

Full Length Research Paper

Farmer segmentation for enhancing technology adoption and smallholder dairy development

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Despite various interventions, smallholder dairy farming in large parts of the tropics remain characterised by low productivity, restricted market participation, and viability challenges. The problem lies in the unavailability, low adoption rates and non-adoption of available improved smallholder dairying technologies. Using Rusitu and Gokwe smallholder dairy projects in Zimbabwe as a case study, this paper explored broad global issues of farmer segmentation, characteristics of the different farmer segments or innovation domains, the domains' influence on technology adoption patterns, and the impact of technology adoption on smallholder dairy development. Through a survey of 227 households and the use of a multivariate analysis approach, Principal Component Analysis identified eight principal components, while follow-up analysis using Cluster Analysis identified five distinct innovation domains. These innovation domains included smallholder dairy producers (61.6% of the surveyed households), smallholder dairy heirs (15.9%), new and emergent producers (4.6%), smallholder dairy pioneers (2.0%), and commercial and market-oriented producers (15.9%). The paper established that innovation domains with higher levels of participation in smallholder dairy innovation platforms had higher rates of dairy technology adoption. The net effects have higher estimated annual dairy incomes, improved total household incomes, and the development of smallholder dairy enterprises. This study provides valuable contributions in advancing the theories and practice of innovation, agricultural research and advisory services.

Key words: Agricultural research, agricultural advisory services, cluster analysis, innovation platforms, principal component analysis.

INTRODUCTION

Smallholder dairy production systems in the world over are heterogeneous and consist of a large number of farmers with different technical characteristics, socio-

economic circumstances and institutional attributes. In reality, seemingly homogenous segments of dairy farms exhibit diverse characteristics *vis á vis* herd sizes,

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adopted breeding systems, land available for grazing, and feed and herd health management practices (Dantas et al., 2016). Farming households also tend to differ in their resource endowments, production orientation and objectives, past experiences, management capacity, livelihood strategies, and in their attitudes towards risks (Tittonell et al., 2010). However, the determination and appropriate segmentation of agricultural production systems into applicable innovation domains remains obscure due to the lack of standardized assessment parameters and procedures (Bidogezza et al., 2009; Nainggolan et al., 2013). This represents a knowledge gap. Nevertheless, farmer segmentation is critical for further research and analysis, target domain mapping, improving the adoptability and performance of innovations, determining potential opportunities and barriers to technology adoption, providing platforms for feedback and learning, and for ensuring the formulation of sector specific policies, appropriate agricultural research and programming for agricultural advisory services, and development of practical tools for the apt targeting of interventions (Srairi and Kiade, 2005; Mubiru et al., 2007; Kaouche-Adjlane et al., 2015; Dantas et al., 2016).

Despite various interventions, smallholder dairy farming in large parts of the tropics remains characterised by low productivity, restricted market participation, and viability challenges (Somda et al., 2004; Moran, 2005; Uddin et al., 2012). The problem lies in the unavailability, the low adoption rates and non-adoption of available improved smallholder dairying technologies (Falvey and Chantalakhana, 2001; Mubiru et al., 2007; Chinogaramombe et al., 2008). In sub-Saharan Africa, past studies ascertain that the unavailability and low technology adoption levels result from, *inter alia*, policy gaps, top-down and supply-driven agricultural research and advisory services, lack of information feedback and limited farmer participation, poor segmentation of target innovation domains, and inappropriate technologies (Mudhara and Hildebrand, 2005; Mburu et al., 2007; Pandey et al., 2007; Hebinck and Cousins, 2013). The objective of this study was to fill the existing knowledge gap by conducting a segmentation of smallholder dairy farmers into innovation domains, identify the characteristics of the different innovation domains, determine the domains' influence on technology adoption patterns, and explore the impact of technology adoption on the development of smallholder dairy enterprises. This is critical for advancing the theories and practice of innovation, agricultural research and advisory services.

Background to the study

Most governments in developing countries embark on increased smallholder dairy production since it is seen as a powerful tool for promoting rural and socio-economic

development (Bennett et al., 2006). Smallholder dairy development can also be viewed as an instrument of rural poverty reduction by focusing on strategies for generating rural jobs through diversifying into labour-intensive, high-value agricultural production linked to a dynamic rural, non-farm sector (World Bank, 2008). The idea to set up smallholder dairy schemes emerged from countries such as India, Kenya and Malawi where the bulk of the total milk production is by smallholder farmers (Marecha, 2009).

In Zimbabwe, the government launched the Dairy Development Programme (DDP) in 1982. The main objective of the programme was to use smallholder dairying, through enhanced milk production and marketing, as a tool for socio-economic development. Currently, the programme has 21 milk collection centres in five of the country's eight rural provinces. However, past studies have highlighted challenges emanating from low herd sizes, low farm level productivity, declining economic efficiency in larger herds, and viability challenges in the Zimbabwean smallholder dairying sector (Kagoro and Chatiza, 2012; SNV, 2013; Chamboko and Mwakiwa, 2016).

Livestock contributes about 40% of global agricultural GDP and 30% of agricultural GDP in developing countries (Gebremedhin and Hoekstra, 2010). In Zimbabwe, livestock production systems contribute directly to food and nutrition security, income growth and poverty reduction at household, micro- and macro-economy levels (SNV, 2013). Smallholder dairying in Zimbabwe also presents the greatest opportunities for unlocking value, generating the highest and quickest returns to investment due to the diversity of dairy products and the higher margins that can be gained from niche markets. In addition, there has been no detailed or systematic study on effects of institutional factors on smallholder dairying (topically and geographically).

