Innovativeness and Adaptations: The Way forward for Small scale Peri-Urban Dairy Farmers in Semi-Arid Regions of South Eastern Kenya

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Abstract

Dairy farming is becoming an important livelihood support activity in the semi-arid regions of Kenya. However, it is becoming clear that the dairy farmers are challenged and in the recent past, milk production has not kept up with the demand. This has been linked to poor adaptations and innovativeness of the dairy farmers in these regions. In endeavours to offer solutions and help the dairy farmers improve their production and become resilient, different stakeholders have advocated for adoption of milk and forage production-enhancing innovations by the dairy farmers. This study sought to establish the kind of innovations and adaptive measures carried out by the peri-urban dairy farmers in south eastern Kenya to improve their milk production and their significance to milk production. A sample of 150 farmers from the peri-urban environs of Wote and Machakos towns was used. A semi-structured questionnaire was used and data analysized using descriptive and inferential statistics. Findings show that adoption of dairy technology, Artificial Insemination (AI), fodder crops and crop residue, Tumbukiza Method, stall-feeding, feedstuff chopping, water harvesting, hay barn technology, hay and silage making significantly improved milk production at $p<0.05$. Co-operative concept had insignificant influence on milk production. It is recommended that the dairy farmers continue to adopt the production-enhancing, forage production-enhancing and forage utilization-enhancing innovations. Mitigation measures should include establishing reliable sources of the dairy cattle, reduction of AI charges and more extension services to the dairy farmers.

Key Words: Adaptations, Adoption, Innovativeness, livelihood sustainability, mitigation measures

1.0 Introduction

There is a general consensus that agriculture remains the main source of livelihood and continues to play a key role in reducing poverty and overcoming hunger for the majority of the rural people in developing countries (FAO, 2003). Hence, growth in agricultural production and productivity is critical in meeting food security and realizing better livelihoods of the people in the world (Amwata, 2013).

Observations shows that animal agriculture sub-sector is equally important in determining household and national economies: provides over half of the value of the global agricultural output; contributes directly to rural livelihoods, food production, employment and poverty relief and; indirectly, it strengthens the household-economy through provision of draught power, organic fertilizer (manure) and fuel, hides, commercial sales of animals and animal products, like milk and meat among others (Swanepoel *et al*., 2011). In addition, it is also useful in meeting household obligations: school fees, celebrations, funerals, marriages and cultural functions as well as allowing resource-poor households and vulnerable groups especially women, who do not own land, to accumulate assets, like small animals (Waters-Bayer and Letty (2010) and Swanepoel *et al.,* (2011).

However, globally, animal agriculture is challenged and integration with crop production, coupled with adoption of sound and resilient innovations, is crucial for realization of higher benefits especially in densely populated areas or climatically disadvantaged semi-arid areas. In Africa, in the integrated smallholdings, the livestock are reared on natural grass, browse and non-food biomass from crops – maize, millet, rice and some legumes –beans, pigeon peas and in turn the livestock supply manure (used to replenish the lost nutrients in the cultivated areas) and animal power (for tillage and transport purposes). In Kenya, the smallholdings are varied, depending on ecological, demographic and socio-economic influences. In addition, most smallholding enterprises only meet the basic subsistence needs of the households. In areas of high population, especially those that are close to growing urban markets in the arid and semi-arid lands (ASALs), there is a more pronounced change in land-use towards market-orientation and an accelerated trend of both intensification and adaptation for the farmers to be resilient.

Given the role of the smallholder crop-livestock production systems and in the face of challenges of high population, climate change, and dynamics of socio-economic factors, there is need for livestock farmers to be innovative and adaptive. For example, farmers in the ASALs are embracing small scale dairying as livelihood support potential contrary to the expert's advice that ASALs are only suitable for Zebu rearing.

Therefore, in Kenya, like other African country, there has been change in land use among the agro-pastoralists in the recent past (Amwata, 2013). This is primarily associated with declining land sizes and emerging issues, like commercialization of agriculture. For example, Kavoi *et al.,* (2009) noted that since the mid-1980s commercial dairy production using exotic cattle by small scale holders has been established in the semi-arid areas in Kenya especially those adjacent to urban centres. This has happened through a slow process of dairy cattle technology diffusion from the high potential zones (Bebe *et al*., 2003). However, it is noted that concentration of the exotic cattle in semi-arid areas in agro-ecological zone IV of South Eastern Kenya remains relatively low but becoming popular.

