ = KSh 103

Besides dairy, businesses undertaken in the study area includes potatoes, cabbages, tomatoes, second hand clothes, maize, retail shops/kiosks, motorcycle taxi and *jua kali*. The results showed that households in Nyandarua County earned significantly ($P < 0.01$) higher business profits, dairy enterprise, the sale of other farm produce, and sale of livestock and other assets compared to households in Nakuru County. In the mentioned categories, households in Nyandarua County earned KSh 13,483, KSh 12,565, KSh 30,561 and KSh 59,717 respectively, while households in Nakuru received KSh 6,850, KSh 6,839, KSh 17,656 and KSh 23,086 respectively. The results showed that the sale of livestock substantially contributed to overall farm incomes in both Nakuru and Nyandarua Counties. Household expenditure on livestock feed was significantly ($P < 0.01$) higher in Nyandarua at KSh 13,014 compared to KSh 5,283 in Nakuru. On the other hand, expenditure on clothing and health were significantly higher in Nakuru compared to Nyandarua. Expenditure on transport and gifts were significantly ($P < 0.05$) higher in Nakuru compared to Nyandarua. Overall, school fees (KSh 47,005), fertilizer (KSh 10,619), livestock feed (KSh 9,465), and seeds (KSh 7,816) were consecutively the largest expenditure items for the households. In Nakuru County, school fees and fertilizer were the major expenditure items while school fees, livestock feeds, labor and fertilizer were the major expenditure items in Nyandarua. Households spent least on weddings and gifts in

both counties. Table 4 indicates household assets and values in the study area. The results showed that the mean value of dairy cattle was significantly (P < 0.1) higher in Nyandarua (KSh 137,535) compared to Nakuru County (KSh 120,035). Farm implements like hoes and slashers in Nyandarua were significantly (P < 0.05 and P < 0.01) higher at KSh 1,726 and KSh 1,066 respectively compared to Nakuru County at KSh 1,338 and KSh 547 respectively.

Table 4: Household Assets and Values (KSh) *1 $ = KSh 103*

Asset	Nakuru	Nyandarua	t-test	Overall
Oxen or Bull	34,134	27,560	1.016	29,685
Dairy cattle	120,035	137,535	-1.821*	129,502
Local cattle	54,075	26,867	1.731*	45,202
Wheel barrow	3,147	2,633	2.236**	2,872
Hoes or Jembes	1,338	1,726	-2.068**	1,536
Pangas or slashers	547	1,066	-5.955***	807
TV	10,960	8,422	2.516**	9,841
Bicycle	9,725	4,991	1.979*	7,570

Source: Calculations by author based on the 2017 survey data. ***p<0.01, **p<0.05, *p<0.1

Households in Nakuru recorded significantly (P < 0.1) higher mean values of local cattle (KSh 54,075), wheelbarrows (KSh 3,147), television (KSh 10,960), and bicycles (KSh 9,725) compared to households in Nyandarua County, which recorded KSh 26,867, KSh 2,633, KSh 8,422 and KSh 4,991 respectively for the listed assets. The overall mean household asset value was about KSh 2 million, a mean value of KSh 2,172,066 in Nyandarua and KSh 1,624,530 in Nakuru. The value of total household assets was higher in Nyandarua compared to Nakuru. The observed difference was from the values of dairy cattle, poultry, carts, vehicles, ploughs, hoes, slashers, radios and mobile phones that were substantially higher in Nyandarua.

3.2 Principal Components Analysis Results

The Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity (BTS) for Principal Components Analysis (PCA) were undertaken and the results are presented in Table 5. The results showed that BTS was 4144.31 with a p-value of 0.0000 indicating that the data was appropriate for PCA. The KMO value was 0.6870 indicating that there were sufficient items for each factor. The tests, therefore, supported the appropriateness of the application of PCA to the analysis.

Table 5: KMO and Bartlett's Test of Principal Components

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy	0.6870
Bartlett Test of Sphericity (Chi-Square)	4144.3050
DF	666
P-value	0.0000

Source: Calculations by author based on the 2017 survey data.

This study applied the "elbow" criteria (Ledesma et at., 2015) in explaining the PCA results. The Kaiser rules for PCA provide that only factors with Eigenvalues greater than one be retained (Pugno & Verme, 2012). In this study, twelve components met this requirement and accounted for 61.58 percent of the total variance. However, from the scree plot (Figure 2), only the first four (accounted for 32 percent of the total variance) factors showed substantial variation from each other and hence retained for this study. Additionally, the Cronbach's alpha test yielded a coefficient of 0.7369 on all items indicating that the scale was reliable. The four retained components also had Cronbach's alpha values of greater than six indicating that the classifications were highly reliable (Gliem & Gliem, 2003). Table 6 provides the results of the results of the components selected and retained.

