Specialization and diversification as adaptive strategies for smallholder dairy farming systems providing a formal milk chain in Indonesia

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Abstract. Smallholder dairy farms encounter challenges in minimal production factors that result in a lack of family income. They react differently to these limits by combining on-farm and off-farm activities (diversifying activity), concentrating exclusively on milk production (specializing activity), or leaving the dairy production to secure family livelihood. As far as adaptive strategies are concerned, they may affect milk production growth at the farm and national levels. We performed an observational case study in the West Java Province (Indonesia) to resolve those problems. We gathered information in two phases: a systematic survey (May to September 2015) to 355 farms and an in-depth interview (January to April 2017) with 20 farms. Our result distinguishes four categories of farms, along with a very small specialized dairy farm (T1), a combination of the dairy farm off-farm activity with very limited land (T2), a small specialized dairy farm (T3), and a mixed crop-dairy farm (T4). The technical-economic value varies depending on the farm type. The six trajectories prevail. The main change was the addition of off-farm activities for poor farmers. Farms in the development trajectory, two strategies coexist between the dairy production system's specialization and the mixed crops-dairy system. In conclusion, this study underscored each farm trajectory's different attributes and drivers. The study also underlined the importance of the initial capital of smallholders to illustrate their future farm trajectory.

1 Introduction

The demand for dairy products has increased enormously over the last few decades. In 2013, the need reached 750 million tons of milk equivalent worldwide, increasing demand occurred, especially in developing nations [1]. This circumstance is explained by three main factors: Massive population growth, rapid economic growth, and consciousness in consuming healthy food [2].

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In several developing nations, dairy industries seeking more milk arrange milk collection to allow smallholders access to the market and facilities (equipment, semen, feed, technical assistance, etc.) for milk production [3]. Classically, larger herds delivering more milk are interesting for farmers' economies of scale and lower collection costs for dairy enterprises. Specialized farms are fascinating to enhance household workers' capabilities, engaged in only one activity. As a result, smallholders generally exhibited in production basins organized through specialized or diversified systems, within a range of sizes depending on their assets.

Smallholder farms are associated with challenges due to minimal production factors (herd size, feed, workers, and access to land), which lead to limited family income [4]. They react in different ways to these limits. Some farmers diversify the activities by combining dairy production with other on-farm [5] and off-farm [5, 6] activities. Some others are increasingly specialized in milk production to benefit from economies of scale and enhanced practices. A few others prefer to abandon the dairy business. These strategies may impact dairy production growth at the farm and national levels. Specialization and diversification could be an adaptive strategy, but we raised some issues. To what extent are diversification and specialization a medium-term strategy for smallholders? Or do they quickly shift from one system to another? Then what are the drivers of these changes? What are the linkages between the starting level of the capital and the farm's ability to capitalize and adjust the strategies? What are the motives of many diversification pathways?

We performed an empirical study to deal with these issues. We worked in Indonesia, where smallholder farms play a crucial role in contributing to rural areas' economic growth. Smallholder dairy production provides income and creates employment opportunities for more than 150 thousand households [7]. Many producers with fewer than four cows could hardly contribute about 64 percent of nationwide milk production [8]. Limited capital might pose a challenge to improving farm-level dairy production to guarantee income and provide for the national market, which is insufficient to meet the milk product's increased consumption.

Diversification and specialization as adaptive strategies to address limited production factors of smallholder farms have received considerable critical attention. However, most studies in Indonesia have only focused on a static condition. This study performed a typology and trajectory approach to explore the effect of farmer strategies on developing milk production to secure household income and supply milk to the national market in Indonesia. Using those approaches, we would better understand the static situation and the dynamic one.

2 Method

2.1 Study Design

Study site. A study has been carried out in the North Bandung Milk Cooperative (KPSBU), involving Bandung Barat and Subang districts. Due to comfortable environmental conditions, these two districts have high farm potential (mostly dairy farms).

Sampling. We surveyed 355 out of 4000 dairy farmers, members of KPSBU. Farmers from all sub-district milk collection points were selected randomly. To better grasp the farm dynamics, We conducted in-depth interviews, including 20 out of 355 randomly chosen farms for each farm type.

