

Full Length Research Paper

Livelihood impacts of *Calliandra calothyrsus* and *Sesbania sesban*: Supplementary feed in smallholder dairy farms in Kenya

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Received 10 May, 2019; Accepted 18 October, 2019

An agroforestry land use system aimed at improving the productivity of smallholder dairy farms using *Calliandra calothyrsus* and *Sesbania sesban* shrubs as feed supplements was introduced to semi-commercial SDFs in Meru, Kenya, as part of a field trial. The objective of this study was to assess the impact of using the *C. calothyrsus* and *S. sesban* on family income and livelihoods during the 16-month trial period. Eighty farmers randomly allocated to four groups (nutrition, reproduction, combined nutrition and reproduction, and a comparison group) were enrolled in this study. The nutrition intervention included nutritional management advice and provision of 150 *C. calothyrsus* seedlings and 150 *S. sesban* seedlings to each farm. Farms were visited every 1-2 months during the trial to collect data on milk production and feeding practices during the previous day. Seventy of these farms completed the trial and were interviewed post-intervention. Partial budget analysis of their farms was done by comparing changes in average monthly profits (from milk) and feeding costs/cow for the first 6 months and last 6 months of the intervention. Focus group discussions were used to collect qualitative information on livelihood effects from the trial. There was a KES 2,380.3 (USD 23.5) increase in average monthly profit/cow in the nutrition group comparing the first and last 6 months of the trial, representing a 68.8% improvement ($p = 0.02$). Average feeding costs significantly decreased across all groups over the trial period. Knowledge on dairy cow nutrition, level of confidence on calf management, and feeling of empowerment to raise calves/heifers to achieve first calving by 27 months were higher among farmers in the nutrition and combined groups than farmers in the other groups. There were positive direct and indirect impacts on the income and livelihoods of farmers in the two groups receiving nutritional interventions. Agroforestry, using *C. calothyrsus* and *S. sesban* shrubs can improve household livelihoods if adopted by SDFs in Kenya.

Key words: Smallholder dairy, agroforestry, partial budget analysis, leguminous shrubs.

INTRODUCTION

Agroforestry has been used in agricultural production to reduce the effects of harsh climatic changes on farmers' incomes and livelihoods (Patel-Weynand et al., 2017) and is a promising pathway out of poverty (Rahman et

al., 2012; Thorlakson and Neufeldt, 2012). The quality of life and household living standards of farmers practicing some level of agroforestry in parts of Kenya was observed to improve as a result of better farm productivity, mitigated

farm losses, increased off-farm income generation and improved general environmental conditions (micro-environment) of their farms (Thorlakson and Neufeldt, 2012; Wilson and Lovell, 2016).

Smallholder dairy production plays a major role in food security and poverty alleviation in Kenya (Muriuki et al., 2001; Van Leeuwen et al., 2012) as has been documented in other neighboring countries (Pandey, 2014). In Kenya, about 40-45% of daily milk production on smallholder farms (SDFs) is not sold but used for household nutrition (~35%) and calf nutrition (~10%) (Muriuki, 2011). The role of livestock in human health and nutrition in developing countries is substantial and is influenced by many factors (Randolph et al., 2007; Makau, 2014). In Kenya, the dairy value chain is one of the largest avenues for job creation and employment in the informal sector, with every 1000 L of daily milk produced estimated to generate approximately 77 jobs (Muriuki, 2011).

Smallholder dairy farming complements crop production through daily/monthly income generation, creation of employment, and stimulation of infrastructural developments, and it is considered a pathway out of poverty (Muriuki, 2003; Van Leeuwen et al., 2012). Both economic recovery and wealth creation in many rural communities in Kenya are directly related to the production level of the dairy sector (The Dairy Policy Forum, 2004). There is a positive association between poverty and food insecurity (Wight et al., 2014); also, households that sell the lowest volumes of milk to collection and processing centers in Kenya are poorer and more food insecure than households selling more milk (Muriuki et al., 2001; Boor, 2012).

Incorporation of diet supplementation with good quality grass and legume fodder in Mexico have resulted in increased lactation performance of cows from an average of USD 866 - 1,311 marginal profits per three lactation lifetimes of a cow (Absalón-Medina et al., 2012). Although SDFs in Uganda adopted growing of Napier grass for fodder, there was a general decrease in family incomes observed in the dry season because of reduced dairy production (a consequence of inadequate feed) coupled with reduced food produced for the family due to small land acreage (Kabirizi et al., 2007). Intercropping of food crops and leguminous forages was subsequently identified as an alternative production technique to mitigate the effects of dry seasons. This integrated farming method was a better production system with additional benefits, including better quality of food crop yields and improving soil health (Kabirizi et al., 2007; Dollinger and Jose, 2018).

In a related study (Makau, 2019), the milk production

benefits of feeding leguminous shrubs were investigated on smallholder dairy farms in Kenya. Two types of leguminous shrubs were used in that study since there was a large difference in altitude among the farms in the study area, and it was unclear which type of shrub would be best on the farms. *Sesbania* is known to be harder at higher altitudes than *Calliandra* but has slightly lower protein content than *Calliandra* (Devendra, 1992; Trees for the Future, 2016). Economic costs and benefits of the extra milk production remain unclear.

Chakeredza et al. (2007) observed that SDFs, in Tanzania, that supplemented their cattle diets with fodder trees saved an average of USD 310/cow/year in production costs, primarily from reduced purchases of commercial concentrate feed for the cows. In Kenya, it is estimated that the cumulative net returns to smallholder farms that had adopted fodder tree technologies between 1993-2008 was between 18.7 - 29.6 million USD/year (World Agroforestry Center, 2011). However, there is a paucity of current research on benefits (to family livelihoods) of using *Calliandra calothyrsus* and *Sesbania sesban* agroforestry on semi-commercial SDFs in Kenya. The objective of this study was to assess the impact of using *C. calothyrsus* and *S. sesban* as feed supplements for dairy cattle on family income and livelihoods on semi-commercial SDFs based on an agroforestry land management model. This assessment was done using income generated from milk production.