Conceptual and theoretical framework

The concept of innovation refers to the search for development, adaptation, imitation and adoption of technologies that are new to a specific context. In this realm, innovation goes beyond science and technology, to include design and institutional innovation (Sumberg, 2005). The perception of innovation processes has also changed from a simplistic and linear process. Leeuwis and van den Ban (2004) argue that innovation processes are continuous and iterative processes, and are characterized by joint learning based on successes and failures, reflection, experimentation and adaptation. Innovation domains, on the other hand, are groups of farmers with similar technical, socio-economic and institutional circumstances and farming practices for whom a given recommendation would be broadly appropriate (van den Ban and Hawkins, 1988; Röling, 1988; Rogers, 2003; Plewa et al., 2012). Conversely, adoption describes the decision by an economic unit to

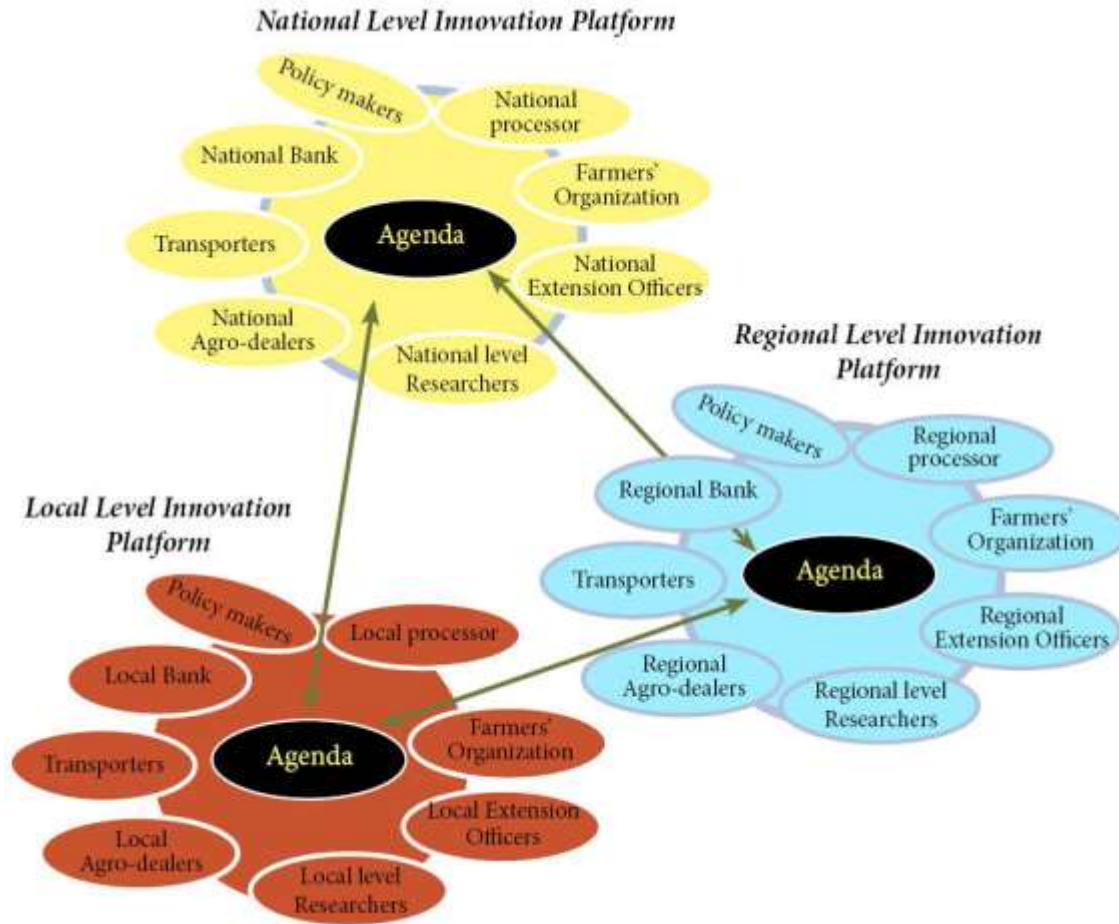


Figure 1. Multi-level innovation platforms.
Source: Makini et al. (2013).

use or not use a particular innovation (Abera, 2008).

This study was guided by the Innovation Platforms (IPs) paradigm. Ideas on IPs are firmly rooted in theories of Systems Thinking (Röling, 1988) and Innovation Systems (Hall et al., 2003; Dantas, 2005; Clark, 2006). IPs are multi-sectoral and multi-institutional coalition of actors in specific value chain systems, which act as mechanisms for encouraging, developing, and/or disseminating innovations to users (Nederlof et al., 2011; Makini et al., 2013). The IP facilitates dialogue between the main players in the value chain, viz, farmers, input suppliers, traders, transporters, processors, wholesalers, retailers, regulators, and the research and development fraternity. This makes IPs participatory approaches for problem solving and knowledge creation (Figure 1).

Within the IP framework, appropriate farmer segmentation is expected to increase technology adoption, with ripple effects on household incomes and welfare. The use of such a comprehensive analytical tool is critical in moving innovations forward, e.g., many of the bottlenecks related to the dissemination and adoption of technology have long been known but with little progress

made to overcome those bottlenecks.

