Cultivating Prospective Thinking: A Gateway into the Future for Peruvian Dairy Farmers in the Mantaro Valley

Experimenting a Support Approach Based on the Use of Modelling Tools

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Abstract

The Mantaro Valley is an Andean region where its dairy sector has been experiencing noticeable growth since the mid 1990s. Moreover, milk production has shown potential in improving the standards of living for farmers in the area. As a result, this study was launched aiming at improving dairy farm development through the use of a support approach, based on the use of modelling tools. This methodology does not serve as an aid for decision making *per se*, but rather as a means to stimulate the farmers' thought process, ultimately aiding them reflect on their foreseen projects.

The experimentation of this approach was conducted with 10 dairy farmers. Results show that, despite all striving to increase volumes of produced milk; each farmer anticipated doing so in a different manner. Their journey through the support approach allowed them to explore various options to attain their objective. The participative nature of the support methodology, the outputs from the modelling tools, and the discussions that materialize during approach proved to be key factors in fostering reflection on behalf of the farmers. Developing farmers' prospective thinking may ultimately contribute to the successful implementation of improvement projects at the farm level, and to the progression of the region's dairy sector. The support approach provides also a mean to evaluate potential impacts of economic and climatic shocks on farm performances. Simulations carried out on the ten studied farms show that intensifying dairy production based on own fodder resources allows farmers to decrease their milk production costs and consequently to increase their resistance to variability of milk prices. Sensitivity of milk production to reduced supply of irrigation water varies according to the kind of fodder system implemented.

The farmers' positive response to the support approach in this study suggests that other farmers in the valley could benefit from this type of agricultural assistance. Extending the methodology to a greater farming population would imply that the simulation tools be overhauled, and that an advisory entity be identified to implement the approach.

Keywords: Support approach, dairy farms, Peru, modelling, prospective thinking

Résumé

La Vallée du Mantaro est une région andine où le secteur laitier connaît une croissance notable depuis le milieu des années 1990. Par ailleurs, la production de lait a montré son potentiel dans l'amélioration du niveau de vie des agriculteurs de la région. Conséquemment, cette étude a été lancée visant à améliorer le développement des fermes laitières par la mise en œuvre d'une démarche d'accompagnement, basée sur l'utilisation d'outils de simulation. Cette méthodologie ne sert pas comme une aide pour la prise de décision en soi, mais plutôt comme un moyen de stimuler la réflexion auprès des agriculteurs, pour finalement les aider à penser à leurs projets anticipés.

L'expérimentation de cette démarche d'accompagnement a été réalisée avec 10 producteurs laitiers. Les résultats montrent que, malgré l'objectif commun d'accroître le volume de lait produit, chaque agriculteur a prévu de le faire d'une manière différente. Leurs expériences à travers la démarche leur a permis d'explorer diverses options pour atteindre leurs objectifs. Le caractère participatif de la méthode, les résultats des outils de simulation, et les discussions qui se matérialisent lors de la démarche se sont avérés être des facteurs clés pour favoriser la réflexion auprès des agriculteurs. Développer la réflexion prospective chez les agriculteurs peut à terme contribuer à une mise en œuvre réussie de projets d'amélioration au niveau de la ferme, et à la progression du secteur laitier dans la région. La démarche d'accompagnement permet également d'évaluer les conséquences potentielles d'une variabilité des prix du lait et de la disponibilité en eau d'irrigation. Les simulations réalisées sur les dix exploitations montrent que l'intensification de la production laitière à partir de leurs propres ressources fourragères permet de réduire les coûts de production du litre de lait, et donc d'améliorer la résistance des exploitations aux chocs économiques. La sensibilité de la production laitière à des réductions d'approvisionnement en eau d'irrigation est variable selon le type de système fourrager choisi.