Observations show that this small scale dairying is very important in improving food security and for sustainable livelihoods of the rural resource poor in Kenya. However, the dairy farming, being adopted in the semi-arid peri-urban environment, is faced with many constraints: climate variability and change affecting rainfall pattern and reliability of rains; drier environment with inadequate feedstuffs and water; land degradation (Amwata, 2013); negative perception of agricultural production as it is viewed as insignificant as compared to commercial urban plots (Swanepoel *at el*., 2011); fragmentation and conversion of agricultural land into commercial urban plots (Amwata, 2004 and Wasonga *et al.,* 2010); inadequate funding (IFAD, 2006); lack of access to credit for essential support services (artificial insemination (AI) and veterinary services); rapid human population growth (World Bank, 2008); increase in urban poverty and urban food insecurity in semi-arid lands (Kodhek, 2004; Kinambuga, 2010) and poor extension services. This calls for the need for the small scale dairy farmers to adopt new adaptive and resilient innovations and better ways of producing milk to meet the ever increasing demand for milk. Therefore, this study sought to investigate the degree of innovativeness and adaptations adopted by the small-scale peri-urban dairy farmers in the semi-arid regions of South Eastern Kenya.

2.0 Materials and Methods

Study sites

The study was carried out in Central division, Machakos County and Wote division, Makueni County, between longitude 37.16^{o} - 37.38^{o}E and latitude 1.31^{o} - 1.47^{o}S. These regions were considered representative of the peri-urban environs in the semi-arid regions of south eastern Kenya. Central division, Machakos County lies in Upper Midlands agro-ecological zone 4 (UM4) while Wote division, Makueni County falls within Lower Midlands agro-ecological zone 4 (LM4) (Jaetzold *et al*., 2007). The medium altitude ranges from 900m a.s.l on the Wote town in LM4 to 1300m a.s.l on the Machakos town in UM4 (Jaetzold *et al*., 2007). These peri-urban regions receive bi-modal rainfall ranging from 550 - 900 mm/annum and mean temperature of between 16 - 24^{o}C. The rains are very erratic, unreliable and frequency of drought and crop failure is common in every 2-5 years (Amwata, 2013). In these semi-arid regions population growth is exerting pressure on the available grazing lands, leading to emergence of landless dairy production by smallholder holdings. This small holder milk production is important (Njarui *et al.,* 2009) in sustaining livelihoods of the peri-urban dairy farmers in the semi-arid regions of South Eastern Kenya. However, the current milk production has not kept up the demand in these semi-arid regions of south eastern Kenya.

Sampling method and data collection

The survey was carried out between November 2012 and March 2014 targeting small scale households carrying out livestock production as a livelihood sustainability strategy within locations in a 15 km radius of Machakos Town and Wote Town. Two stage sampling technique was used to select the households. The first stage involved stratified purposive sampling for selection of the two divisions from the two counties in which ASARECA's "*Harnessing crop-livestock integration to enhancing food security and livelihoods resilience to effects of climate variability and change in East and Central Africa"* project had been implemented since 2010. Then, the second stage employed purposive simple random sampling to select proportional number of farmers from a list of farmers in the locations from each of the two divisions engaged in the ASARECA/KALRO project.

One hundred and fifty (150) households (seventy from Machakos County and eighty from Makueni County) were selected and interviewed by a cross-sectional household visits with the help of a pre-tested semi-structured interview schedule. Information collected included; household demographic and farm characteristics, dairying features and extent of innovativeness and adaptations of the farmers for resilient dairying as sustainable livelihood. Data collection techniques included direct questioning, informal discussion and field observation of adopted adaptive innovations in the sampling sites and households.

Data analysis and presentation

Data were analysized using Statistical Package for Social Sciences (SPSS), Ms Excel 07 and Origin Version 7 computer software for descriptive and inferential statistics. A characterization was done using cross-tabulation tables to compare the proportion of adopters and non-adopters. For each innovation, the farmers were categorized into two classes (1=adopters or 0=non-adopters) on basis of whether they had adopted the innovation or not. Basic descriptive statistics such as mean, frequency of occurrences and percentages of adopters and non-adopters were computed to summarize the extent of adoption of the adaptive innovations. Chi-square tests ($P<0.05$) to assess the relationships between the dependent (average milk yield) and independent variables (self-practiced adaptive innovations) were done. The results were tabulated in the frequency (percentage of adopters and non-adopters), mean average milk yield, standard deviation, chi-square and p-value tables.

Independent Variables

The independent variables were the self-practised innovations that the farmers were adopting in order to improve their livestock enterprises. The adoption of each innovation was suspected to significantly influence the milk yields attained by the adopters. Therefore, it was expected that there were significant differences of the average milk yields between adopters and non-adopters. This was expected to be significantly shown by the mean values of milk yields of the adopters and non-adopters of the innovations.