A review of the role and effects of other institutional factors on smallholder dairying has been insightful. While strides have been made in improving smallholder farmers' access to general financial services, relatively little progress has been made in financial services specific to their agricultural activities. Notable has been the lack of tailored financial tools to meeting the range of financial needs of different segments of smallholder farmers, including for specific enterprises and for poor households (Christen and Anderson, 2013). In an assessment based on a study of smallholder dairy farmers in Kenya, it was established that the amount of microfinance credit accessed by smallholder dairy farmers influenced the type of breeds kept by the farmers (Kenduiwa et al., 2016). This represents both a constraint and the potential of micro-financial resources in smallholder dairy farmers' efforts to improve their breeds. In a lot of the cases, lack of collateral acts as the biggest barrier to smallholder dairy farmers' access to finance. Small and medium scale enterprises (SMEs) have also been noted as having great potential and a strong future

role in the global market place. What remains outstanding though is a solid internationalization strategy for SMEs.

Innovation domains in smallholder dairying

Smallholder dairy production systems in the tropics share common characteristics but remain diversified, thus exhibiting heterogeneity rather than homogeneity. Based on studies in Asia, Latin America, and Northern and Eastern Africa, Devendra (2001) classified smallholder dairy production systems into three broad innovation domains, *viz*, (i) traditional, usually with *ad hoc* marketing arrangements which is typical of most peri-urban smallholder dairy farms, (ii) cooperatives whose foundations are natural aggregation and/or concentration of farms, and (iii) intensive production systems with herd sizes of up to 200 dairy cows. According to Moran (2005), smallholder dairy innovation domains can also be determined on the basis of physical factors (magnitude of scale, stock type, forage and feeding systems), farm characteristics (land and stock ownership, labour, farm income), and institutional factors (marketing channels, farmer support systems, economic policies).

Dantas et al. (2016) used cluster analysis in identifying four innovation domains in the Eastern Amazon in Brazil, in which two variables, *viz*, farmer education and management levels, influenced the rate of technology and innovation adoption. In the Mediterranean Basin in Algeria, Kaouche-Adjlane et al. (2015) characterised breeding dairy cattle systems into four groups of farms based on their structure and management systems. In Morocco, feeding strategies and economic efficiency were used to classify dairy cattle farming systems into five innovation domains using Principal Component Analysis (PCA) and Cluster Analysis (CA) (Srairi and Kiade, 2005). Mubiru et al. (2007), based on intensification level analysis in Uganda, lamented the negligence of systematic parametric variations in smallholder dairying which could provide entry points for research and targeting interventions. In the Kenyan highlands, Mburu et al. (2007) used cluster and discriminant analysis in categorising smallholder dairy farms into four different innovation domains based on risk management strategies, level of household resources, technology adoption, dairy intensification, and their access to services and markets. Social scientists investigating farmers' adoption behaviour in Nigeria also produced evidence showing that various characteristics inherent within innovation domains affect adoption behaviour (Oladele, 2005). No similar studies have been conducted in Zimbabwe and most other countries in Southern Africa. On the other hand, a wholesome adoption of the diverse and overlapping innovation domains highlighted earlier, based on non-uniform criteria and methods, makes intervention targeting rather subjective and inconsistent, hence, the need for more scientific, systematic and quantifiable segmentation parameters and procedures.

RESEARCH METHODOLOGY

Research context

The study was carried out within the context of two DDP project sites, *viz*, Rusitu and Gokwe. The two research sites were purposively selected to capture their diverse and contrasting agro-ecological, production, historical, intervention, and institutional scenarios. Rusitu Dairy Resettlement Scheme is located about 440 km east of Harare in Manicaland Province and falls within latitude 20° 02' S and longitude 33° 48' E. The scheme is located in agro-ecological region I, characterized by high rainfall, low temperatures, well-drained soils and provides a perfect environment for dairying (SNV, 2013). It was established as a pioneer and special smallholder dairy resettlement scheme in 1983, went through various challenges, managed to reinvent itself, and is now marketing raw milk to Dairibord Zimbabwe Limited (DZL). DZL is a nationwide depot network which has been in operation since the 1950s. The Gokwe Smallholder Dairy Scheme, on the other hand, is located at 338 km west of Harare in the Midlands Province and falls within latitude 18° 13' S and longitude 28° 56' E. The scheme is located in agro-ecological regions III and IV characterized by low rainfall, fairly severe mid-season dry spells and is, therefore, marginal for dairying (SNV, 2013). It was one of the follow-up DDP projects in 1994, has maintained consistency, and has a contract farming arrangement for raw milk with Dendairy. Dendairy is an emerging dairy processing firm located within the Midlands Province. The Gokwe Smallholder Dairy Scheme also processes and markets processed dairy products locally. The two schemes are largely representative of smallholder dairy projects in Zimbabwe.

Sampling

Multistage sampling, a complex form of cluster sampling, was adopted to guide sampling for the household questionnaire survey. Rusitu and Gokwe smallholder dairy projects were purposively selected as the two research sites for reasons discussed earlier. During the second stage, smallholder dairy farmers in both Rusitu and Gokwe were stratified on the basis of their level of participation in dairy innovation platforms. The household was then used as the unit of sampling during the third and final stage of sampling. At this stage and within the strata, a probability sampling method was used as the basis of selection of households included in the survey. The choice of such a sampling method was based on the need to capture the multi-dimensional characteristics of each project. In all, 227 smallholder dairy households were sampled for the study, with 152 households sampled from Rusitu and 75 households sampled from Gokwe.