La réaction positive des agriculteurs à la démarche d'accompagnement expérimentée dans cette étude suggère que d'autres producteurs de la vallée pourraient bénéficier de ce type de conseil agricole. Diffuser cette méthodologie à une communauté agricole plus grange impliquerait que les outils de simulation soient révisés, et qu'une organisation de conseil soit identifiée pour mettre en œuvre la démarche.

Mots clés: Démarche d'accompagnement, fermes laitières, Pérou, outils de simulation, réflexion prospective

Resumen

El Valle del Mantaro es una región andina, dónde el sector lechero está experimentando un crecimiento notable desde mediados de 1990. Por otra parte, la producción de leche ha demostrado su potencial en mejorar la calidad de vida de los ganaderos de la zona. Como resultado de ello, este estudio se puso en marcha con el objetivo de mejorar el desarrollo de la producción lechera a través del uso de un enfoque de apoyo, basado en el uso de herramientas de modelación. Esta metodología no sirve como una ayuda para la toma de decisiones por sí mismo, sino más como un medio para estimular el proceso de pensamiento de los ganaderos, por último ayudar a reflexionar sobre sus proyectos previstos.

La experimentación de esta metodología se realizó con 10 productores de leche. Los resultados muestran que, a pesar de que todos tratan de aumentar el volumen de leche producida, cada ganadero ha previsto hacerlo de una manera diferente. La experiencia a través del método de apoyo les ha permitido explorar varias opciones para alcanzar sus objetivos. El carácter participativo de la metodología de apoyo, los resultados de las herramientas de modelación, y las discusiones que se materializan durante el método han demostrado ser factores claves en el fomento de la reflexión en los ganaderos. Desarrollar la reflexión prospectiva en ganaderos puede contribuir a la implementación exitosa de proyectos de mejora a nivel de la finca, y a la progresión del sector lechero de la región. El metodo de acompañamiento también permite evaluar las consecuencias potenciales de una variabilidad de los precios de la leche y de la disponibilidad en agua de irrigación. Las simulaciones realizadas con diez explotaciones muestran que la intensificación de la producción lechera a partir de sus propios recursos forrajeros permite reducir los costos de producción del litro de leche, y pues mejorar la resistencia de las explotaciones a los choques económicos. La sensibilidad de la producción lechera a reducciones de abastecimiento de agua de irrigación es variable según el tipo de sistema de foraje escogido.

La reacción positiva de los ganaderos en este estudio sugiere que otros ganaderos en el valle podrían beneficiarse de este tipo de asistencia agrícola. Utilizar la metodología con una población agrícola más grande implicaría que las herramientas de simulación sean revisadas, y que una organización de asesoramiento agrícola se identifica para implementar el método.

Palabras clave: Metodología de apoyo, granjas lecheras, Perú, modelación, reflexión prospectiva

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[1] Bienz N., 2011. *Cultivating Prospective Thinking: A Gateway into the Future for Peruvian Dairy Farmers in the Mantaro Valley. Experimenting a Support Approach Based on the Use of Modelling Tools.* Master Thesis, SupAgro, Copenhagen University, Cirad, 60 p. + appendix.

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1. Introduction

Dairy production has been recognized as a pivotal agricultural activity for small-scale farmers in many regions around the world, given the regular and secure income it provides. In certain developing nations, upsurges in urban populations have led to a greater demand for milk at the national level. This phenomenon ultimately provides interesting prospects for dairy farmers if market access is made available (Bernet *et al.*, 2001).

Population growth and urbanization have notably fostered an augmentation in the demand for milk in Peru. The rise in demand in due course led to the development of links between urban markets and isolated dairy producing areas, like the Andes (Aubron, 2007). Consequently, highland farmers have since been able to participate in this growing sector, which has proven to be an effective development strategy for them (Bernet and Gómez, 2001). The Mantaro Valley confirms this observation, as illustrated by Cortijo *et al.* (2010) study. Indeed, dairy production in the area holds potential in improving the standards of living for small-scale farmers.

