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STRUCTURAL CHARACTERIZATION OF DAIRY PRODUCTION SYSTEMS IN FAISALABAD, PAKISTAN AS BASIS FOR THEIR EFFICIENT RESOURCE MANAGEMENT

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Qualitative and semi-quantitative data from 139 interviews with farmers in Faisalabad, Pakistan, was subjected to cluster analysis to identify homogenous groups of farms regarding production strategies, milk yields and marketing. Four distinct production systems were identified. Semi-commercial smallholder-mixed systems (SSM; 31%) combined crop and livestock production, and fodder was primarily produced for own livestock. Semi-commercial smallholder dairy producers (SSD; 21.6%) had few buffaloes and cattle and low income. Commercial smallholder dairy producers (CSD; 37.4%) were mostly well-off and produced substantial quantities of milk year-round. Commercial large-holder dairy farms (CLD; 10%) showed the highest input and output levels. In all systems, most of the produced milk was sold in the increasing order of percentage (SSM: 69%, SSD: 69%, CSD: 87%; CLD: 94%). Negligence in breeding, wastage of high yielding buffaloes, high costs of feedstuffs, an unfavorable marketing system and lack of a diversified dairy value chain were the main constraints for all production systems. Improving efficiency of the resources usage; especially with respect to animal genetics and nutrition, should be encouraged in dairy farmers of Faisalabad as well as other major cities in Pakistan to produce milk upto the maximum potential of their animals. This could satisfy the need of milk production for sale, serving both the increasing urban demand for milk, as well as income generation for the farmers. To this end farmers' endeavors must be supported by initiatives from government and private bodies.

Keywords: Cluster analysis, dairy value chain, farm typology, milk buffalo, CatPCA (Categorical Principal Component analysis)

INTRODUCTION

The livestock sector is an important sub-sector of agriculture and plays a key role in the economy of Pakistan. It contributed 55.9% to agriculture value added, 11.5% to the country's GDP and 13% to the total export during 2013-14 (Pakistan Economic Survey, 2013-2014). The milk production increased by 3.2 percent and meat 4.5 percent during 2013-14 as compared to corresponding period last year. Yet, agricultural development in Pakistan, especially the development of the livestock sub-sector, is lagging behind in the national demand for respective demand.

As far as the livestock production is concerned in Faisalabad the dairy animals accounted for about 60% of the herds consisting of buffaloes (Nili-Ravi breed) and cows (mostly crossbred, also Sahiwal) nevertheless, buffalo is the preferred dairy animal than cattle most probably due to higher milk yield along with high butter fat contents (Hagmann, 2010). On overall basis 50% of the milk produced in the district is used for domestic consumption (Aden *et al.,* 2008). The income elasticities of meat and livestock products in Faisalabad districts were highest compared to all other food items except fruits, defining the future role of livestock sector in our food basket (Abedullah *et al.,* 2009).

Demand for food in general, and for livestock products in particular, will continue to rise in and around cities with increasing urbanization (Lanyasunya *et al*., 2001). The growing demand of urban dwellers for milk has been a major driving force for the establishment of urban and peri-urban dairy farms in cities such as Karachi, Lahore, Faisalabad and Islamabad (Moaeen-ud-Din and Babar, 2006; Habib *et al*., 2007; Jalil *et al*., 2009), whereby the number of such farms in Pakistan has tripled from 1986 to 1996 (Habib *et al*., 2007). Rather than lack of access to product markets, the principal constraints to urban and peri-urban livestock rearing in developing countries are of technical nature and policy-related (Smith and Olaloku, 1998). Burki *et al*. (2005) underlined that research on production structures in the dairy sector would allow for the identification of the necessary structural changes. In Pakistan, peri-urban dairy farmers are usually poorly connected to financial institutions and livestock services, and get negligible returns from their dairy enterprise (Qureshi, 2000). Further, problems of the peri-

urban dairy buffalo sector are high calf mortalities, unsystematic breeding, imbalanced feeding, high loans and a hostile marketing system dominated by middlemen (Qureshi, 2000). Yet, urban livestock keeping is a multi-functional activity that fits different livelihood strategies and contributes to food security, income and employment generation, savings and social status (Guendel, 2002).

The lack of a systematic classification of Pakistan's peri-urban dairy farms in view of their resources endowment, socio-economic characteristics and management strategies is an obstacle to policy and development efforts that aim at increasing the milk output from this sector. Such systematic approaches would enable a sound understanding of the dairy systems and contribute to the prediction of their future evolution (Girard *et al*., 2001; Mburu *et al*., 2007). Differentiating between groups of dairy farmers with similar practices and circumstances is therefore a key to the development of appropriate interventions. In view of these aspects, we aimed to develop a typology for peri-urban dairy farms and analyze their strategies of resource allocation and management, thereby focusing on Pakistan's third largest city, Faisalabad.

MATERIALS AND METHODS

***Study area*:** The city of Faisalabad, second largest in Punjab province and third largest in Pakistan, had a population of more than 2.5 in 2005 with an average annual growth rate of 2.2% (Government of Pakistan, 2005). The District Faisalabad is located between 31°20' - 31°33' N and 73°13' - 72°55' E at an altitude of 184 m a.s.l. (Cheema *et al.,* 2006). Four seasons can be distinguished, namely winter (December - March) with cool weather and moderate rainfall, dry summer (April - June), which is extremely hot and dry, humid summer (July - September) with high temperatures and scattered rainfall, and autumn (October - November) with cold and dry weather (Mustafa and Khan, 2005). The climate is semi-arid subtropical with average annual temperature and rainfall during the period 1975 - 2004 being 24.5°C and 408 mm, respectively. The highest temperature in summer may hit 50°C, and the lowest in winter may fall below the freezing point (Cheema *et al.,* 2006).