Data collection

The study adopted the use of both quantitative and qualitative data collection as a way of improving analytical rigour. Field data collection was based on a phased and concurrent use of case studies, desk studies, Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and a structured household questionnaire survey. The use of numerous data collection methods was deliberate since this is a way of triangulating collected data for purposes of verification, validation and improving the reliability of collected data (Babbie et al., 2001; Wagner et al., 2012). Despite their controversy and criticism for lack of rigour, case studies are a robust research tool that provides a platform for exploration and understanding of complex issues (Zainal, 2007). Meticulous and systematic literature review is also recognised across academic domains as critical to the foundation of new knowledge and theory

Table 1. Description of variables used for PCA.

Variable name	Description and units	Descriptive statistics		
		n	Mean	Std. Dev.
Gender of HHH	1 if HHH is male, 0 otherwise	227	0.79	0.406
Age of HHH	Farmer's age in years	227	56.41	13.88
Years of education	Number of years in formal education	221	8.13	4.123
Farming experience	Years in commercial dairy	213	17.32	10.87
Total household income	Total income in USD	227	3,583.84	6,372.28
Area under fodder	Total area under fodder pastures (ha)	225	0.9633	2.734
Dairy cattle	Total number of dairy herd	227	4.44	6.367
Dairy cows	Total number of dairy cows	227	1.92	2.734
Average milk in wet season	Average litres in wet season	227	14.92	25.85
Average milk in dry season	Average litres in dry season	226	9.74	16.36
Farming as a business	1 if yes and 0 otherwise	227	0.86	0.344
Improved dairy herd	1 if yes and 0 otherwise	225	0.76	0.428
Heat detection	1 if yes and 0 otherwise	226	0.83	0.379
Artificial insemination	1 if yes and 0 otherwise	222	0.61	0.489
Fodder production	1 if yes and 0 otherwise	225	0.76	0.431
Supplementary feeding	1 if yes and 0 otherwise	226	0.65	0.479
Vaccination	1 if yes and 0 otherwise	227	0.62	0.487
Silage making	1 if yes and 0 otherwise	227	0.90	0.296
Vaccination training	1 if yes and 0 otherwise	227	0.79	0.406
Disease training	1 if yes and 0 otherwise	227	0.92	0.278
Access to MCC	1 if yes and 0 otherwise	227	0.93	0.249
Access to breeding tech	1 if yes and 0 otherwise	227	0.88	0.330
Access to product markets	1 if yes and 0 otherwise	227	0.86	0.349
Distance from MCC	Measured in km	218	4.913	6.810

evolution (Gaffar et al., 2015).

A formal survey using a structured household questionnaire was used to collect data on household demographics, participation in innovation platforms, farm amenities and conditions, asset ownership, livestock numbers and dynamics, dairy production and marketing, crop production, household food security, livelihood-based coping strategies, as well as access to livestock technology, inputs and support services. In-depth literature reviews and preliminary KIs at national level ensured content validity, encompassing guidance on theoretical, conceptual and empirical insights. Drafted data collection instruments were also subjected to a series of reviews by peers, academic advisors and experts in various fields to ensure face validity. In addition, a pilot survey of 20 households was conducted in Chikwaka Smallholder Dairy Scheme in Mashonaland East province about 30 km north-east of Harare for purposes of gaining a conceptual clarification and ensuring that the study was based on relevant questions. The pilot study also presented an opportunity for pre-testing the data collection instruments for ensuring that the study generates accurate, consistent, dependable and reliable data.

Analytical framework

Innovation domains were established through the sequential use of multivariate statistical tools, viz, (i) PCA using the Statistical Package for Social Sciences (SPSS) version 23 and (ii) Cluster Analysis (CA) using STATA. First, the Kaiser-Meyer-Olkin (KMO) test, for assessing the sampling adequacy, was conducted yielding a result of 0.766 which was more than the 0.5 threshold, while the

Bartlett's test of Sphericity was determined to be significant at $p < 0.01$ indicating adequacy of correlation.

PCA, a dimension reduction technique used to classify data, was used to identify non-correlated socio-economic variables for use as proxies for the segmentation of smallholder dairy farms into innovation domains. PCA is regarded as the best tool in survey research for data reduction that includes all critical data (Mick, 1990) despite recent criticism for information loss (Lattin et al., 2005), hence its continued use. A total of 24 variables were used for the PCA, following Kaiser's criterion of limiting the number of variables to less than 30 (Field, 2005). A description of all the 24 explanatory variables used in the PCA empirical model is shown in Table 1.

From the results, 21 of the selected 24 variables were loaded into components (>0.5). Only three variables (practising farming as a business, using improved dairy breeds, and access to markets) were not explained by the eight principle components. The number of components to be retained was again determined by Kaiser's criterion which stipulates that components need to have eigenvalues greater than one. Factors were also rotated using the varimax method to improve the interpretability of the results, with only loadings of 0.5 or more being considered as significant.

CA was then run using factors retained from PCA to determine a final distribution of smallholder dairy farms into homogenous segments, as well as ascertaining the attributes of the different clusters based on the significance of the differences between the cluster means. CA has been criticised in the past for failing to determine an appropriate number of clusters (Everitt, 1993) but remains an indispensable statistical tool for developing clusters based on entities displaying similar propensities for given variables

(Steel et al., 1997). The final smallholder dairy farm clusters/segments were restricted to five. In addition to CA, one-way ANOVA tests were conducted to determine the variance between group (cluster) means.