Table 6: The principal Components Factor Loading

Factor and Item Description	**Factor Loadings**	**% Variance Explained**	**Cronbach Alpha Test**
Factor 1: Milk output factor		*11.47*	*0.7659*
Highest amount of milk produced per day	0.4025		
Lowest amount of milk produced per day	0.4049		
Factor 2: Land control factor		*8.67*	*0.9295*
Owned acres	0.3989		
Total acres accessed	0.3912		
Factor 3: Household income factor		*6.25*	*0.8881*
Occupation of the household head	0.4915		
Source of Household Head income	0.4962		
Factor 4: Physical infrastructure factor		5.39	0.5770
Distance to Market	*0.3696*		
Distance to Extension service	0.4033		
Total Variance explained		31.78	

Source: Calculations by author based on the 2017 survey data.

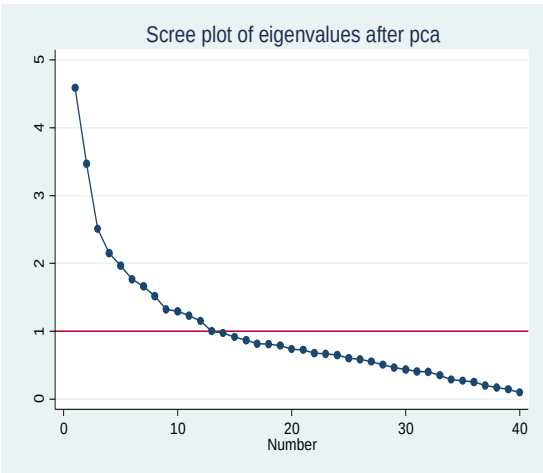

Figure 2: Scree Plot for the Eigen Values

The first retained component had a Cronbach's alpha value of 0.7659 and it accounted for 11.47 percent of the variance. The component included two items namely; the highest amount of milk produced per day (0.4025), and the lowest amount of milk produced per day (0.4049). This component was labeled as *'Milk output factor'.* The second retained component had a Cronbach's alpha value of 0.9295 and accounted for 8.67 percent of the total variation. The component had two items including owned acres and total acres accessed with the factor loadings of 0.3989 and 0.3912 respectively. This component was labeled as *'Land control factor'* as it only includes land variables. The third retained component had a Cronbach's alpha value of 0.888 and accounted for 6.25 percent of the variation. It included two items namely, the occupation of the head (0.4915) and the source of household income (0.4962). The third component was labeled *'household income factor'* since it is characterized by income-related variables. The fourth and the last retained component had a Cronbach's alpha value of 0.577 and accounted for 5.39 percent of the variation. The component was labeled as *'physical infrastructure factor'* and contained two items namely; distance to market and distance to the nearest extension with factor loadings of 0.3696 and 0.4033 respectively. Therefore, based on the Eigenvalues and factor loadings results; output, land, income, and infrastructure are the most important considerations in the characterization of smallholder dairy households.

3.3 Cluster Analysis Results

3.3.1 Smallholder Dairy Farming Typologies

Table 7 provides the results for the smallholder dairy farming typologies from the cluster analysis. The ANOVA analysis results showed that three clusters were significantly different based on various characteristics. The results indicated that cluster 1, 2 and 3 had 59.21, 35.26 and 5.53 percent of the households respectively.

Table 7: Characteristics of Clusters Based on Means

Characteristics	Cluster 1	Cluster 2	Cluster 3	F	Prob>F
Household commercialization (HCI)	0.691	0.781	0.819	8.63	0.0002
Gender of head	0.804	0.888	0.905	2.54	0.0799
Age of head (Years)	51.853	52.269	53.333	0.14	0.8702
Household size	5.538	5.134	6.048	1.76	0.1737
Distance to market (Km)	4.078	4.049	3.143	1.07	0.3436
Distance to tarmac (Km)	3.499	4.079	3.098	0.74	0.4779
Distance to extension (Km)	4.832	4.681	5.976	1.17	0.3119
Owned acres	2.311	3.212	4.660	8.75	0.0002
Total acres	3.164	3.936	5.886	7.06	0.0010
Dairy years	11.283	14.119	12.476	3.32	0.0372
Current number of cows owned	2.044	3.567	4.952	55.87	0.0000

