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Effectiveness of the farmer-field-school approach in small-scale mixed crop-livestock systems in Burundi

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Abstract

Dairy farming is one of the means to meet the growing demand for milk and reduce rural poverty in developing countries. To improve its productivity, many agricultural approaches have been tried, including the Farmer-Field-School (FFS) approach. This study aimed at evaluating the effectiveness of this approach in terms of the adoption of new technologies introduced in small-scale mixed crop livestock systems in Burundi to improve its productivity. A survey was carried out among 98 FFS members and 78 non-members. Technology adoption rates were calculated among FFS and non-FFS members, as well as annual profits per cow. The results showed higher adoption rates among FFS respondents compared to non-FFS respondents for cemented barn floors, traditional lick-blocks, and manure composting, whereas fertilisation of fodder crops, treatment of hay with molasses/urea, and concentrate making were less adopted for the two groups. The annual gross margin was higher for the FFS-group (median: 654 US$) compared to the non-FFS one (median: 542 US$). The study showed that the dissemination of new technologies among non-supported, non-FFS farmers remained low. It is concluded from the results that FFS approach brings about a positive change in farmers' behaviour towards adopting improved technologies. However, the results identified a number of constraints limiting the effectiveness of this approach including the low availability of inputs, the low financial capacities of farmers, and the complexity and/or the high price of certain technologies. Our results may provide useful information for strengthening the FFS approach in Burundi. For instance, a consistent financial support and follow-up are important for the sustainability of FFS practices. Harmonizing the market prices along the milk value chain is also proposed to increase incomes from the sale of milk.

Keywords: annual margins, dairy cattle farming, improved technologies, multifunctionality, participatory extension

1 Introduction

Dairy farming is seen as one of the important means to meet the increasing demand for milk and reducing rural poverty, particularly in developing countries (Kidoido & Korir, 2015; Groot & Van't Hooft, 2016). It is perceived as a multipurpose activity that increases the level of diversification of livelihoods and reinforces the synergy with crop production (Tarawali *et al.*, 2011). Dairy farming also has a significant social impact by creating jobs through dairy farmer cooperatives and by providing a feed market to people who do not necessarily possess livestock (Udo *et al.*, 2011; Balak & Mukul, 2015). However, this sector still faces many challenges that have limited its potential in terms of milk productivity (Leroy *et al.*, 2015). Indeed, sustainable improvement of milk production involves appropriate agricultural innovations in the field of feeding, genetics, and health care, as well as in the value chain approach (FAO, 2018).

Public agricultural extension services have been always considered as an essential means of enabling farmers to take ownership of these technologies. However, they have been criticized for their ineffectiveness, due to difficulties to reach marginalised farmers and the resistance of some farmers to change their habits (Ponniah *et al.*, 2007; FAO, 2018). New agricultural innovative approaches have been tried, including Farmer-Field-Schools (FFS), particularly in eastern and southern Africa (Kilelu *et al.*, 2013). The FFS approach

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is described as a forum where farmers (25 to 30 members per FFS) regularly meet, interact and find solutions locally for a specific topic such as dairy farming. FFS creates a social solidarity network where farmers discuss their problems, share experiences and help each other. A facilitator guides the group members in their search for solution and helps them to diagnose a problem and to find a solution (Braun & Duveskog, 2011). The benefit of such an approach is that small-scale dairy farmers will adopt innovations that they have tested and validated, which strengthen their technical skills through “learning by doing” (FAO, 2018). Participants are encouraged to share their knowledge with other neighbouring farmers. Thus, another expected advantage of FFS is the spin-off effect for non-FFS farmers living in the same communities as FFS farmers, through knowledge dissemination and replication of technologies (Waddington *et al.*, 2014; Butt *et al.*, 2015). The FFS approach could also provide a window to negotiate with input and output markets and strengthen links with research and development institutions (De Vries, 2008). The result would be an improvement in dairy production and farmers’ incomes. However, the effectiveness of the FFS approach may be hampered by several problems that impede spontaneous adoption and diffusion of knowledge and practices. These include, for example, the limited access to agricultural inputs and markets, and farmers’ habits and attitudes (Waddington *et al.*, 2014; Butt *et al.*, 2015).