Study's limitations

By adopting the case study approach for this analysis, the researcher was quite conscious of the potential limitations in terms of the generalisability of the findings. Case studies cover many facets of the total picture and extend over a long period of time and are, therefore, costly exercises. After this, it then became unfeasible to conduct several case studies to allow for greater generalization. To reduce bias and enhance the applicability of generated findings, efforts were made during sampling of the research sites to make them as representative of smallholder dairy projects in Zimbabwe as possible. In some instances, data collection also had to rely on recall, with the challenge that in some cases respondents were unable to recall past events and details. As such, the use of multiple data collection methods and probing ensured a greater reliability of collected data. Furthermore, there were also possibilities for unobservable differences between comparator groups, thus making comprehensive comparative analysis difficult.

RESULTS

Insights from KIIs and FGDs

KIIs and FGDs segmented smallholder dairy farmers into four distinct innovation domains. According to the KIIs and FGDs, the first innovation domain comprises subsistence smallholder dairy producers. These are smallholder dairy farmers who become a part of the dairy enterprise as a result of assimilation, that is, because they see others doing it. They are not commercially oriented and maybe seasonal dairy producers. Usually, they have 1 to 3 milking cows. Their adoption of innovations is low and production levels are very low, with average production of 1 to 5 L of milk per cow per day. Calving intervals could be as high as 3 years. Feed, health and general cow management is also poor. Unfortunately, these constitute the bulk (about 60%) of smallholder dairy farmers in the sampled schemes. The second innovation domain is made up of emerging or semi-commercial smallholder dairy farmers. These are smallholder dairy farmers who are attempting to go into commercial dairy farming but are not yet there. Innovation adoption, while improved, remains poor and inconsistent. Their productivity levels, based on milk yields, calving interval and other parameters such as mortality rates are a slight improvement from the levels attained by subsistence smallholder dairy farmers. As examples, dairy herd sizes may average 3 to 5 milking cows, while milk yields may average 8 to 10 L per cow per day. Most of these farmers are breaking even while others are making a small profit. According to the conducted KIIs and FGDs, this second segment represents about 20% of smallholder dairy farmers.

The third innovation domain constitutes emerging commercial smallholder dairy farmers. They have a dairy

herd size that averages 5 to 10 milking cows. Milk yield per cow ranges from 10 to 15 L per cow per day. Innovations drive the smallholder dairy commercialisation process. The dairy herds have a normal calving interval of 365 days. They have a good animal health management system characterized by routine dipping and vaccinations. Feed and nutrition management is also improved, with adequate feed reserves that match what the dairy herd requires. They may suffer on standards, e.g., struggle with maintaining consistent milk quality, but they are close to standards in the large-scale commercial dairying sector. As such most of the dairy enterprises are viable entities. This group constitutes about 15% of smallholder dairy farmers in the sampled schemes. Lastly, the fourth innovation domain signifies a group of commercial and market-oriented smallholder dairy farmers. These are smallholder dairy farmers by scale of production but are qualified to break into large-scale commercial dairying. Their dairy herd sizes range from 10 to 60 milking cows, with milk yield levels of between 15 and 25 L per cow per day. They have gone commercial because they have realized the benefits of dairying. Within this innovation domain are smallholder dairy farmers who want to exit smallholder dairy farmer associations because they may feel that they are subsidizing the rest of the cooperative group, e.g. in terms of milk collection centre running costs, and want to move into individual supply chains. While the first three categories depend on each other in terms of marketing arrangements, members of this group can afford to individually supply dairy processors. This group constitutes only 5% of smallholder dairy farmers in the research sites.

Principal component analysis (PCA) results

PCA produced clear dimensions between the selected variables resulting in distinct innovation domains. A total of 8 principal components having eigenvalues of >1 were deemed capable of effectively explaining the variance in the data set. This entails that 8 innovation domains were initially identified for categorizing smallholder dairy farmers in Rusitu and Gokwe. A notable 68.7% of the variation in the data is explained by the 8 components. The first component explains 22.1% of the total data variance, the second component (13.5%), third component (7.5%), fourth component (6.2%), fifth component (5.5%), sixth component (5.1%), and seventh component (4.5%), while the eighth component accounts for 4.3% of the variance. Table 2 shows the results of the rotated component matrix, which highlights the loadings and shows the correlations between individual variables and the components.

For the first component, 5 variables are significant in explaining it. These are the number of dairy cattle owned, the number of dairy cows owned, average milk production per day during the wet season, average

Table 2. Varimax-rotated component matrix showing the identified principal components, loadings for selected variables, and the percent cumulative variance explained.