In this study, livelihoods were defined as the means of living as constituted by various capabilities, assets, and activities (Serrat, 2017). Therefore, livelihoods would be considered sustainable based on their ability to withstand and recover from stresses and threats to the means of living. Such livelihoods are capable of enhancing interventions that mitigate vulnerability to stressful situations (Krantz, 2001). Level of income/economic capital is one of the indicators used to gauge a sustainable livelihood (Department for International Development, 1999; Ma et al., 2018).

MATERIALS AND METHODS

Description of the study area

This randomized controlled field trial was carried out in Naari sub-location of Meru County, Kenya (0°6'0" N and 37°35'0" E). Meru County is located on the slopes of Mount Kenya, 270 km north of Nairobi, the capital city of Kenya (Figure 1). Naari sub-location has an altitude of approximately 2,000 m above sea level. The main agricultural activities in Naari include dairying, subsistence crop farming, horticulture, and lumbering. The study area was purposively selected since this research was part of a larger study involving dairy farmers in the area. A non-governmental organization,

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Eighty farms had been randomly selected based on the inclusion criteria of active membership with the NDFCS, zero-grazing, and <4 milking cows. Membership with NDFCS was prerequisite since the project was a partnership between UPEI, FHF and NDFCS. Farms included in the study had to be practicing zero grazing since this form of livestock keeping allowed some control in feeding. Farms with more than 4 milking cows would be considered medium-sized. Selected farms were part of a larger study that included observational studies (Muraya et al., 2018; Makau et al., 2018) and randomized controlled trials (Kathambi et al., 2018; Makau, 2019; Muraya, 2019). The 80 farms were randomly block-allocated into four different groups in the randomized controlled field trial, with average days in milk (DIM) as a blocking variable. Since changes in milk production due to enhanced feeding are likely to be greater in early lactation, DIM was deemed a very important variable for block randomization. The four intervention groups included nutrition interventions only, reproduction interventions only, nutrition + reproduction (combined) interventions, and a comparison group that received neither intervention. Farmers in the nutrition and combined groups were issued with at least 150 *C. calothyrsus* seedlings and 150 *S. sesban* seedlings (in early 2016) to plant on their farms prior to the commencement of the monitoring visits (July 2016-October 2017) of the project. The nutrition and combined groups also received monthly advice on how to feed their cattle better with the feeds and resources available on the farm. Seventy out of the 80 farms completed the trial from July 2016 to October 2017 (Makau, 2019). On average, 500 shrubs in smallholder farms in Kenya were estimated to produce enough foliage to feed 6 kg/cow/day for one year (Franzel et al., 2003; Trees for the Future, 2016).

Farms in the 2 nutrition intervention groups were visited monthly during the trial to troubleshoot any issues with tending or harvesting of the *C. calothyrsus* and *S. sesban* shrubs. Additionally, data on milk production and feeding practices during the previous day were recorded in a questionnaire adapted and modified from the 2015 baseline study (Makau et al., 2018). Farms in the reproduction and comparison group were visited bi-monthly to collect similar milk and nutrition data.

A post-intervention questionnaire was administered to assess the knowledge, attitudes, and practices (KAP) of the farmers on the use of leguminous shrubs and dairy cow management at the end of the trial period, and whether farmers' KAP was different by intervention group. The analysis in this paper focuses on some indicators of farmers' livelihood impact assessment which included a feeling of empowerment in dairy management, knowledge and awareness of general nutrition and use of *C. calothyrsus* and *S. sesban* shrubs on their farms, as well as confidence in the management of dairy cows and calves. The level of confidence on dairy cow nutrition was assessed on a scale of 1 (Not confident), 2 (Somewhat confident), 3 (Confident), and 4 (Very confident).

Focus group discussions (FGDs) were used to collect qualitative information on livelihood effects from the trial. Discussions were classified into four themes relevant to the intervention (that is, milk production and feeding practices, the importance of dairy products to the households, the project intervention and its effect on household livelihoods (economies) and knowledge dissemination to and by the farmers). Farmers in the nutrition and combined groups were invited to the first FGD, while a second separate FGD was held for the reproduction and comparison groups on the following day. Proceedings of the FGDs were facilitated by the researcher and were recorded for reference to inform the quantitative data.

Data management and analysis

Data from the questionnaires were entered into MS Excel 2010 (Microsoft, Sacramento, California, USA) and checked for errors. Data were then transferred to STATA software Version 13.0 (Stata

Corp LLC, College Station, Texas, USA) for statistical analysis. Descriptive statistical analysis (summarizing distributions, means, and medians) was done for continuous variables. Categorical variables were also summarized using frequencies and percentages. Significant differences among these demographic and other characteristics were determined using ANOVA.

Partial budget analysis was used to assess marginal changes in revenues in Kenya shillings (KES) by comparing farms receiving nutritional interventions with those not receiving nutritional interventions. A comparison of milk production revenue and feeding costs was done for the baseline (that is, first 6 months – July to December 2016) and the end-line (that is, last 6 months of the trial – May to October 2017) for each farm. The comparative periods included both dry and wet seasons.

