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Associations between intensification interventions and herd productivity in smallholder dairy farms in the Kenyan Highlands

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ABSTRACT
Smallholder dairy farms intensify their milk production through genetics, ecological and socioeconomic interventions to attain increased milk production for food and income security, but viability of the interventions may be an impediment towards sustainability. This study established the association between intensification interventions and herd productivity for a random sample of 140 smallholder dairy farms benefitting from Kenya Market led Dairy Program (KMDP) in Kiambu and Meru Counties in Kenya. Data obtained in cross sectional survey were processed in excel spreadsheet for descriptive statistics, Principle Component Analysis (PCA) and regression modelling to derive optimal predictive models for describing association of intensification intervention and herd productivity indicators. All the indicators showed large variations between farms in intensification interventions and herd productivity. From the indicators, PCA extracted two principle components (PC) of which positive associations were realized between indicators of intensification interventions and herd productivity. Socioeconomic interventions (concentrates, milk sales, credit uptake) had the most contributions (50.7% and 39.7%) towards the total variations in milk yield (R^2 =58%) and margins per litre of milk (R^2 = 45%) respectively as compared to genetic (insemination costs-6.7% and 3.7%) and ecological (manure recycling-0% and 2.4%). Sensitivity analysis with the optimal predictive model showed that a ten percent increase in concentrate fed would increase milk yield by 0.13% but reduce the margins earned by 0.09% per liter of milk. Spending more on insemination, however, would marginally reduce yield and margins while ten percent more milk sales would increase margins by 9.16%. Overall, socio-economic intervention contributed more towards positive externalities in herd productivity. As such use of dairy inputs especially concentrates is necessary to enable farmers attain profitable returns and assure economic sustainability of dairy farming.

Key words: Diary farming, Kenya, milk yield, principle component analysis, regression analysis

RÉSUMÉ
Les petites exploitations laitières intensifient leur production de lait grâce à des interventions génétiques, écologiques et socio-économiques dans le but d'atteindre une production accrue de lait pour la sécurité alimentaire et des revenus, mais la viabilité des interventions peut être un obstacle à la durabilité. Cette étude a établi l'association entre les interventions d'intensification et la productivité du troupeau pour un échantillon aléatoire de 140 petites exploitations laitières bénéficiant du programme laitier dirigé par le marché du Kenya (KMDP) dans les comtés de Kiambu et de Meru au Kenya. Les données obtenues dans le cadre de l'enquête transversale ont été traitées dans le tableur Excel pour les statistiques descriptives, l'analyse en composantes

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principales (ACP) et la modélisation de régression afin de dériver des modèles prédictifs optimaux pour décrire l'association de l'intervention d'intensification et les indicateurs de productivité du troupeau. Tous les indicateurs ont montré de grandes variations entre les exploitations dans les interventions d'intensification et la productivité du troupeau. À partir des indicateurs, l'ACP a extrait deux composantes principales (PC) dont des associations positives ont été réalisées entre les indicateurs des interventions d'intensification et la productivité du troupeau. Les interventions socioéconomiques (concentrés, ventes de lait, utilisation de crédits) ont eu le plus de contributions (50,7% et 39,7%) aux variations totales du rendement en lait (R^2 = 58%) et des marges par litre de lait (R^2 = 45%) respectivement par rapport au génétique (coûts d'insémination-6,7% et 3,7%) et à l'écologique (recyclage du fumier-0% et 2,4%). Une analyse de sensibilité avec le modèle prédictif optimal a montré qu'une augmentation de 10% du concentré nourri augmenterait le rendement en lait de 0,13% mais réduirait les marges gagnées de 0,09% par litre de lait. Dépenser davantage pour l'insémination, cependant, réduirait légèrement le rendement et les marges tandis que les ventes de lait de plus de dix pour cent augmenteraient les marges de 9,16%. Dans l'ensemble, l'intervention socio-économique a davantage contribué aux externalités positives de la productivité du troupeau. Une telle utilisation des intrants laitiers, en particulier des concentrés, est nécessaire pour permettre aux agriculteurs d'obtenir des rendements rentables et assurer la durabilité économique de l'élevage laitier.