Number of permanent employees	0.076	0.254	0.476	10.42	0.0000
Number of casual employees	0.502	0.530	0.762	0.63	0.5307
Group membership	0.676	0.597	0.571	1.37	0.2559
Household income (KSh)	38865.19	45357.35	123704.8	20.13	0.0000
Asset value (KSh)	128502.4	294054.0	1242476.0	179.53	0.0000
Number of pure breeds	1.173	2.187	2.952	26.05	0.0000
Amount of milk consumed (Ltr)	1.804	2.168	2.214	5.24	0.0057
Highest milk produced (Ltr)	11.202	17.168	24.524	23.34	0.0000
Operation costs (KSh)	7530.013	9634.433	14439.52	3.61	0.0279
School fees (KSh)	35488.94	30828.33	35173.33	0.26	0.7726
Labor costs (KSh)	3585.556	6961.194	10800.000	4.65	0.0101
Cluster frequency	*225*	*134*	*21*		
Cluster distribution	*59.21%*	*35.26%*	*5.53%*		

Source: Calculations by author based on the 2017 survey data. 1$ = 103 KSh

Typology 1: Low resource endowed and Low commercialisation

Typology 1 was composed of 225 households representing 59.21 % of the sample. This typology was categorized as Cluster 1. Households in this cluster had access to relatively less land. They owned an average of 2.3 acres and had an access to a total of 3.2 acres. They are relatively less experienced in dairy farming with an average of 11 years in the enterprise. They owned an average of 2 dairy cows. These farmers exhibited less resource endowment with an average total asset value of KSh 128,502 and an average monthly income of KSh 38,865. The households were also relatively less productive with the highest average amount of milk produced per day being 11.2 liters and a daily household consumption of 1.8 liters. Their monthly dairy operation cost was the lowest at KSh 7,530 and KSh 3,585 for farm operations and labor respectively. This cluster reported no permanent employee. These households are the least commercialised with Household Commercialization Index (HCI) of 0.691.

Typology 2: Moderate resource endowed and Moderate commercialization

Typology 2 was composed of 134 households representing 35.26 % of the sample. This typology was categorized as Cluster 2. Smallholder dairy farmers' commercialization in this cluster was moderate with HCI of 0.781. Households in this cluster had a moderate landholding, owning an average of 3.2 acres and had an access to a total of 3.94 acres. They were the most experienced in dairy farming with an average of 14 years in the enterprise. They owned an average of 4 dairy cows. These farmers were moderately resource endowed with an average total asset value of KSh 249,054. They also had an average monthly income of KSh 45,357. The households exhibited moderate milk production with the highest average amount of milk produced per day of 17.2 liters. Their daily household milk consumption was 2.2 liters. Their monthly expenditure was KSh 9,634 and KSh 6,961 on farm operations and labor respectively. This cluster reported no permanent employees.

Typology 3: High resource endowed and High commercialisation

Typology 3 was composed of 21 households representing 5.53% of the sample. This typology was categorized as Cluster 3. Households in this cluster were accessible to relatively more land owning at an average of 4.7 acres and having access to a total of 5.9 acres. They were moderately experienced in dairy farming with an average of 12.5 years in the enterprise. They owned an average of 5 dairy cows. The farmers in this cluster were more resource endowed. They had an average total asset value of KSh 1,242,476. Their average monthly income was KSh 123,704. The households were also relatively more productive with the highest average amount of milk produced per day of 24.5 liters and a daily household consumption of 2.2 liters. Their monthly expenditure was relatively higher at KSh 14,440 and KSh 10,800 on farm operations and labor respectively. This cluster registered no permanent employees. These households were the highly commercialized with HCI of 0.819.

3.3.2 Determinants of Smallholder Dairy Farming Typologies

Tables 6 and 7 provided results from PCA and Cluster Analysis, of the distinctive factors that determine smallholder dairy typologies.

Land factors were key in smallholder dairy farming. Smallholders in the study area use both own land and leased land for dairy activities. The results indicated that own land acreage and total acres of land both significantly ($P < 0.01$) determined smallholder dairy farming types. Land defined, the size of dairy stock kept, dairy feed availability and amount of labor required. Dairy farmers who had less land or relied on leased land were restricted in the decisions regarding their dairy enterprises including the willingness to try out new undertakings to progress their income. Conversely, a farmer who leased the land emphasized on making a profit in the short run hence intensified production. Farmers who leased land were constrained in carrying out some specific activities on the land including dairy infrastructure and mechanization because they would vacate the land upon the expiry of the tenancy. The size of land coupled with the type of ownership influenced the intensity, type of dairy system as well as the extent of dairy production. The land could also be used as a collateral when sourcing for finance hence it dictated the financial ability in smallholder dairy farming. The accessible land could highly be divided into small and inefficient units (Wily, 2012), resulting to land fragmentation, production systems and reduced production in smallholder dairy subsector. Decreasing size of land holdings is a major threat among smallholder dairy farmers (Makoni et al., 2014). Reduced land holding also compromised productivity of enough quality fodder to feed the dairy animals and hence negatively affecting the cost of production.