This partial budget was focused on the milk production revenue and typically purchased feed costs and assumed that all other costs (e.g. labor associated with tending and harvesting fodder crops) were constant. Purchased feeds of interest for the analyses were: dairy meal, maize germ, wheat bran, and mineral supplementation. Maize silage was also included in the cost of production for three reasons: 1) there is a substantial amount of energy in maize silage (Kordi and Naserian, 2012), having a substantial impact on milk production (Rengman et al., 2014); 2) some farmers fed maize silage while others did not; and 3) there are costs associated with the proper storage of maize silage from the harvested maize plants (e.g. chopping, mixing in molasses or some other product to assist fermentation, packing and plastic), which should be reflected in the feed costs. The cost of the *C. calothyrsus* and *S. sesban* seedlings was a one-time small cost, and therefore was not included in the partial budget but is factored in at the end. Profit was used for the analysis of net change in monthly profit/cow between the first six months and last six months within groups, for each intervention group.

Average monthly profit (μ) was calculated using the formula below:

$$\mu = \left(\frac{\sum x}{t} \right) - \left(\frac{\sum y}{t} \right)$$

Where: $\sum x$ = sum of assessments of milk (L/cow/day) \times 30 days \times average price of milk (KES/L),

$\sum y$ = sum of assessments of feed volumes consumed/cow \times 30 days \times the average cost of feed (KES/kg or g) for each purchased feed and corn silage.

t = number of assessments during the 6-month period.

Bonferroni adjusted one-way ANOVA was used to evaluate statistically significant differences in average monthly production costs and profits among study groups. Significant differences in net change in profit were calculated within the intervention groups using paired t-tests, comparing average monthly profit during the baseline 6 months and during the end-line 6 months. Unpaired t-tests were used to determine significant differences between two-way group comparisons of net profit changes for all possible combinations of intervention groups.

For dichotomous variables from the post-intervention interview data, Pearson's Chi-square and Fisher's exact tests (if cells had fewer than 5 farmers) were used to check for differences between the different groups. Results were considered significant when p -value ≤ 0.05 . Focus group discussion data were recorded and transcribed for qualitative analysis to provide contextual information. Farmers agreed to the use of the data for research purposes as long as confidentiality was maintained.

RESULTS

During the 16-month study period, 10 farms were lost to

Table 1. Demographic and other characteristics of 114 cows from 80 Kenyan smallholder dairy farms on 378 farm-visits (606 cow-visit observations) over a 6-month baseline period in 2016-2017, by intervention group.

Parameter	Overall (n=606)	Comparison group (n=119)	Nutrition group (n=194)	Combined group (n=183)	Reproduction group (n=110)	ANOVA P- value
Average # of milking cows/farm (s.d.)	1.8 (0.7)	2.1 (0.6) ^a	1.8 (0.7) ^{bc}	1.7 (0.6) ^c	1.9 (0.8) ^b	0.0002
Average # of acres/farm (s.d.)	2.1 (1.8)	2.1 (1.8) ^a	1.8 (1.5) ^a	1.9 (0.6) ^a	2.8 (2.7) ^b	0.338
Average # of days in milk (s.d.)	242.5 (176)	251.8 (166) ^a	276.9 (73) ^{ab}	215.6 (182) ^{ac}	216.2 (176) ^{ac}	0.002
Breed						<0.001
Zebu or dual purpose (#)	2.6% (16)	5.0% (6) ^a	0% (0) ^b	3.3% (6) ^a	3.6% (4) ^a	
Friesian crosses (#)	56.6% (343)	46.2% (55) ^a	52.6% (102) ^a	57.4% (105) ^a	73.6% (81) ^b	
Ayrshire crosses (#)	15.0% (91)	13.5% (16) ^a	16.4% (32) ^{ab}	11.5% (21) ^{ac}	20.0% (22) ^{ab}	
Guernsey crosses (#)	19.5% (118)	33.6% (40) ^a	21.7% (42) ^b	18.0% (33) ^b	2.7% (3) ^c	
Jersey crosses (#)	6.3% (38)	1.7% (2) ^a	9.3% (18) ^b	9.8% (18) ^b	0% (0) ^a	
Pregnant (#)	23.8% (144)	24.4% (29) ^a	27.3% (53) ^a	16.4% (30) ^{ab}	29.1% (32) ^{ac}	0.030
Subclinical mastitis positive (#)	27.1% (164)	26.1% (31) ^a	34.5% (67) ^{ab}	22.9% (42) ^{ac}	21.8% (24) ^{ac}	0.038
Wet Season (#)	24.6% (149)	16.8% (20) ^a	18.0% (35) ^a	19.7% (36) ^a	52.7% (58) ^b	<0.001

^{a-c} Different letter superscripts represent significant differences between coefficients of different levels (other than the reference level which use the category p-values) for interaction variables and categorical variables not involved in interactions when they have more than 2 levels.

follow-up at different times of the study (3 from each of the nutrition, combined and comparison groups and 1 from the reproduction group). Reasons for the losses to follow-up included cessation of membership to NDFCS, cattle sales or death, change in farm priorities, and family issues. These reasons were not related to the objective of the study and so minimal selection bias was expected from this attrition of farms.

Table 1 provides a summary of demographic and other characteristics of the cows and farms over the first 6 months of the study, by intervention group and overall. Despite the random allocation of herds, some of the herd demographics (number of milking cows/farm), animal characteristics (days in milk, breed, and pregnancy status), the prevalence of subclinical mastitis and number of cow observations during the different seasons were different among the four trial groups at baseline. In particular, the nutrition group cows had the highest DIM and most subclinical mastitis at baseline. Conversely, the reproduction group had a higher proportion of Friesian crosses (Table 1).