***Data collection*:** 145 households (HH) keeping dairy buffaloes and dairy cattle in the urban and peri-urban zone of Faisalabad within a radius of 4.0 - 9.4 km from the city center (Fig. 1) were interviewed face to face using a structured questionnaire from August to October 2009. The questions were orally translated during the interviews into Punjabi or Urdu for the respondents. In return, the answers of the respondents were directly translated into English and noted down by the interviewer. The questionnaire covered

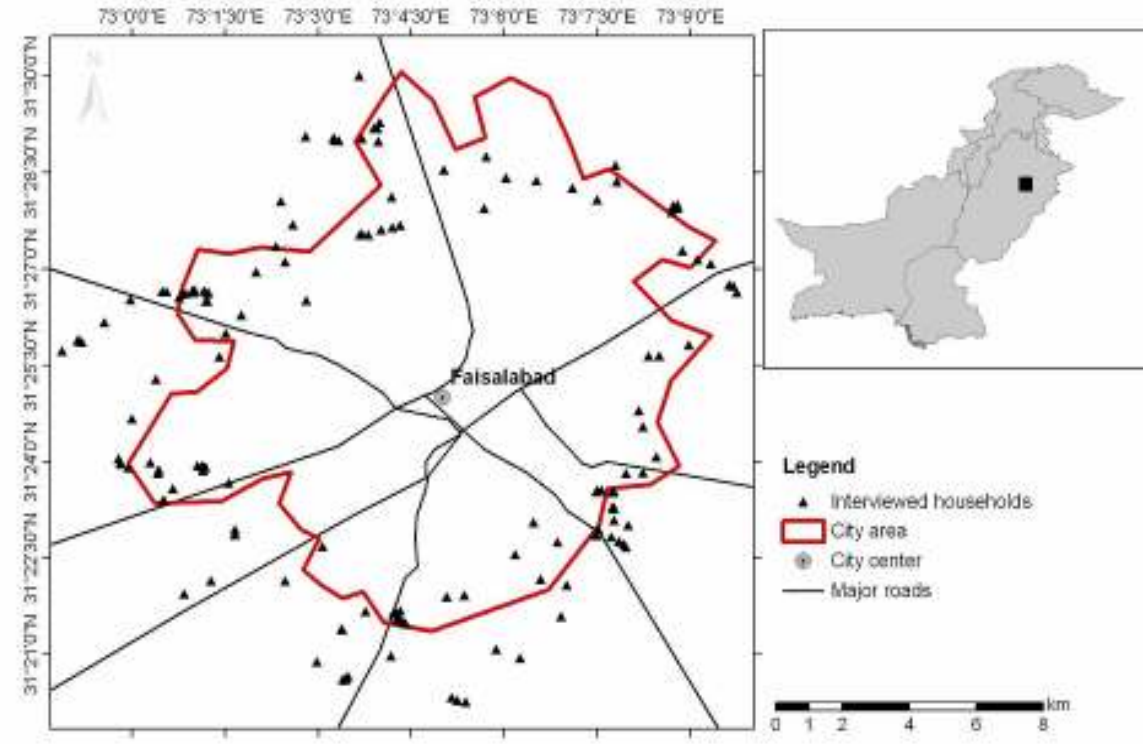

Figure 1. GIS-based map of Faisalabad city with the approximate expansion of the dense housing area (within red border) and the location of the 145 interviewed households.

socio-economic aspects (HH size, hired labor, production assets owned, total HH income and off-farm occupation) as well as animal feeding, housing, health care and breeding, milk production and marketing. Moreover, farmers' perceptions of own wealth (poor, well-off, rich), and of problems and future prospects with respect to their dairy activities were recorded. The duration of an interview ranged from 18 - 78 minutes (mean: 37 minutes). A pre-test of the questionnaire was conducted with 16 farmers, and the final questionnaire was modified where necessary.

A snowball sampling procedure (Babbie, 2009) was used to randomly select and interview the respondents. For sample selection, the first HH that visibly kept dairy animals in different regions of the city (Faisalabad is divided into six regions by main roads, Fig. 1) was chosen, informed about the reasons for the survey and interviewed immediately if the respondent agreed; in most cases, the interviewer and the interpreter as well as the interviewee and her/his relatives, friends and neighbors were sitting in public places under a shade tree; the respondents were often but not necessarily the HH head or the person actually taking care of the dairy animals.

After the interview, the respondents were asked to give names and addresses of three other HH keeping dairy animals. From these three names one was randomly selected, visited, informed and immediately interviewed once the respondent agreed. If all three of the addresses given were spatially too close to the formerly interviewed HH, none of them was chosen and another visually identified dairy HH further away was selected. Thus, the interviewed HH were evenly scattered along the built-up city fringe (Fig. 1).