Mots-clés : Laiterie, Kenya, rendement en lait, analyse en composantes principales, analyse de régression

INTRODUCTION

Dairy farmers intensify their milk production to attain more output per unit input (The Montpellier Panel, 2013). In dairy farms, indicators of output are productivity measures represented by milk yields resulting from improved high yielding livestock breeds, better feeding and nutrition and practicing best animal husbandry practices. Muia *et al*. (2011) indicated that milk production per hectare increased with increasing level of intensification and attributed this to access to extension services which aid in knowledge provision on better dairy husbandry management and practices. However, Kibiego *et al*. (2015) observed that as milk yield increases, gross margin and profit per litre of milk may decrease with increase in the level of intensification within smallholder dairy farms. This was attributable to increase in production costs involving feeds, drugs and labour costs. The authors further observed that farmers need extension services and finances to improve on feed production and utilization technologies essential for increasing profitability. This is partly achieved through cooperative movements where farmers are able to access supplementary feeding through provision of feeds on credit arrangements (Bebe, 2008). The objective of this study was to establish relationships between herd productivity indicators and intensification interventions within smallholder dairy farms to inform management interventions for sustainable dairy farming in Kenya.

MATERIALS AND METHODS

Study area. The study was undertaken in Kiambu and Meru Counties on smallholder dairy farms benefitting from the Kenya Market Led Dairy Program (KMDP) interventions being beneficiaries of intensification interventions. The farms represent the leading milk sheds in Kenya with a large population of smallholders intensifying their dairy production, favorable climatic conditions for dairy production, the high participation in dairy farmer cooperatives and small land holdings on which dairy is integrated with crops (Bebe *et al.,* 2003; Bebe, 2004).

Survey methodology. A cross sectional survey was undertaken between February and June 2016. A sample size of 140 farms was determined (Anderson *et al.,* 2003):

$$n = \frac{z^2 . p . q}{e^2}$$

Where z is desired confidence interval level set at 1.96 for 95% confidence interval, p is the proportion of a characteristic of the population to be sampled, which was set at 0.735 being the proportion of households in the Kenya highlands that keep dairy obtained from (Bebe *et al.,* 2003), q = (1- p), and e is the error margin allowable for detecting a difference in the sample and was set at 0.1.

The farms were randomly selected from lists provided by SNV, the NGO implementing the KMDP program in Meru and Kiambu Counties in Kenya for the members of the Cooperatives.

Data collection. Data collection was through observations and farm household interviews using a pre-tested structured questionnaire designed to capture individual animal and farm level data on indicator variables of genetics, ecological, socioeconomic interventions and herd productivity. The indicators were either measured directly in scale variable units or computed from the raw collected data. The computed indicator variables included concentrates, Napier, crop residues, legumes and off farm sourced feeds per Tropical Livestock Unit (TLU) on the farm. The TLU was computed from herd composition on the basis of 1 for bull, 0.7 for cow, 0.5 for heifer and 0.2 for calves (Bebe, 2004). Production costs and gross margin per litre of milk was computed from revenues and input costs.

Data analysis. The analysis aimed at detecting the association between intensification interventions and herd productivity indicators. The analysis involved processing indicator variables on each sample farm in excel spreadsheet to generate descriptive statistics, Principle Component Analysis (PCA) using Statistical Package for Social Sciences (SPSS) version 20 (SPSS, 2011) and multiple linear regression modelling using the regression procedures of Statistical Analysis System (SAS, 2009) version 9.1. Data analysis proceeded in two stages involving PCA to reduce dimensionality in the data set and to select indicator variables for regression analysis. The goodness of fit of PCA was assessed on basis of Varimax rotation with Kaiser-Meyer-Olkin Normalization procedure (KMO). The varimax rotation aided in extracting fewer PCs with highly correlated variables that maximize sum of variances to simplify interpretation of the extracted PCs. Hair *et al*. (2006) and Che *et al*. (2013) explains application of the KMO as a measure of sampling adequacy which is satisfied when KMO value is at 0.5 and is significant ($p<0.05$). In addition, Bartlett's test of sphericity was computed to check that the correlation matrix was not an identity matrix for which a p value <0.05 is indicative. A factor loading of ±0.3 was set prior and a rule of thumb applied in which an extracted PC had to explain at least 100/PC% of the variance to be selected for the next stage of regression modelling (Afifi and Clark, 1984; Rougoor *et al.,* 2000).

The second stage of data analysis involved fitting selected indicator variables from the PCA into a multiple regression model to determine optimal predictive model that explains association of herd productivity with the three groups of intensification interventions.

The multiple linear regression model fitted was in the form:

$$Y_{ij} = a + b1(x1) + b2(x2) + b3(x3) + \ldots + bn(xn) + e_{ij}$$

where a is the intercept, b_1, b_2, b_3 … bn are the coefficients for variable x_1, x_2, x_3 … x_n respectively and e_{ij} is the random error.

In this model, x predictor variables are represented by indicators of the intensification interventions while the y dependent variables are herd productivity. The model goodnes of fit was judged on the criteria of smallest

AIC or BIC and SSE and largest adjusted R^2 to obtain an optimal predictive model that defines the association between intensification interventions and herd productivity.