Table 2 provides a summary of demographic and other characteristics of the cows and farms over the last 6 months of the study, by intervention group and overall. For the 70 farms that completed the trial, the mean land size and mean a number of milking cows per farm remained unchanged at 2.1 acres and 1.8 milking cows per farm respectively. The breeds and percent pregnant were also similar among the 80 farms starting the trial and the 70 farms completing the trial (Tables 1 and 2). Furthermore, similar group differences were observed between the two-timeframes. However, cases of mastitis decreased significantly ($p < 0.05$) in all groups when comparing baseline versus end-line data (due to interventions provided to the farms during the visits).

Also, the proportion of observations when cows were pregnant in the combined group also increased significantly from 16.4% at baseline to 28.2% at end-line (Tables 1 and 2). With the higher proportion of pregnant cows in the combined group, along with modest increases in proportion of pregnant cows in the comparison group and overall, substantial increases in DIM were also observed.

Partial budget analysis

The average cost of dairy meal was calculated as the average retail price of all dairy meal brands sold at the NDFCS during the trial period, which was (34.8 KES/kg). The same approach was used for the other feeds of interest, producing the following average costs: maize germ (18.7 KES/kg), bran (19.0 KES/kg), and mineral supplement (0.6 KES/g). The estimated cost of maize silage was 12.8 KES/kg, calculated as an average of retail prices for silage and labor costs for silage-making documented between 2015 and 2018 (Sawa, 2015; Caroline, 2016; Nanjinia, 2018; Obi, 2018).

The average monthly milk production among the 70 farms ranged between 161.5 – 204.5 L/cow at baseline (Table 3) and between 167.9 – 237.2 L/cow at the end of the study, which represented an increase in all groups except the farms in the combined group, who had a 17.6 L decrease in their average milk production (Table 3), likely due to the significant increase in pregnant late lactation cows. The changes in milk production were only significant in the nutrition and reproduction groups (Table 3). The average price of milk, calculated as an average of prices offered to the farmers by NDFCS during the trial period, was KES 37.0/L.

Table 2. Demographic and other characteristics of 121 cows from 70 Kenyan smallholder dairy farms on 326 farm-visits (519 cow-visit observations) over a 6-month end-line period in 2016-2017, by intervention group.

Parameter	Overall (n=519)	Comparison group (n=71)	Nutrition group (n=129)	Combined group (n=163)	Reproduction group (n=156)	ANOVA P-value
Average # of milking cows/farm (s.d.)	1.8 (0.8)	1.8 (0.7) ^a	1.6 (0.8) ^{ab}	2.0 (0.8) ^{ac}	1.8 (0.7) ^{ad}	0.002
Average # of acres/farm (s.d.)	2.1 (1.7)	1.6 (1) ^a	1.7 (1.4) ^{ab}	2.0 (0.6) ^c	2.8 (2.7) ^{ad}	0.11
Average # of days in milk (s.d.)	330.6 (210)	404.1 (252) ^a	318.8 (174) ^{bc}	288.8 (171) ^d	350.5 (243) ^{ac}	0.001
Breed						<0.001
Zebu or dual purpose (#)	3.7% (19)	2.8% (2) ^a	3.1% (4) ^a	0% (0) ^b	8.3% (13) ^a	
Friesian crosses (#)	59.9% (311)	50.7% (36) ^a	58.9% (76) ^a	55.2% (90) ^a	69.9% (109) ^b	
Ayrshire crosses (#)	15.6% (81)	16.9% (12) ^a	18.6% (24) ^a	12.3% (20) ^a	16.0% (25) ^a	
Guernsey crosses (#)	17.0% (88)	25.4% (18) ^a	15.5% (20) ^a	25.2% (41) ^{ab}	5.8% (9) ^c	
Jersey crosses (#)	3.9% (20)	4.2% (3) ^a	3.9% (5) ^a	7.4% (12) ^{ab}	0% (0) ^c	
Pregnant (#)	25.6% (133)	29.6% (21) ^a	27.9% (36) ^a	28.2% (46) ^a	19.2% (30) ^a	0.183
Subclinical mastitis positive (#)	7.9% (41)	11.3% (8) ^a	7.0% (9) ^a	9.2% (15) ^a	5.8 (9) ^a	0.45
Wet Season (#)	13.3% (69)	0% (0) ^a	12.4% (16) ^b	11.7% (19) ^b	21.8% (34) ^c	<0.001

^{a-c} Different letter superscripts represent significant differences between coefficients of different levels (other than the reference level which use the category p-values) for interaction variables and categorical variables not involved in interactions when they have more than 2 levels.

Table 3. Average monthly milk production cow⁻¹ at the start of the intervention (6-month baseline) and at the end of the intervention (6-month end-line) for 70 Kenyan smallholder dairy farms from 2016-2017, by intervention group (1 USD=KES 101.2).

Group	Average milk production - Baseline (liters)	Average milk production - End-line (liters)	Change in milk production (liters)	Paired t-test p-value
Comparison (n=17 farms)	161.5	167.9	+6.4	0.80
Nutrition (n=17 farms)	183.3	237.2	+53.9	0.04
Combined (n=17 farms)	204.5	186.9	-17.6	0.40
Reproduction (n=19 farms)	169.2	201.7	+32.5	0.05

Table 4. Average monthly feeding cost cow⁻¹ per month at the start of the intervention (6-month baseline) and at the end of the intervention (6-month end-line), for 70 Kenyan smallholder dairy farms in 2016-2017, by intervention group (1 USD=KES 101.2).

