Food Security, Poverty and Diversification: Relative Contribution of Livestock Activities on Small-scale Farms in Egypt

VINCENT MARTIN, VÉRONIQUE ALARY, ANNABELLE DABURON, AHMED ALI , MONA A. OSMAN, EHAB SALAH, ADEL ABOULNAGA, EITEDAL HASSAN, ADEL ABDEL AZIZ, AND CÉLINE DUTILLY

Abstract: The often-cited means to reduce poverty in rural areas is to push the sustainable intensification of the agricultural sector or to favor a livelihood diversification strategy. However, rural households that invest their resources in multiple domains can achieve contrasting livelihood returns and benefits. The present paper explores the contribution of livestock activities, especially dairy, in the various livelihood strategies of rural households, based on an evaluation of revenue repartition, poverty level, and nutrient input in the diverse households, using a simulation tool at the farm household level. Our research was carried out in a case study on the viability of rural households in the governorate of Beni Suef (Middle Egypt). The results show that the diversification of activities towards cropping activities and off-farm jobs in the household contributed more to poverty reduction than dairy activities. Householders with small herds and land access benefited weakly from milk price increases and more generally, from a specialization of dairy activities due to structural constraints. This calls for identifying new rural policies for small-scale (less than 2.5ha) units that represent more than 90 percent of family farms in Egypt. Notably, new job opportunities and diversification should be developed along the agro-food value chain process.

Keywords: Food security, poverty, diversification, livelihood, rural household, dairy activity, milk prices, simulation, Egypt

Introduction

Although agriculture is often seen as a way to get out of poverty, 70 percent of the people who suffer from hunger in the world belong to farming households.[1] One of the often-cited means to

Vincent Martin[1], Véronique Alary[2,3], Annabelle Daburon[3], Ahmed Ali [5], Mona A. Osman[5], Ehab Salah[5], Adel Aboulnaga[5], Eitedal Hassan[5], Adel Abdel Aziz [5], and Céline Dutilly[6,7]

[1] CIRAD, ICARDA, 15 (G) Radwan Ibn El-Tabib St., P.O.box 2416, Giza, Egypt

[2] CIRAD, ICARDA, Station Exp. INRA-Quich, Rue Hafiane Cherkaoui. Agdal, B.P. 6299, Rabat, Morocco; Corresponding author: Email: veronique.alary@cirad.fr, Mobile ph.: (212) 6 54 07 22 48; ORCID: orcid.org/0000-0003-4844-5423

[3] CIRAD, UMR SELMET, TA C-112/A, Campus international de Baillarguet, 34398 Montpellier Cedex 5, France ;

[4] SELMET, Univ Montpellier, CIRAD, Montpellier, France.

[5] Animal production Research Institute (APRI)/ Agricultural Research Centre (ARC), Nadi El-Said St., Dokki, Giza, Egypt.

[6] CIRAD, UMR MOISA, F-34398 Montpellier, France.

[7] MOISA, Univ Montpellier, CIRAD, Montpellier, France.

http://www.africa.ufl.edu/asq/v19/v19i1a4.pdf

ISSN: 2152-2448

reduce rural poverty is to push intensification of the agricultural sector. A key element of sustainable intensification is improving efficiency gains to produce more food using less land, water, or other resources.[2] Technology plays a major role in increasing production in small areas, thus ensuring food security for family farms and high returns from farming through increased profitability.[3] For Garnett, this type of farming development could reach a sustainable intensification if new technologies are easily widespread to farmers, adopted by them, and applied in their fields. However, the expected outputs of technology adoption by farmers are seldom reached. The reasons are multiple, but generally, to adopt an intensification strategy, farmers need to have access to means to finance and to apply these new technologies. The potential risks induced by the introduction of new technologies (mainly economic risks in link with the investment) are often cited as major brakes to adoption.[4] Indeed, in the context of land pressure, most smallholders cultivate not more than one hectare and return on investments in new technologies is generally low. Another objection is that the farming sector faces many environmental or institutional stresses and shocks that make subsistence farmers vulnerable, especially if the livelihood strategy focuses on a unique sector.[5] Studying the coping behavior of households and the nature of risks that communities face is fundamental before proposing antipoverty policies for local livelihood contexts.[6] More generally, intensification is not a unique solution.

Another strategy to lift farming households out of poverty and improve their food security is the livelihood diversification strategy. Ellis described this as "the process by which rural families construct a diverse portfolio of activities and social support capabilities in order to survive and to improve their standards of living."[7] Many studies show that a diversification strategy in nonfarm activities enables households to get better incomes, improve food security, and even increase crop and livestock production through the transfer of capital between activities which decrease household vulnerability.[8] Thus, when nonfarm activities enable households to invest capital in farming activities, households adopt an accumulation livelihood strategy rather than a survival strategy by necessity.[9] Nevertheless, the authors observed that minimum endowments in terms of liquidity, market access, and skill are necessary to enter in an accumulation livelihood strategy for the highest lucrative nonfarm activities. The poor endowment of some rural households creates a "barrier entry" to the poorest.[10] Other studies emphasize the role of social capital in improving access to non-farm activities. Poorer households lacking social networks and other forms of social capital are least able to diversify into non-farm activities.[11]

For further livelihood analysis, this study proposes combining assets' parameters as described in the livelihood approach and farming system parameters based on a systemic approach, with all these parameters implemented in a tool called ALive Toolkit.[12] This tool generates indicators of monetary poverty (revenue per capita) and food security (household satisfaction of calorie and protein needs) by considering the whole household system. In this approach, food security and monetary indicators yield the non-monetary and monetary dimensions of poverty. The agricultural and non-agricultural net income per capita is the most prevalent indicator of the monetary poverty. A derived indicator is the relative part of net income from all economic activities in the household poverty line. From this indicator, we can estimate the order of magnitude of livestock's contribution to total household incomes.

Compared to the poverty line per capita, these indicators enable us to assess the livestock contribution to poverty reduction and also identify the most vulnerable households in the population. However, if these indicators are pertinent in a market economy, it may be insufficient in a traditional economy, in which part of the income serves to increase live assets like livestock and self-consumption.

Related to food security, if the nutrient approach refers to the requirements of basic nutrients to ensure biological functions, the food approach is embedded in the habits of the population. In the nutritional approach, priority is given to caloric, protein and lipid inputs, taking into account the nutrient content of different products. Related to the crop-livestock system, a key indicator can be the contribution of animal products to the family's nutritional needs, especially in terms of protein intake, representing almost 22 percent of protein requirements in developing countries.[13] The indicator for assessing the contribution of livestock to the caloric intake of the household may also be the coverage of the total cereal needs of the household (estimated in monetary value from the income of livestock activities excluding self-consumption).

Based on these two dimensions of monetary poverty and food security, this paper explores the relative contribution of livestock activities, especially through dairy activities, in the various livelihood strategies of rural households. In a constraining environment where land is very limited, the main goal is to see how livestock activities may contribute to poverty alleviation and even create new opportunities for household livelihood improvement. Moreover, the paper proposes an evaluation of revenue repartition, monetary poverty level, and nutrient requirement satisfaction in diverse household types to understand the links between poverty, food security and diversification. To do that, we have combined two empirical methods i.e., farming systems' typology and livelihood assessment, to gain a more comprehensive understanding of the challenges of smallholder farm households. Notably, this approach allowed approaching the poverty and food security issues related to endowment levels within a systemic approach. Furthermore, to measure the potential of dairy activity in poverty reduction and food security at the family farm level, we simulated different changes of milk prices and feed cost to examine the potential impact of development policies based only on the dairy sector while varying milk price or milk quality. This constitutes one of the major efforts promoted by governmental and development agencies in rural zones where land fragmentation reaches high thresholds as in Egypt or India. This analysis has been implemented in a case study on the viability of small-scale farms systems in the governorate of Beni Suef in Middle Egypt.

Review of the Livelihood Context for Dairy Smallholders Along the Nile Valley

Demographic pressure is one of the greatest issues facing Egypt . Indeed, the population in Egypt has tripled over the last fifty years, from 28 million in 1960 to around 95 million in 2016 mostly concentrated around the Nile Delta and Nile Valley.[14] With only 3.6 percent of land suitable for agriculure, population growth has generated strong land and water pressures, limiting agricultural development in particular for small-scale family farms due to urban growth and land competition between farmers. The average farm size was estimated at 2.2 *feddan* (i.e. one hectare) in 2010, compared to 6.13 *feddan* in 1929 and 3.8 *feddan* in 1960.[15] In arid and semi-arid climates, the agricultural sector remains dependent on the Nile water for irrigation for more

than 94 percent of the cultivated land. Egypt is facing water scarcity and water management constraints to increase arable lands on the Nile Delta border.