RESULTS

Table 1 presents the descriptive statistics for herd productivity indicators from sampled smallholder dairy farmers. The means have large standard deviations, indicative of large heterogeneity between the farms in levels attained in herd productivity.

In Table 2, the PCA fitted for indicators defining intensification interventions and herd productivity was satisfactory in sampling adequacy (KMO=0.616) and the correlation matrix was not an identity matrix (Bartlett's test Chi square =1457.48, p=0.000). Two PCs were extracted that explained 99.63% of the total variance and applying the rule of thumb (100/2PCs=50%), only variables loading on PC 1 explaining 90.06% of the total variance were selected for further regression analysis. The variables loading highly on it were three socioeconomic indicators (credit uptake, milk sales and concentrate use), one ecological indicator (manure recycling) and one indicator of genetics (insemination costs) interventions and all had positive associations with milk yield and margins per litre of milk. Two regression models were subsequently fitted to explain milk yield and margin per litre with the indicators of ecological, genetic and socioeconomic interventions in intensification of dairy production.

Table 1. Descriptive statistics for indicator variables of herd productivity in sampled dairy farms (n=140)

Herd productivity	Units	Mean	SD
Production cost	KES/ kg of milk	20.4	5.3
Milk yield	Kg/cow/month	342	130
Calving interval	Months	17.0	2.0
Age at first calving	Months	30.1	3.2
Margin/litre	KES/litre of milk	4.2	7.5

KES= Kenya shillings

Table 2. Retained variables for herd productivity and intensification interventions from PCA

Indicator variables	Principle component 1	Principle component 2
Credit uptake	0.944	
Replacement cost		0.767
Milk sales	0.551	
Insemination cost	0.399	
Concentrates use	0.382	
Milk yield	0.342	
Manure recycling	0.340	
Margin per litre of milk	0.331	
Total variance explained (%)	90.063	9.566

Rotation method: Varimax with Kaiser-Meyer-Olkin Normalisation. Sampling adequacy (KMO=0.616). Bartlett's test of sphericity (Chi square =1457.477, Sig=0.000).

The retained variables were submitted to regression model to derive an optimal predictive model for milk yield and margins per litre of milk. The results are presented in Table 3 for optimal model from a selection of 15 and 31 models evaluated for milk yield and margins per litre of milk respectively on the basis of smallest AIC, BIC, C(p) and SSE values and largest R^2. More than half (58%) of the variations in milk yield was explained by socioeconomic interventions (concentrate use, milk sales and credit uptake) and genetic intervention (insemination costs) without ecological intervention indicators. In contrast, about half (45%) of the variations in margins per litre of milk were explained by socioeconomic (concentrates use, milk sales), genetics (insemination costs) and ecological intervention (manure recycling) indicators.

The optimal models derived for estimating the milk yields (M) and margin per litre of milk (G) respectively were:

$$M = 6.38007 + 0.00061571(C) + 0.23152(S) - 0.00001009(L) - 0.00051878(I)$$

$$G = 6.34086 + 0.59428(S) - 0.00111(C) - 0.00100(I) - 0.82356(MU)$$

Where M = milk yield in kg per cow, G = margins per litre of milk, C = concentrates used in kg dry matter per tropical livestock unit, S = milk sales in kg per herd, L = credit uptake in Kenyan Shillings per year, I = insemination costs in Kenya shillings per animal and MU = manure recycling. The optimal model for milk yield show that socioeconomic indicators of significance (Table 4) are concentrate use, credit uptake and milk sales which accounted for 50.7% of the variance and genetics has one indicator variable of significance, insemination costs, which accounted for only 6.7%. Concentrate use and milk sales show positive association with milk yield while credit and insemination costs had negative associations. In the optimal model for explaining margins per litre of milk, the socioeconomic indicators of significance were concentrate use and milk sales which accounted for 39.7% of the variance, much higher than variance accounted for by genetics (3.7%) intervention represented by insemination costs or ecological intervention (2.4%) represented by manure recycling. The margin per litre of milk was positively associated with milk sales but was negatively associated with manure recycling, insemination costs or concentrate use.

With the regression equation, sensitivity analysis of the selected optimal intensification intervention variables on milk yield and margins per litre of milk was performed and results are presented in Figure 1. The analysis showed that, a ten percent increase in concentrate feed would increase milk yield by 0.13% but reduce the margins earned by 0.09% per liter of milk. Spending more on insemination, however, would marginally reduce milk yield and margins while ten percent more milk sales would increase margins by 9.16%.