Group	Average feeding cost - Baseline in KES (USD)	Average feeding cost - End-line KES (USD)	Change in average feeding cost in KES (USD)	Paired t-test p-value
Comparison (n=17)	3,669.3 (36.3)	2,286.9 (22.6)	-1,382.4 (13.7)	0.03
Nutrition (n=17)	3,325.1 (32.9)	2,939.7 (29.1)	-385.4 (3.8)	0.35
Combined (n=17)	3,879.1 (38.3)	2,529.0 (25.0)	-1,350.1 (13.3)	0.001
Reproduction (n=19)	4,699.6 (46.4)	3,597.5 (35.6)	-1,102.1 (10.8)	0.04

Mean feeding expenses decreased from baseline to end-line across all groups by 44.1% for maize silage, 40.4% for wheat bran, 32.2% for dairy meal and 31.7% for maize germ. Across the groups, the mean monthly feeding expenditure decreased, from an average of KES 3,325.1 – 4,699.6 (USD 32.9 – 46.4)/cow at baseline to KES 2,286.9 – 3,597.5 (USD 22.6 – 35.6)/cow at end-line (Table 4). The decrease in feeding expenses was significant in all groups ($p < 0.05$), except for the nutrition group.

The average monthly profits/cow significantly increased from the baseline to the end-line for all groups except the

combined group (Table 5). The change in average monthly profits/cow in the nutrition group increased by 68.8%. Table 6 provides two-way group comparisons of net profit changes for all possible combinations of intervention groups. There were significant net changes in average monthly profits/cow across all groups except between the nutrition and reproduction groups.

KAP questionnaire responses

Compared to the comparison and reproduction groups,

Table 5. Average monthly profit cow⁻¹ at the start of the intervention (6-month baseline) and at the end of the intervention (6-month end-line), for 70 Kenyan smallholder dairy farms in 2016-2017, by intervention group (1 USD=KES 101.2).

Group	Average profit – Baseline in KES (USD)	Average profit – End-line in KES (USD)	Change in average profit in KES (USD) (%)	Paired t-test p-value
Comparison (n=17)	2,307 (22.8)	3,923.5 (38.8)	+1,616.5 (16.0)	0.03
Nutrition (n=17)	3,457.6 (34.2)	5,837.9 (57.7)	+2,380.3 (23.5)	0.02
Combined (n=17)	3,688.1 (36.4)	4,387.9 (43.3)	+699.8 (6.9)	0.40
Reproduction (n=19)	1,561.5 (15.4)	3,866.9 (38.2)	+2,305.4 (22.8)	0.002

Table 6. Two-way group comparisons of net change in average monthly profit cow⁻¹ at the start of the intervention (6-month baseline) and at the end of the intervention (6-month end-line), for 70 Kenyan smallholder dairy farms in 2016-2017 (1 USD=KES 101.2).

Profit change in KES (USD)	Profit change in KES (USD)	Unpaired t-test p-value
Comparison= 1,616.5 (16.0)	Nutrition = 2,380.3 (23.5)	0.01
Comparison= 1,616.5 (16.0)	Combined = 699.8 (6.9)	0.001
Comparison= 1,616.5 (16.0)	Reproduction = 2,305.4 (22.8)	0.004
Reproduction = 2,305.4 (22.8)	Nutrition = 2,380.3 (23.5)	0.78
Reproduction = 2,305.4 (22.8)	Combined = 699.8 (6.9)	<0.001
Combined = 699.8 (6.9)	Nutrition = 2,380.3 (23.5)	<0.001

Profit change = (Average baseline profit) - (Average end-line profit).

Table 7. Summary of selected questionnaire responses by 70 smallholder dairy farmers post-intervention in Kenya in 2017, by intervention group.

Question	Comparison group (n=17)	Nutrition group (n=17)	Combined group (n=17)	Reproduction group (n=19)	P-value
Feeling of empowerment to raise calves/heifers to achieve first calving at 27 months					<0.001
Yes	17.6% (3) ^a	100% (17) ^b	88.2% (15) ^b	21.1% (4) ^a	
No	82.4% (14)	0% (0)	11.8% (2)	78.9% (15)	
There is special mineral supplement for dry cows					0.007
True	52.9% (9) ^a	82.4% (14) ^a	100% (17) ^b	73.7% (14) ^a	
False	47.1% (8)	17.6% (3)	0% (0)	26.3% (5)	
Agroforestry can be a sustainable land use system					<0.001
Yes	0% (0) ^a	94.1% (16) ^b	64.7% (11) ^c	5.3% (1) ^a	
No	100% (17)	5.9% (1)	35.3% (6)	94.7% (18)	

all the farmers in the nutrition group and most of the combined group (88.2%) felt they were now more empowered in dairy management. For example, at the end of the trial, these farmers felt that they were able to raise calves and heifers optimally to achieve age at first calving (AFC) of about 27 months of age (Table 7). As well, significantly more farmers in the nutrition and combined group than the comparison group correctly indicated that the main benefit of colostrum was to

provide the calf with immunity (Figure 2). Also, more farmers in the combined group than in the other groups knew that there was a difference in mineral for dry cows and for milking cows (Table 7). More farmers in both the nutrition and combined groups than the comparison and reproduction groups reported that agroforestry could be a sustainable land use system (Table 7).