This finding fuelled the development of the current project financed by the World Bank and jointly conducted by the CIRAD (*Centre de coopération internationale en recherche agronomique pour le développement*) and UNALM (*Universidad Nacional Agraria La Molina*). The first component of the project, subject of this report, aims to improve dairy farm development in the valley through the experimentation of a support methodology, featuring the use of simulation tools (Technical Proposal, 2010). Modelling integrated within a support approach makes for a powerful entity as it enables the exploration of possible solutions to a practical problem posed by decision makers (here farmers), while fostering his/her prospective reflection (Moisdon, 1997). It also provides tools for evaluating *ex-ante* sensitivity of production systems to economic shocks leading to price variability and climatic shocks leading to reduction of water availability in the context studied.

This report will first provide greater detail on the nature of the dairy sector found in the Mantaro Valley, while better positioning the objective behind the implementation of the support methodology. Moreover, the origin and character of the simulation tools will be presented. This will then be followed by a description of the various facets of the approach and how the modelling implements are used. Secondly, the carrying out of the methodology with 10 farmers from the valley will be introduced; highlighting the various questions that were addressed and the different strategies that were explored. This section also includes results from an evaluation of the support approach by the farmers, and a sensitivity analysis of farm performances to economic and climatic shocks respectively characterized by milk production costs variability and irrigation water availability. Finally, the last chapter consists of a discussion where the role of the methodology in promoting farmers' prospective thinking is conferred, the possibility of extending the approach to a greater farming population is explored, the limitations of the method and potential improvements for the simulation tools are addressed, and the lessons from the sensitivity analysis are drawn.

2. Context and Problem Position

Since the beginning of the 1990s, milk production in Peru has experienced strong growth on the Pacific coast and in the Andes (Aubron, 2007). The unprecedented annual rate of development of 4.2%, from 1996 to 2005, has been attributed to a number of factors (Gómez *et al.*, 2007). Firstly, the start of the last decade of the 20th century was marked by a significant amendment in the country's dairy policy; Peru went from a policy of subsidizing imports of powdered milk to a policy aiming at protecting its national market. Secondly, demographic growth in conjunction with increased urbanization led to changes in consumption patterns, where dairy products increasingly gained importance in people's diets. Lastly, the evolution of Peru's dairy sector since 1990 has stemmed from the development of communication channels and transportation courses. These elements contributed to expanding and improving milk collection routes and fostering faster transportation of highly perishable items such as raw milk, cheese and yogurt, to urban centers. Areas once isolated from these markets, notably Andean regions, were thus provided with access, which enabled their populations to participate in the emerging sector (Aubron and Cochet, 2009).

The Mantaro Valley, located in the department of Junín in the central Andes, is known as one of Lima's leading suppliers of fresh produce given its geographical proximity. In addition to its horticultural sector, dairy production is also present and incidentally, has reflected much of the dynamic growth found at the national level (Figure 1) (Cortijo *et al.*, 2010).