In Burundi, small-scale dairy farming (1 to 3 dairy cows) has received particular attention as a strategic way to overcome hunger and poverty. Indeed, after a decade of civil war (1993-2002), the Government promoted, through rural development projects, the restocking of small-scale farms with dairy cattle (Ankole-Holstein crossbreds), particularly in the densely populated highlands. This was strengthened by an approach of community solidarity chain, in which the first beneficiary gave his first calf to another beneficiary of the chain. Then, with an optimal integration of fodder crops in the fields, a household with at least 0.5 ha of arable land could keep a dairy cow. The income from the sold milk would help reduce poverty in that household (PARSE, 2012; PAIVA-B, 2017). However, dairy milk production remained lower than expected, thereby limiting household profits from the dairy farming activity (Manirakiza *et al.*, 2017). Hence since 2014, the Ministry of Environment, Agriculture and Livestock of Burundi, through rural development projects, adopted the FFS approach and construction of milk collection centres to increase both dairy production and market accessibility (Ministry of Environment, Agriculture and Livestock, 2014). In this paper, restocking of dairy cattle, the FFS approach, and construction of milk collection centres will be referred to as the ‘project’. The project started with the training of eighteen master trainers in the FFS approach in Nairobi at FAO Kenya institution, for a period of six weeks towards the end of 2014. Thereafter, each master trainer had to implement a pilot FFS and to organise weekly training sessions for the FFS members. At the end of the implementation cycle of one year, the master trainers were brought together to share their experiences with the pilot FFSs. These master trainers were then authorised to train local facilitators (a veterinary technician per commune), who had to organise and carry out FFS activities under the supervision of master trainers. Up to 2018, around 200 FFSs (25 to 30 members each) have been implemented throughout the country. Two out of three FFSs focused on dairy production of milk and were connected to almost 24 milk collection centres (FAO, 2018). Despite this widespread adoption of the FFS approach in the dairy sector, it is unclear whether it is not constrained by rural area factors, including the low level of access to the inputs required to adopt the innovations proposed within the FFS. Indeed, the innovation process is influenced by many factors such as infrastructure, markets, policies, rules and regulations, and cultural practices (Yadav *et al.*, 2020), which are generally lacking in the smallholding systems in Burundi.

As suggested by Mvena *et al.*, (2013), the effectiveness of the FFS approach should be understood as a measure of the achievement of its objectives, i.e., in terms of the acquisition and adoption of improved practices by FFS and neighbouring non-FFS members and in terms of improving the economic productivity of the herd. Indicators of this economic productivity are usually the annual gross margin (AGM) and the annual net margin (ANM) per the most limiting resource, i.e., the dairy cow in the small-scale dairy farming system of Burundi (Tokarev *et al.*, 2016; Kashish *et al.*, 2016; Datta *et al.*, 2019).

Therefore, the present study aimed to assess the effectiveness of the FFS approach in terms of adoption of new technologies proposed within the FFS members (adoption by the FFS and neighbouring non-FFS farmers) and its economic impact, taking into account the multifunctionality of dairy cattle.

2 Materials and methods

2.1 *Study area and data collection*

The study was carried out in Muramvya and Gitega provinces, located in the central highlands of Burundi, where most interventions of the project took place. The region is densely populated with an average number of 300 people km². Based on preliminary information provided by key informants (representatives of rural development projects and local extension services), six pilot FFSs were selected from the eighteen FFSs implemented by the master trainers with a focus on dairy cattle (three in each province). Within these FFSs, we selected all FFS-members who agreed to participate in the study (n=98). Neighbouring non-FFS dairy farmers (n=78) were also selected using respondent-driven sampling (snowball sampling), starting with two or three initial farmers identified by FFS members in each location. We then asked them to identify other farmers they knew who might be dairy farmers but not involved in FFS activities. The initial non-FFS farmers may be more likely to recommend people who share their characteristics or experiences, which could lead to sample bias. To minimise this type of bias, we suggested that they diversify the type of respondents according to socio-economic conditions such as age, gender and farm size. We repeated this process until we had few or no relevant new responses, thus satisfying the principle of saturation (Hennink & Kaiser, 2022).