Data analysis: Methodologically we opted for a combination of categorical principal component analysis (CatPCA) and two-step clustering which has been successfully used for farm classification in West Africa (Dossa *et al.,* 2011) and China (Riedel *et al.,* 2012). All variables (692) were coded into numbers, whereby scaled variables were kept in their original state, and two-class nominal variables (e.g., fodder/concentrate feeding yes/no) were coded into binaries. Each qualitative trait with more than two expressions was coded into a nominal categorical scheme where one numeric value represented one trait expression.

Sometimes, answers to specific questions were missing for a HH, either because respondents were reluctant to give the answer, or it was skipped accidently; these cases were classified as missing values and are the reason for differences in the number (n) of HH appearing in different tables. All steps of data analysis were performed with SPSS 17.0 (SPSS Inc., Chicago, Illinois). Variables were pre-selected through expert validation (Vyas and Kumaranayake, 2006) and CatPCA. The variables maintained for further analysis are listed in Table 1. The cluster analysis was run several times testing different combinations of the selected variables, and the measure of silhouette coherence and separation was used to select the best clustering solution. When the final results of the clustering were obtained (Fig. 2), a variable "cluster membership" was created and used for consequent comparison of the dependent variables such as size of crop land, own perception of wealth status, off-farm occupation of household members, total female adult buffalo number, total female adult cattle number, lactating buffalo number, lactating cattle number, maximum milk yield of best buffalo (l/d), maximum milk yield of best cattle (l/d) and percent of produced milk sold out. The comparison was done using ANOVA followed by Tamhane post-hoc test for normally distributed variables and Kruskal-Wallis test for not normally distributed variables; significance was declared at $P<0.05$.

Table 1. Abbreviations and definition of variables used for the final classification of farming systems in the urban and peri-urban area of Faisalabad.

Variable name	Description and unit of measurement
Socio-economic characteristics	
Money	Total household income (in Pakistani Rupees [PKS] per month)
Land	Cropland managed by farm (1=yes, 2=no)
Status	Household's own perception of wealth status (1= well-off, 2= rich, 3= poor)
Off-farm	Off-farm occupation of household members including household head (1=yes, 2=no)
Livestock keeping	
Buff_T	Total number of female adult buffaloes
Cat_T	Total number of female adult cattle
Buff_L	Number of lactating female buffaloes at the moment of interview
Cat_L	Number of lactating female cattle at the moment of interview
Milk_B	Maximum milk yield of the best buffalo (liters/day)
Milk_C	Maximum milk yield of the best cow (liters/day)
Milksale	Percent of produced milk sold out

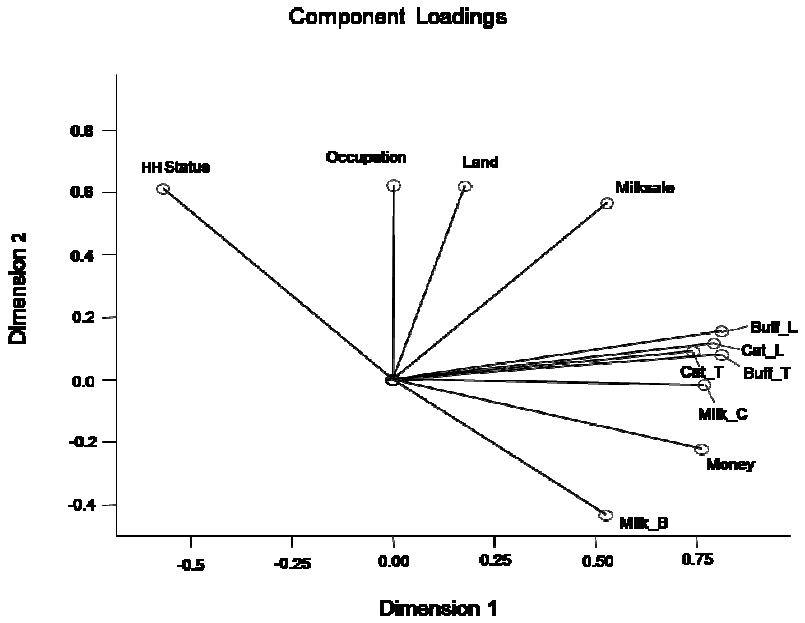

Figure 2. Result of the categorical principal component analysis identifying major variables that characterize buffalo and cattle dairy farming systems in the urban and peri-urban area of Faisalabad. Distance to centre indicates relevance of the variable for cluster creation (larger distance = higher relevance), and distance between two variables indicates their degree of correlation (larger distance = lower correlation). For variable names and definitions see Table 1.

RESULTS

A four-cluster solution was retained from CatPCA and two-step cluster analysis. Out of 145 HH, 139 were unanimously classified, while six HH were rejected by the software due to missing observations on particular parameters. The four identified production systems were differentiated according to the size of their dairy herd, size of cropland holding and market orientation (Table 2, Fig. 3).

Semi-commercial smallholder mixed production system (SSM): The 43 HH grouped under this production system were involved in both crop and livestock production. Buffaloes were their major dairy animals, but small numbers of cattle were also present on the farms, with the ratio of

Table 2. Name and characteristics of the four dairy production systems identified for the urban and peri-urban area of Faisalabad as determined by categorical principal component analysis and two-step cluster analysis.