Moreover, the financial crisis of 2007-2009 and the difficult macroeconomic context that followed the revolution of 2011 have aggravated household poverty in Egypt.[16] World Food Programme (WFP) also recorded that poverty in rural areas was twice as high as in urban areas. Middle and Upper Egypt (along the Nile Valley in the south of Nile Delta) were the poorest and most food-insecure regions in Egypt in 2013. Demographic growth led to a deterioration of food security partly due to the food supply not being able to meet rising demand (particularly animal products in urban areas), but also due to financial difficulties and asset reduction. Therefore, the Egyptian agricultural sector should be at the core of policy concerns to respond to poverty and food security issues.

The family farming system is the most common model in Egypt, accounting for around 90 percent of farms.[17] Most family farms are small scale, with only two to three dairy cows and less than one hectare of land. Thus, they have a great role to play in poverty reduction and food security issues in rural areas given that they represent the majority of the poor population in Egypt. Nevertheless, land pressure and difficulties accessing basic farming services (veterinary services, credit access, fertilizers, and pesticides' prices) prevent growth in livestock and cultivation. Despite many development projects to help farmers facing land resource constraints, around 31 percent of the rural population were still below the poverty line in 2011, compared to 24.3 percent at the national level.[18]

The complementarities between livestock and crops, especially through organic resources and feed management, favor an intensification of farming practices while maintaining the recycling of resources.[19] However, in our study we observed a diversity of systems, and crop-livestock integration differs by crop type (cash crop, fodder, vegetable) and animal species (small ruminant or large ruminant) according to the farm's capacity to diversify. The sustainable livelihood approach posited that by the combination of a range of assets (natural, economic, human and social capitals) and livelihood strategies (agricultural intensification, livelihood diversification and migration), the farming system could regenerate or develop sustainable livelihood pathways.[20] For further livelihood analysis, the paper proposes combining a farming systems' typology focused on the farm activities and a livelihood approach focused on the stocks and flows of food and cash to meet basic needs or even enhance capabilities. The objective was to highlight the complexity of these smallholder farm households and the diversity of combined activities at the household level.

Case Study, Materials and Methods

Case-study: Small-scale Family Farms at Beni Suef (Middle Egypt)

The Beni Suef governorate, located in the old land area along the Nile Valley, is 120km south of Cairo. Most farms of this region belong to the scheme of old patriarchal family farms in which dairy activity is completely integrated into the farm and family system. Most farms in the area process cheese and butter which they partly consume (30-40 percent by our observations) and remaining dairy products are usually sold to neighbors, at local markets, or to traders selling to milk shops or dairies.[21]

In these systems, the herds usually comprise two or three cattle, a mix of buffalos and cows. In 2016, the cow breeds were mainly native breed (called *baladi*), accounting for 28 percent of the herd, and crossbreds (*baladi* crossed with Holstein, Brown, Abundance, or Tarentaise), accounting for 53 percent of the herd. Genetic performance variations are a significant factor that determines the differences in management in dairy activities. In addition to cattle and buffalos, the families raise small ruminants, sheep and goats often slaughtered at home or sold for the *Korban Eid* feast. Livestock is integrated into the whole farm system through feed and nitrogen management e.g. manure is spread on arable lands. Families produce the majority of green and dry fodder like wheat straw, maize grain or silage and berseem (*Trifolium alexandrinum* L.) or alfa-alfa (*Medicago sativa*), the most common legumes for fodder in the South Mediterranean. Moreover, each family cultivates wheat, and some of them produce seasonal vegetable cash crops such as beans, peas or garlic.

A partnership between a multinational organization in the dairy processing sector, a non-governmental organization, and a research institute was created in 2014 to achieve a socio-economic impact assessment of a social business project in the dairy sector (SIADEEP project). This last aimed to implement Milk Collection Centres (MCC). These MCC were conceived as social business units that collected milk from small-scale farms to supply the investing company and provided farming services like artificial insemination (AI), quality feed, or veterinary services to farmers. The paper focuses on three villages in the Beni Suef governorate investigated in this partnership project, where the crop-livestock integration is the dominant system of the smallholder household systems and constitutes the main source of milk supply in the area.[22]

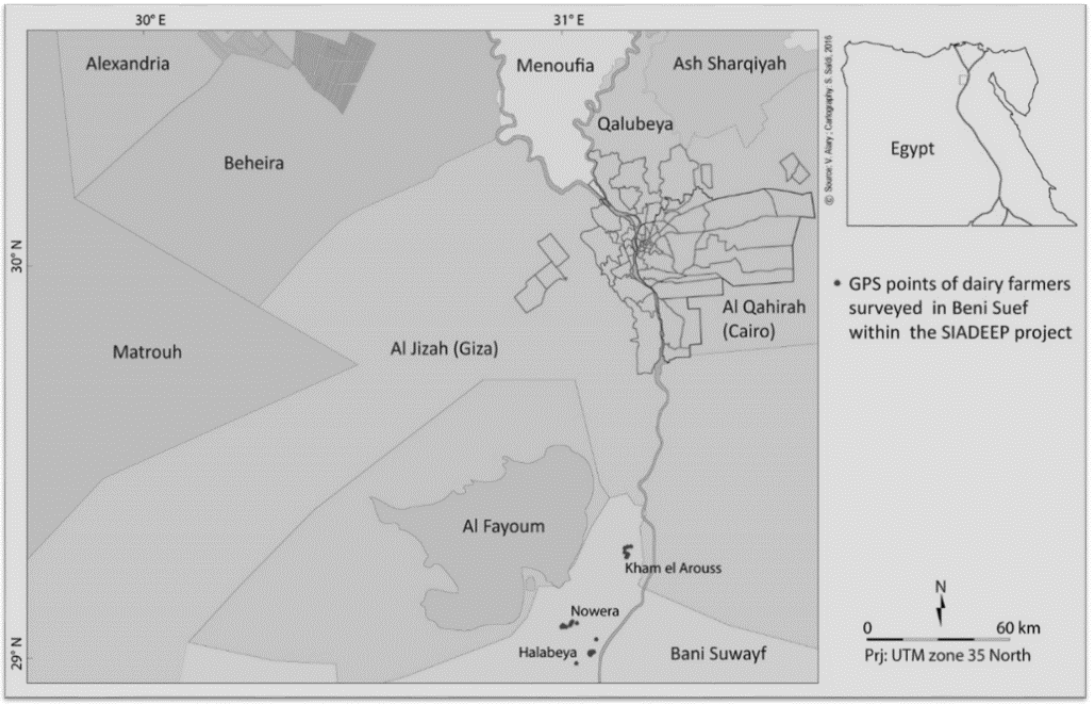


Figure 1. Location of the surveyed farm households (dots) in the three villages investigated in Beni Suef governorate (Egypt)

Data Collection and Identification of Profile Types

Over the three-year project (2014-2016), we followed seventy-two dairy smallholders with one household farm survey annually. Interviews were based on a semi-structured questionnaire with the household head (mainly men) often accompanied by his spouse. The questionnaire included five components related to family and housing, land and cropping system, structure and management of livestock, social network, and the role of women in the community. Based on preliminary exploratory work in the area consisting of opened interviews with various stakeholders (producers, traditional or governmental representatives, milk traders, vets, feed providers, associations, etc.), we identified diverse household farm systems according to land access and livestock activities. That constituted the basis for selecting household farm types involved in the study. The choice of households resulted from a snowball sampling approach by mobilizing different sources for the identification.[23] An Egyptian-French research team comprised of animal scientists and socio-economists conducted this survey. Each household farmer was interviewed three times so the final sample count consisted of 216 surveys.

We used a method based on multiple factor analysis (MFA) for the typology construction to identify different farming systems. The purpose of the typology was firstly to describe the diversity of smallholder farm systems and, by crossing with a livelihood approach, to show whether specific links (proximity or causality) existed between certain combinations of farm activities and the satisfaction of basic needs (based on the poverty and food security indicators). This, in turn, would explain the different types of coping strategies. The indicators used in the farming systems' approach were: rate of land ownership, crop distribution, herd size and structure (in terms of species, physiological stage), education and school level of family members, and off-farm employment. Moreover, data from technical performances were used as secondary data to link structural parameters to performances (milk production per head, concentrate quantity per liter of milk produced per animal, stocking rate, artificial insemination rate, and milk home consumption rate). This allowed analyzing the contribution of structural variables on farming performances for each profile type.

Since we have three observations for each farm household, it was possible to highlight farm trajectories over three years through profile changes within a unique typology. For example, some households could be in one profile in T0 (first year of farm survey) and change to another profile in T1 (second year of survey). Thus, we could analyze factors that determine diverse livelihood profile evolutions.