Data were collected in two phases using mixed methods that included both qualitative and quantitative features to understand the system, but also to ensure reliability and validity through triangulation (Carter *et al.*, 2014). The first phase was exploratory in nature as it aimed at gathering the first insights concerning the FFS activities in the study area, while the second phase was to collect data about the technologies adopted and about milk production. During the first phase (25 November to 10 December 2019), we conducted interviews with five key project contacts and four focus group discussions (FGDs) with FFS members (with 10 to 15 persons for each FGD). During the second phase (from 18 September to 30 December 2020), we conducted two FGDs of eight persons each with non-FFS members and in-depth individual interviews with 98 FFS and 78 non-FFS members. During the FGDs, we used an interview guide to collect insights on the farmers' perceptions of FFSs, as well as on the dairy cattle production. The topics developed were mainly: (1); history of the FFS activities; (2) livestock technologies recommended during the FFS training period, those adopted and the reasons for their adoption; (3) the willingness to continue FFS-activities after the end of the project; and (4) the dairy cattle functions and their relative importance to the interviewees. During the individual interviews, farmers (1) provided information on their main socioeconomic attributes and on how they raise their cattle, (2) ranked the stated cattle functions using a proportional piling method with 100 "counters", which is a participatory method used to visualise relative proportions (Gizaw *et al.*, 2018), (3) enumerated the technologies that they adopted from those recommended and the reasons for their choice, and (4) provided the information required to estimate the annual costs and outputs from their dairy cattle activity. The latter information included (1) expenditures and opportunity costs related to cattle raising in the last year prior to the survey; (2) daily milk quantities collected during the first, middle and last trimester of lactation; daily milk quantities consumed at home and sold; (3) annual yields of the main crops that benefit from cow manure before and after cattle keeping, and (4) herd dynamics. i.e., the number of calvings, animals sold, deaths, and gifts. In addition, information on milk sold was recorded on individual sheets kept at the milk collection centres.

2.2 *Data analysis*

The data collected was firstly entered in Excel for further analysis. Data were analysed using the R software (R version 3.5.1). Summary statistics were computed for all variables. Categorical variables were described by percentages, numerical values through their mean and standard deviation. Proportional piling results were expressed as percentages ascribed to each of the categories to be ranked. The effectiveness of the FFS approach in the adoption of technologies was assessed as the percentage of respondents using them before and after the training period, according to the FFS membership. Chi-square test was used to assess the significant difference (p value < 0.05) between those percentages.

2.3 *Economic analysis*

We calculated the annual gross margin (AGM) and the annual net margin (ANM) per cow (taking into account the dairy cattle multifunctionality), with the following formula:

$$\text{AGM} = \text{AGR} - \text{AVC} \quad (1)$$

$$\text{ANM} = \text{AGR} - \text{AVC} + \text{AFC} \quad (2)$$

Where AGR = annual gross revenue, AVC = annual variable costs, and AFC = annual fixed costs.

$$\begin{aligned}\text{AGR} = &\text{ milk value + manure value + calves' sales +} \\ &\text{inventory change in the cowherd + calf given} \quad (3) \\ &\text{to neighbour through the community solidarity chain}\end{aligned}$$

$$\text{Milk value} = \text{milk sold} + \text{milk consumed at home} \quad (4)$$

with a market price of 0.36 US$/L. In the absence of market valuation of manure, its economic value was indirectly assessed as the annual yield difference of the main crops that benefit from manure (i.e. beans, maize and banana) before and after cattle keeping. This difference was multiplied by the market price of the crops and divided by the number of animals. As an indication, the market price was 0.55 US\$ kg^{-1}, 0.38 US\$ kg^{-1} and 3.83 US\$ $bunch^{-1}$ for beans, maize, and banana, respectively. To assess the value of the change in the herd's stock, we computed the difference between its market value on arrival at the farm (estimated by livestock service agents at the day of donation) and its value at the time of the survey (estimated with the help of a trader experienced in selling animals in collaboration with the farmer). To this was added the value of its calves and an interest rate on the estimated change in the herd (with an annual interest rate of 10 %), to take account of the traditions that underpin the ownership of a dairy cow. The total was divided by the number of years since the farmer owned the cow. As an indication, the market prices for a calf and an adult cow were estimated at US\$ 355.74 and US\$ 656.74, respectively.

$$\text{AVC} = \text{APL} + \text{OCFL} + \text{purchased LFCLV} \quad (5)$$

With AVC = annual variable costs; APL = annual paid labour; OPFL = opportunity-cost of family labour, estimated based on the daily time used to cut and carry forage, to search for drinking water and litter, to clean the barn, and to sow and weed forages. This was estimated based on the daily salary for one man-day of US\$ 1.1, with a work time of 8 hours. Purchased LFCLV means purchase of litter, forage, concentrates and lick-blocks as well as the expenses for veterinary care.