Dependent Variable

The dependent variable was the average milk yield that was realized by the farmers. The average milk yield was an outcome variable with a categorical dichotomy. This is because the milk yield of the farmers was classified into classes (1= high or 0=low).

3.0 Results and Discussion

Demographic and Farm Features

Most households (80%, n=150) were male headed and had relatively medium family size (3-4 members). Household heads were averagely aged 51±3 years and with majority (67.7%, n=150) of them being literate as they had attained post-primary education.

Significantly, the land sizes were smaller in Machakos (1.2ha) than in Wote (6.4ha). Land fragmentation was relatively high with 43.3% in both counties having more than one parcel of land. This fragmentation of land concurs with observations by Place *et al.,* (2009) that the farm size will continue to shrink and be sub-divided. This fragmentation of land is likely to affect the man-hours of family members or employed personnel and the probability of adoption of dairy and forage innovations by smallholders. This expected negative effect on man-hours concurs further with Wambugu *et al*. (2003), who noted that farm sizes are smaller in peri-urban areas, exacerbating feed constraints. This small farm size is a requisite for influencing the adoption of dairying, intensification of dairying and adoption of other improved dairy and forage innovations.

Most households had insecure land tenure systems in both counties. This was attributed to the finding that a small proportion of the farmers (26.4%, n=150) had free-hold land tenure system. Most land households had ancestral land tenure system which was not adjudicated and allotment papers issued. They never felt secure in investing in the capital-intensive dairying enterprises.

Adoption of Dairy cattle technology and Milk Production

Most farmers (67.3%, n=150) had adopted dairying as a farming enterprise. Friesians, Aryshire, Jersey and Sahiwal were the common breeds that were kept by the adopters. This implies that the livestock farmers were realizing the importance of dairying as livelihood sustainability in these semi-arid regions. In addition, descriptive statistics showed that adoption level of dairy cattle was higher in Machakos (38.0%) compared to Wote town (29.3%). This was attributed to the fact commercial dairying was introduced in the UM 4 of Machakos earlier than in LM 4 of Wote. However, in Machakos, the households averagely owned fewer (3) dairy cattle than those in Wote (4). This was attributed to the larger land sizes in Wote that also correlated to better feed supply in Wote environs.

The average milk productivity was generally low compared to the genetic potential of the breeds among these smallholder farmers but it was much better (Table 1) among the adopters (14.76 litres /cow/day) than the non-adopters (2.4 litres /cow/day). These adopters acknowledged that the dairy cattle were most suited for the small land sizes and had better returns compared to beef production. Further the smallholder farmers observed that milk supply in these semi-arid regions remained low than demand as evidenced of gradual increase of the milk prices. However, they noted that there was gradual increase in the average animal milk productivity since 2010 among adopters. This can be attributed to adoption of adaptive innovations by the farmers in these semi-arid regions.

Descriptive statistics showed that the milk produce was sold to farmers' neighbours, milk vendors, catering units, institutions, and some to co-operative societies. The informal marketing to the neighbours (72.4%, n=150) remained the dominant channel in both counties while the formal marketing to co-operatives or milk processors remained low. This was attributed to preference of the consumers towards raw milk compared to processed milk. This was also attributed to limited access to sound co-operative societies that they were supposed to process and market the processed milk.

Table 1. Dairy and Forage technologies used by farmers and milk yields

Technology	Category	Percentage of Farmers	Milk Yields			
		(%)	Mean (Litres)	SD	χ2	p-value
Dairy Cattle	Adopters	67.3	14.46	5.67	14.67	0.001*
	Non-Adopters	32.7	2.4	1.20		
AI	Adopters	16.4	24.0	6.21	9.87	0.001*
	Non-Adopters	80.6	11.6	5.45		
Fodder Crops	Adopters	35.5	22.0	3.58	24.68	0.001*
	Non-Adopters	64.5	11.04	3.89		
Tumbukiza	Adopters	44.4	9.56	3.57	4.22	0.002*
	Non-Adopters	55.6	4.44	2.95		
Stall-Feeding	Adopters	39.7	16.0	0.63	2.88	0.012*
	Non-Adopters	60.4	12.4	2.66		
Crop Residues	Adopters	72.0	9.72	2.35	3.11	0.025*
	Non-Adopters	18.0	5.41	2.54		
Feed Chopping	Adopters	85.5	15.66	3.65	15.62	0.001*
	Non-Adopters	14.5	7.47	2.64		
Water Harvesting	Adopters	65.0	14.99	4.32	4.69	0.010*
	Non-Adopters	35.0	7.11	2.96		
Hay Making	Adopters	20.8	12.00	1.12	13.21	0.002*
	Non-Adopters	79.2	8.82	2.61		
Silage Making	Adopters	12.0	18.02	3.96	34.34	0.003*
	Non-Adopters	88.0	7.11	1.56		
Hay Barn	Adopters	72.5	15.11	2.61	12.45	0.001*
	Non-Adopters	27.5	7.22	3.82		
Co-operative Movement	Adopters	12.0	19.41	3.87	1.88	0.066
	Non-Adopters	88.0	10.22	3.62		