Production System	Farms (n)	Name	Characteristics
SSM	43	Semi-commercial small scale mixed production system	100% of farms manage farmland; farmers perceive themselves as well-off; comparatively few lactating animals and thus low proportion of milk marketed. Household income is based on cash crops, fodder and milk sales.
SSD	30	Semi-commercial small scale dairy production system	Landless, mostly poor farmers; lowest number of lactating animals, very little milk production and sale; earn external income mostly from labor jobs, and have lowest total household income.
CSD	52	Commercial small scale dairy production system	All farmers perceive themselves as well-off; high proportion of off-farm income, total household income is comparatively high; sizeable number of lactating animals, high proportion of milk marketed.
CLD	14	Commercial large-scale dairy production system	Highest number of lactating animals, highest proportion of milk marketed; low share of revenues from off-farm activities but high household income; farmers perceive themselves as either well-off or rich.

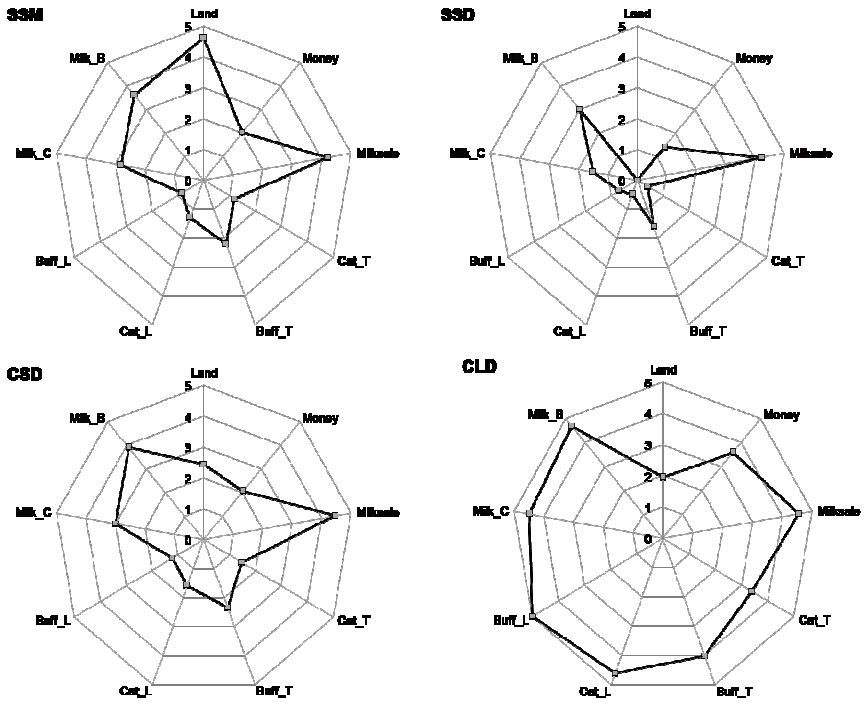

Figure 3. Characterization of semi-commercial small scale mixed (SSM; n=43), semi-commercial small scale dairy (SSD; n=30), commercial small scale dairy (CSD; n=52) and commercial large-scale dairy (CLD, n=14) production systems in the urban and peri-urban areas of Faisalabad. Each dot in the spider web displays the relative importance of the respective variable in relation to the overall sample of 139farms. For variable names and definitions see Table 1.

cattle to buffalo being 1.0: 2.5. To stimulate milk let down of their buffaloes, 28% of SSM farmers were regularly using oxytocin. The HH usually sell the surplus of milk that is left after fulfilling household needs; 37% of the HH were moreover regularly processing surplus milk into ghee. SSM farmers produce both cash crops and fodder crops on their agricultural land. The fodder is primarily used to feed their livestock while the rest is sold.

There is a strong linkage between crop and livestock production on the farms: the residues from cash crops were used to feed the animals, and the farmyard manure is used to increase soil fertility. Male and young female buffaloes were also used as draught animals for field work and for transporting fodder and manure. All wealth groups were present in this production system (Table 3).

***Semi-commercial smallholder dairy production system (SSD)*:** The 30 HH in SSD keeps relatively smaller number of buffaloes and cattle and in consequence produces little milk (Table 4). Their income is low and they do not possess cropland. Surplus milk is sold; 13% of the HH were processing milk into ghee, and 20% of the farmers were regularly using oxytocin for milk let down in buffaloes. Incoming money is spent on daily necessities and livestock fodder, which is purchased from fodder markets year-round. SSD farmers also use meal leftovers, vegetable leaves, fruit peelings and cash crop residues to feed their dairy animals. Most of the poor HH (90%) were concentrated in this cluster; in addition to work in their own dairy unit, male family members and household heads work as day laborers, and the role of the dairy animals is primarily a supportive one.

***Commercial smallholder dairy production system (CSD)*:** This is the largest group (52 HH) among all clusters. Similar to the first two production systems, buffaloes and cattle were kept mainly for milk production and buffaloes were more important than cattle in terms of number of animals and milk production. Overall milk production per dairy animal averaged 16 l d^{-1} (SD 6.42) across buffalo and cattle, which was higher than the 12 l d^{-1} (SD 3.34; buffaloes) and 10 l d^{-1} (SD 10.1; cattle) in the SSM cluster, and the 11 l d^{-1} (SD 2.74; buffaloes) and 5 l d^{-1} (SD 6.07; cattle) on SSD farms ($P<0.05$). In this production system 23% of the farmers make ghee from milk, and 40% were using oxytocin for milk let down in buffaloes, which is highest among all four

Table 3. Cluster-determining nominal variables (expressed in %) identified through categorical principal component analysis and two-step cluster analysis for grouping 139 households in the urban and peri-urban area of Faisalabad.