As suggested by Kashish *et al.* (2016), the AFC was estimated by including the annual depreciation cost of the barn (estimated from our observations and the farmers' declarations) and the annual interest on the value of the cow when it was given to the farmer (considering a cow as a credit that can be repaid). The interest rate was set at 10 % because this is the rate used in savings and credit cooperatives in Burundi.

The Kruskal-Wallis test was used to determine whether the medians of the economic parameters (AVC, AFC, AGR, AGM, and ANM) were significantly different between FFS and non-FFS members. The p-values have been set at 5 %.

3 Results

3.1 General characteristics of farmers and dairy farming

The general characteristics of the farmers surveyed are summarised in Table 1. No significant difference was found between respondents of the FFS and non-FFS groups (overlap between ranges), although the non-FFS respondents appear to have higher means than the FFS respondents. They all lived on farms with an average land size of 1.6 ha and had about 4 years of experience of rearing cattle. Educational levels were moderate, with almost half of the FFS respondents having completed primary school and 40 % of the non-FFS respondents having more than 6 years of schooling. The average herd size was 3.5 TLU. All FFS respondents had received a cow directly from the project or indirectly through the community solidarity chain, while 75 % of the non-FFS respondents had not received project support. Of the 176 respondents, 85 also kept pigs, 93 kept goats, and 60 kept chickens (Table 2). In terms of dairy cattle management, all farmers practised semi-zero-grazing or stall-feeding, with cultivated grasses (*Tripsacum laxum* and *Pennisetum* sp.) and crop by-products as the main feeds.

Table 1: *Means and standard deviations (SD), medians and ranges (minimum-maximum) for the characteristics of surveyed farmers according to their membership of a farmer field school (FFS).*

	FFS respondents (N=98)			*Non-FFS respondents (N=78)*		
Characteristics	*Mean (SD)*	*Median*	*Range*	*Mean (SD)*	*Median*	*Range*
HH sex:						
Men (%)	79			91		
Women (%)	21			9		
Formal education HH*						
None (%)	18.4			21.8		
Primary (%)	52.0			35.9		
Secondary (%)	29.6			42.3		
Age HH (years)	43.2 (10.6)	39.5	28-73	48.8 (13.2)	46	28-78
Number HH members	6.4 (3.1)	6	3-8	5.4 (3.1)	5 (3.8)	2-9
Farm size (ha)	1.3 (0.7)	1.2	0.5-3	1.7 (0.9)	1.6	0.5-4
Experience (years)†	3.4 (1.4)	3	2-9	6.2 (1.6)	5	3-12

HH = household head; *Primary: 1 to 6 years of education; Secondary: more than 6 years of education; †Experience in cattle rearing.

Table 2: *Means and standard deviations (SD), medians and ranges (minimum-maximum) in tropical livestock units (TLU) for animals owned according to a farmer's membership of a farmer-field school (FFS).*

	FFS respondents (N = 98)			*Non-FFS respondents (N = 78)*		
Animals owned	*Mean (SD)*	*Median*	*Range*	*Mean (SD)*	*Median*	*Range*
Cows	2.8 (0.7)	3.2	1 – 4	4.5 (0.9)	4.8	1 – 7
Calves	0.6 (0.5)	0.6	0 – 2	0.6 (0.4)	0.6	0 – 2
Goats	0.37 (0.12)	0.3	0.1 – 0.7	0.43 (0.3)	0.4	0.1 – 0.8
Pigs	0.88 (0.3)	0.2	0.2 – 0.4	0.36 (0.2)	0.2	0.2 – 0.6
Chickens	0.07 (0.04)	0.06	0.01 – 0.15	0.05 (0.03)	0.06	0.04 – 0.07

Table 3: *Technologies used in farmer field schools (FFS) and percentage of FFS and non-FFS respondents using them before and after FFS training period.*