Data collection. Data were obtained by a formal survey from May to September 2015 to describe the characteristics of the farms in the area. In-depth interviews with dairy producers were also carried from January to April 2017 to better understand each type of farm's trajectory. Additional data were obtained from the coop and the public authorities.

Information is taken into account. We gathered data from farmers & the coop on the characteristics and the diversity of the farm, such as the number of workers, herd size, number of lactating cows, access to land, land for forage cultivation, net income. Net dairy income was obtained from the justification of the cooperative and the farmer. Also, annual net income from on-farm or off-farm activities was collected from the rationale of the farmer.
Essential performance and productivity were also identified: total net income per farm, total net income per family worker, net agricultural income per land unit, and net dairy income per LU. To better comprehend the calculation of net dairy income per LU, we also calculated daily milk yield per LU, milk income per LU, cost of feed concentrate per LU, additional milk income per LU, and other costs per LU.

At present, we described the trajectories of 20 farms that carry out the method suggested by [9] examined the various strategies of maintaining dairy production among farm types. We collected details, including income-generating activities, herd size, and access to land at the starting of the dairy activity and the current situation. As a study reported by [10], we developed qualitative variables to analyze pathways of employees' work on dairy farms, with modalities indicating the dynamics between the starting of the dairy business and nowadays.

2.2 Data Analysis

This study performed typology and trajectory analysis. To describe farm type (typology analysis), this study conducted a multivariate analysis based on seven variables included: a combination of activities (contribution of dairy, crop, and off-farm to total income), the balance between the herd and the land dedicated to foraging (forage per LU), farm size and ratio among factors of production (total land, total workers, herd size). We performed ANOVA, the Fisher test (alpha = 0.05), and the descriptive study for 355 farms to classify the farm types and essential performance using Minitab 17.

This study conducted a visual analysis to define trajectories, as suggested by [11] and [12] in related animal science research. A cross-table was generated with 20 farms in lines and separate variables in rows. A variety of color shades defined the modalities. Moving lines and rows allowed the identification of farms with the same visually profiled modalities.

3 Results

3.1 Farm typology

Four types of farms have been identified (Table 1). Type 1 (T1) was a very small specialized dairy farm (almost 40 percent of the sample). Farmers had minimal land access. Type 2 (T2) still had very restricted land access; however, farmers mixed dairy production with off-farm activity. Type 3 (T3) was a small specialized dairy farm. Type 4 (T4) was a mixed crop-dairy activity.

Based on production factors, T1 and T2 had the same features, with minimal land access and a small herd (3.5 LU). T3 and T4 had higher capital. T1 and T3 had the same high dairy contribution (more than 85 percent) to the total income. It means that they focused more on dairy activity. On the other hand, T2 and T4 farms have less dairy income contribution (less than 60 percent) to the total income. Crops (T4) or off-farm activities (T2) also played an essential role in generating income. On average, T2 had a smaller herd size and limited land access, while T4 had better production factors.

Table 1. Characteristics of the four farm types (mean value and standard deviation)

Farm types	T1 (n=138)	T2 (n=62)	T3 (n=94)	T4 (n=61)
Dairy contribution to total income (%)	96.3 ± 6.6 ^{A}	53.4 ± 25.8 ^{C}	85.9 ± 24.7 ^{B}	42,5 ± 27.2 ^{D}
Crop contribution to total income (%)	1.2 ± 4.1 ^{B}	1.5 ± 4.4 ^{B}	3.6 ± 12.4 ^{B}	47.6 ± 29.9 ^{A}
Off-farm contribution to total income (%)	2.4 ± 5.7 ^{C}	45.1 ± 26.8 ^{A}	10.5 ± 21.4 ^{B}	9.9 ± 22.2 ^{B}
Forage land per herd (m2/LU)	292 ± 294 ^{C}	725 ± 703 ^{B}	1907 ± 1824 ^{A}	541 ± 682 ^{BC}
Total land access (m2)	1328 ± 1115 ^{C}	1791 ± 1723 ^{BC}	7735 ± 5586 ^{A}	3294 ± 2795 ^{B}
Total workers (person)	1.9 ± 0.6 ^{B}	1.8 ± 0.6 ^{B}	2.4 ± 0.8 ^{A}	2.0 ± 0.7 ^{B}
Herd size (LU)	3.5 ± 1.6 ^{B}	2.2 ± 1.0 ^{C}	5.5 ± 4.8 ^{A}	3.9 ± 1.8 ^{B}