	Production system*				
Variable	**SSM** (n=43)	**SSD** (n=30)	**CSD** (n=52)	**CLD** (n=14)	**P< ****
Cropland					
Yes	100	0	11	7	n.s.
No	0	100	89	93	0.001
Own perception of wealth status					
Poor	21	90	0	0	0.01
Well-off	67	7	100	64	n.s.
Rich	12	3	0	36	n.s.
Off-farm occupation of at least one household member					
Yes	7	30	31	7	n.s.
No	93	70	69	93	0.001

* For definition and description of production systems see Table 2.
**Chi-Square test for differences between production systems, significance at P<0.05; n.s. not significant.

Table 4. Cluster-determining continuous variables (Means ±SD) identified through categorical principal component analysis and two-step cluster analysis for grouping 139households in the urban and peri-urban area of Faisalabad.

Variable*	Production system*			
	SSM (n=43)	**SSD (n=30)**	**CSD (n=52)**	**CLD (n=14)**
Money (1000PKR**/ month)	76.1^{b}±69.08	40.6^{a}±34.09	77.4^{b}±32.55	361.2^{c}±181.05
Buff_T (n)	6.3^{b}±3.45	3.9^{a}±2.41	7.0^{b}±3.60	28.4^{c}±15.26
Cat_T (n)	1.9^{ab}±2.09	1.0^{a}±1.30	2.1^{b}±1.92	5.5^{c}±5.54
Buff_L (n)	3.9^{a}±2.59	3.0^{a}±2.41	5.6^{b}±2.97	22.6^{c}±12.34
Cat_L (n)	1.3^{b}±1.54	0.5^{a}±0.86	1.6^{b}±1.60	4.6^{c}±4.26
Milk_B(l/d)	12.6^{b}±3.34	10.8^{a}±2.74	13.6^{b}±4.10	16.4^{c}±3.15
Milk_C (l/d)	9.9^{b}±10.11	5.2^{a}±6.08	10.7^{b}±7.88	15.8^{c}±9.73
Milksale (%)	69.0^{a}±25.67	69.0^{a}±32.95	87.0^{b}±11.71	94.0^{c}±3.41

* For definition of independent variables, see Table 1; for definition and description of production systems see Table 2.; ** PKR Pakistani Rupees; 1,000 PKR = 8.00 Euro at the time of study; [a, b, c:] Within rows, means with different superscripts differ at P<0.05 (Kruskal-Wallis test).

production systems. All CSD farmers perceived themselves as well-off, but the households were landless and had to purchase fodder for their livestock. Thirty one percent of them were earning additional income from off-farm occupation of the HH head. This allowed them to allocate a sizable amount of money to the dairy operation for purchasing concentrates, health care and construction of sheds.

***Commercial large-holder dairy production system (CLD)*:** This cluster comprises the smallest number of HH (14), but the total number of lactating buffaloes and cattle is the highest among all groups. Additionally, milk produced per animal is also high, pointing to better feeding and genetic makeup in comparison to the animals of the other farm types; oxytocin for buffalo milk letdown is only used by 12% of CLD farmers. Compared to the other three groups, this dairy production system is characterized by its higher input-output ratio and highest degree of commercialization - about 94% of the produced milk is sold. Although their milk processing is the lowest (12%) of all the production systems, CLD farmers dispose of a good milk marketing infrastructure and one of them also runs his own retail shop. Almost no farmer in this production system owns cropland, and all fodder is purchased year-round.

***General characteristics of urban and peri-urban dairy farms in Faisalabad*:** Across the four farm types, the total number of HH members averaged 10 and ranged from 1 to 23. Taking males and females together, on average 4 members were children aged up to 15 years, about 6 were 16 - 55 years old and 1 member was older than 55 years. Household heads were almost exclusively male - only one out of 139 was female. The majority of HH heads were

married (93%); some were widowed (6.5%) or single (0.7%). More than 62% of the HH heads who perceived themselves as poor had not attended school at all, and none of them had an education above 10 years, whereas 14% and 10% of the well-off and rich HH heads had benefited from secondary education (12 years) or even graduated from universities. Still, 36% of the well-off, 9% of the rich and in total 41% of all HH heads did not have any education. The commonest but not always the most important source of income was milk sale. Other sources of income, mostly contributed by HH members were off-farm day labor (such as in government guards, textile industry, on neighboring farms), running own small shops or larger businesses as well as the sale of field crops (mainly wheat and fodder crops). Some of the HH heads themselves had additional occupations such as trading animals or teaching at primary school. HH heads earning off-farm income (n=30) had a significantly higher level of education than those without off-farm occupation (n=109), pointing to the fact that a higher literacy level provided better chances to find a job.

The majority of the HH were landless (64%); the rest possessed agricultural land. The areas they owned (calculated from the answers of only 17 HH, as interviewees were not explicitly asked for their area sizes) ranged from 0.1 to 10.1 ha, the average being 2.76 ha. Typical crops were green fodder plants such as: maize (*Zea mays* L.), sorghum (*Sorghum bicolor* [L.] Moench) and pearl millet (*Pennisetumglaucum* [L.]R.Br.) cultivated in summer. Berseem (*Trifoliumalexandrinum* L.), sugar cane (*Saccharumofficinarum* L.) for fodder and wheat (*Triticumaestivum* L.) for grain production were grown in winter.