More farmers in the nutrition and combined groups felt confident and informed on matters of dairy farming and

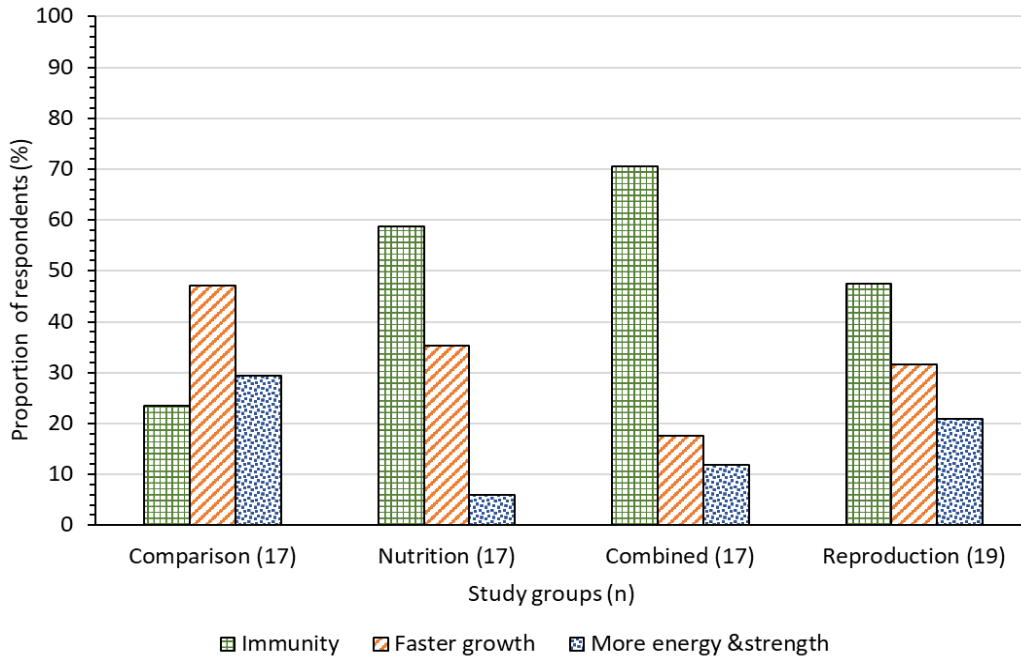


Figure 2. Post-intervention descriptive analysis of the knowledge of farmers on the main reason for feeding first colostrum to calves among 70 Kenyan smallholder farms in 2017, by intervention group.

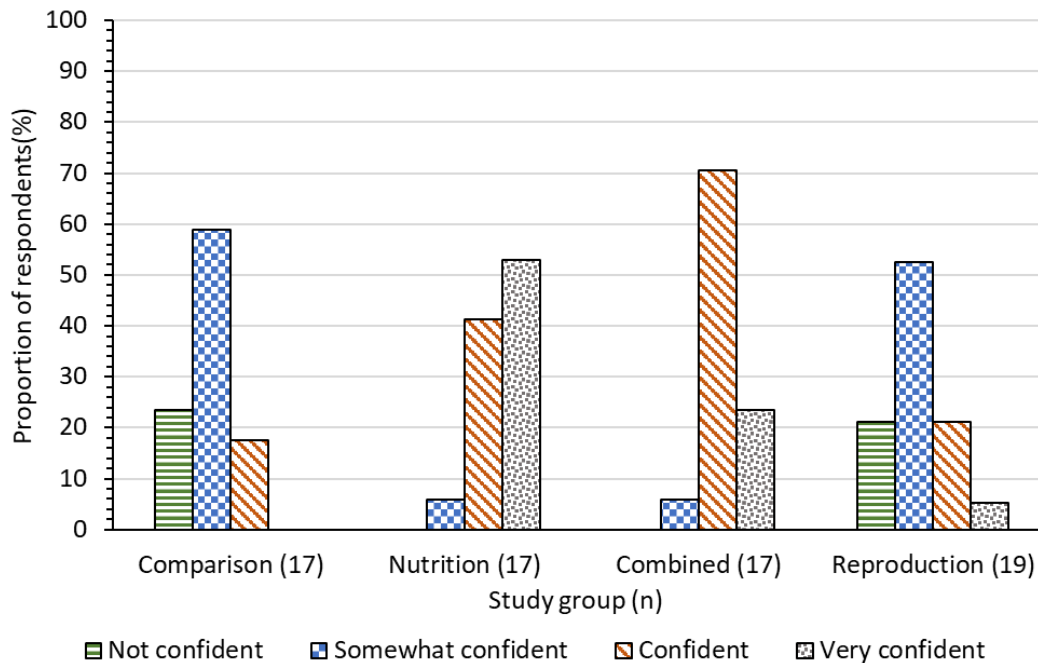


Figure 3. Post-intervention descriptive analysis of levels of confidence of farmers on dairy farming and nutrition among 70 Kenyan smallholder farms in 2017, by intervention group.

nutrition, compared to the comparison and reproduction groups (Figure 3). The mean, standard deviation and median scores of confidence levels were 1.9, 0.7, 2.0 for the comparison group, 3.5, 0.6, 4.0 for the nutrition group, 3.1, 0.7, 3.0 for the combined group, and 2.1, 0.8,

2.0 for the reproduction group. These scores were significantly higher for the nutrition and combined groups compared to the comparison and reproduction groups ($p < 0.001$), while there was no significant difference in scores between the nutrition vs combined groups and

between the comparison vs reproduction groups ($p > 0.05$).

Focus group discussion

From the intervention and comparison groups, 20 farmers (67% women) participated in the focus group discussions. Farmers unanimously reported that dairy production was the main source of livelihood in the area and indicated that they would not substitute it with any other form of farming. Some farmers said, "Dairy farming is the backbone of our households". Some of the benefits farmers reported to have accrued from dairy production, especially with improved milk production, included: better nutrition through drinking fresh milk/yoghurt; a source of family income through milk sales, and thus it was a major pathway from poverty; collateral for credit acquisition; a source of school fees for the children through milk sales; cattle as a form of savings for future liquidation, if necessary; livelihoods security that allowed farmers to diversify into other kinds of farming; a source of manure for sale and use on farms for better crop yields and animal feed production; beverages (milk/tea) for hosting social functions for visitors; and use of cows/heifers for dowry payment. Given the extent of the role of dairy production, farmers were positive that any improvement in the productivity of their enterprises would be of great benefit to their households.