Note: Means in the same line with a different superscript differ significantly (P<0.05); NS: not significant. Source: a survey (2015)

3.2 Performances Based on Farm Types

Farms T3 and T4, which had better land access and herd size (Table 2), reached the highest total net income per farm. Labor productivity in both types was the highest. The annual net total income on average was above the average salary. The average labor productivity for T1 and T2, with less land access, was below the threshold. Land productivity was the highest in both types. Farmers with narrow land access remain in a position to produce milk and earn cash by using, for example, natural grass nearby and paddy straw. On the other hand, T3 and T4 farms had lower land productivity.

Table 2. Economic performances and productivity of the production factor (labor, land, and herd) of the four farm types

Farm types	T1 (n=138)	T2 (n=62)	T3 (n=94)	T4 (n=61)
Total net annual income per farm (million IDR)	28 ± 20.8^{C}	32.6 ± 20.8 ^{BC}	51.2 ± 52.9 ^{A}	44.6 ± 48.2 ^{AB}
Total net annual income per family worker (million IDR)	16.6 ± 13.7 ^{B}	20.7 ± 15.6 ^{AB}	28.2 ± 34.9 ^{A}	24.9 ± 27.8 ^{A}
Net annual agriculture income per hectare (million IDR)	532.2 ± 790 ^{A}	576 ± 1416.7 ^{A}	136.5 ± 326.6 ^{B}	379 ± 965.7 ^{AB}
The net annual dairy income per LU (million IDR) [1]	9.1 ± 5.8 ^{B}	13.1 ± 18.2 ^{A}	9.9 ± 6.9 ^{B}	5.9 ± 5.6 ^{C}

Note: Means in the same line with a different superscript differ significantly (P<0.05); NS not significant (Fisher, LSD). [1] = milk income coop + additional product (cows, calves, manure sales) – cattle purchase – additional feed cost (tofu and cassava waste). Source: a survey (2015)

Two characteristics were apparent given herd productivity (Net Dairy Income per LU, Table 2). Herd productivity was very low in T4 and was the highest but high variability in T2 (Table 2). The milk yield was highest in T2, but it was very variable, which can be seen from three times higher standard deviation than other types. The milk income from the cooperative showed the same trends. In T2 and T4, the proportion of the concentrate ration was different. T2 used an amount of feed concentrates from the cooperative and additional feed (cassava and tofu waste). It might explain the higher milk yield in T2 and with high variability. On the other side, the T4 farms used many cassavas and tofu waste, although far less concentrate feeds from the cooperative. In the survey year, Farms T4 produced just 2.6 million (IDR) additional income per LU from the herd's sales and its products, half of the

amount of T2 farms. This was also demonstrated by the disparity in herd productivity between T2 and T4. Specialized dairy farms with more (T3) or less (T1) capital endowment had a similar feeding activity (concentrate) and performance. Thereby, the level of net dairy income per LU was the same and intermediate between the levels of income for T4 (minimum) and T2 (maximum).

Table 3. The dairy activity's technical and economic results are according to the four farm types.

Variables	T1 (n=138)	T2 (n=62)	T3 (n=94)	T4 (n=61)
Daily milk yield per LU (liters)	8.4 ± 3.3 ^{B}	11.5 ± 12.3 ^{A}	8.8 ± 3.2 ^{B}	7.4 ± 2.9 ^{B}
Annual milk income from coop[1] per LU (million IDR)	9.1 ± 4.5 ^{B}	13.4 ± 17.1 ^{A}	9.9 ± 4.7 ^{B}	8.8 ± 4.3 ^{B}
Annual concentrate feed cost[2] per LU (million IDR)	4.32 ± 2.21 ^{B}	5.07 ± 3.52 ^{A}	4.27 ± 2.01 ^{B}	3.12 ± 1.86 ^{C}
Annual additional dairy income[3] per LU (million IDR)	3.41 ± 4.06 ^{B}	5.62 ± 7.24 ^{A}	3.78 ± 4.95 ^{B}	2.57 ±3.56 ^{B}
Annual additional feed cost[4] and purchase cattle per LU (million IDR)	3.48 ± 3.90 ^{B}	5.88 ± 8.73 ^{A}	3.73 ± 3.59 ^{B}	5.49 ± 4.53 ^{A}