***Significant @p<0.05**

Adoption of Improved Breeding practices and Milk Production

Artificial insemination (AI) is farmer-friendly breeding practice that makes maximum use of superior sires and allows good economic returns in the dairy farms (Wambugu *et al.,* 2003). It also enables control of breeding disease among the breeding cattle. Despite these advantages the research showed that the adoption of AI was low (Table 1) compared to the use of bulls for serving the females on heat. The farmers attributed this to high costs of administering AI services. The research revealed that the charges ranged between 1500/= and 4000/= for the AI services. In addition, most farmers in Wote paid higher charges for the AI services compared to those in Machakos. This was attributed to the fact that Wote environ was far from Nairobi – the source of the semen for AI services compared to Machakos environs. This was a contributory factor to the low adoption of AI by the farmers in in Wote (5.7%) compared to those in Machakos (21.0%). In hence, this implied that most farmers in both counties relied on bulls to serve their dairy cows that were on heat. The farmers noted that high AI charges continue to be a major impediment to adoption of the improved breeding practices in semi-arid regions of South Eastern Kenya. In addition, none of the farmers had adopted the expensive ET.

However, the adopters of AI had better milk yields than the non-adopters (Table 1). This concurs with Khanal *et al.,* (2010) that proper and better breeding practices, like use of AI, helps in developing good dairy herd and better returns are obtained than use of natural mating.

Adoption of fodder Crops' technique and Milk Production

Substantial proportion of the farmers had adopted the fodder crops' technique in the peri-urban areas of Machakos (33%) and Wote towns (38%). This was aimed at supplying quality and adequate feedstuffs to the dairy cattle. This was attributed to the fact that the adopted dairy cattle were heavy feeders and the farmers in the semi-arid areas were faced with scarcity of grazing materials especially in the dry season. In addition, there was decreasing land size due to human population pressure. Therefore, in line with Lusweti *et al*., (2005), the dairy farmers needed adoption of fodder crop technique to increase the feeds supply.

In addition, the adopters realized better milk yields (Table 1) and continued production of these higher milk yields even in the dry spells. Consistent with findings of Orodho, (2006), high quality fodder crops, like grasses (Napier and Rhodes) and trees (*Leucaena* species) were grown and harvested and the harvested feedstuff used to feed animals in confinement for better milk yields. Napier, Panicum and Rhodes grasses remained the widely adopted grasses while Lablab legume was relatively preferred in the drier Wote division in Makueni County. However, the farmers observed that fresh lablab feedstuff fed to the lactating cows tainted their milk, which lowered the acceptance of milk to their clients.

The adopters acknowledged that the fodder crops had other benefits: reduction of production cost; improvement of soil fertility through nitrogen fixation; high crude protein – used as protein supplements for cattle and high minerals (calcium, phosphorus) and vitamins (A & D) – used as mineral and vitamins supplements.

However, source of reliable planting materials remained a challenge for adoption of quality fodder crops. This was attributed to the fact that majority of the farmers in peri-urban areas of Machakos (47.8%) and Wote (56.0%) obtained their planting materials from neighbours, whose quality was suspicious. KALRO – Katumani research station in Machakos remained a significant single source of planting materials in Machakos (30.4%) and Wote (21.0%).

Adoption of Crop residue as feedstuffs and Milk Production

Feedstuff scarcity remains a challenge and threat to dairying in semi-arid regions. To avoid dire consequences in the dry spells most farmers (72%) have become innovative and adaptive by using crop residues as feedstuff for their dairy cattle. Observations have showed that the crop residues utilized include remains of annual crops of maize, pigeon peas and beans after harvesting. The adopters removed the dry crop residues from the fields immediately after harvesting to avoid further losses in nutrients and stored them in waterproof sheds with raised floors to avoid spoilage. However, the adopters acknowledged that, although the crops residues are of low quality, they are beneficial and useful animal feedstuffs especially in the dry spells in these semi-arid areas or are used as dry supplements during wet season (Lusweti *et al*., 2005). The adopters also acknowledged better milk production (Table 1) and sustained feedstuff supply in the dry spells compared to non-adopters. This calls for the dairy farmers to continue using the crop residues as feedstuffs to alleviate feedstuff scarcity especially in the semi-arid southern rangelands.