Livelihood Profile Types and Trends

To estimate the contribution of livestock to family livelihood in terms of well-being and food security, we used the LSIPT toolkit, a comprehensive analytical tool designed in the ALive platform under the leadership of the World Bank and with scientific contributions of CIRAD and FAO. The LSIPT toolkit contains five modules and provides various functionalities such as descriptive analysis of livestock production systems, the socio-economic approach of vulnerability and viability of household systems and value chains, and assessment of contribution of livestock to poverty alleviation and national gross domestic product (GDP).[24] The first tool, called DynMod-EcoRum, is composed of two articulated Excel sheets: (i) projection of the livestock population and performances over twenty years and (ii) socio-

economic assessment of farm performances in terms of income generation and food security by adding non-farm and farm activities (see supplemental materials).[25] We can simulate possible investment scenarios or technical changes to help decision-makers choose the most appropriate investment options.

We selected one pilot case study farm in each livelihood profile to show how the farming system for each profile is structured. We simulated the parameters linked with the milk production and feeding system thanks to the average of the profiles, whereas the structural data about livestock composition and management, land, cropping system, and family structure were collected from the selected pilot farms (Appendix 1). For each pilot case study farm, we used DynMod tool to estimate the livestock capital and animal productions that were input parameters in the EcoRum tool to estimate the socio-economic performances (Figure 2). For this study, we considered that the herd dynamic was constant over time due to land access constraints in the local context.

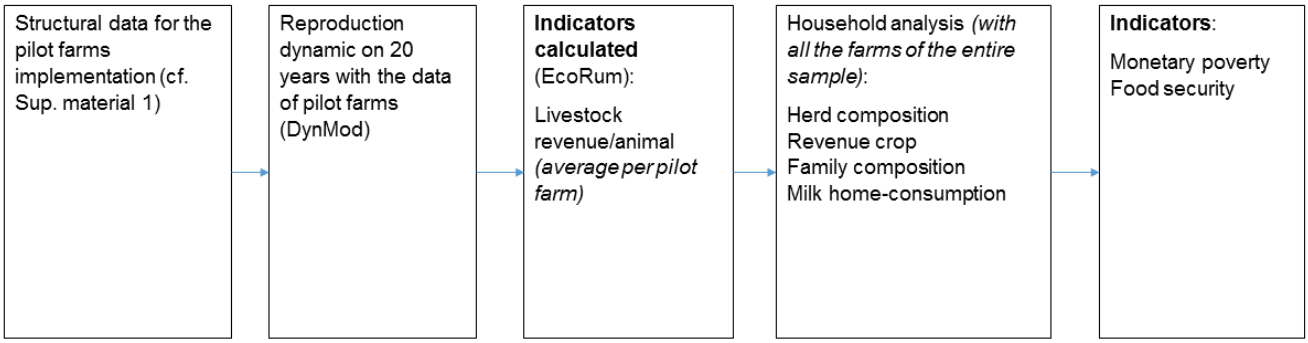


Figure 2. ALive Toolkit operating in the case study of dairy farms in Egypt

The pilot farm analysis enabled obtaining a revenue net per cattle head that was implemented in the household analysis tool of ALive as average breeding revenue of each profile. In addition to livestock revenue, household analysis integrated other vulnerability indicators such as crop production revenue, off-farm job revenue, family composition, herd structure, and cereal home consumed, whereas pilot farm analysis yielded revenue per animal and home consumption rate of meat and milk. This analysis was performed for the whole sample, i.e., the seventy-two farm households that were interviewed three times.

This second tool enabled analysis of the financial situation (poverty analysis) and nutritive needs (food security analysis) of all households with specific data per household survey. Poverty analysis of households enabled classifying households according to three main revenue sources based on net income (livestock keeping, cropping, and off-farm activities) in four categories according to the contribution of the activity: mixed, breeder, cultivator, and off-farm activities. A farm is classified in a specific category if this activity generates more than 50 percent of the total household net income. If no activity generates more than 50 percent of net income, the household is considered mixed, i.e. without a dominant source of income from one activity. Moreover, for each category of activity, this tool classifies households according to their poverty level determined by income tercile: (i) very poor; (ii) poor; and (iii) rich.

The determination of the poverty line is commonly based on an assessment of expenditure to ensure a minimum standard of living. This threshold generally covers a basket of food items (caloric requirements) and non-food items (clothing, transport, health, water, energy, and housing) needed for everyday life. We can use the basket of food and non-food commodities considered in the country or using consumption or standard of living surveys. In all cases, it is necessary to update the poverty line calculated according to the average cost of living indices corresponding to the reference periods of the surveys and the year considered for the study.

Regarding nutrient satisfaction to address food security at the household level, we calculate the protein and calorie contribution of home-consumed milk in the total household needs for each pilot farm. We hold there was no home cattle meat consumption because live cattle were mainly sold. Moreover, we estimate the caloric needs for an adult at around 2500 kcal/day and 0.66g/kg/day for protein.[26]

Finally, the ALive Toolkit allowed making simulations of milk price variations on pilot farms to examine the sensitivity of the volume of dairy products to milk price and the potential of development policies, notably through milk quality upgrades, to improve household livelihood profiles. To explore the impact of support policies based on milk quality improvement or milk price, we used an impact pathway method that separates the impact pathway into five steps (Figure 3).[27] In our case, we have focused on the increase of milk prices to facilitate access to feed with high protein content. The use of feeds with a high protein content constitutes a key factor for increasing milk production and improving milk quality. Moreover, this model fitted to agricultural support policies for milk quality improvement in the studied SIADEEP project. The simulation included four increases of 0.2 E£/L, from 0.2 E£/L to 0.8 E£/L. We hypothesize that the totality of benefit from the milk sales due to the increase of milk prices was invested in feed concentrates with high protein content (around 18 percent) with an average price of 3 E£/kg, to create this positive trend regarding milk production and milk quality. Milk production increases with the amount of concentrate distributed.[28] Therefore, we implemented the data generated from the EcoRum tool in the five pilot case study farms to extract revenue per animal for animal production activities that we entered into ALive for household analysis, yielding net income per capita increase and the household trajectories by both poverty and main activity classes.

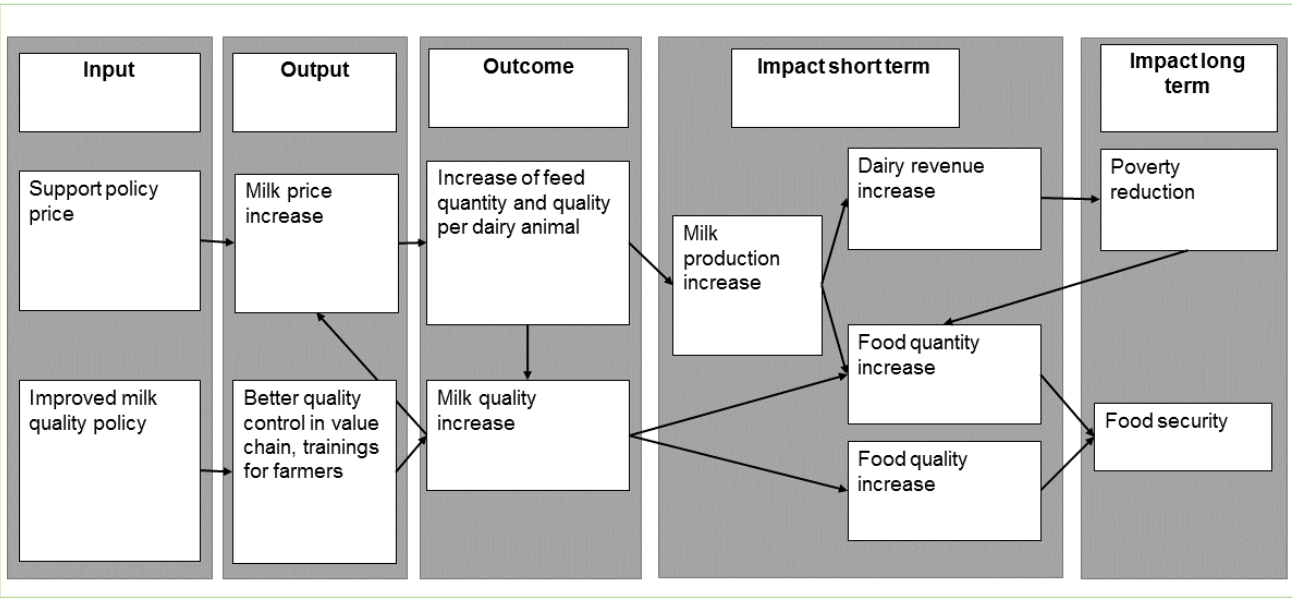


Figure 3. Representation of the impact pathway of policy of quality improvement and milk price support

Results

Livelihood Profiles for Various Livelihood Strategies

Using a multiple factorial analysis performed on the 216 observations, we obtained five livelihood profiles (see the projection on the two first axes in Figure 4 and descriptive data in Appendix 2). Four profiles, from two to five, called respectively micro, small, medium and large, differed mainly on structural data (herd size, land area and cropping system) on the first axis in Figure 4. While profile one, called small social, was similar to profile three (small) in terms of physical assets (livestock and land), it differed regarding the educational level of the family head and the governmental job rate. That explains why this group was detached from the first axis of differentiation (corresponding to structural variables) to the second axis corresponding to social variables.