Note: Means in the same line with a different superscript differ significantly ($P<0.05$); NS not significant. [1] = milk sold – concentrate feed cost; [2] = concentrate feed cost from coop; [3] = cows, calves, and manure sales; [4] = tofu and cassava waste. Source: a survey (2015)

3.3 Farm Trajectories

In the study of 20 farms, dairy activity started between 1979 and 2013 (Table 4). In the beginning, most farmers engaged in the activity only with one or two cows (n=9) or even only with calves or heifers (n=12). Just one farmer began with five cows. Some farmers (n=9) were able to capitalize on natural growth and the purchase of animals, with a high annual growth rate (more than 10 percent), and reached a herd size of more than 3 LU in 2017. Some have recently begun their business (5 years), while some have been in the dairy business for a long time (30 years). In contrast, with a low annual growth rate (less than 10%), six farmers did not improve the herd above 3 LU, with less than three cows in the herd, after at least ten years of activity (n=6). In the intermediate group (n=4), farmers starting with just one or two heifers could reach 3 LU with 2 or 3 cows in 2017, after 5 or 10 years.

We defined six farm trajectories (Figure 1). These six trajectories could be clustered into three main groups. First, farmers with minimal access to land (types T1 and T2) could stay at the same type or move from T1 to T2 and vice versa, depending on the practice of off-farm activities. Even if they have been in dairy farming for a long time, they could not expand their land access and maintained a limited cow.

Among such types (T1 and T2), it was challenging for most farmers to raise herd size. For the remaining dairy farm-off-farm activity (T2), one farmer profits from off-farm activity (tofu waste trading) than dairy activity. His child operated the dairy business, and the income was also shared equitably. On the other hand, another farmer obtained more income from the dairy activity than from off-farm activity (wage worker). If farmers wanted funds for tuition, wedding ceremonies, health care, or undisclosed regular expenditures, they sold cows. As a result, the herd's scale stayed constant, becoming more considered saving.

Farmers attempted to increase the size of the herds in the trajectory remaining in T1. They added more cows through the cooperative credit scheme and kept the calves born as replacement stocks. Nevertheless, due to the barn's limited space and the need for cash to cover living costs, they had difficulty adding more cows. Farmers might also have credit facilities from the coop, although this amount depends on their resources, such as financial and physical capital. It describes the potential reason for less access to credit for T1 and T2 farms than other types. As a result, some calves or even all of them were sold to get cash. In T1 and T2, the total annual income was smaller than the unskilled worker's salaries. Dairy activities did not entirely support the household income.

Table 4. Development of herd size since the beginning of dairy farming activity until 2017

		Beginning year		2017			
Farmers ID	Beginning dairy business (year)	Cows	Heifers	Cows	Heifers	LU[1]	Annual herd growth
Low increase and do not reach more than 3 LU							
RF074	2006	0	1	1	0	1	0.05
RF063	2007	1	0	2	0	2	0.10
TP045	2004	2	0	2	1	2.5	0.04
RF004	2000	2	0	2	1	2.5	0.03
PS010	1995	1	1	2	1	2.5	0.05
GD003	2007	0	3	2	1	2.5	0.10
High increase but do not reach more than 3 LU							
PS015	2001	0	1	2	2	3	0.16
GD078	2003	0	1	3	0	3	0.18
RF015	2005	0	1	3	0	3	0.21
IN047	2013	0	2	2	2	3	0.50
High increase and reach more than 3 LU							
RF050	1993	0	1	3	1	3.5	0.13
RF055	2008	1	0	3	1	3.5	0.28
RF018	2012	0	1	2	3	3.5	0.60
RF073	2012	1	1	3	2	4	0.50
IN040	1992	0	2	2	6	5	0.16
RF005	2007	0	3	4	4	6	0.45
RF054	1979	0	2	5	2	6	0.13
PS057	2007	0	3	5	2	6	0.45
RF011	2000	1	2	14	10	19	1.00
More than 3 LU from the beginning with no increase							
IN038	2000	5	0	5	0	5	0.00

Note: LU= Livestock Unit (1 cow = 1 LU; 1 heifer = 0.5 LU)

Farmers in T3 had high and fast growth in herd size (Figure 1). Discussions with farmers confirmed that the dairy income could cover living costs. They had better assets than other

types, too. Under these conditions, some calves could be kept as replacement stocks. It reflected stable natural growth as they had more heifers than culled cows. This helped them to increase their herd size. Farmers had another chance to obtain cows via credit schemes or grants from a dairy development project. It might increase the herd size. As a result, more forage is needed to feed the cows. Both farmers accessed more land to grow forage. Some of them configured workers to cut and carry grass, both family and hired workers.