	Percentages of respondents using the technologies					
	FFS respondents			*Non-FFS respondents*		
Technologies in the FFS trainings	*Before*	*After*	*P value*	*Before*	*After*	*P value*
Grass-hedges around crop fields	100	100		100	100	
Planting *Calliandra* sp.	0	48.5	**	0	17.6	**
Fodder crop fertilisation	0	29.3		0	0	
Cow supplementation with cereal brans	50	100	**	78.7	100	
Traditional lick-blocks	0	91.4	**	0	36.4	
Hay treatment with molasses/urea	0	29.3		0	0	
Concentrate making	0	0		0	0	
Internal deworming	100	100		100	100	
Acaricide spraying	65.5	100	**	100	100	
Diagnosis of Theileriosis	37.9	100	**	46.8	100	**
Cemented floor in the barn	0	98.3	**	0	0	
Sanitary milking control	0	45	**	0	15	
Oestrus detection	100	100		100	100	
Inbreeding control	0	100	***	0	100	***
Improved composting of manure	20.7	86.2	**	0	18.2	
Improving banana productivity	0	62	**	0	17	

***: 1 % significance level; **: 5 % significance level.

On a proportional basis, respondents perceived that crop and dairy farming contributed 59 % and 32 % respectively to their livelihoods. They perceived the functions of dairy cattle to be mainly the production of manure (37 %) and milk (23 %), but also for savings/insurance (19 %), social prestige for the household (14 %), and social role in the community through the solidarity chain (8 %).

3.2 Impact of FFS approach on the adoption of new practices

Sixteen livestock technologies were discussed during the FFS training period (Table 3). Of these, seven focused on improving animal nutrition, five on hygiene and health conditions, two on reproduction management practices, and two on improving crop yields. Overall, the percentage of respondents who adopted new technologies was higher among FFS respondents than among non-FFS respondents (Table 3). The majority of household heads who adopted new technologies (73 %) were relatively well educated (primary and secondary education levels) and were under 50 years of age. In contrast, those who did not adopt these technologies were uneducated and almost over 50 years old. In the FGD, FFS members outlined the financial empowerment derived from the project. These included the provision of cement on credit to enhance hygiene conditions in the barns, the establishment of feed and medicine shops at milk collection centres, the distribution of grass seedlings (*Pennisetum purpureum*, *Tripsacum laxum* and *Calliandra* sp.) to increase forage

Table 4: *Means (standard deviations: SD) and medians of costs and revenues of surveyed smallholder dairy farmers by farmer field school (FFS) membership in $.*

	FFS respondents (N=98)			Non-FFS respondents (N=78)			
Parameters	n^*	*Mean (SD)*	*Median*	n^*	*Mean (SD)*	*Median*	Sign.
Costs:							
Annual barn depreciation	98	38 (10)	38	78	23 (15)	16	**
Interest rate on initial investment†	98	49 (11)	49		43 (12)	44	
Total annual fixed costs	98	87 (15)	90	78	66 (24)	62	**
Fodder purchase	51	53 (38)	44	35	50 (30)	44	
Licking blocks purchase	98	10 (6)	9	78	10 (7)	8	
Cereal bran purchase	98	69 (46)	74	78	97 (70)	82	**
Total feed costs	98	132 (38)	123	78	157 (56)	138	**
Litter purchase	3	28 (14)	27	27	37 (23)	27	
Veterinary care expenses	98	24 (12)	25	78	28 (13)	29	
Family labour value	98	241 (72)	246	78	233 (97)	222	**
Paid labour	6	87 (27)	77	8	92 (18)	82	
Total annual variables costs	98	512	488	78	547	520	**
Total annual costs	98	599 (90)	585	78	613 (213)	585	
Revenues:							
Milk sales	98	271 (126)	251	78	252 (105)	234	
Milk home consumed	98	172 (81)	154	78	148 (68)	156	
Total milk value	98	443 (211)	404	78	400 (175)	384	
Manure value	98	474 (238)	396	78	418 (259)	387	**
Calves' sales (annualised)	16	78 (17)	77	27	95 (25)	83	**
Herd inventory change	98	102 (74)	93	78	148 (97)	115	**
Value of calves paid back	47	79 (42)	82	12	49 (36)	44	***
Annual Gross revenue	98	1135 (370)	1056	78	1064 (355)	1028	**
Annual Gross margin	98	623 (314)	654	78	517 (219)	542	**
Annual Net Margin	98	536 (282)	570	78	451 (279)	496	

*Number of farmers; †cow value at dairying beginning; Sign. = Significance; ***: 1 % significance level; **: 5 % significance level.

availability at the farm level and that of banana as a means of generating incomes from banana cultivation.