***Livestock husbandry practices and labor involvement*:** The only breed of buffalo that was recorded was Nili-Ravi, considered the best dairy breed in Pakistan (Khan, 2009). For cattle, the genetic makeup was more diverse. Of the 89 HH keeping at least one dairy cow, the vast majority (93%) kept crossbred cows, often between local zebu and exotic taurine breeds. The number of dairy animals per HH ranged from 2 to 50 buffaloes and from 0 to 20 cows. Buffaloes were the preferred dairy animals, accounting for 85% of all animals recorded.

To feed their animals, most of the farmers were using green fodder crops (99%), wheat straw (89%) and concentrate feeds (96%, mostly industrial by-products: cottonseed cake, maize oil cake, cereal by-products). One HH was feeding rice hulls instead of wheat straw, whereas another HH only let the animals graze. Usually green fodder was bought daily on one of the four important fodder markets in Faisalabad; only few farmers grew their own fodder; wheat straw was also mostly bought on a daily basis from retailers dispersed in town. In general, HH were chopping the green roughages to 2-3 cm length and mixed these with concentrate feeds and finely chopped wheat straw to make a total mixed ration which was offered to the animals. Many farmers had their own choppers - poor farmers had hand-driven ones while well-off farmers were having animal-driven or electric choppers; others purchased already chopped fodder.

In total, 399 people within the 139 interviewed HH were taking care of the animals. Of those, 81.5% were HH members and only 18.5% were hired laborers – all of them male, and all of them working full-time. Most of the women engaged in livestock management (89%) worked only part-time. On average a hired laborer earned 4,826 PKR per month (SD 1,345; range 2,000 – 8,000), but one HH paid the worker only with fodder for his own animals. In addition to their wages, the laborers received meals, were offered residence and five HH also gave some milk to their workers.

As far as the disposal or use of animal dung is concerned, interviewees were able to give multiple answers. Use of dried dung cakes as fuel for cooking was the most frequent use, mentioned by 52% of the HH. Thirty six percent of all farmers or, respectively, 72% of the HH possessing cropland, used the dung as soil amendment on their fields. Forty one percent of all HH also gave away dung or just dumped it without use, sometimes even within the peri-urban living quarters.

***Milk production and marketing*:** Dairy animals were milked twice daily, exclusively by hand. During peak lactation an intra-muscular injection of 2 ml oxytocin before milking was practiced by many dairy farmers to stimulate milk letdown in their buffaloes (see above). On average, 98.6% of the produced milk was sold. The range was very wide (0 to 99%) since 2 HH did not sell milk because they were keeping animals only for domestic needs and mostly consumed their total production. About two thirds (69%) of the HH sold their milk to middlemen ("dhodis") whereas 31% of HH sold milk to neighbors; three HH did doorstep delivery and one HH had its own shop. Thirty seven HH sold pure buffalo milk because they were not keeping cattle; of the 63% HH keeping buffaloes and cattle and selling milk, the vast majority (97%) mixed buffalo and cattle milk before sale; only three HH sold buffalo and cattle milk separately, the cattle milk to a dhodi and the buffalo milk to neighbors (1 HH) or also to dhodis (2 HH). More than two thirds (69%) of the HH selling mixed milk sold exclusively to a dhodi, 19% sold only to neighbors, 9% to a dhodi and to neighbours, two did doorstep delivery and one HH used all three options.

There was a difference between the average prices that HH usually got from different clients. The lowest average price was paid by dhodis for pure cattle milk (30 PKR l^{-1}, SD 3.5) and the highest for mixed milk sold via doorstep delivery (43 PKR l^{-1}, SD 4.6). Surprisingly, pure buffalo milk did not fetch higher prices from the respective clients than mixed milk, even though buffalo milk has higher fat contents and preference by most Pakistani people. More determinant for the milk price were the clients farmers sold to: on an

Table 5. Poblems of milk production in Pakistan from the literature*, observed by the author during the present survey in Faisalabad, as well as problems and plans for improvements named by 139 peri-urban milk producers and respective proposed strategies for improved milk production. Both questions (problems/plans) were asked openly and independently from each other; respondents could name as many problems and improvements as they liked. 11.5% of the respondents did not name any problems and 30.2% did not have any plans for improvements.

Problems named by respondents	Planned improvements by respondents	Problems described in the literature*	Problems found during the present study	Proposed strategies
33.9% feeding costs 32.4% high costs/low profit		high feeding costs inefficiencies		Use of UMB and non-conventional feed resource and improving resource use efficiency through better management
23% little space 3.6% no own land	3.6% more space 2.9% buy land	little space crowded	stables and backyards	Commercial dairy production on scientific lines
19.3% fodder shortage		fodder shortage		Adaptation of silage and hay making technologies
10.8% low financial resources	7.2% take loan 1.4% get subsidies			Initiatives and incentives by govt. and private sector
9% diseases or reproductive problems	0.7% medical care	bad health care	diseases, reproductive problems, unhygienic oxytocin injections, private practitioners	Use of ethno-veterinary and alternative treatments
9.4% animal removal from cities		animal removal from cities		
6.0% no time for management	2.2% to Improve General management			Extension of knowledge about good livestock management practices and feed quality
5% low water quality	0.7% water quality			
4.4% vet./extension service		little technical public support	no extension service little gov. vet./AI service	Awareness raising on issues of animal health and welfare
2.9% improper dung disposal	1.4% sanitation improper disposal of dung	hazards to humans: dung	storage, disposal; burning instead of recycling	Awareness rising on issues of public health and safety
2.2% unavailability of electricity	18.1% infrastructure			
2.2% feed quality		aflatoxin in feed		
1.4% theft				
	16.5% animal nutrition	improper feeding	imbalanced feeding	Feeding dairy animals according to physiological and productive needs
1.4% animal housing	13.7% animal housing			
0.7% bad marketing 0.7% monopoly of dhodis		bad marketing monopoly of dhodis	milk price formation	Developing a veritable dairy value chain
0.7% low milk yield	50.4% keep animals with higher milk yield	low genetic potential		Extension of knowledge about selection with high potential
	7.2% breeding	neglected breeding	breeding unplanned	
		unhygienic milk high mortality rates	yes, looked like it high calf mortality	Public health awareness
		slaughtering of good dairy animals and their offspring	genetic erosion by movement of best animals from rural to urban areas, many get slaughtered	Discouragement of indiscriminate culling of genetically high-potential animals
			"dung work" mostly done by women	Efforts made for the introduction of descent work development for dairy labour