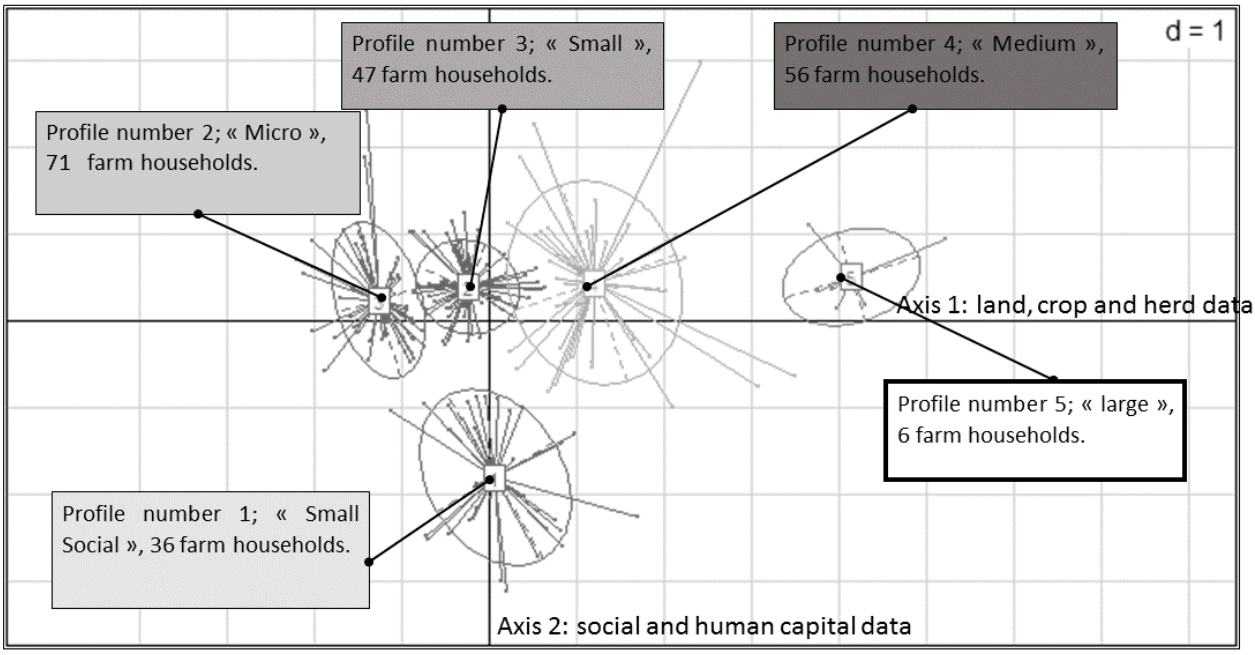


Figure 4. Projection of the five types on the two first axes of the factorial plan (with one grey colour for each group) (sample: 216 farm households)

Profile two (micro), corresponds to the poorest endowment group in our sample. These farmers usually cultivated small land areas (around one *feddan* or 0.42 ha), and only 18 percent owned their cultivated land. Mainly due to land pressure, they possessed a small herd of one or two dairy cows and focused on dairy production. However, a high crossbred rate indicates a will to increase genetic performance and consequentially milk production. Indeed, the land was mainly used to produce animal feed and not for cash crop production (only 4 percent of the total cultivated land area). However, despite a high rate of crossbreeding in the herd and the cultivation of fodders, these farms did not reach high milk production (an average of 1168 liter/head) due to the high stocking rate per fodder area and consequent inefficient feeding system. At the social level, the family comprised an average number of seven members with a very low educational level of the family head (mainly illiterate). Nevertheless, the profile differed in terms of off-farm employment rate, given the high rate of occasional work (12 percent) compared with the other profiles. Occasional employment consisted of daily work such as labor for other farms and should be considered precarious because it still depended on the agricultural sector.

Profile three (small) corresponds to an intermediary profile in the given typology with almost one hectare of cultivated land (36 percent of study sample). The cropping system is mainly based on fodder and maize (59 percent of cultivated area); cereals and cash crops are produced but on smaller areas. However, with two or three dairy cows (mainly *baladi* and buffalos), the stocking rate was higher, and milk production was low due to an inefficient feeding system and a lower genetic level. The education level of the family head was the lowest of the sample and this explains the difficulties of family members in this profile to get non-farm jobs.

Farms classified as profile one (small social) are close to profile three in terms of land access, crop distribution, and the number of dairy animals. However, they register a high technical efficiency, whether for milk production (average of 2300 liters/dairy animal/year), feeding system (0.92 kg of concentrate/liter) or for genetics (50 percent AI and 68 percent crossbred). We can link these performances with social networks created by their strong presence in governmental jobs (20 percent), due to a relatively high level of education compared to other profiles.

For profile four (medium) ,the percentage of cultivated area dedicated to cash crops (21 percent) means that these farms can diversify their farming while maintaining dairy activity. Indeed, we observed a high cattle number (two or three dairy head) and medium technical efficiency despite the low genetic performance (44 percent crossbred and 13 percent AI). The physical assets balanced the weakness of human capital: few off-farm jobs and a moderate level of education, similar to profile three. Nevertheless, the particularity of this social part was a high number of family members balancing better structural assets per capita.

Profile five (large), less than 3 percent of our sample, possess strong assets in structural data, and, like the medium profile, the area dedicated to cash crop production was high (25 percent). However, the share of land area for animal feeding was slightly lower (56 percent). Thus, through the livelihood diversification of the farming activities, the profile was less responsive to market variations of milk prices. We can also relate this profile with profile three (small) in term of human capital because their strong presence in several types of jobs (private 30 percent and governmental 17 percent) increased access and claims regarding farming services (veterinary support and AI). This correlated to high technical performances in milk production (2266 liter/head/year) and AI rate (33 percent).

Income Repartition According to Main Activities

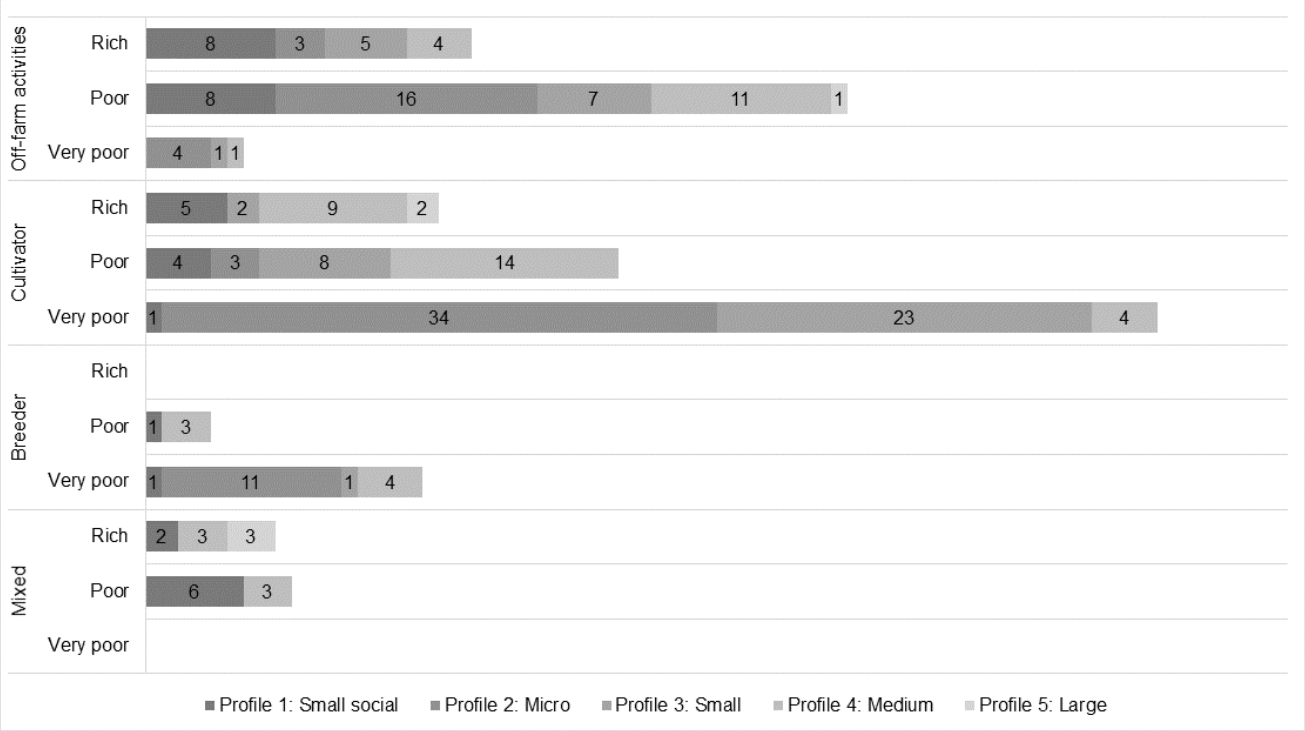
The pilot farm study highlighted heterogeneity about net revenues of animal production activities. Profiles two and three (micro and small) were considerably less lucrative, with 273 E£/head/year and 325 E£/head/year (between 30 and 37 US$/head/year in April 2016), respectively. Livestock net income doubled or even tripled for the other profiles (from 699 E£/head/year for large farms to 1357 E£/head/year for small social farms, representing 78.5 and 152 US$/head/year respectively). Profile two (micro) was strongly represented in "cultivator" and "breeder" categories (mainly in the "very poor" class, 52 percent) due to their orientation in the dairy sector (Figure 5). However, some households of this profile were present in the "off-farm activities" category and can be classified either in the "poor" or "rich" category depending on their access to occasional job revenue. Nevertheless, they were still dependent on the agricultural sector and its multiple risks.