Theileriosis diagnosis and inbreeding control (exchange of bulls between administrative villages with the help of veterinary services) were not common before the training period but were adopted by 100 % of respondents in both groups. However, participants expressed the constraints associated to the failure of artificial insemination and infertility of some bulls distributed. The use of traditional licking blocks (2.3 ± 1.1 blocks of 5 kg per year) and of cemented flooring in the barn were also not common before the training period but were mostly adopted by FFS respondents. Traditional licking blocks were manufactured by FFS members for sale. The prices of these blocks were lower for FFS members (US$ 1.5 and US$ 3 for 2 kg and 5 kg of licking blocks, respectively), while these prices were doubled for non-FFS members. Planting grass hedges around crop fields, acaricide spraying and internal deworming were common practices among farmers, but their use increased among FFs farmers after the training period. In the FGDs, these farmers expressed that they had increased the quantity of forage production by about two times after the training; they also expressed that they had increased the frequency of acaricide spraying from two or three times a month to once or twice a week.

Planting *Calliandra* sp. (a tree legume), forage fertilisation, hay treatment with molasses/urea, and sanitary milking control were less adopted by farmers from both groups. From the FGDs, legumes were scarcely utilised in animal feeding, while the legume seeds introduced (*Desmodium* sp., *Mucuna* sp.) in the demonstration plots as seed multiplication plots did not perform as well as expected. For *Calliandra* sp., the project provided seedlings to dairy FFS members, while non-FFS members had to purchase seedlings themselves. Neither FFS nor non-FFS respondents produced concentrates, cereal bran being the most popular supplement used during the lactation period, with an average daily intake of 2 kg. This amount was significantly higher among FFS respondents (2.6 kg day-1) compared to non-FFS respondents (1.7 kg day^{-1}).

Most FFS respondents (86.2 %) improved manure composting. As expressed during the FGDs, this consisted of collecting the solid fraction, urine, feed refusals, and occasional litter and storing it in a covered heap/pit. The majority of non-FFS respondents (81.8 %) did not adopt this technology. They expressed that they spread litter directly in the barn to increase the amount of manure; 57.4 % of them had to purchase litter. Thanks to the manure compost, more than half of the FFS respondents (62 %) increased their banana yield, while only 17 % of the non-FFS respondents increased their yield. The reason given by the farmers is that the more successful FFS members were supported with improved banana seedlings, whereas the non-FFS farmers had to buy these seedlings.

During the FGDs, FFS respondents stated that they will continue to practice the FFS activities after the end of the project and some non-FFS respondents expressed their willingness to join FFS groups. The reasons given were to acquire knowledge and skills in dairy cow management and to earn more income from increased milk yield. However, both FFS and non-FFS farmers mentioned that milk prices in collection centres were lower than those offered by informal traders. They also said that collection centres often reduced the volumes collected during the raining season, when milk production increases.

4 Discussion

The first point of discussion in this study is the methodological issue of selecting the pilot FFSs implemented by the master trainers. These FFSs are likely to be better trained and ultimately more successful than those implemented by local facilitators. If the effectiveness of FFSs set up by master trainers is questionable, there is reason to believe that those set up by local facilitators may be even less effective, as adequate training of facilitators plays a key role in the effectiveness of FFSs (Waddington *et al.* 2014).

4.1 Impact of FFS in adoption of improved technologies

The results showed a higher proportion of respondents who adopted new technologies after the training period among FFS than among non-FFS respondents. The reason behind could be that in addition to trainings, FFS respondents have received financial support to access the various inputs needed to adopt these technologies. Indeed, almost all FFS respondents (98 %) constructed cemented floors in their barns because of the cement granted by the project, while non-FFS respondents would have to purchase cement. They were also connected to small input shops implemented at the milk collection centres, hence the majority of them used cereal brans in animal feeding, sprayed and dewormed their animals. Furthermore, the majority of FFS respondents adopted improved composting technology whereas non-FFS respondents did not adopt such technology. Besides this improved composting, it was discussed in FGDs that FFS members were trained and supported in planting improved banana seedlings, to make their farms more economically viable. All these observations closely align with the results of other authors, who indicated that in addition to trainings, the availability of required resources and other facilities, such as markets, were significantly and positively associated with the adoption of the FFS approach and the introduction of new technologies (Minjauw *et al.*, 2017; Braun & Duveskog, 2011; Melesse, 2018).