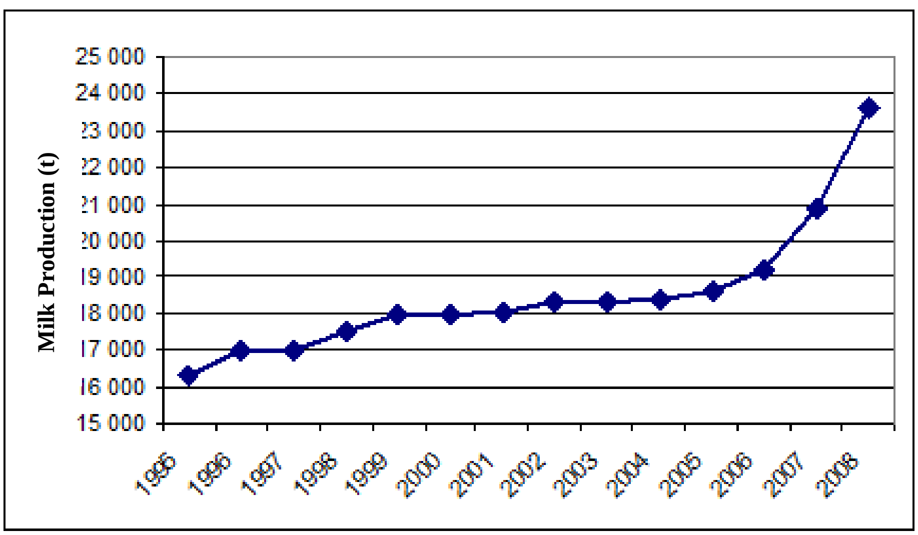


Figure 1: Evolution of dairy production in the department of Junín from 1998 to 2005
(source: Cortijo *et al.*, 2010)

While the department of Junín only supplies 1.35% to national milk production, 73% of this contribution originates from the Mantaro Valley. Out of the 108 398 ha of arable land found in this area, 27% are irrigated, which greatly favours forage crop production, a valuable asset in the dairy sector. In 2008, forages produced in both irrigated and rainfed systems, represented 28% of the total harvested area in the valley. The dominant breeds of cows found in the region are Holstein and Brown Swiss. Crosses are also commonly found on farms throughout this river basin (Cortijo *et al.*, 2010).

An increase in the presence of artisanal cheesemakers and the development of small to medium size dairies have been associated with the augmentation of milk production in the area, particularly in the last decade. As for the influx of processing actors in the valley, this occurrence stemmed from two principal aspects: the arrival of Gloria, a major national dairy, that installed a collection center in the region in 2005, and the implementation of the social program PRONAA (*Programa Nacional de Asistencia Alimentaria*), that provides milk to school children and which began purchasing its milk in 2000 from local dairies. Consequently, the arrival of these important stakeholders allowed for an increase in the price for milk; originally at 0.70 to 0.80 soles[2] per litre, offered by local processing bodies, the going rate jumped to about 1.00 S/. Today, approximately 68% of the milk produced in the valley is collected by Gloria. The artisanal cheesemakers find themselves gathering and processing about 19% of total volumes into *queso fresco* (a soft non-aged cheese with a smooth light texture). Finally, the local dairies amass 13% of the river basin's production and transform it into *queso fresco*, butter, yogurt, ice-cream and *manjar blanco* (a whole-milk caramel spread) (Cortijo *et al.*, 2010).

Different from other local supply basins located on irrigated perimeters, like the one described in Le Gal *et al.* (2007) Moroccan study, where milk collection is centered around one main entity, Mantaro's features a large diversity of actors offering different opportunities to the farmer and various entry points to downstream markets. The presence of numerous and diverse stakeholders has thus resulted in a considerably competitive environment, where milk is in demand and highly sought after by collectors and processors (Cortijo *et al.*, 2010).

As diverse as the collecting and processing actors, are the dairy farmers of the valley. The study conducted by Cortijo *et al.* (2010) highlighted six main farm types, characterized according to their degree of specialization in milk production and their stocking rate, presented in greater detail in Appendix 1. In essence, the production systems vary from large-scale farms following a rather intensive technical model, to small-scale operations with diversified activities. Herds generally vary between 3 and 23 cows and are principally fed from irrigated forage systems featuring a variety of species including alfalfa, clover, ryegrass, oat and vetch. Other feedstuffs

[2] Peruvian nuevo sol (S/.): Peru's currency. The approximate exchange rate is 3.5 soles for 1 euro ; 2.6 soles for 1 american dollar.

such as *chala* (corn stover) and concentrates are often distributed to complete the rations. Milk production is highly variable from one animal to another and also from farm to farm. Daily milk supplies can vary anywhere from 5 to 300 L per farm.