Most farmers in the mixed crop-dairy model (T4) did not abandon crops or improve their herd size. Some farmers expanded access to land; however, more was required to produce cropping activity, not dairy activity. This was due to the low availability of workers, access to land, and barn capacity. Another factor was the uncertainty of the dairy business, such as animal health issues. The farmers' income to increase the herd size was affected by this issue.

Farmers ID	Farm traject.	Current farm type	Off-farm activities	Herd growth	Land access	Crops
RF015	1-2	2				
RF063		2				
IN040	2	2				
TP045		2				
IN047	2-1	1				
RF055	1	1				
RF004		1				
IN038		1				
RF018		1				
RF073	3	3				
RF050		3				
PS057		3				
RF054		3				
RF005		3				
RF011		3				
PS015	4	4				
GD078		4				
PS010		4				
GD003		4				
RF074		4				

Figure 1. Six farm trajectories based on activities, land access, and herd growth

Note: ***Off-farm activities.*** *White: no; Soft grey: abandoning; Dark grey: starting; Black: keeping.* ***Herd growth.*** *Soft grey: low increase and do not reach more than 3 LU; Dark grey: high increase but do not get more than 3 LU; Black: high increase and reach more than 3 LU.* ***Land access.*** *White: low land access without increase; Soft grey: low land access with increase; Dark grey: high land access without increase; Black: high land access with increase.* ***Crops.*** *White: low contribution to income / Dark: high contribution to income*

4 Discussion

4.1 Technical and Economic Performances of the Dairy Activity

It is surprising that low milk yields in mixed crops-dairy farms (T4). This is mainly caused by the low nutritional value of feed provided by farmers. Farmers gave only a small amount of concentrate feed, as referred to in feed costs. Farmers preferred tofu waste and cassava waste. However, those feeds have low energy values [13] and nitrogen [14]. It is shown by the high additional feed costs used by the T4 farms.

Our findings are also somewhat surprising since there is high variability in T2 farm performance. Consequently, these differences are linked to the quality of feed and the buy-sale of livestock in the year of data collection. This, in principle, can give rise to a low quantity of feed due to low land access in a very dense population area. Farmers replaced high-quality feed such as Napier grass with low-nutrient feed such as paddy straw [15]. They also provided a high amount of concentrates that could lead to digestive issues and poor performance [16].

4.2 The Future of the Development of Dairy Production based on the Farm Types

The most intriguing finding is that the significant pathways of development of the farms' types are the rise in herd size, access to land, and diversification of the activity generating income. These alterations are the reaction of the capital endowment. It affects milk produced at the farmer's level to guarantee income and supply for the Indonesian market.

Farms with very small land access. These farms are essential in the national market. They provide milk to the dairy industries and the national dairy market. They are multiple and provide significant contributions in milk supply to the coop: T1 and T2 account for 56% of the farms – out of 355 farm samples, and contribute 47% of the milk sold to the cooperative. Small farmers with two cows selling milk to the dairy industry (through cooperative) are ordinary in Indonesia [17].

The smallholders are in a challenging position. Farms with little capital might be more vulnerable to the continuation of the dairy business. Dairy activities may not always cover regular expenditures due to low economic conditions. This is because of the limitations of enhancing other production factors, particularly access to land and herd size. In strategies to adapt to the shortage of land access, some farmers utilize non-cultivated forage by buying, cutting, and transporting natural grass. Even so, the continuity of the future remains unknown, given the availability of fodder and land in the nearby area. Farmers could have credit access from the cooperative to increase the herd, but the total is based on their assets. It means that they only have access to limited cash.