Component	1	2	3	4	5	6	7	8
Distance from MCC	-0.060	0.036	-0.033	0.090	-0.061	0.813	-0.094	-0.088
Gender of HH head	0.140	0.125	-0.051	0.036	-0.114	-0.016	0.239	-0.756
Age of HH head	0.052	-0.042	0.054	-0.070	0.862	-0.039	0.237	0.023
Years in formal schooling	0.107	-0.026	0.092	-0.056	-0.748	-0.066	0.315	0.074
Years in commercial dairying	0.167	0.351	0.169	0.172	0.488	-0.426	-0.226	0.092
Total annual HH income	0.866	0.010	-0.013	-0.004	-0.011	0.034	0.092	0.080
Area under fodder	0.084	0.175	-0.062	0.025	-0.155	-0.052	0.193	0.630
Dairy cattle owned	0.908	0.083	0.110	0.074	0.035	-0.098	-0.076	-0.011
Dairy cows owned	0.870	0.032	0.139	0.040	0.026	-0.106	-0.127	-0.020
FaaB adoption	0.053	0.270	0.182	0.017	0.160	0.450	0.184	0.308
Use of imp dairy breeds	0.104	0.602	0.212	0.087	0.133	0.119	0.011	0.204
Heat detection practised	0.090	0.729	0.094	0.255	-0.031	-0.099	-0.004	0.057
AI adoption for breeding	0.186	0.696	0.088	-0.018	0.026	0.015	-0.096	-0.076
Fodder prod on at least 0.1ha	-0.065	0.718	0.250	0.068	0.007	-0.022	0.139	0.036
Basal and supplementary feeding	0.138	0.704	0.159	-0.001	-0.070	0.120	0.230	-0.069
Vaccination adoption	-0.070	0.139	0.038	0.070	-0.043	-0.003	0.881	-0.014
Trained in silage making	0.040	0.310	0.521	0.613	-0.021	-0.145	-0.020	0.027
Trained in vaccinations	0.056	-0.106	0.060	0.739	0.055	0.356	0.086	0.108
Trained in disease treatment	0.008	0.286	0.075	0.839	-0.016	-0.085	0.013	-0.114
Access to MCC	0.057	0.222	0.821	-0.060	-0.034	-0.046	0.026	-0.048
Access to impr. breeding techn.	0.140	0.229	0.729	0.168	-0.022	0.071	-0.076	0.048
Access to markets	0.047747	0.118	0.657	0.098	0.061	0.018	0.081	0.010
Average milk prod/day wet season	0.91919	0.151	0.039	0.007	-0.024	0.021	0.003	-0.034
Average milk sold/day dry season	0.864	0.180	0.038	-0.009	-0.021	0.057	0.036	-0.052
Total (%)	22.1	13.5	7.5	6.2	5.5	5.1	4.5	4.3

amount of milk sold per day during the wet season, and total annual household income. This first component represents the group of “*productivity and market-oriented farmers*”. The second component, “*breeding and feeding conscious farmers*”, is strongly and positively correlated to 5 variables, that is, the use of improved dairy breeds, adherence to heat detection in dairy cows, adoption of artificial insemination as a breeding technology, fodder production on at least 0.1 ha, and adherence to basal feeding of 2 kg and supplementary feeding of 0.5 kg feed for an additional litre of milk. The third component, “*farmers with access to essential services*”, has the following 4 significant variables: training in silage making, access to the milk collection centre, access to improved breeding technologies, and access to markets. An emerging pattern here is that strong necessary conditions/drivers lead to better innovation uptake.

The fourth component, “*capacitated farmers*”, had three issues that loaded heavily on the component: training in silage making, training in vaccinations, and training in disease treatment implying that capacity building is a critical determinant of the adoption of innovations. The fifth component, “*old farmers with less formal education*”, shows a negative relationship between the age of

household head and the number of years in formal schooling implying that older farmers are associated with less education, and maybe less innovation. The sixth component, “*access to markets oriented farmers*”, has only 1 dominant factor, the distance from the milk collection centre, while the seventh component “*health concerned farmers*” is heavily weighted by the adoption of vaccinations. The eighth component, “*gender and fodder production sensitive farmers*”, shows a negative relationship between the gender of the household head and the area under fodder implying that more female headed households turn to have a higher area of fodder under production. However, insights from the Scree Plot, which determines how many components are to be retained, reduced the number of identified innovation domains that we can effectively work with to five.

Identified innovation domains

The identified five innovation domains were retained and used for Cluster Analysis (CA). Results of one-way ANOVA, where F is significant (<0.1), imply that there are significant variances among the innovation domains for a

number of variables. This in turn entails that there are some innovation domains where variables are dominant over others. Results from CA are shown in Table 3. The five different innovation domains are each denoted with ID. Of interest, is establishing the characteristics that differentiate the five innovation domains.

Socio-economic variables that differentiate the five innovation domains include membership to collective smallholder dairy association groups, milk collection centre membership registration, full payment of membership subscriptions, period of registration as a milk collection centre member, and a household's milk production status. All these socio-economic variables are related to a household's participation in smallholder dairying innovation platforms. However, an unexpected result was the fact that the variable on households' milk delivering status, which is also related to a household's participation in smallholder dairying innovation platforms is not significant. On the other hand, all technology adoption variables are significant, with the exception of branding, which is a form of livestock identification. The characteristics that differentiate the five innovation domains are discussed subsequently.

Core dairy producers (Innovation Domain 1)

This first innovation domain comprises 61.6% of the farm households. This innovation domain can be distinguished from the other innovation domains largely on the basis of milk production and delivering status of producers in these strata. The innovation domain has the highest proportion of households currently producing milk (77%) and delivering milk to milk collection centres (57%). Comparative averages from all the 5 domains are 66 and 52%, respectively. The innovation domain thus comprises a core group of smallholder dairy producers. It also has the highest proportion of members with fully paid subscriptions. As expected, the innovation domain recorded the second largest number of technologies adopted by any innovation domain. It recorded the adoption of the use of paddocks, stainless steel bucket for milking, use of artificial insemination in breeding, fodder production on at least 0.1 ha, new fodder crops, and silage making.

The Heirs (Innovation Domain 2)

The second innovation domain, which accounts for 15.9% of the farm households, is peculiar in the amount of dividends received by members of this cluster. The innovation domain encompasses smallholder dairy farmer association members who receive the highest amount of dividends. This is the group of smallholder dairy heirs who inherited enterprises upon the death of the original entrepreneurs. The cluster's average dividend

is USD101.74 against an average of USD58.94, with the third and fourth innovation domains receiving USD0.00 dividends. They also have the second least period of registration as milk collection centre members, a handful of milk producers, and the second lowest proportion of members delivering milk to milk collection centres. There is nothing peculiar about their technology adoption patterns.