Adoption of Water Retention-enhancing technique (Tumbukiza Method)

Establishment of good fodder crops and production of enough herbage still remains a major challenge. This is exercabated further by rain failure and occurrence of prolonged droughts in the semi-arid southern rangelands. To address this, a sizeable proportion of the dairy farmers in Machakos (40.0%) and Wote (48.8%) towns' peri-urban environs were improving water retention in the soils for establishment and herbage growth of high quality fodder crops by adopting the *Tumbukiza* method (TM). The TM involves use of rectangular or circular pits – which are 60cm deep, 60cm wide and 60cm apart (Orodho, 2006) for planting the fodder crops. In the wet season, the rain water accumulates in the pits instead of it being a surface run-off. This enhances the water availability in the rooting zone of the fodder crops resulting in better yield of crops. However, in the dry season moisture content in the pits is construed and forage production is bound to decline. The adopters were found to cope with this by adding one 20-litre *jerrycan* of water per hole per day. This practice was found beneficial in ensuring constant supply of feedstuffs and better milk yields. Orodho (2006) found out that this amount of water is retained in the pit for about 30 days allowing the napier to grow fast and enabling its survival through long dry spells.

Significantly, adopters of the TM had better milk yields (Table 1) than the non-adopters. In addition, the adopters acknowledged that TM guarantees optimum utilization of available land and sustains more dairy cows. Further it allows better method of watering and ensures long cycle in the watering regime and success in supporting the dairy production in dry areas. Further, the retained moisture enhanced fodder growth and its survival through the long dry spells. This concurs with Wambugu, (2003) and Place *et al*., (2009) that fodder crop production using TM is superior to fodder crop production under the conventional methods. Further, with farm sizes declining in both counties and changing of grazing systems towards stall-feeding, TM was found essential in increasing forage production, where the forage is cut and carried to feed the confined animals.

Adoption of feed conservation techniques and Milk Production

In these semi-arid regions, acute feedstuff fluctuation is common. The farmers were coping with this problem by adopting sound fodder conservation techniques aimed at conserving excess pastures and quality fodder in the wet season. These practices helped in bridging the gap between the feed requirement of the animals and the production of the feedstuffs especially in the dry spells (Muriuki, 2003). Further, the farmers acknowledged that proper forage conservation practices produce stable feedstuff products at low cost with minimum loss of their nutritive values. The feed conservation measures adopted by the farmers include;

i) Hay Making

The adoption of hay making remained relatively low in Wote (22.3%) and Machakos (19.3%) despite hay making being the most common feed conservation method amongst the commercial dairy farmers (Lusweti *et al*., 2005). However, there was an upward trend of adoption of hay making in both sites since 2010. In addition, hay-box remained the common equipment used for hay making. This was attributed to its convenience and affordability. However, a sizeable proportion (79.2%) of the farmers had not adopted the hay cutting technique. They would preserve standing hay in some parts of their farms for use in the dry seasons or after onset of the rains.

The adopters acknowledged that hay making conserves the excess forage for future use in acceptable and palatable forms. In addition, in line with Moran (2005) findings, the adopters had reduced the cost of concentrate feeding and had better milk yields (Table 1). However, wet weather conditions remained an impediment to hay making. In line with Moran (2005) findings, the adopters appreciated that fodder crops with thin stems and more leaves were better suited for hay-making as they dry faster than those with thick, pity stems and small leaves.

ii). Silage Making

The farmers appreciated that forage is also conserved as silage that is produced under anaerobic conditions in a silo in which the chopped forages with high moisture contents produce quality silage. Adoption of silage making using the polythene bags was comparatively low in Wote (13.3%) and Machakos (10.7%). This concurs with Moran (2005) that silage making is more technical. This contributed largely to the low adoption rate of silage making amongst small-scale dairy farmers. The adopters further acknowledged that experience and skills were required in order to produce good quality silage, with pleasant smell and high nutritional value - which is better forage than hay (Lusweti *et al*., 2005 and Orodho, 2006). The adopters had better milk yields compared to the non-adopters (Table 1). Further, the adopters felt challenged in maintenance of the anaerobic conditions in the polythene silo which, at times, affected quality of silage (Muriuki, 2003).

The non-adopters observed that silage making was more technical and required skills and experience, hence there was need to educate the farmers. Further, the low adoption was associated to several other factors: rejection of the silage by livestock due to unfamiliar odour, lack of excess forage for preservation and farmers failing to see the direct benefit of feeding the livestock on technically and delicate silage prepared. However, in line with Moran, (2005) findings, extension services are required to educate the farmers on silage making, so they can reap benefits as silage making is not weather-dependent compared to hay making.