*As summarized by (Hagmann, 2010)

average, neighbors paid 13% and 11% more than dhodis for pure buffalo and mixed milk, the other marketing channels fetched 29% and 19% more for pure buffalo and mixed milk compared to the prices paid by dhodis.

***Breeding strategies and animal trade*:** Most of the farmers were using natural service for breeding their dairy buffaloes (95%) and 13.7% of the farmers were having their own breeding bull. In case of cattle 70% used artificial

insemination (AI) and 30% used natural service; 7.2% of the cattle keeping farmers possessed a breeding bull. The average age of maturity and the calving interval reported for buffalo were 36.5 months (range 24 - 48) and 26 months (range: 15 - 48), respectively; the values given for cattle were 19 months (range 14 - 24) and 16 months (range: 11 - 24). A large proportion of the adult dairy animals and young males sold by the dairy producers went to butchers – especially in buffaloes many females were culled after single lactation already, because the animal had not conceived or because the farmer didn't even want to breed the animal again and replaced it by a calving or freshly lactating female. In addition to milk sales, three HH heads were also engaged in livestock trade, selling and buying large numbers of animals. However, middlemen livestock traders play the most important role for buying and selling dairy animals in Faisalabad. Between 35% and 40% of the households' most recently bought or sold cattle and buffaloes came from or went to one of these businessmen. Other important business partners for the purchase of animals were rural farmers, peri-urban neighbors and vendors at local livestock markets. Prices reported by the respondents for animals they had bought during the twelve months preceding the interview varied greatly; however, the average for buffaloes was 60,000 PKR. The difference between animal species was only significant for purchased animals, where farmers had to pay 61,100 PKR per buffalo on average and 52,900 PKR per cow, but not for sold animals (buffalo: 34,216 PKR; cattle: 36,501 PKR). However, the difference between average purchase and sales price within one species was significant ($P<0.05$) and relatively high, with the purchasing price being 44% and 31% higher than the sales price for buffaloes and cows, respectively.

***Farmers' perception of constraints and opportunities of dairy production*:** Problems of milk production in Pakistan from the literature*, observed by the author during the present survey in Faisalabad, as well as problems and plans for improvements named by 139 peri-urban milk producers and respective proposed strategies for improved milk production have been summerized in Table 5

DISCUSSION

The combination of CatPCA with SPSS two-step clustering allowed to create meaningful classes and reliably allot urban and peri-urban buffalo and cattle dairy farmers to these; the four farm types were significantly different in their setup and dairy management practices. The SPSS two-step clustering approach is well-suited for identifying an adequate number of clusters and coping with multi-attributed and multi-distributed data sets consisting of scale as well as categorical variables (Bacher *et al*., 2004). Similar soundness of the combination of CatPCA with two-step clustering to classify multi-attributed household data was reported from studies in West Africa (Dossa *et al*., 2011) and China (Riedel *et al*., 2012). According to Notenbaert *et al*. (2009) a sound exploration of smallholder livestock producers' full situation, including social, natural, and technical aspects, is required to successfully support their development, which in the case of peri-urban dairy producers in Faisalabad and other major cities of Pakistan is badly needed given the increasing city population and thus demand for milk in (Younas, 2013).

The four dairy production systems identified in Faisalabad differed in socio-economic structure, size of cropland holding, number of lactating buffaloes and cattle, level of income, intensity of milk production and market orientation. The main characteristic of the SSM system is its combination of crop and livestock units in a supplementary and/or complementary manner (Agbonlabor *et al*., 2003), thereby integrating the resources of the farming system (Tipraqsa, 2006). Faisalabad's SSM farms were not only run by poor but also by well-off and rich farmers, and despite the strong linkage between crop and livestock activities the latter rather play a supportive role for family income (Yisehak, 2008). However, under appropriate political and economic conditions the better-off of the SSM farmers presumably could transfer know-how quickly from one farm activity to another (Garcia *et al*., 2003) and thus adopt modern technologies such as cultivation of high-yielding fodder varieties and appropriate fodder preservation; they also could purchase high-yielding dairy animals and thus shift to commercial milk production within a short time delay.