Profiles three and four (small and medium) were similar in terms of revenue repartition, mainly represented in "cultivator" and "off-farm" activities categories. The households in these two profiles were present equally in the "off-farm activities" category. However, in the "cultivator" category, these two profile types had different positions. Indeed, small farm households were poorer than those of medium farms. Their better technical level (milk yield, feed efficiency, and stocking rate) and higher physical assets (land area and the number of heads) explain this difference. It is worth noting that, thanks to complementary revenue from off-farm employment, certain small farm households had a better well-being level, which is

remarkable because of their presence in "poor" and "rich" categories in the "off-farm activity" category.

Regarding households from profile one (small social), their high technical efficiency (despite small herds), and their presence in governmental jobs allowed them to be well represented in the "rich" (66 percent) and "poor" (34 percent) categories. Thus, they were less economically vulnerable. Moreover, they were well distributed in "mixed" (23 percent), "cultivator" (26 percent), and "off-farm activities" (46 percent) categories. Finally, profile five, (large), composed of 100 percent rich households, were present in mixed (50 percent), off-farm activities (17 percent) and cultivator (33 percent) categories. This group was the least vulnerable thanks to important physical assets and diverse revenue sources.

The household analysis revealed that 78 percent of households were below the poverty line (2 US$/day/capita), and half of them were considered "very poor" in our study (which fit national statistics), i.e., 39 percent of households. The rate of households below the poverty line is the highest for profiles two and three, with respectively 96 percent and 83 percent, followed by profile four (71 percent), profile one (56 percent) and profile five farms with only 17 percent. We note that only 22 percent were above the poverty line of 2US$/capita (corresponding to the "rich" category in our study).



Stability over Time: Poverty and Off-farm Activities

A similar differentiation of monetary poverty was observed over the three years, reflecting a sort of stability in the categories of monetary poverty. However, the number of "cultivators" increased while the "breeder" number decreased in connection with a drastic reduction of livestock capital in one village due mainly to the abandonment of buffalo and local breed animals following the implementation of the Milk Collection Center which purchased only cow

milk and encouraged genetic improvement. For the households of this village, the reduction of herd size and then animal production revenue explained their change from "breeders" to "cultivators" (Figure 6).

We did not observe significant changes in diversification of activities over the three years, partly because education or other abilities to diversify out of farm activities remained constant. For profile one (social small), the number of households was unchanged over the three years of investigation. Moreover, the rates of non-farm governmental and private employments were almost constant.

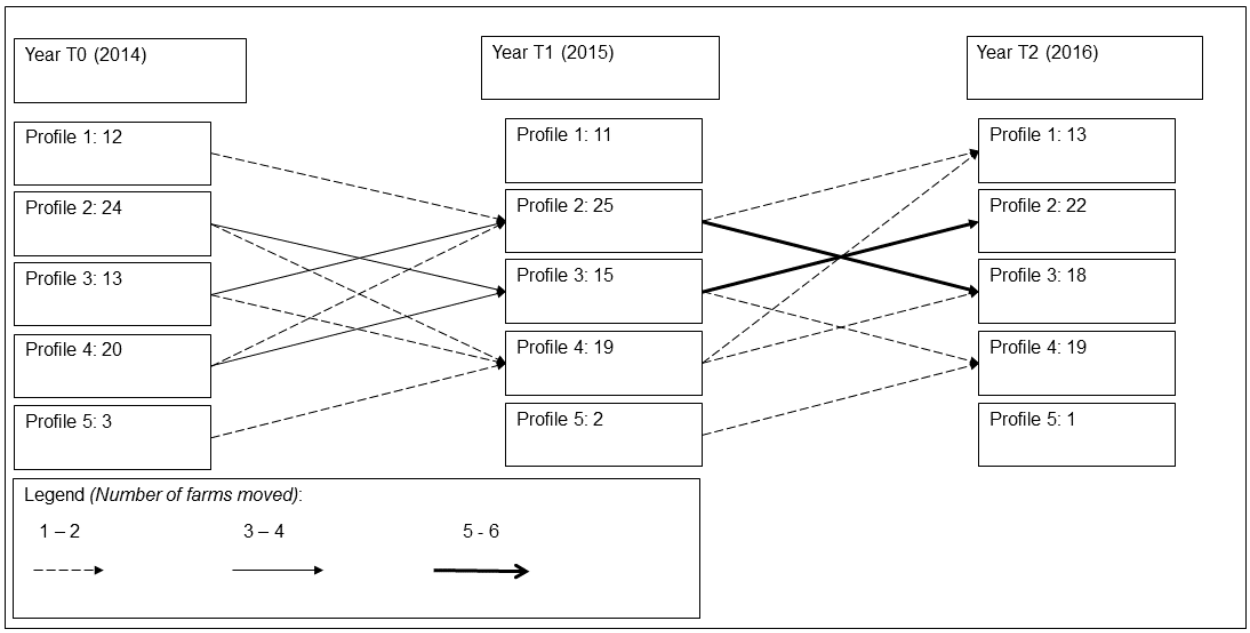


Figure 6. Trajectories of profiles over the three-year period (from 2014 to 2016) (sample: 72 farmers surveyed three times)

Link between Food Security and Poverty Level

The analysis of protein and calorie "coverage" through home consumption of milk and milk products (cheese and butter) shows that for "breeder" and "cultivator" categories, "poor" and "rich" households were able to cover their needs, especially due to a high home consumption level and higher milk production than "very poor" ones (Figure 7). Nevertheless, "very poor" categories of "breeder" and "cultivator" covered protein needs, and approximately three-quarters of their caloric needs only with milk produced on the farm. Thus, for these two categories, milk consumption allowed ensuring the correct nutrient coverage of household needs. On the other hand, households from the off-farm activities category usually did not cover their needs with their milk, mostly because they sold a large portion of milk production and bought nutrient complements from outside the home.

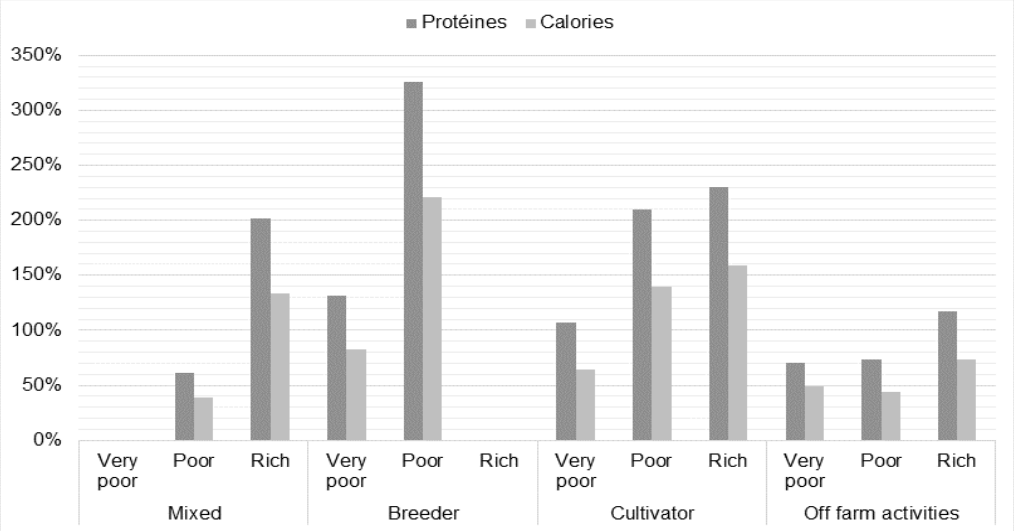


Figure 7. Contribution of livestock (milk and meat) to the protein and calorie needs of households through home-consumption according to the activity-related and poverty-related categories over the three years of the survey (Sample: 72 farmers surveyed three times)

As we saw in the typology analysis, households from profile one (small social) had low home consumption rates and low milk production explained by their small productive herds (Appendix 2). Their livelihood strategy was oriented towards selling milk, which offset the dietary insufficiency by high revenues, as we saw previously for off-farm activities categories. However, for this group, it is not a matter of food insecurity because they can purchase high-quality food on the market. On the other hand, households from profile two (micro) had a high rate of home consumption, few cattle, and low milk production that explained their difficulty in covering their protein and calorie requirements. Likewise, profiles three (small) and four (medium) had the same high home consumption rate but more cattle meant they covered more than 100 percent of their needs.