Adoption of Hay Barn (HB) Technique

The dairy farmers acknowledged that traditional methods of storage of feedstuff, like on tree-tops, reduces the quality and palatability of the stored feedstuffs. In line with Lusweti *et al*., (2005) findings, rudimentary methods expose the conserved feedstuff to rains and aflatoxin and hence risks the health of the animals and consumers of milk and meat. Through experience, the dairy farmers realized the need to conserve forage in better facilities in order to retain the original nutritional value of the feed at the highest value possible. They acknowledged that this can be attainable through the use of modern HB storage facilities. This was consistent with Moran (2005) that HB preserves feedstuff in hygienic conditions to reduce damage from rains and development of aflatoxin infestation.

Majority (72.5% on average) of the farmers had adopted the HB technology. Significantly, the adopters had better milk yields (Table1) and sound feeding regime of their dairy cattle compared to the non-adopters. HB is a lowly-raised timber or metallic well-ventilated roofed structure used for stacking of forage safely. The HB structures were constructed using timber or metallic posts and roofed using iron sheets, strong polythene sheets or dry grasses. However, non-adopters stored feedstuffs on tree branches or on tree-tops (3.3%), granaries (3.35% on average) and gunny bags (3.65% on average).

Feedstuff Chopping - Feed Utilization Efficient Technique

Most (85.5%) of the farmers had adopted the chopping technique in Machakos and Wote peri-urban environs. The adopters had better milk yields (Table 1) and feed utilization efficiencies compared to the non-adopters. Further, different equipments were used for chopping of the feedstuffs but the *Panga* remained the main equipment for chopping. This was attributed to its easiness of use and affordability by these resource-poor farmers. However, most adopters acknowledged that it is tedious and time-consuming to chop feedstuffs using the panga in households with intensified dairy unit or with scarcity of labour. More effective and time-saving equipments, like chaff-cutter and fixed knife cutter, were lowly adopted by the farmers. The low adoption of improved equipments was attributed to numerous constraints the farmers faced; expensive equipments (58.8%), lack of power supply (22.7%), expensive labour (12.2%) and lack of awareness of equipments and skills (6.3%). Adopters using modern chopping equipments, together with the use of modern feed troughs, acknowledged that there was minimal wastage and contamination of chopped feedstuffs.

Water Harvesting Technique

The adopters (65%) acknowledged that water harvesting is the remedy to solve inadequate supply of water in these semi-arid areas. In addition, the adopters acknowledged better milk yields (Table 1) than the non-adopters. Observations showed that water was suitably and mainly harvested from roof-tops of building and rocky surface areas in the semi-arid regions and then the harvested water is stored in concrete tanks or plastic tanks placed on the ground surface or underground. Further, some adopters (13.2%) collected water from the road sides or bare lands or valleys and stored it in earth dams or water pans. The harvested and stored water was utilized efficiently to water the dairy cattle as need arises. The harvested water was also used to water or irrigate the fodder crops to increase the feed supply when the rains are not adequate.

Adoption of Stall-Feeding /Zero-Grazing Technique

Sizeable proportion of farmers had fully adopted the stall-feeding technique in Machakos (44.3%) and Wote division (35.0%). Adoption of stall-feeding was higher in Machakos compared to that in Wote environs. This was attributed to fact that the land sizes in Machakos are smaller and the farmers have limited pastures for free-ranging system of grazing their dairy cattle. The adopters realized better milk yields (Table 1). This was attributed to fact the confined dairy cattle had minimal wastage of energy compared to free ranging dairy cattle. However, the farmers faced the challenge of labour scarcity as stall-fed dairying is very labourious and cases of unhygienic conditions in the Zero-grazing units were reported.

Dairy farmers' co-operative society concept

The farmers acknowledged the need for power of collective action in the agricultural sector where the farmers could demand formulation of policies useful in acquiring loans, farm inputs and marketing of their produce. This is attainable only by adopting the co-operative concept. The like-minded farmers forms the co-operative society with clear objectives and pulls resources together. Through the co-operative movement, the farmers can access credit facilities and have better market prices of their milk. However, the adoption of the co-operative movement was low (12%). This was attributed to corruption and mismanagement of these co-operative societies. In addition, there were no significant differences for the milk yields (Table 1) between the adopters and non-adopters. However, the adopters felt that adoption of co-operative model was the key to accessing credit, farm inputs and obtaining their market share in the milk industry.

4.0 Conclusions and implications

Most households were male headed. The male headed households are more likely to adopt new innovations and influence decision-making in the households. More training and extension services should be extended to vulnerable female-headed households.