New and emergent producers (Innovation Domain 3)

The third innovation domain includes 4.6% of the farm households. The innovation domain sets itself apart on the basis of two distinguishing features which include the shortest period registered as milk collection centre members at 5.3 years against an average of 19.4 years, and the lowest proportion of households currently producing milk. The group has the lowest proportion of membership to collective smallholder dairy groups, and the lowest proportion of registered milk collection centre membership. Overall, this group of new and emergent producers has the lowest technology adoption levels for all technologies considered in this study, with the exception of urea treatment.

The Pioneers (Innovation Domain 4)

The fourth innovation domain, which encompasses 2.0% of the farm households, is differentiated by the period of registration as milk collection centre members. The innovation domain is constituted by smallholder dairy farmers with the highest period of registration as milk collection centre members, with a group average of 27.0 years against an average of 19.4 years. This is an assemblage of smallholder dairy pioneers. Technology adoption in this assemblage is insignificant. This is because this group of pioneers has the highest level of adoption of farming as a business approach and use of improved dairy breeds, but also has the lowest adoption of tagging and urea treatment.

Commercial and market-oriented producers (Innovation Domain 5)

This fifth and final innovation domain consists of 15.9% of the farm households. This innovation domain dissociates itself from other innovation domains on the basis of generated income. The constellation has the highest estimated total annual household income, at USD 4,548 against an average of USD 3,614, and the estimated total annually dairy income, at USD 1,885 compared to an average of USD 1,488. This is the constellation of commercial and market-oriented producers. This constellation has the highest number of technologies

Table 3. Characteristics of selected innovation domains (IDs) and results of one way ANOVA testing for equality of group means.

Socio-economic variable	ID 1 (n=93)	ID 2 (n=24)	ID 3 (n=7)	ID 4 (n=3)	ID 5 (n=24)	Group means	Group Std. Dev.	Prob > F
Membership to dairy group ¹	1.00	1.00	0.57	1.00	0.99	0.98	0.14	0.00***
Registered MCC member ¹	1.00	1.00	0.43	1.00	0.99	0.97	0.16	0.00***
Fully paid up membership subs ²	0.86	0.79	0.14	0.67	0.84	0.81	0.39	0.00***
Period registered As MCC member (years)	25.07	10.36	5.29	27.00	15.72	19.36	11.91	0.00***
Position in local MCC	6.45	7.00	7.00	7.00	6.20	6.46	1.48	0.20
HH currently producing milk ²	0.77	0.54	0.29	0.33	0.62	0.66	0.47	0.01***
HH currently delivering milk ²	0.57	0.42	0.29	0.67	0.52	0.52	0.56	0.56
Est. total annual income (US\$)	3382.66	2606.88	1605.00	2676.67	4548.24	3614.18	6686.68	0.62
Est. total annual dairy income (US\$)	1391.12	1249.33	83.33	324.00	1885.39	1488.84	3181.91	0.59
Dairy livestock sales (US\$)	164.99	93.75	57.14	0.00	214.32	166.52	496.29	0.77
Fodder entrepreneurship (US\$)	12.00	3.54	0.00	0.00	3.94	7.52	47.03	0.81
Dividends received (US\$)	35.31	101.74	0.00	0.00	85.95	58.94	299.88	0.75
Total dairy gross income (US\$)	2199.92	1489.51	303.57	600.00	4726.09	2894.89	11917.02	0.62
Technology adoption								
FaaB approach ³	0.91	0.79	0.57	1.00	0.90	0.88	0.32	0.04**
Record keeping ³	2.83	1.75	1.43	2.33	2.88	2.65	1.36	0.00***
Viability assessments ³	2.80	1.54	1.29	1.67	3.00	2.63	1.24	0.00***
Use of paddocks ³	2.90	1.50	0.71	2.00	2.54	2.51	1.43	0.00***
Stainless steel bucket ³	3.12	1.71	0.67	1.67	2.97	2.79	1.48	0.00***
Tagging ³	0.43	0.38	0.00	0.00	0.48	0.42	0.49	0.08*
Branding ³	0.37	0.34	0.00	0.00	0.42	0.17	0.38	0.49
Timely weaning ³	1.92	1.46	0.40	0.67	2.16	1.89	1.46	0.02**
Improved dairy breeds ³	0.89	0.46	0.14	1.00	0.81	0.78	0.41	0.00***
Cross breeding ³	2.76	0.83	0.57	2.00	3.00	2.51	1.37	0.00***
Artificial insemination (AI) ³	0.73	0.17	0.00	0.67	0.67	0.61	0.49	0.00***
Fodder production ³	0.89	0.29	0.14	0.33	0.85	0.77	0.42	0.00***
New fodder crops ³	2.56	0.63	0.57	1.33	2.19	2.10	1.38	0.00***
Silage making ³	2.69	0.88	0.29	1.67	2.48	2.29	1.44	0.00***
Urea treatment ³	1.04	0.71	0.14	0.00	1.75	1.20	1.51	0.00***
Adherence to dipping regimes ³	3.10	2.29	1.43	2.00	3.37	3.02	1.19	0.00***
Vaccination ³	0.54	0.54	0.29	0.67	0.72	0.59	0.49	0.08*

¹1 if member and 0 otherwise; ²1 if yes and 0 otherwise; ³1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Frequently, and 5 = Always. *Significant at 0.10 level, **Significant at 0.05 level, ***Significant at 0.01 level.

adopted at a rate of adoption greater than other innovation domains. Technologies adopted at higher rate include record keeping, viability assessments, tagging, timely weaning, cross breeding, urea treatment, adherence to dipping regimes, and dairy animal vaccinations.