Impact of Milk Price Increases on Monetary Poverty

After modeling farming systems based on the five pilot farms through LSIPT Toolkit, we implemented a series of four milk price increases from 0.2E£/L to 0.8 E£/L. What was the impact on poverty levels from the successive price increases? Firstly, the percentage of households below the poverty line diminished from 79 percent to 65 percent, with the last increase counting 0.8 E£/L, i.e., a reduction of 14.4 percent (while milk prices increased from approximately 2.5 to 3.3 E£/L, or 24 percent). Table 1 gives an overview of the impact of milk price increase of 0.8 E£/L on milk productivity and livestock contribution to poverty reduction.

	Feed supplementation (kg/head/day) with change	Change of milk yield (%)	Change of milk production cost (%)	Change of net income/ animal (%)	Ratio of Net income livestock/poverty line without change	Ratio of Net income livestock/poverty line with change
Farm type 2: 'Micro'	0.71	44.8%	-47.1%	86.8%	1%	18%
Farm type 1: 'Social small'	1.30	32.0%	-12.5%	58.1%	14%	35%
Farm type 3: 'Small'	0.72	44.5%	-57.9%	85.2%	3%	33%
Farm type 4: 'Medium'	0.84	42.1%	-57.9%	60.8%	44%	121%
Farm type 4: 'Large'	1.30	31.8%	-15.0%	72.9%	50%	131%

Table 1. Impact of milk price increase of 0.8 EGP/L on milk productivity and poverty level at the household level

Nevertheless, results were below what we could expect for the most vulnerable households of the sample, micro farms. With an increase of 0.8 E£/L, only 1.4 percent of households got out of poverty. Only households from medium farms benefited significantly from the price increase: 14 percent got out of poverty. The milk price increase benefited farms with strong assets. Finally, we observed that the increase of price changed the structure of the sample in terms of main activities due to increased breeding revenue share in households. Thus, the number of "cultivators" was reduced by a factor of three whereas the "breeder" number multiplied by a factor of four, meaning a significant change of the contribution of livestock activity in the total household net income.

Discussion

Diversification: a Link with Social Networks

Some households were able to face land pressure by diversifying to non-farm activities (Figure 6). Governmental employment appears to be a stable source of revenue, but education is required. The private sector has higher returns, but it requires a certain level of capabilities (education and skills) and complementary inputs, such as capital, credit. It can also be an inconsistent source of revenue due to market instability. Whatever the non-farm activity is, both governmental and private jobs improve social networks, which improve access to farming services. Thus, even if households intend to diversify through non-farm activities, social networks contributed to enhanced technical efficiency and outcomes through better access to farming services and the consequent strengthening of agricultural activities. That confirms observations elsewhere, indicating that social position is one of the main driving forces towards livelihood diversification.[29] Because the involvement in these remunerative sectors requires various financial, social and human capital, poor households are unable to overcome such entry barriers and gain access.

On the other hand, Figure 8 shows that with weak assets, in particular education and land area or herd size, households had difficulties in diversifying to non-farm activities beyond off-

farm occasional employment (often in the farming sector) without improving social networks. These households were forced to adopt a survival livelihood strategy rather than an accumulation livelihood strategy. Thus, the poorest households are trapped in low return activities that hinder them from increasing the diversity of their livelihood portfolio.[30]

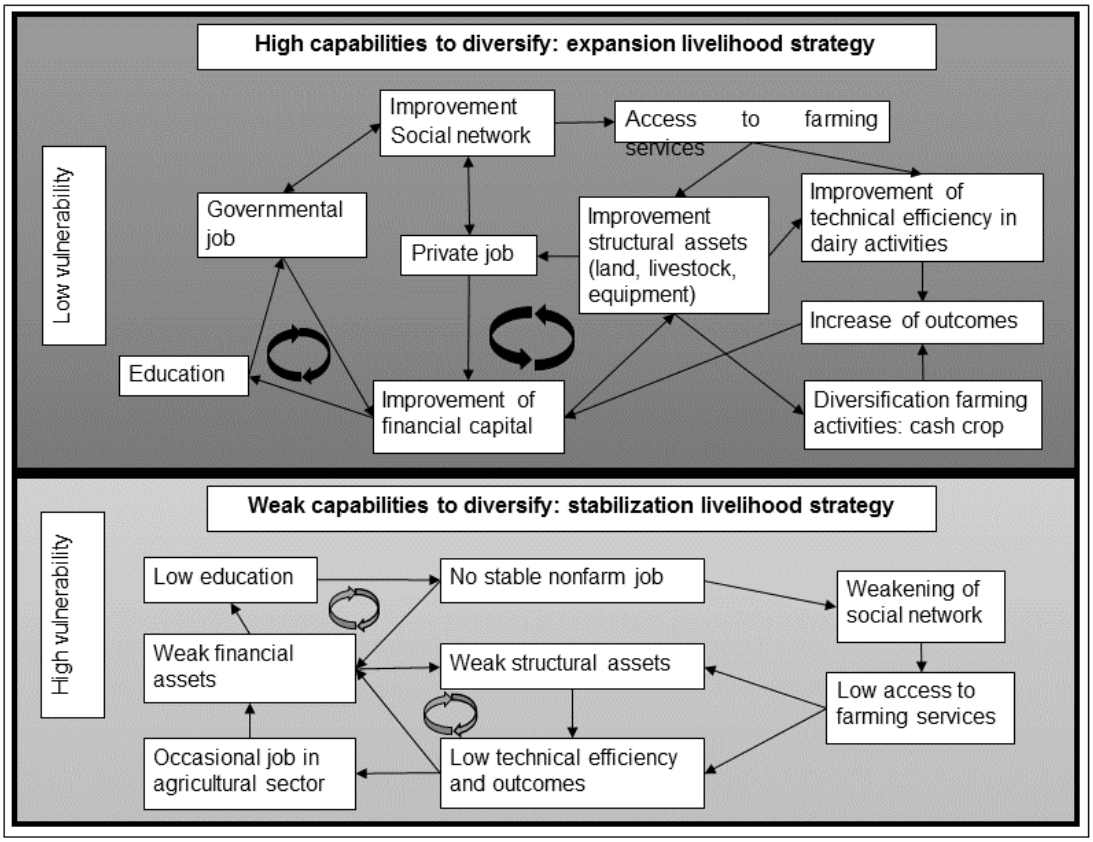


Figure 8. Livelihood strategies according to capabilities to diversify

Households whose revenues derived mostly from animal breeding are among the poorest and none of them fall into the "rich" category. Their weakness in human (education) and physical (land area that restricts herd size) capital, which partly constitutes their high level of vulnerability, is often the reason for their difficulties in adopting an expansion livelihood strategy.

The more activities are diversified in the household, the higher the percentage of rich households in the activity-related category (starting from "breeder" and "cultivator" categories, then "off-farm" activity and finally "mixed" farming), and conversely for the "very poor" category (see Table 2). We can conclude that, in the present case study, the diversification of activities towards livestock and cropping activities and off-farm jobs, contributes to poverty reduction. Nevertheless, some structural parameters are fundamental to achieve mixed farming, especially education, social networks, land area, herd size, milk yield, and technical level. Moreover, in the trajectory analysis of the householders between profile types, we can highlight the rigidity of the repartition of households between profiles. These results show the weight of structural parameters, especially land access and education, in explaining the low flexibility of households in livelihood diversification. In Egypt, land fragmentation linked with demographic

increase in rural areas constitutes a major challenge to farm diversification even as some farmers attempt to diversify by raising sheep or goats that demand less in feed supply. Education level should increase with parents' investment in education. However, this change in human capital could create frustrations without accompanying economic growth in other related agricultural sectors.