Household heads were averagely aged 51±3 years, were experienced and were likely to adopt adaptive innovations to improve milk production. However, adoption of these innovations could also be high amongst youthful households as the youths are more innovative and flexible compared to their peers. The extension officers should work with each group cautiously for better adoption indexes of the adaptive innovations and concepts.

Literacy level in the study areas was high. These literate farmers had better likelihood of adopting innovations. This is attributed to the fact that literate farmers are more innovative and easily understands concepts taught and workability of principles of innovations. The training and extension services should be extended to the illiterate farmers in order to increase their acceptance and perception of the more technical innovations, like silage making.

Household size in both counties was small. This was attributed to the declining farm size and probably successful family planning programs. This small household size limits family labour available for the intensive dairying. This forced many households to engage employee (s) on temporarily or permanent basis. This was likely to be a major impediment in adoption of labour-intensive innovations as the skilled permanent labour is expensive. Therefore, the farmers should adopt labour-saving innovations, like improved chopping equipments.

Farm size is moderately small in both counties. In addition, most farmers own fragmented land units in both counties which were averaged distanced at nearly 2km. This could be attributed to increased human population, urbanization and sub-division of agricultural lands as agriculture is considered less profitable. This calls for adoption of improved innovations for intensive dairying.

Free-hold land tenure system assured the farmers of security of land ownership and increased their probability to adopt innovations to better investment and production. There is need to carry out land adjudication so that the farmers can have secure land ownership that will encourage adoption of capital-intensive innovations.

Faced with livelihood-threatening challenges and the drive to produce milk to meet the high milk demand, the farmers adopted dairying as livelihood support and income-generating activity. Livestock farmers were adopting dairying, mainly composed of female cattle, contrary to earlier expert’s advice that dairying is a preserve of the highlands. However, there need to have reliable source of the dairy cattle and affordable support services, like AI and veterinary services. Extension services must be extended to the farmers to increase awareness of the AI.

Constant feedstuff supply for the adopted intensified dairying in both counties was a big challenge. The farmers need to continue adopting production of quality fodder crops in order to meet feedstuff scarcity. Fodder crops should be used as supplements to form attractive alternative to the expensive protein concentrates that farmers feed their dairy cows. In addition, on-farm trials should be done to increase multiplication and supply of the planting materials to the farmers. Adoption of fodder crops should be matched with climatic suitability of the area. For example, Panicum and Rhodes grasses are more suited in Wote than in Machakos while napier was ecologically suited in the wetter Machakos than in Wote environs. Training and extension services should be extended to all the farmers to create awareness and production of fodder crops.

Due to the drive to have good fodder crops established to solve feed constraints, adoption of water-retention enhancing tumbukiza technique is considered paramount. TM is suitable for growing fodder in low rainfall areas as it enhance soil fertility conservation and moisture retention. Extension services should be done to educate the farmers on how to prepare and maintain the TM pits for better fodder production returns.

In both counties, the farmers were faced with water scarcity and unreliable and insufficient rainfall (most of it lost through run-off and evaporation) as major constraints for improved productivity. The farmers became innovative and adopted in-field water harvesting and efficient water-utilizing technologies to reduce the vulnerability of farmers to water shortage and increase the availability and reliability of water. The farmers harvested water from many surfaces - roof-tops, rock surfaces or underground levels and stored in water tanks in order to alleviate the water shortage. This was found out to supply adequate water for the adopted dairy cattle and improved fodder crops. However, high cost of investment remains a challenge to water harvesting option. Financial support is deemed necessary to offer credit to the farmers to adopt water harvesting techniques and proper storage facilities.

The farmers adopted the chopping innovation in order to increase efficiency of utilization of harvested and conserved feedstuffs. However, chopping was mostly done using traditional *panga* – which is tedious, time-consuming and less efficient for intensified stall-fed dairying. Faced with this impediment, the able dairy farmers adopted lowly modern chopping equipment to increase efficiency of utilization, increase silage making and reduce wastage of feedstuffs. However, the adoption index of chopping innovation was low in Wote than in Machakos environs. This was attributed to lack of awareness of affordable modern chopping equipments. For example, cost of improved chaff-cutter remained high in both counties. Therefore training programme should be conducted to improve the knowledge of farmers about importance and usefulness of chopping using improved equipments. In addition, farm sudsidies should be given to the farmers to enable them purchase costly chopping equipments.

Due to change of feeding system towards sedentary stall-feeding and high fluctuations of feedstuffs, conservation of excess forage is a remedy. Hay conservation, found to be less technical, was the commonly used method compared to the more technical silage making. However, baling of hay was low due lack of adequate feedstuffs and skills and equipments. Training and extension services are deemed suitable to improve adoption of the hay making.