Dairy farming experience, expressed in years, significantly ($P < 0.05$) determined smallholder farming typology. The dairy farming typologies differed considerably with dairy farming experience. The results suggested that farmers differed in years of experience. Experience caused variations in dairy management under different

environmental and economic situations. Farmers with many dairy farming years fed and managed their dairy stock relatively better, realizing more milk production, and therefore received higher revenues compared to farmers with relatively less years of dairy farming. More experienced farmers exhibited four advantages. First, they manifested better dairy farming management, which included cleaner stables, better water access, and more comfortable milking practices. Second was better dairy nutrition, which included cheaper food alternatives such as corn silage, grass silage, brewer grain, dry leucaena leaf and cassava leaves that provided high nutritional value especially during difficult economic times. Third, was better dairy health care because of their better knowledge on common disease treatment including tick fever, mastitis, acidosis and laminitis without calling veterinarians, thus keeping costs low (Yeamkong et al., 2010). Fourth, Practical skills acquired over time enabled smallholder dairy farmers to apply good animal husbandry practices in feeding, housing, fertility management, calf rearing, and record keeping. This is essential to improve productivity and cost of production reduction for greater profitability (Ettema, 2012). Experience improves efficiency, dairy resources decisions and management. Dairy farming experience is achieved in several ways; i) attaining formal education and training, ii) relations with an informal network and iii) learning by doing over time. Variations in dairy farming experience and hence dairy husbandry resulted in the observed differences in the farming typologies.

Dairy stock determined smallholder farming typology. Dairy herd stock varies significantly ($P < 0.01$) among the typologies. Farmers with bigger herds were likely to purchase more of dairy farming inputs. The daily feedstuff requirement of dairy cattle always varied for different ages of stock, quality of feed and level of production. Smallholder dairy farmers, therefore, had to harmonize the demand and supply of feedstuff in such a way as to achieve high desired sustainable production of milk. Hence, the need to match the resources and the needs of the animals reared. The number of dairy animals kept determined the amount of resources and the way the farm was managed which varied from typology to typology.

Cost of labor significantly ($P < 0.05$) determined smallholder dairy farming typology. Dairy farming is labor intensive and is therefore highly dependent on labor quality, quantity, availability as well as labor cost. These labor factors affected dairy farming decisions. Labor factors determined the timing of all the dairy daily activities. The various kinds of daily work in a dairy farm included feeding the cows, watering and cleaning, maintaining cowshed, checking the health of cow, milking the cow, processing and marketing of the produce. A dairy farmer with off-farm engagements would be relatively less available to provide decisions or work on the dairy activities. The size of the dairy herd determined the variation in labor input requirement. As the number of dairy animals' increased, there was need for more labor and hence engagement on casual, permanent, part-time, or full-time arrangement.

Household income was also a significant (P < 0.01) determinant of smallholder dairy typology. Income defined a households' capability to finance farm capital and secures contemporary necessary dairy inputs. Income determined farm's capital investment level in addition to farm input purchase, necessary appropriate technology adoption and intensification of dairy production. Income could also be a collateral in sourcing for credit. Available income determined the purchase of farm equipment that substituted the human labor and reduction of human labor demanded. Additionally, income could reduce overall income risk for the smallholder dairy-farming households. Income increased the incentive of adoption of risky but profitable farm technologies besides commercialization of smallholder dairy. More household income could facilitate increment in the land for dairy production.

Dairy output and consumption levels defined the type of smallholder dairy farming. The results indicated that both the amount of milk produced and amount of milk consumed by the smallholder dairy farmers both significantly (P < 0.01) affected the farming typology. Seasonality in production, quantity and quality of animal feed compounded by the use of supplement feeds affected milk production and consumption. Inappropriate animal husbandry and farming practices, poor access to breeding, animal health and credit services in addition to the high cost of artificial insemination (AI) service are some of the main limiting factors. Dairy producing areas majorly had poor dairy infrastructure like cold storage, insufficient milk collection and marketing system, poor interaction and priority setting between research, extension and training, and limited farmers' involvement in the input and output market.