Activity-related category	Mixed			Breeder			Cultivator			Off-farm activity		
Poverty category	Very poor	Poor	Rich	Very poor	Poor	Rich	Very poor	Poor	Rich	Very poor	Poor	Rich
Number of HH	0	9	8	17	4	0	62	29	18	6	43	20
% of HH by poverty category in activity-related category	0%	53%	47%	81%	19%	0%	57%	27%	16%	8%	62%	30%

Table 2. Proportion of households distributed in each poverty category by activity-related category

Contribution of Livestock to Food Security

Households from "breeder" and "cultivator" categories, which live essentially on their farming revenues, dedicate a large part of their milk production for home consumption and ensure the nutritional coverage of protein and calories. In these categories, householders do not have access to another source of revenue to improve the diversity of their food sources. Livestock appears to be a secure food source, especially for the poorest householders and so decreases their food vulnerability. Beyond the livestock contribution to food security, the majority of farmers cultivate cash crops, at least wheat in small areas and sometimes vegetables, and consumed part of their production. Moreover, a mixed crop-livestock system takes advantage of agronomic synergies between livestock and crops through the valorization of manure for soil fertilization plus straw supply and crop residues for livestock, thus contributing to food security and regular income.[31] The present finding confirms this contribution in reducing food vulnerability for smallholders in the context of climate change and economic instability. For households with diversified revenue sources, particularly towards off-farm activities, we noted a decrease in the proportion of home-consumed milk. Nevertheless, they still conserved their milk production and home consumption, thus improving their resilience to shock incidents.

Role of Livestock in the Mixed Crop-livestock System

Why is it that the majority of households based around on-farm activities (mainly the "cultivator" and "breeders" categories) persist in raising cattle or buffalos despite low-revenue generating livestock activities? Is livestock income sufficient to understand these systems? Are there other functions of breeding activity?

We notice that households in the "cultivator" category were the most numerous (compared to "breeder" category). Moreover, in these two categories, most farmers fall into the "very poor" and "poor" categories, particularly the "breeder" category. Nevertheless, it makes no sense to separate these two agricultural activities to analyze the system because they are intimately linked.[32] Cropping activities are indeed profitable only because livestock contributes to improving the fertility of the soil and, vice versa, livestock becomes gainful when valorizing

crop-residues or leguminous crops. Thus, the cropping activities associated with livestock production are essential to reduce the monetary vulnerability of the householders.

Despite the low return of the dairy sector when considered separately, farmers from the "breeder" category kept animal production as a part of their farming system, particularly for fertilization. In this category, farmers also perceived livestock as a financial resource in case of important family events like weddings or unanticipated events, and even as a form of prestigious capital to maintain their status in the community. While the dairy sector is a stable revenue source, livestock is also vulnerable live capital exposed to many depreciation risks such as disease or market price variations.

Conclusion

Farms with low technical performance, particularly in milk production, and medium herd size were able to improve their dairy activity outcomes through increased feed quantity and quality. However, small and micro households remained the most vulnerable, due mainly to their low endowments. Therefore, a price support policy based only on the dairy sector faces difficulties in significantly reducing poverty for the majority of household farms of less than one hectare. However, given that milk quality and quantity increased, households had better resources to cover their nutritional needs even if they did escape poverty. Although vulnerable farms did not benefit from milk price increases in terms of income improvement, the price support policy could be helpful to farms with larger herds but low profitability. The issue for vulnerable farms is knowing which measure or policy is best adapted to these farms. We saw that small scale farms with a large spectrum of assets, in particular education and social networks, had access to off-farm revenues. Moreover, in addition to the improvement of access to education, reducing the isolation of households by improving transport via new infrastructure should improve access to off-farm jobs and launch the expansion livelihood strategy (Figure 5). Education, social networks, and transport are key drivers to ensure vulnerable farms escape poverty. In summary, knowing that milk activity is fully embedded in a system at the farm and local level, only coordinated interventions taking into account the internal functioning (complementarity of activities at household level) and external functioning (horizontal and vertical relationships) of the systems will have impacts on poverty reduction or economic growth.

From a methodological point of view, this approach allowed a comparison of the differential impact of milk price increases on livelihood according to asset composition. However, this approach is not dynamic and cannot integrate changes of activities following one scenario. For example, increasing feed quantity and quality and diet improvement should improve fertility/health of the herd, which will have positive impacts and consequently induce new investment. However, due to increasingly constrained land access, water dependence on the Nile, and demographic growth, agricultural investment is often limited. Moreover, Egypt faced a drastic currency devaluation in 2016 that resulted in feed price increases. If a policy that makes feed more available/affordable to smallholders is to be impactful (as shown in the paper), it requires financial support and a well-organized system to reach the most vulnerable. In the current context of financial contraction in Egypt, activity diversification of households, particularly into off-farm employment (including transformation and then valorization of agricultural products), can generate skills and added value. This calls for developing new rural policies for the small-scale holdings that represent more than 90 percent of Egyptian farms. New

job opportunities and diversification along the agro-food value chain process must be prioritized in any new policies. Due to the long tradition and culture of milk processing and cheese consumption, and the demand increase with demographic growth, rural policies that favor milk processing and distribution for medium or high-quality milk products may generate important opportunities. However, this development also needs investments in infrastructure for maintaining the cold storage chain and skills development in terms of hygiene and conservation of fresh products.

Supplementary Material

	Small Social		Micro		Small		Medium		Large	
Typologies/profile number	**1**		**2**		**3**		**4**		**5**	
Number of household surveys	*36*		*71*		*47*		*56*		*6*	
Structural data used for the construction of typologies as active variables in factorial analysis										
Land and crop data (first axis)										
Land cultivated area (feddan[1])	1.99	±1.23	1.04	±0.51	1.81	±0.78	3.06	±1.44	9.00	±2.49
Rate area in ownership	45%	±36%	18%	±32%	36%	±36%	55%	±37%	61%	±19%
Rate of area for animal feeding	65%	±29%	71%	±31%	59%	±31%	59%	±25%	56%	±24%
Rate cash crop area	9%	±14%	4%	±9%	16%	±21%	21%	±20%	25%	±14%
Rate wheat area	20%	±11%	21%	±13%	19%	±11%	20%	±7%	19%	±9%
Livestock data (first axis)										
TLU[2] total number	4.97	±1.71	4.22	±1.5	6.84	±2.73	10.24	±4.24	19.58	±3.22
Rate of crossbred	68%	±47%	65%	±44%	52%	±42%	44%	±44%	46%	±38%
TLU[2] milk number	3.01	±1.33	2.59	±1.02	3.87	±1.72	6.57	±2.23	13.19	±2.69
Social data (second axis)										
Family members	4.86	±1.46	6.97	±3.64	7.16	±2.86	9.21	±4.88	6.50	±1.52
Education level of family head	4.78	±1.48	1.21	±0.84	1.09	±0.54	2.41	±1.84	1.17	±1.47
Governmental job ratio	20%	±14%	2%	±5%	1%	±4%	1%	±3%	17%	±18%
Private job ratio	8%	±16%	1%	±3%	6%	±14%	7%	±11%	30%	±16%
Occasional job ratio	1%	±5%	12%	±23%	0%	±2%	2%	±7%	0%	±0%
Technical efficiency implemented as secondary data in factorial analysis										
TLU number per fodder area (feddan[1])	2.94	±1.47	3.58	±2.08	6.18	±10.89	4.89	±4.32	2.83	±0.71
Artificial insemination rate	0.50	±0.50	0.24	±0.43	0.09	±0.28	0.13	±0.33	0.33	±0.47
Concentrate distributed per milk litre	0.92	±1.07	1.37	±0.89	1.37	±0.96	0.90	±0.63	1.18	±0.79
Cattle[3] milk yield per head per year	2121	±1020	1168	±687	1152	±592	1373	±615	2266	±1350
Milk home-consumption rate	23%	±36%	49%	±44%	51%	±38%	31%	±34%	0%	±0%

[1] feddan=0.42 hectare; [2] TLU=250 kg live body weigh; [3] buffalo and cow.