Silage making is another innovative way of conserving excess forage. However, low adoption indexes were observed in Wote and Machakos. This was attributed to fact that silage making is a more technical and expensive innovation and farmers are reluctant to adopt risky innovation. Training programmes should be done to create better understanding of this technical silage making. Subsidies should be extended to the farmers so that they can purchase the expensive inputs.

Conserved feedstuffs easily spoil if rudimentary methods of storage, like placing feedstuffs on tree-tops or on branches of trees, are used. Adoption of modern hay barn technology to conserve to hay, silage and crop residue is considered paramount for improve dairying. This HB technology also aims at economizing and protecting the scarce feedstuffs obtained from fodder crops, crop residues and pastures from the limited land. More extension services and credit should be extended to the farmers for to construct modern HB.

The co-operative model is helpful in advocating of agendas for the dairy farmers in the dairy sector – soliciting for affordable farm inputs and good market prices of the milk. This calls for strengthening of the co-operative movement to champion the rights of the farmers. In addition, sound management of the societies is essential in order to avoid mismanagement and internal wrangles of the members.

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REFERENCES

Amwata, D.A. (2004). Effects of communal and individual land tenure systems on land-use and food security in Kajiado District, Kenya: *MSc Thesis, University of Nairobi, Kenya*

Amwata, D.A. (2013). The influence of climate variability and change on land-use and livelihoods in Kenya's southern rangelands: *PhD Thesis, University of Nairobi, Kenya*

Bebe, B. O., Udo H. M. J., Rowlands, G. J and Thorpe, W. (2003): "Smallholder Dairy Systems in the Kenya Highlands: Breed Preferences and Breeding Practices". Livestock Production Science 82: 117-127.

FAO. (2003). Trade Reforms and Food Security: Conceptualizing the linkages.

IFAD. (2006). Technical Agreement Grant: Enhancing livelihoods of poor livestock keepers through increasing use of fodder. <http://fodder-adoption-project.wikispaces.com/

Jaetzold, R., Hornetz, B., Shisanya,C.A., and Schimdt, H., Eds. (2007). Farm management handbook of Kenya: Vol. III (Eastern Province), Nairobi.

Kavoi, M. M., Dana, L. H. and Pritchett, J. (2009): Production structure and derived demand for factor inputs in smallholder dairying in Kenya: *AFJARE Vol 3 No 2* September 2009.

Khanal, A.R., Gillespie, J and MacDonald, J (2010). Adoption of of technology, management practices and production system in US milk production. J.Dairy Sci. 93: 6022 -6022

Kinambuga, D. (2010). Evaluation of the constraints to profitable smallholder dairying: A case of Nakuru County, Kenya. *MSc Thesis, University of Nairobi, Kenya*

Kodhek, G.A (2004). Feast and Famine: *Financial Services for Rural Kenya. Working Paper,* Tegemeo Institute, Nairobi.

Lusweti, F.N., Muyekho, F.N., Kamau, J.N., Cheruiyot, D.T., Gitahi,F., Kungu, J. and Kute, C. (2005). Coping with feed shortages during the dry season:

Moran, J. (2005): Tropical dairy farming: Feeding management for smallholder dairy farmers in the humid tropics: Landlinks Press; pp 312-324: www.landlinks.com.au.

Muriuki, G.B (2003). The policy environment in the Kenya Dairy sub-sector: A review." Smallholder Dairy Project (SDP) research and development report No.2, Nairobi: International Livestock Research Institute (ILRI).

Njarui, D.M.G., Gatheru, M., Wambua, J.M., Nguluu, S.N., Mwangi, D.M. and Keya, G.A. (2009): Dairy cattle value chain assessment: Characterization of milk production in semi-arid Kenya. Working document, Kenya Arid and Semi-Arid Land Programme (KASAL)

Orodho, A.B. (2006). *Tumbukiza* Technology: Alternative method of napier grass production

Place, F., Roothaert, R., Maina, L., Franzel, S., Sinja, J. And Wanjiku, J. (2009). The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research.

Swanepoel, F., Stroebel, A. and Moyo, S. (2011). The Role of Livestock in Developing Communities: Enhancing Multifunctionality.

Wambugu, C., Franzel, S., and Tuwei, P. (2003). The adoption and dissemination of fodder shrubs in Central Kenya: *Journal of Agricultural Research & Extension Network*

Wasonga, V. O., Steeg, J., Ouma, R and Mude, A. (2010). Risk management and adaptations options for pastoral and agro-pastoral systems in east and central Africa: *A review paper on uncertainty in current seasonal rainfall and future climate variability and change, ILRI, Nairobi, Kenya.*

Waters-Beyer, A. and Letty, B. (2010). Promoting gender equality and empowering woman thorough livestock.