The results revealed that among respondents in both groups, more than 70 % of adopters had a higher level of education, whereas the non-adopters were almost not educated. This indicates that the low education level of the farmers (either FFS or non-FFS members) hinders an effective adoption of improved technologies, thereby representing an additional factor influencing technology adoption. Korir *et al.* (2023) also showed that as farmers' education level increase, the more likely farmers are to adopt additional dairy technologies. We also observed that non-FFS respondents who did not adopt the manure composting, argued that cemented floors reduce the quantity of manure production. As discussed by other authors (Melesse, 2018; Korir *et al.*, 2023), they were not persuaded to use new technologies because they only believe their own longstanding experience.

Traditional lick-blocks were used significantly more often in the FFS group than in the non-FFS group. This may be due to the fact that these blocks were made by the FFS members for sale, and the price per block was lower for FFS members than for non-FFS members. Some non-FFS respondents purchased such blocks because of their accessibility if made locally and for their lower price when compared to imported blocks (US$ 9 for a block of 5 kg). Thus, the production and sale of such blocks would provide a continuous source of income to sustain this innovation. This indicates the advantage of social capital, which facilitates the adoption of some complex practices (Kilelu *et al.*, 2013). Indeed, it is easier for a group of farmers to obtain the required materials to make traditional blocks than for an individual farmer. Although almost half of the FFS members used *Calliandra* sp. in animal feeding, it was observed that forage legumes were less used to balance animal diets. This was also underlined by Shelton (2000), that although forage legumes remain essential, they are still under-exploited in tropical farming systems. For *Calliandra* sp., its utilisation rate in animal feeding was still low for both groups because seedlings were often planted too late in the middle of the rainy season, and the dry season arrived before reaching the effective size needed to be drought-resistant.

All FFS and non-FFS members incorporated grass-hedges into and around crop fields, either before or after the training period. Although FFS- farmers started to increase fodder production after the training period, they were still limited by their small farm size to produce enough fodder for their dairy cattle. Thus, they had to buy forage from non-dairy farmers, especially during the dry season. This could be seen as a forage market opportunity for non-dairy farmers. It should also be noted that some practices were not well adopted by either FFS or non-FFS members. The reasons given by farmers were poor access to the necessary resources, their low financial capacity, and insufficient training to adopt some complex technologies. In addition, farmers were constrained by the low prices offered by milk collection centres compared to informal private traders, which contributed to reducing the revenues from dairy farming and discouraged farmers to bring their milk to these centres. Waddington *et al.* (2014) and Butt *et al.* (2015) reported the same observations as main factors impeding the effectiveness of the FFS approach.

Although some technologies tended to be adopted by non-FFS members, it was observed that the FFS approach did not effectively diffuse technologies among them. As discussed by Mvena *et al.*, (2013), this observation indicates that the dairy milk production and incomes may be less compelling for FFS members and, consequently, non-FFS farmers may not be convinced of the merits of the FFS outcomes. Indeed, a socioeconomic disparity has been observed between FFS and non-FFS participants, with the former typically being less affluent and possessing fewer assets such as land and livestock. This may have hindered the dissemination of technologies, as non-FFS participants may have perceived that they had nothing to gain from learning from FFS participants. This is consistent with the findings by Najjar *et al.*, (2013), who reported that elite farmers did not perceive any benefits from participating in FFS and considered farmer learning to be a waste of time. Therefore, the new technology to be transferred should have a tangible and positive impact. A good internal dissemination mechanism is also needed to facilitate the dissemination of such technologies.

To address all the issues discussed in this section, ongoing consistent support and follow up are needed to improve the accessibility of inputs and technical skills of farmers, as well as to change some farmers' habits. Milk market prices should be harmonised along the value chain to enhance farmers' revenues from the sale of milk.

4.2 Impact of the FFS approach on improvement of dairy cattle productivity

Results of financial analysis showed that daily milk yield per cow and the annual gross margin per cow were significantly higher for FFS members compared to non-FFS members. This could be associated to the new technologies adopted by FFS members, as also indicated by Kidoido & Korir (2015), that adoption of dairy innovations had a significant and positive effect on dairy incomes. For non-FFS respondents, their large herds are likely to increase the competition for feed, which may consequently result in a reduction in milk yield per cow. This observation is congruent to that of Mugambi (2014), who underlined an inverse impact of herd size on milk yield per cow in the Kenyan highlands. Indeed, an increase in herd size would require a proportionate increase in feed availability, which is not the case in the smallholding system of Burundi.