Off-farm activities in very small farms. In their trajectories, poor farmers (T2 farms) seem more changeable. Adding off-farm activity becomes a reasonable reaction if a farm has available workers but limited access to land. There are two explanations for this, incomplete market and risk reduction [6]. Because of incomplete land and labor markets, family workers would be assigned to other activities to optimize production factors. In the case of incomplete financial markets (credit and insurance), off-farm activity plays a vital role in addressing purchasing production factors [6]. Reduction of risk is another reason why farmers broaden their activities [6, 18]. This study showed that poor farmers (especially in T2) add off-farm activities to mitigate the risk of dairy farming. Studies performed by [19] confirm that diversifying activity can minimize the dairy business's risk.

On the other side, the reduction of off-farm activity was mainly due to the lack of availability of family workers. It may be associated with a missing labor market [6]. Reduced

family workers while growing the number of cows allow farmers to quit their off-farm activity and focus solely on dairy farming. Following [20], highlight the significance of labor force and capital on the farm development pathway.
The strategy for adding off-farm activities is a wise decision to ensure family incomes and mitigate production factors' limitations. Also, improving herd by a credit scheme may not be sufficient to encourage these farms. It might be successful if it is accompanied by an improvement in other factors of production. This research confirms findings from previous observations reported by [4].

Farms with more access to land and mixed crop-dairy system. The attention of the crop-dairy system might be seen from both the technical-economic performance. We did not identify any dynamics for dairy production development in the hybrid system (T4 farms). However, the family may have decided to leave the dairy activity and focused on crop production (but not seen based on our sample).

T4 farms can maintain dairy activity. Regarding dairy production growth to guarantee income and meet national demand, these farms appear to be steady or slightly improved. The number of farms is small (17 percent of farms), and they support only 15 percent of the milk supply to the cooperative. The size of the farm (herd, access to land, workers) is slowly growing. It may relate to their capital (especially family workers and land), which should be optimally kept for two activities (crop-dairy) to have higher household incomes. Also, workers' productivity in crops could be better than in dairy farming. Therefore, there is less motivation for the family to improve more dairy than crops, enlarge the land to cultivate forage at the expense of crops. Most of them also rely heavily on the land of Perhutani or PTPN for foraging. Given the complexity of land conversion, it could be fragile in the future. It highlights the importance of self-sufficiency in production factors, such as land [21].

Farms with better access to land and dairy specialization. Bigger dairy farms (T3) have the main reasons for choosing a dairy business specialization rather than a mixed farm. First, there is a lack of family workers. The second reason was limited land for crops nearby. Allowing only one activity is the easiest way to manage capital efficiently.

These farms (T3) are in the development pathway. They were able to capitalize (herd and land access). They had higher capital than other farms' types. Higher capital allows farmers to obtain more credit to overcome limited production factors. Farmers have a complete market under this condition. [6] demonstrated that farmers use a small part of their income and save the rest if a complete financial market exists. It enables farmers to have steadily natural growth of their animals.

The total of T3 farms is around 26% of the total farms, but they can deliver 38% of the total milk supply to the cooperative. On average, other farm types (T1, T2, and T3) provide ten kiloliters of milk to the coop annually. The farm of the T3 produces 17 kiloliters. These farms may play a significant role in developing the dairy sector in the area and at the national level. However, in the context of a strategy to supply the national market, focusing only on T3 farms seems irrelevant. It is because there is not too much difference in size among producers.

5 Conclusion

This study reveals a classical circumstance with a gradient among smallholders in difficulties to secure their families' livelihoods and those in the development trajectory of their farms through dairy and commercial crops. The study also underlines the significance of the smallholders' initial assets to illustrate their further farm trajectory. For those in the development trajectory, two strategies coexist between the dairy business's specialization and the system of mixed crops-dairy. The decision of one or the other is more related to pathway dependency. The mixed system could generate a similar net income with the specialized dairy

system but with more levers of protection, combining two activities to secure livelihoods. The dairy activity provides income, and livestock plays a vital role in saving. Even so, this activity on a tiny scale is highly responsive to risks. As they are multiple, these very small producers provide a significant portion of the milk supply to the cooperative. Given the current growth of milk consumption and its significance to food security in developing nations, these very small producers are also crucial in participating in food security at the national level.

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