Variables	Estimation of the variables	Sources and comments
Structural data		
Herd composition	Declarative data from pilot farms	
Mortality rate (< 1 year)	0.19	(Tabana, 2000)
Calving rate	0.89	(Tabana, 2000)
Exploitation rate	Calculated to keep the same number of dairy animals over 20 years	
Daily needs for upkeep (% of alive weigh)	2.3% for dairy animals 2.5% for calves, heifers and bulls	
Cattle alive price	Regional prices by age category	Bulls, dairy cattle, fattened males, heifers and calves <1year
Cultivated land area	Declarative data from pilot farms	
Feed and fodder production		
Area for animal feeding	Declarative data from pilot farms	Structural data from pilot farm to assure a coherence in the production system
Workforce cost	Declarative data from pilot farms	
Fertilizer cost	Reference from the CLIMED project (https://climed.cirad.fr/content/download/4561/32972/version/2/file/WP3_Egypt_team_CLIMED_jan+2015_Egypt.pdf)	
Rental land cost	Declarative data from pilot farms	
Veterinary cost	Declarative data from pilot farms	
Feed and fodder purchased		
Concentrate price	From profiles average data	Feed price of the first year of data collection
Quantity concentrate per head	From profiles average data	Quantity distributed average over three years
Fodder	From profiles average data	Average cost over three years
Dairy activities		
Milk production	From profiles average data	Quantity produced average over three years
Milk price	From profiles average data	Milk price of the first year of data collection

Supplemental material 1: Variables used for characterising the pilot farms

References

Aboulnaga, Adel et al. 2017. "Study on small-scale agriculture in the Near East and North Africa region (NENA)." *Focus Country: Egypt. FAO, CIRAD and CIHEAM*, http://www.fao.org/3/a-i6497e.pdf.

Alary, Véronique et al. 2017. "Atlas of the traditional milk sector around grater Cairo in Egypt." *Atlas.* https://umr-selmet.cirad.fr/FichiersComplementaires/Atlas_finale_BR1_end.pdf

Alary, Véronique et al. 2016. "Social Network and Vulnerability: A Clear Link in Bedouin Society (Egypt)." *Human Ecology*. DOI 10.1007/s10745-016-9807-z.

Alary, Véronique et al. 2014. "The Livestock Sector Investment and Policy Toolkit (LSIPT), Diagnostic phase, Manual 2." *Montpellier, France: CIRAD.* IDDN.FR.001.500017.000.S.P.2014.000.10000

Babatunde, Raphael, and Matin Qaim. 2010. "Impact of off-farm income on food security and nutrition in Nigeria." *Food Policy* 35.4: 303-11.

Barrett, Chistopher, et al. 2001. "Income diversification, poverty traps and policy shocks in Cote d'Ivoire and Kenya." *Food Policy* 26.4: 367-84.

Daburon, Annabelle et al. 2016. "Evolution of a milkshed and role of alternative milk collection centres in Egypt." *Cah. Agric.* 25.6. http://www.cahiersagricultures.fr/articles/cagri/pdf/2016/06/cagri160007.pdf

Douthwaite, Boru et al. 2003. "Impact pathway evaluation: an approach for achieving and attributing impact in complex systems." *Agricultural Systems* 78: 243–65.

Dutilly, Céline et al. 2019. "Multi-scale assessment of the livestock sector for policy design in Zambia." *Journal of Policy Modeling*. https://doi.org/10.1016/j.jpolmod.2019.07.004

Eakin, Hallie. 2005. "Institutional change, climate risk, and rural vulnerability: cases from central Mexico." *World Development* 33.11: 1923-38.

Ellis, Frank. 2000. "The determinants of rural livelihood diversification in developing countries." *J. Agric. Econ.* 51.2: 289-302.

_____. 1998. "Household strategies and rural livelihood diversification." *J. Dev. Stud*. 35.1: 1-38.

FAO. 1981. "Energy and protein requirements: past work and future prospects at the international level." *Report* http://www.fao.org/docrep/meeting/004/m2995e/m2995e00.htm.

Garnett, Tara et al. 2013. "Sustainable Intensification in Agriculture: Premises and Policies." *Science* 341: 33-34.

Goodman, A. Leo. 1961. "Snowball sampling." *Annals of Mathematical Statistics* 32.1: 148–70.

Guang, Lei and Lu Zheng. 2005. "Migration as the second-best option: local power and off farm employment." *The China Quarterly* 181: 22-45

Herrero, Mario et al. 2010." Smart investments in sustainable food production: revisiting mixed crop-livestock systems." *Science* 327.5967: 822-25.

Hoang, X. Trung et al. 2014. "Non-farm activity, household expenditure, and poverty reduction in rural Vietnam: 2002-2008." *World Development* 64: 554-68.

Khatun, Dilruba and Bihan Chandra Roy. 2012. "Rural livelihood diversification in West Bengal: Determinants and Constraints." *Agricultural Economics Research Review* 25.1: 115-24.

Lesnoff, Matthieu. 2010. "DYNMOD: A spreadsheet interface for demographic projections of tropical livestock populations - User's Manual, Montpellier." Manual. http://livtools.cirad.fr. Available at: http://livtools.cirad.fr.

LSIPT. 2012. "Livestock Sector Investment Policy Toolkit." www.alive-lsiptoolkit.org/tools/download (login: alive, password: toolkit).

Marra, Michele et al. 2003. "The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?" *Agric. Syst.* 75: 215-34.

Matson, A. Pamela et al. 1997. "Agricultural Intensification and Ecosystem Properties." *Science* 277.5325 : 504-09.

Mazoyer, Marcel and Laurence Roudart. 2011. "La fracture alimentaire et agricole mondiale: état des lieux, causes, perspectives, propositions d'action." In Christine Verschuur (ed.), *Genre, développement rural et alimentation. Du grain à moudre* https://books.openedition.org/iheid/pdf/6746

Morton, F. John. 2007. "The impact of climate change on smallholder and subsistence agriculture." *Proc. Natl. Acad. Sci.* 104.50. 19680-85.

O'Brien, Karen et al. 2009. "Vulnerability interventions in the context of multiple stressors: lessons from the southern Africa vulnerability initiative (SAVI)." *Environ. Sci. Policy* 12.1: 23-32.

Sancoucy, René et al. 1995. "Keynote paper: The contribution of livestock to food security and sustainable development". https://www.researchgate.net/publication/264448802_Keynote_paper_The_contribution_of_livestock_to_food_security_and_sustainable_development

Scoones, Ian. 1998. "Sustainable Rural Livelihoods: A Framework for Analysis." *Working Paper 72*. https://www.staff.ncl.ac.uk/david.harvey/AEF806/Sconnes1998.pdf.

Tabana, A. 2000. "Development of a decision support system for individual dairy farms in mixed irrigated farming systems in the Nile Delta." Ph.D. Dissertation Wageningen University.

Thornton, K. and M. Herrero. 2015, "Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa." *Nature Climate Change* 5. www.nature.com/natureclimatechange.

Tschakert, Petra. 2007. "Views from the vulnerable: understanding climatic and other stressors in the Sahel." *Glob. Environ. Change* 17.3: 381-96.

Turner, B. et al. 2003. "A framework for vulnerability analysis in sustainability science." PNAS 100.14: 8074-79.

Wilbanks, J. Thomas. 2003. "Integrating climate change and sustainable development in a place-based context." *Clim. Policy* 3.1: S147-54.

WFP. 2003. "The status of poverty and food security in Egypt: Analysis and policy recommendations preliminary - Summary report". http://documents.wfp.org/stellent/groups/public/documents/ena/wfp257467.pdf?_ga=2.158525818.1169879038.1512394922-1514704725.1512394922)

Zhang, Xiaobo, and Guo Li. 2003. "Does Guanxi matter to nonfarm employment? " *J. Comp. Econ.* 31.2: 315-31.

World Bank. 2016. DataBank. https://data.worldbank.org/country/egypt-arab-rep

Notes

1 Mazoyer and Roudart 2011.
2 Matson et al. 1997.
3 Garnett et al. 2013.
4 Marra et al. 2003.
5 Eakin 2005; Morton 2007; Tschakert 2007.

6 Turner et al. 2003; Wilbanks 2003; O'Brien et al. 2009.
7 Ellis 1998, p.4.
8 Barrett et al. 2001; Babatunde and Qaim 2010; Hoang et al. 2014.
9 Ellis 2000; Barrett et al. 2001.
10 Ellis 2000; Barrett et al. 2001.
11 Zhang and Li 2003; Guang and Zheng 2005; Alary et al. 2016.
12 LSIPT 2012 (developed jointly by the World Bank, CIRAD and FAO); Alary et al. 2014; Dutilly et al. 2019.
13 Sancoucy 1995.
14 World Bank 2016.
15 Aboulnaga et al. 2017.
16 WFP 2013.
17 Aboulnaga et al. 2017.
18 World Bank 2015.
19 Herrero et al. 2010.
20 Ellis 1998; Scoones 1998.
21 Daburon et al. 2016.
22 Alary et al. 2017.
23 Goodman 1961.
24 Dutilly et al. 2019.
25 The livestock demographic projection model uses the DynMod tool presented in Lesnoff 2010.
26 FAO 1981.
27 Douthwaite et al. 2003.
28 Tabana 2000.
29 Khatun and Roy 2012.
30 Ellis 1998; Ellis 2000.
31 Thornton and Herrero 2015.
32 Thornton and Herrero 2015.