The nutrition and combined groups (those who received shrubs and education) unanimously reported that they had seen some improvement in returns from their dairy enterprises since they began participating in this trial. The comparison and reproduction groups (those who did not receive shrubs) indicated that they had seen a slight improvement but would wish to have made more improvement. Although the comparison group did not receive any direct intervention, farmers cited the informal advice offered during the farm visits and from other farmers to have contributed to the improvements observed. Some farmers within the comparison group reported that their friends in the nutrition-related intervention groups had shared seeds of the *C. calothyrsus*/*S. sesban* shrubs with them and they had started some nurseries of their own on their farms.

The most important challenge raised by the farmers in both the intervention and comparison groups was low milk production during the dry season and early rainy season due to inadequate quality and quantity of feed. This low milk production was mentioned as a more serious constraint in the comparison groups than it was in the intervention groups who reported, "Milk production has not reduced much in the last dry season as it has been in other years". Some farmers said that since they started using the shrubs, they no longer used dairy meal on their farms and instead used the shrub foliage with wheat bran and that milk production was still good.

Although farmers in both groups knew about silage-making, the largest hindrance for this form of feed conservation was the costs involved.

Farmers in the intervention groups unanimously reported that they would recommend these shrubs to other farmers saying, "Because they increase milk production!". As a result, the women reported they had shared this information in different women's groups, and some women had been requested to supply seeds to the women groups while others had managed to convince new members to join NDFCS to benefit from such interventions in the future. Male farmers indicated that although they did not share the knowledge about the shrubs in men groups/gatherings, they had shared their knowledge with neighbors and managed to convince their neighbors to attempt using these shrubs on their farms.

DISCUSSION

From the partial budget analysis, it was evident that there were significant changes in monthly milk production and profit/cow between the first 6 months and last 6 months of the trial. These time periods were selected purposively because it was expected that at the beginning of the trial, the shrubs were not evenly mature to provide constant foliage to the cows enough to significantly affect milk production. Additionally, replacement of dead seedlings was also done during the middle of the trial period. During the last six months of the trial, it was assumed that all shrubs in the nutrition and combined farms were evenly mature and were being used on all the farms, providing a basis for comparison between farms that had shrubs and those who had not received any shrubs.

The 68.8% increase in monthly profits/cow in the nutrition group (Table 5) was associated with a significant improvement in average monthly milk production/cow (Table 3). This increase in milk production would be largely attributed to the nutritional interventions (feeding shrubs and farmer education) implemented on farms in these groups. Better nutritional management and feeding of higher amounts of CP to cows would lead to an increase in the amount of milk produced by lactating cows. Farmers feeding these shrubs to cows could also reduce the amount of dairy meal fed and still maintain a good level of production. Similar observations have been made after adoption of different feeding interventions in SDFs in Kenya and other African countries (Omoro et al., 2004; Van Leeuwen et al., 2012; Trees for the Future, 2016). With an average of more than 50% of household income in SDFs typically attributed to dairy production (Van Leeuwen et al., 2012), this increase would undoubtedly translate to better livelihoods.

The cost for *C. calothyrsus* and *S. sesban* seedlings at the time of publication in Kenya was approximately KES 25, therefore 300 seedlings would total KES 7,500. Assuming the seedlings were purchased at this price,

with the nutrition group having increased its monthly profit by over KES 2,300, the return on the investment would only take 3.5 months, after which time, the additional profit would be available for other expenditures.

The average monthly feeding expenses decreased for farms in all groups. The decrease was significant for all groups except the nutrition group; probably because they had already started feeding the shrubs around the baseline period and already made some adjustments to their feeding practices. These farmers may also have felt that with the additional CP from shrubs, they needed to maintain energy to enhance milk production and reproduction. Some of the reduction in feeding expenses attributable to maize silage could be because farmers were running low on amounts of silage. However, there were no significant changes in monthly profits for SDFs in the combined group, primarily due to a decrease in milk production (Tables 3 and 5). This decrease in milk production could be attributed to farmers in the combined and reproduction groups focusing more on getting their cows pregnant (the primary objective of reproduction interventions). For example, in the reproduction group, farmers were observed to reduce their milking frequency when cows seemed to be losing body condition and taking a long time to come in heat, especially when there were feed shortages. These farmers' rationale was that reduced milk production would counter the negative energy balance experienced during suboptimal feeding.

Farmers in the nutrition and combined groups were significantly more knowledgeable and aware of good dairy nutrition practices compared to the comparison and reproduction groups (Figure 2 and Table 7), which demonstrates a benefit of the nutrition intervention. Better knowledge of dairy nutrition would promote better on-farm and off-farm decision-making, thus resulting in more efficient farm management and increased profits, leading to improved livelihoods (Chapman et al., 2003; Mtega, 2017). Moreover, farmers in the nutrition and combined groups reported that agroforestry could be a sustainable land use system (Table 7). Generally, SDFs in this area, as is common in other parts of Kenya, are on relatively small acreages (Richards, 2017; Maina et al., 2018). Adoption of agroforestry would reduce vulnerability to, and effects of, feed shortages on household income and economies, translating to improved and sustainable livelihoods (Kiptot et al., 2014; General Secretariat of the Organization of American States, 2015). Franzel et al. (2013) cited similar impacts and benefits on farmer livelihoods in Zimbabwe, Ethiopia and Uganda after planting and using fodder trees on their farms.