As indicated by Jena (1988), landless farmers in any of the four classes substantially depend upon livestock keeping as an integral part of their livelihood strategy. Most of Faisalabad's smallholder farms, but also some of the larger farms, can be described as family farms that depend on household members for most of the farm labor (Hazell *et al*., 2007). Food security in smallholder livestock households is guaranteed through the direct use of products or by using the income from milk, manure or animal sales to buy human food and animal feeds (Yisehak, 2008). In the case of Pakistan, landless smallholder dairy farmers manage dairy animals and sometimes a few small ruminants as their only source of income (Moaeen-ud-Din and Babar, 2006). There is little capital available for dairying and this until today hampers investments in breeding stock, milk production, processing and on-farm infrastructure needed to support dairying. The situation of the small landless dairy farmers could be improved by lowering production costs, increasing productivity per dairy animal and enabling investment in modern farm infrastructure (De Boer, 1999).

The third group of Faisalabad's dairy farmers is also landless but more commercially oriented, allocating more resources to their dairy production. The additional off-farm income on one third of the CSD farms helps these to better manage the

risks of the peri-urban dairy business, such as, for example, adverse effects of animal diseases (Roland-Holst *et al*., 2007). For these farmers a more competitive milk marketing system that caters for their specific needs in terms of milk prices, and opportunities for cooperative marketing systems could motivate them to mobilize their own financial resources and improve and intensify their dairy operation, though, among others, effective transfer of technologies (Garcia *et al*., 2003; Tariq *et al*., 2008). These should focus on an optimization of the feeding practices and systematic cross-breeding for cattle well-adapted to local environmental and nutritional conditions (ILRI, 1995).

The commercial large-holder dairy production system comprises the smallest number of farmers. Commercial dairy farms operate at lower costs and can implement more advanced technologies that were often not available to small farmers due to economies of scale (Venugopal, 2012). This allows CLD farmers to save on labor and fodder costs as compared to the three smallholder systems, which is a considerable advantage since feed accounts for more than two thirds of the operational costs of commercial peri-urban dairy farms in Pakistan where animals were stall-fed with purchased feedstuffs year-round (Habib *et al*., 2007). Therefore, strategies aiming at increasing farm income on CLD farms should focus on lowering feed costs and further increasing dairy animal productivity. Both targets require improved nutritional management to increase the efficiency of feed utilization by the animal (Habib *et al*., 2007). After feeding, poor breeding management is also contributing to low productivity and loss in profit of peri-urban dairy farmers. Suboptimal feeding and breeding result in late age at maturity, low conception rate, long calving intervals and high calf mortality. Good female fertility is therefore of high economic relevance for dairy enterprises - it can be improved by means of better management (Biffani *et al*., 2003). Yet, many genetically high-potential animals from rural Punjab are transported to the cities where a large number is slaughtered after only one lactation, together with their offspring. In the longer run the currently practiced indiscriminate culling of females might lead to genetic erosion and decline of the yield potential of the good dairy buffalo and cattle breeds in the country, and especially in Punjab (Khan *et al*., 2007; Klein *et al*., 2008).

Shortage of fodder, high feed costs of and poor breeding were among the major problems faced by all dairy production systems, and improvements suggested specifically for CLD farms also apply to all other farm types, even the mixed crop-livestock farmers who should have sufficient land to produce fodder for their animals but who were more interested in growing cash crops (Moaeen-ud-Din and Babar, 2006). Ultimately, income generation on a dairy farm is directly related to the efficiency of milk production and marketing. A producer obtaining more milk per animal with the same inputs through better management, and a producer receiving a higher price per liter of milk will have higher returns immediately. Thus, improving on-farm resource use efficiency, developing feed supply chains and milk transformation schemes for a broader range of products than only raw milk and ghee, and breaking the cartel of dhodis ultimately should prompt peri-urban dairy farmers to produce more milk. However, analysing peri-urban dairy production near Lahore, Jalil *et al*. (2009) pointed to additional factors such as lack of dairy-related education and training, lack of marketing opportunities and supply chains for dairy products to be responsible for the slow development of the peri-urban dairy sector in Pakistan. Measures should therefore also include training of farmers, especially those of low educational background, in the areas of animal management and milk marketing. To improve the efficiency of scales of the majority of smallholder producers, fostering cooperative marketing and credit schemes for dairy farmers might be successful strategies.

If Faisalabad city keeps growing as fast as in the past years – and this is very likely – today's peri-urban and rural farmers will become tomorrow's urban and peri-urban farmers, respectively. This will expose them to further shrinking of arable land and consequently feed shortage, limit of space for animal housing, problems of waste disposal coupled with herd health problems, and increased societal as well as governmental pressure to expel animals from the urban area. However, against increasing consumer demand for fresh milk and quality milk products, and in view of maintaining farmers, their families and their employees in decent and gainful employment, a holistic and interdisciplinary multi-stakeholder approach is needed to create an economic, ecological and social framework in which dairy production serves producers and consumers of Pakistan's rapidly growing urban centers.

***Conclusions*:** Although peri-urban dairy farming in Faisalabad is essentially market-oriented, problems such as limited and high cost of space for animal housing, unsolved waste disposal and unfavorable milk marketing schemes are currently hampering its performance. Improving resources use efficiency by especially targeting animal nutrition and breeding could be first steps towards betterment. Further areas where interventions by private and governmental bodies might yield quick improvements are the milk marketing system and the development of an efficient and diverse dairy value chain. The different improvement options should be tested with respect to their feasibility and ecological, economic and social sustainability in view of the specificities of the different types of dairy producers.

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