DISCUSSION

The results of PCA and CA, which yielded the distinct five innovation domains, are consistent with the findings of previous studies conducted elsewhere that classified smallholder dairy production systems on the basis of the level of intensification, management structure and market engagement (Devendra, 2001; Mubiru et al., 2007), physical factors, farm characteristics and institutional factors (Moran, 2005), dairy cattle farm structure and management systems (Kaouche-Adjlane et al., 2015), feeding strategies (Srairi and Kiade, 2005), as well as the risk management strategies of identified dairy production systems and their access to services and markets (Mburu et al., 2007). The paper, however, serves as a departure from conventional farmer typology studies that explicate technology adoption patterns through characteristics such as farm size, dairy herd size, milk production, farmer age, education level and management levels (Mburu et al., 2007; Dantas et al., 2016). It, however, remains unclear the roles of Geographic Information System (GIS) spatial coverage, networking, transportation grids, and routes of agricultural goods in differentiating farmer segments.

The paper established that smallholder dairy farmers segmented within innovation domains with higher levels of participation in smallholder dairy innovation platforms, such as the *Core Dairy Producers* and *Commercial and Market-Oriented Producers*, had higher rates of technology adoption. This can be explained by several factors. Smallholder dairy farmers in innovation domains with higher levels of participation in smallholder dairy innovation platforms tend to have greater access to agricultural advisory services and other support services (policy, research, credit and finance, market information), and greater interaction with other innovation platform actors (other farmers, researchers, agricultural advisory service agents, traders, processors, wholesalers, retailers, transporters, other private sector placers such as finance institutions, NGOs and policy makers at local, regional and national levels). This notion is supported by the results of earlier studies that argues that this also allows for the joint identification of bottlenecks and opportunities in production, marketing and the policy environment, and the leveraging of innovation to address the identified constraints and take advantage of opportunities across the entire impact pathway (Nederlof et al., 2011; Bill and Melinda Gates Foundation (BMGF), 2013), and hence a greater rate of technology adoption.

Results from the case study also support findings in

fields outside the smallholder dairy sector. Studies in Zambia showed that the adoption rate of technologies for underutilized crops, including sorghum, were higher within innovation platforms (Mbulwe, 2015). This the author attributed to a higher market demand for inputs and crop commodities. Similarly, an assessment of the effectiveness of the innovation platforms for technology adoption along the maize value chain in the province of Sissili, Burkina Faso succeeded against the backdrop of drivers such as the existence of champions of change, market opportunities to produce and sell quality seed and grain maize, access to information through community radio, and a string training and capacity building programme (Sanyang, 2012).

For the same reasons cited earlier, innovation domains with a lower level of participation in smallholder dairy innovation platforms (notably *The Heirs*, and *New and Emergent Producers*) tend to have lower rates of technology adoption. The *Pioneers*, on the other hand, sit on the fence because both their participation in smallholder dairy innovation platforms and rate of technology adoption are inconsequential. The results presented in this paper are also proof that there is a positive relationship between the level of participation in smallholder dairy innovation platforms, the rate of technology adoption, and the incomes generated from the smallholder dairy enterprise. This has implications and positive ripple effects on annual dairy incomes, household incomes, and household welfare.

However, other scholars argue that access to information and technology alone is not a sufficient condition for technology adoption without additional support from resource availability, technical guidance and improved perspectives (Batalha, cited by Dantas et al., 2016). Using a variant of the Innovation Platforms paradigm, the Integrated Agricultural Research and Development (IAR4D) in analysing its impact on adoption of soil fertility management technologies among smallholder farmers in Southern Africa, Nyikahadzo et al. (2012) also established that socio-economic factors are more important in influencing adoption than participation in innovation platforms.

Conclusion

Innovation domains have several implications for agricultural research and advisory services, some positive and others negative. Different innovation domains have different circumstances and needs, hence the need for targeted interventions and recommendations. Thus, farmer segmentation and the categorization of smallholder dairy farms into appropriate innovation domains allows for better targeting and priority setting in dairy improvement research and development, and in improving the participation in intensive production and marketing systems by oftentimes marginalized and

neglected smallholder dairy farmers. Interventions in the smallholder dairying sector should, therefore, factor in the characteristics of different innovation domains. An appreciation of the concept of innovation domains and knowledge of existing innovation domains within the target intervention context are also key for designing sectoral policies and strategies for the sustainable development of smallholder dairy value chains across the sub-Saharan Africa region.

Appropriate farmer segmentation is critical for target domain mapping, improving the adoptability and performance of innovations, determining potential opportunities and barriers to technology adoption, providing platforms for feedback and learning, and for ensuring the formulation of sector specific policies, appropriate agricultural research and programming for agricultural advisory services, and development of practical tools for the apt targeting of interventions. There is conviction that information generated by this study will also provide insights on issues critical for the academic advancement of innovation theory, formulation of realistic dairy development policies, as well as feedback to technology development and dissemination processes.

Beyond the segmentation of smallholder dairy farmers into innovation domains, further research could look into:

- (1) Use of panel data over a longer time frame, e.g. at least 5 years, to denote the dynamic changes in adoption patterns across the different innovation domains.
- (2) The innovation domains' influence and impact on other key parameters such as smallholder dairy productivity and viability.
- (3) A value chain analysis of the smallholder dairying sub-sector to examine and establish its full socio-economic potential.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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