Table 3. Optimal model selected for explaining milk yield and margin per litre of milk

Model	Variables in the model	Adj R^2	AIC	BIC	C(p)	SSE
Milk yield	Concentrates, Milk sales, Credit uptake, Insemination cost	0.58	318.03	320.40	5.00	1263.75
Margin per litre of milk	Concentrates, Insemination cost, Milk sales, Manure recycling	0.45	498.71	501.15	4.06	4593.56

Table 4. Coefficients and variance contribution explaining milk yield and gross margins/litre of milk

Intensification indicators	Milk yield (kg/cow/month)		Gross margin (KES/Litre milk)	
	Coefficients	Variance (%)	Coefficients	Variance (%)
Insemination costs (KES/cow)	-0.00051878	6.7	-0.00100	3.7
Concentrate use (kg/TLU)	0.00061571	7.0	-0.00111	3.5
Milk sale (KES/herd/month)	0.23152	41.3	0.59428	36.2
Credit uptake (KES/year)	-0.00001009	2.4		
Manure recycling (kg/year)			-0.82356	
Constant	6.38008		6.34086	
Total variance explained (%)		57.5		45.8

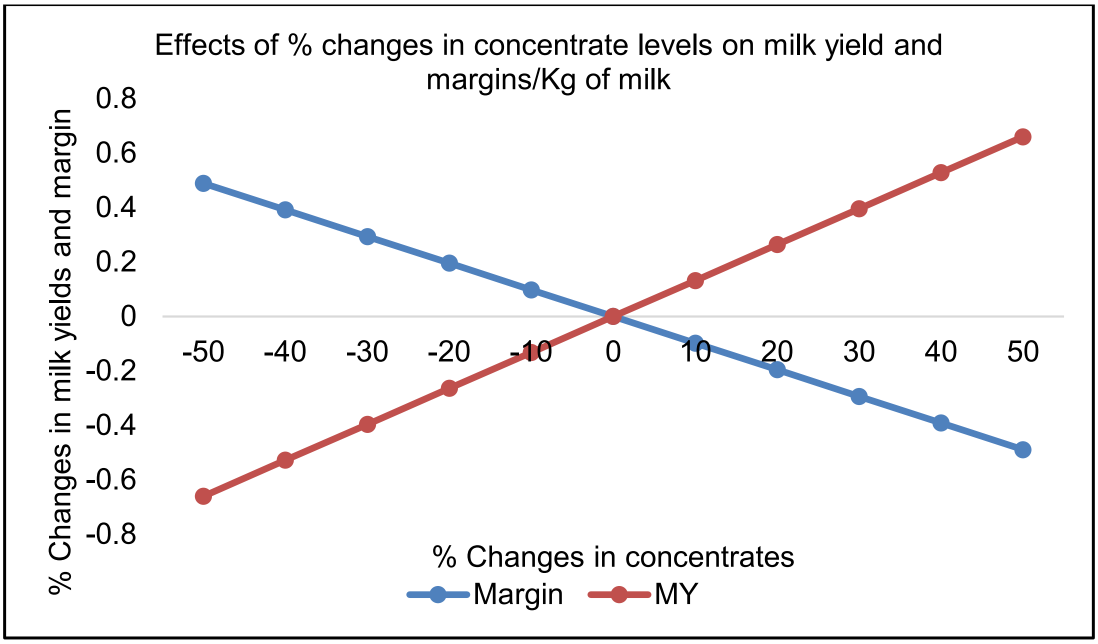

Figure 1. Effects of % changes in concentrates on milk yield (MY) and margins

DISCUSSION

The indicator variables of significance in the association between intensification interventions and herd productivity were milk yield and margins per litre of milk, which represent positive externalities. Milk production was estimated at 324.4 litres per cow per month (Table 1), which translates to about 10 litres per cow per day, comparing well with 309 litres per cow per month observed in the Kenya highlands (Mburu *et al*., 2007; Tegemeo, 2016). The margins per litre of milk was estimated at KES 4.2 which also compares well to KES 3.45 to 8.25 range obtained in previous empirical studies (Mburu *et al*., 2007; Kibiego *et al*., 2015; Tegemeo, 2016). However, the means of milk yield and margins per litre of milk had large standard deviations, typical of recall data, which in this study was one year recall data because record keeping is not well practiced in smallholder farms (Murage and Ilatsia, 2011; Bett, 2016). Production costs of up to KES 20.40 per litre of milk are comparable to KES 18.10 and KES19.00 reported by Mburu *et al*. (2007) and Tegemeo (2011) and points to farmers spending more on inputs to maximize milk production, but this stepping up of production costs erodes profitability despite supporting increased milk productivity. Milk production per cow per year is influenced by calving intervals, which averaged 17 months, typical of smallholder farms (Bebe *et al.,* 2003) which can be explained by imbalanced feeding, poor heat detection and insemination failures and long periods of lactation in excess of 330 days (Staal *et al.,* 2001).