Dairy farming assets affected smallholder farming typology. The dairy farming assets varied significantly (P < 0.01) among the typologies. Farming assets like fodder cutter, knapsack sprayers', milking cans, treatment equipment's, transportation equipment and other relevant animal husbandry equipment possessed by the farmer defined the competency in smallholder dairy enterprise. They provided for the correct timing for dairy decision needed, which varied from farm to farm.

Operation cost significantly (P < 0.05) determined smallholder farming typology. The concentrate feed for the dairy animals were inadequate and highly priced due to low and varied quality, high cost of feed, reliance on imported feed ingredients and rampant trade malpractices in the feed industry. AI was also expensive and unreliable. Another cost constraint in dairy farming was the high cost of improved and pure breeds. Dairy animals were subject to several health conditions and needed resources. Dairy farming involved farm and dairy equipment's (e.g. bailers, feed mixers, dryers or milk-cooling equipment) whose costs tended to be high pausing a challenge to the smallholder dairy farmers. Kenya has exhibited gradual change from low cost to high cost of milk production.

4.0 Conclusion and Recommendation

The results of this study led to the conclusion that ownership, accessibility, and management of land remain to be critical in smallholder dairy farming. There were

uncertainties about ownership of land and accessibility inadequacies. This posed a critical limitation to the smallholder dairy farmers in the study area. Land defined the size of dairy stock; dairy feed availability and amount of labor required. Dairy farmers who had less land or who relied on rented land were restricted in the decisions regarding their dairy enterprises including the willingness to try out new undertakings to progress their income. The land was also widely used as a collateral when sourcing for finance hence it dictated financial ability in smallholder dairy farming.

Income defined the financial availability of a household, hence the ability to finance farm capital and secure necessary dairy inputs, and credit accessibility, which were important for success in farming. Income determined a farm's capital investment level in addition to farm input purchase, necessary appropriate technology adoption and intensification of dairy production. Smallholder dairy farmers relied on incomes from transferred payments, and informal money lending besides own sources with minimum dependency on family and friends. Farmers cited inadequate capital and expensive credit as factors behind the low productivity and marketing for dairy.

Relevant and efficient dairy farming assets and resources remained key to improving performance in the subsector. Assets could be used as collateral hence determined income and capital besides being used during production and marketing. Their quantity, quality and nature also influenced the type of investments that a smallholder dairy farmer could easily engage in and hence smallholder dairy farming typology. Seasonality in production, inadequate quantity and quality of animal feed compounded by the use of supplement feeds explained the smallholder dairy subsector. Inappropriate animal husbandry and farming practices, poor access to breeding, animal health and credit services in addition to high cost of dairy services were cited as the draw backs for the sector success. Substantial quantities of their milk produced tend to go bad and not marketed. Farmers on their own could not meet the expected quantity, high quality, and safety demands as well as delivery schedules to enable them to have a competitive advantage in the markets.

Infrastructure played a significant part in the dairy subsector. Distance to the markets determined opportunities and how new investment could produce the expected added income. Market distance defined the exchange relations between smallholder dairy producer and other stakeholders in the sector including extension services. It dictated the extent of price stability or volatility. Distance was key in defining the overall relationship between smallholder dairy farmers and other players.

Based on the conclusions, the study fronts several recommendations. First, there is a need to increase access to land through land reform processes. Security of land tenure is necessary for the smallholder dairy farmers, by executing strategies on

responsible control of tenure of land ownership and accessibility. There is also need to have appropriate procedures to advance cooperation and governance in the controlling common property resources, including open grazing. Second, there is the need for improvement in smallholder access to financial resources. This includes easing monetary transactions (such as mobile phone-based money transfers), safe savings deposits with incentives to save, low-price credit such as through joint-liability group lending. The policies should seek to minimize financial risks, lower transaction costs and enable long-term investments. Third, smallholder dairy farmers need adequate access to public goods on both the input and output sides. Policies need to emphasis on investment in infrastructural development including roads and electricity, health services, education, sanitation, and social amenities. This would be critical in enhancing dairy welfare and operation effectiveness. Fourth, policies need to refocus on national research and extension systems accustomed to the needs of smallholders' dairy farmers' typologies. Interventions should target stakeholders in the dairy industry with an aim of addressing systemic issues that hamper the growth of smallholder dairy subsector. Piloting innovations and best practice solutions to address systemic issues related to high cost of production, poor raw milk quality, feeding/fodder, total farm management, and productivity, as well as the subsector governance are advisable.

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