Farmers in the nutrition and combined groups felt more empowered and were significantly more confident about general dairy nutrition and raising calves and heifers for earlier age at first calving (Table 7 and Figure 3). The average AFC of heifers in SDFs in Kenya was estimated at 34 months but could be up to 40 months (Menjo et al., 2009). A reduction in AFC would subsequently translate

to high returns resulting from higher lactation days per lifetime (Krpáľková et al., 2014) which would lead to improved livelihoods. Moreover, increased empowerment and confidence observed among farmers in the nutrition and combined groups was likely indicative of intangible impacts of the interventions towards improved livelihoods (Ashley and Hussein, 2000; Oxfam, 2014; Horsley et al., 2015). These farmers would most likely be able to make effective decisions on farm management, leading to more efficient production and increased returns.

It was encouraging to get positive responses from the farmers during the FGDs regarding the agroforestry systems offered in the trial and how the leguminous shrubs helped mitigate the effects of feed shortage in milk production. Given the central role of dairy farming in this community, it was clear that any benefits in productivity and profit observed on the farms translated into better livelihoods for the household. Similar findings were observed in a longer study that integrated a suite of interventions to improve SDFs production in rural Kenya, including nutrition, reproduction, cow comfort, deworming and mastitis control (Van Leeuwen et al., 2012). Farmers who fed cows on leguminous shrubs in Ethiopia, Zimbabwe, Uganda and Kenya also reported benefits through increased milk production and reduction in feeding costs (reduced dairy meal use) (Cook et al., 2005; Franzel et al., 2013; Richards, 2017).

Farmers in the study had participated in different knowledge transfer activities within their circle of friends and neighbors, resulting in increased membership to the NDFCS. Such indirect benefits of the intervention are encouraging. Growth in NDFCS would translate into other socioeconomic benefits to the Naari area since the Dairy also supplied basic foods and household amenities to the community, and availed a credit facility to active members who shipped milk to the NDFCS, as was observed in Nyeri County, Kenya (Van Leeuwen et al., 2012).

Among the limitations of this study, farmers in this trial were not able to accurately indicate how much time they used to plant and manage the shrubs. There were no reports of any additional hired labor since most of the farms were generally worked with household members whose primary occupation was farming. Lack of that additional information limited the quantification of indirect costs and opportunity costs of having the shrubs on the farm. These potential costs were not factored into the partial budget. However, the labor to manage the shrubs beyond the first few months when the shrubs were establishing their roots would be minimal and would be similar to the management of other forage crops in terms of tending, fertilizing, and harvesting the forage crops.

Another limitation to the study was that the random allocation did not lead to completely equal farm and animal demographics and management, due to the small size of the farms and that there were just 20 farms in each group. For example, breed, DIM, the prevalence of

subclinical mastitis, and pregnancy status were significantly different between groups, and the number of cow observations during the wet season was not the same among the four trial groups at baseline (Table 1). Some of these factors could have also had an impact on the changes in milk production and feed costs, and therefore changes in profit. However, factors such as pregnancy and DIM would be less likely to affect profit since farmers would likely reduce purchased feeds provided to pregnant cows and those with high DIM, coinciding with their lower milk production.

Notwithstanding these possible confounding factors on milk production and profit, the estimates of improvements to these outcomes from the nutritional interventions are likely conservative for a couple of reasons. The initial 6 months was a quasi-baseline in the sense that there were already nutritional interventions in the form of nutritional advice provided to the farmers during this time. A monitoring period prior to this time frame was not possible for logistical reasons. Secondly, the research team noticed that on a minority of farms with leguminous shrubs, the shrubs were already being harvested and fed to the cows during this first six months of baseline. Both of these circumstances likely led to a baseline level of milk production that was potentially higher than if neither of these situations happened, suggesting that the impacts on milk production and dairy net income were possibly underestimated.

As a third limitation, due to the close geographical placement of the intervention and comparison farms, it was likely that some level of unintentional information transfer to the comparison farmers from the intervention farmers occurred. This information transfer could bias the responses and practices of those comparison group farmers and the measurements of their cows. However, the farmers in the comparison group did not have leguminous shrubs on their farms, except perhaps from neighbors at the very end of the study, reducing this possible bias. If anything, this bias would only make the estimates in the differences in profits between groups more conservative than they really are. However, from a livelihood development perspective, this spread of leguminous shrubs would be a 'good problem' to have. The natural spread of this land management model could have extensive benefits to the incomes and livelihoods of the community and SDFs.

Conclusion

The nutritional interventions (education and *C. calothyrsus* and *S. sesban* shrubs) with and without reproductive interventions had positive financial, knowledge, and practice impact on the livelihoods of farmers. Agroforestry, using *C. calothyrsus* / *S. sesban*, with supportive education/training, can improve dairy farm household incomes and livelihoods if adopted by SDFs in Kenya,

where agroecologically appropriate.

RECOMMENDATIONS

Use of *C. calothyrsus* and *S. sesban* in an agroforestry land management system has many benefits (tangible and intangible) not only to the farmer but to the environment as well. Adoption of this land management system by farmers would be optimized with adequate infrastructural and extension support by relevant authorities. A more detailed study on the impact of intercropping these shrubs with food crops and using them in the long-term sustainability of agricultural ecosystems would elucidate other benefits not explored in these analyses.

With the increasing human population and land fragmentation, leading to shrinking land available to individual dairy farmers, there is need for more intensive but sustainable farming methods. Smallholder dairy farms should adopt an agroforestry land management model for more intensive and sustainable production and more stable incomes from their dairy cows.

From our findings and other cited research, use of leguminous shrubs has the potential to reduce production costs while improving milk production in dairy cows. These two factors are directly related with better incomes. Stable household incomes, prevailing weather notwithstanding, would contribute to less vulnerable household economies and more sustainable livelihoods.

Ethical approval

This study was approved by the Research Ethics Board and the Animal Care Committee of UPEI, NDFCS, and FHF, a partner non-governmental organization. Consent of all participants was obtained after the study was fully explained.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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