The optimal model for milk yield had an explanatory power of 57.5% of which the socioeconomic indicators contributed the most (50.7%) and the genetic indicators just a little (6.7%) while the ecological interventions had no contribution. The socioeconomic indicator variables were concentrate use, credit uptake and milk sales while the genetics indicator variable was insemination costs. The socioeconomic indicator variables of significance in the derived model demonstrate interventions that were targeted to provide an enabling environment for accessing input and output markets while the genetic indicator variable demonstrate interventions that targeted improving genetic quality of the herd, and investments in reproductive technology to attain high milk yielding potential. Linking farmers with markets for both inputs and outputs provide a pathway to intensification adoption because milk is a perishable commodity that requires marketing arrangements for collection, distribution and sale.

Results showed that farmers would obtain more milk yield with feeding more concentrates and selling more milk because these indicator variables had positive association with milk yield. Lukuyu *et al*. (2007) in a study of the feeding regimes in smallholder dairy farms explained that concentrates provide balanced supplementary diets to milking cows which are pervasively underfed with crop residues and roughages of poor quality. Supplementing concentrates will therefore have marked effect on increasing milk yield in smallholder dairy cows, as demonstrated in the studies of Duncan *et al*. (2013), Kashongwe *et al*. (2014) and Kashongwe *et al*. (2017). The production of large volume of milk is expected to trigger market participation with the surplus milk on the farm, hence the positive association between milk yield and milk sales because income from milk sales is a major goal in the decision to intensify dairy production.

On the other hand, uptake of credit and insemination costs had decreasing effects on milk yield. Several situations in smallholder farms could possible explain this. The credit though obtained for dairy investments, may be invested in other farm productive activities that support but take long to influence milk yield. These can include improving quality of the breed, housing and equipment and on-farm feed production. The credit uptake referred to last one year recall data. Results on the insemination costs imply that increased investments in insemination services were associated with a decline in milk yield. Increased insemination is likely aimed at improving quality of breeding stock but it may be that farmers failed to match quality of the breeding stock with their management standards, especially feeding and health, resulting in improved stock failing to express full genetic potential.

The optimal model explaining margins per litre of milk had socioeconomic, genetics and ecological intervention indicator variables. The model explained 45.8% of the variation in margins per litre of milk and the socioeconomic indicator variables accounted for the largest variance (39.7%) compared to the genetic (3.7%) or ecological (2.4%) indicator variables. The socioeconomic indicator variables were concentrate use and milk sales while the genetics indicator variable was insemination costs and ecological indicator variable was the amount of manure recycled on the farm. The large variations in margins per litre explained by the socioeconomic indicators further serve to demonstrate the importance of an enabling environment for supporting intensification of dairy production because unreliable milk markets can impede commercialization and discourage intensification process.

Margins per litre of milk had positive associations with milk sales but negatively associated with concentrate use, manure recycling and insemination costs. The positive association of margins per litre of milk with milk sales may be explained by better milk price obtained by the farmers delivering more milk to cooperatives because they can negotiate price (Rademaker *et al*., 2016) as the sample farmers were members of farmer cooperative societies. The negative association of insemination costs and concentrate use with the margins obtained per litre of milk could have resulted from increased production costs incurred in using these inputs, because they are highly priced in Kenyan markets, hence decreasing the margins as obtained in the studies of Kibiego *et al*. (2015) and Tegemeo, (2016). Spending more on semen would mean that farmers were ordering for higher quality semen but not realizing immediate benefits of quality genetics, because of increased cost of production and hence the negative associations with the margins earned. This applies as well to feeding more concentrates purchased at high market price thereby increasing the production costs and subsequently lowered margins earned. This could be related to inefficient resource use on the farms as suggested in the findings of Kibiego *et al*. (2015) that economic efficiency in producing milk under intensive systems is 65% and that margins per litre of milk decreases with increasing costs of feeds. This is possible via enhanced resource management and allocation as demonstrated by Cortez-Arriola *et al*. (2016) in smallholder dairy intensification in North-West Michoacán of Mexico that just re-allocating the current resources itself leads to economic, social and/or environmental improvements.

CONCLUSION

Socioeconomic interventions had the greatest contribution to both milk yield and margins earned. Both genetic and ecological interventions had little influence. Concentrate use is important for increasing milk production, but the price will be prohibitive to more use of concentrates, because of reduced margins.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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