The annual incomes from calf sales appeared to be more important for non-FFS members; the number of respondents who sold a calf was significantly lower for the FFS group (16 in 98 respondents) compared to the non-FFS group (27 in 78 respondents). This could be ascribed to the fact that FFS members had to pass on their first calf to the next beneficiary, which prolonged the time to get a marketable calf. However, this also constituted a socio-economic advantage, as it strengthened the social bond in the community.

Estimated calving intervals (25-31 months) for respondents in this study were longer compared to the 18 months, similar to what has been reported by Chapaux *et al.* (2012) for dairy smallholders located near the Mahwa station in the south of Burundi. As discussed in FGDs, PAIVA-B (2017) reported the insufficiency of bulls and the absence of qualified local services for artificial insemination, which reduce the reproductive performance of dairy cattle in the smallholding system of Burundi. Another factor could be the prevalence of some diseases, such as brucellosis, which was suspected to be endemic although not regularly detected (Merker & Schlichting, 1984; Musallam *et al.*, 2019). In terms of costs, the total cost per cow for FFS respondents was increased by the value of cement in the barn and that of the family labour, as the value of annual barn depreciation and that of family labour were significantly higher for them than for non-FFS respondents. This indicates that in addition to the initial investment required to adopt improved technologies, FFS activities were more time consuming for FFS respondents. Butt *et al.* (2015) also underlined that the FFS approach is classified as costly in terms of time and investment, which may also prevent farmers from fully participating in FFS.

As economic advantage, farmers argued that incomes from the milk sold contributed to buying livestock inputs and other family needs, such as school fees, while those from calves sold were used to purchase cropland or to construct a house. Moreover, most of the farmers connected to the milk collection centres were able to take credit in case of need, which would be reimbursed through a deduction from their monthly milk payment. In addition to these financial advantages, farmers clearly expressed an increase in crop yields since they got the cattle. All these considerations make dairy farming a preferred way for farmers to deal with rural poverty, as expressed by Muthui *et al.* (2014) in Kenya. A further economic advantage is presented by livestock ownership, which has been mentioned as a saving/insurance function for future investments and in the context where the banking system is underdeveloped or where households are not integrated into credit markets. Results showed that this function was significantly lower among FFS respondents than among non-FFS who owned the largest herds. This may point at the importance of large herds in intangible benefits of providing social security to smallholders (Moll, 2005).

The manure function was assigned the highest-ranking rate and had a significantly higher contribution to gross revenues than other functions. This is in consonance with the result of Davis *et al.* (2012), who indicated that the increase in livestock productivity due to FFS was smaller (14 %) than to crop productivity (32 %). These considerations indicate the great importance of manure in such cropping-based smallholding systems. Together, these economic advantages highlight that a financial analysis of livestock value in smallholder systems alone poorly addresses the real contribution of livestock (Moll, 2005). The non-market functions are often ignored since they are difficult to value, while they may contribute to a better understanding of existing livestock production systems and may drive the behaviour of smallholder farmers.

Although some constraints contributed to limiting the effectiveness of the FFS approach, overall the results showed positive returns. Thus, if FFS could be sustained over time, it could be considered as a way to strengthen the capacities of smallholder farmers and improve their livelihoods in Burundi. Extension efforts should focus more on long-term self-financing mechanisms (Ponniah *et al.*, 2007), such as the production and sale of traditional lick-blocks.

5 Conclusions

The FFS approach seems to allow an easy adoption of new technologies and leads to improvements in dairy cattle productivity if complementary support is provided. However, the low financial capacity and low level of education of both FFS and non-FFS farmers, the poor access to the required resources, the small farm size, the unattractive milk price, the complexity of some practices, and milk marketing issues were the main constraints that hindered the adoption and diffusion of technologies through the FFS approach. This approach could be strengthened by continued and consistent technical and financial support to improve access to inputs and farmers' technical skills, as well as by harmonising market prices along the milk value chain.

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Conflict of interest
The authors declare that they have no competing interests.

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