In addition to illustrating that dairy production in the valley manifests potential in improving standards of living for small-scale farmers, notably through stable and regular income generation, the previously carried out work helped identify focal domains for further action in Mantaro, which set this current project. Suggested areas to be undertaken consisted of: water management and forage production in the dry season, herd management and dairy farm development, empowerment of farmers' organizations in the dairy sector, development of private and public services, and support of local processing firms (Technical Proposal, 2010).

Accordingly, the CIRAD and its new joint partner UNALM have embarked on an endeavour to address these issues through farmer and processor support methodologies. The present study deals with the first component of this new project, which represents the third successive venture tied to actions initiated in the Mantaro Valley by the CIRAD and the World Bank since 2008 (Laporte *et al.*, 2008; Cortijo *et al.*, 2010).

The initial support methodology that was introduced in the valley was one aimed at dairy farmers, which featured the use of modelling tools. Dairy farms, much like those present in Mantaro, integrate a livestock unit with a fodder production unit, eventually completed by horticultural/cereal crops. Consequently, these production systems are characterized by a number of complex affiliations between their different units. Examples of such relationships include: (i) the over year balance of herd feed demand tied to the forage supply generated on the farm, (ii) the portion of purchased fodder found in the feed system, (iii) the impact of decisions made with regards to the demand for labour, (iv) manure management considered on both an environmental and fertilization level. Modelling thus becomes a powerful means to portray these intricate relationships, while fostering the exploration of new combinations in which *ex ante* impacts on the technical, economic, and environmental performance of the studied production system are explored. Nonetheless, if the combinations are destined as a support to farmers, it is vital that the representations found in the model are consistent with farmers' conceptualizations of their personal production systems (Le Gal *et al.*, 2011a).

Over the years, a wide range of models have been designed and applied to dairy farms, destined to ameliorate the understanding of how systems function or to assist farmers in decision making. Models aiming to improve overall comprehension, often referred to as research models, aspire to portray the system/object in question and to highlight areas in which information is missing. As for decision support models, their intention is to depict the studied system/object in order to assess the impact of a set of decisions on its performance, investigate new combinations, and ultimately provide greater insight on decisions to be made. A distinguishing feature of this type of model is its ability to foster discussions among farmers and researchers or advisors.

Consequently, this may imply that comprehensibility takes precedence over precision (Le Gal *et al.*, 2011b).

Of the variety of models that exist today intended to be used as decision-support tools by or with farmers, several feature restrictive and/or elaborate characteristics. As described in Kerr *et al.* (1999), these types of models may be founded on statistical relationships and only applicable to a particular region. Others, as discussed in Vayssières *et al.* (2007), may be established on mechanistic relationships and necessitate significant amounts of information. Furthermore, certain models in this category, much like the one presented in Dobos *et al.* (2004), are confined to decisions of a specific nature, e.g. balancing forage supply with a herd's demand for feed. In addition to these conditional attributes, there can also be operational constraints such as parameterization tied to the use of mathematical models, highlighted in studies conducted by Herrero *et al.* (1999) and Schils *et al.* (2007). Therefore, in an attempt to secede from restrictiveness, undue complexity and operational hindrances, a spreadsheet application based on a Moroccan case (Le Gal *et al.*, 2009) was developed, further experimented in Brazil (Bernard, 2010) and extended to mixed crop-livestock farms in Burkina Faso (Andrieu *et al.*, 2010) and Madagascar (Douhard, 2010). This application was the basis of the model used in the Mantaro Valley for this study. The underlying ideas behind the spreadsheet rooted model are essentially ease of use, in addition to suitability for different types of crop-livestock farms, including dairy farms, and for the diverse nature of farmers' concerns (Technical Proposal, 2010).

The essence of this study consisted of the experimentation of a dairy farmer support approach based on the use of spreadsheet modelling tools, as a mean for decreasing the vulnerability of small-scale dairy farms to economic and climatic shocks by increasing the anticipation and planning capacities of farmers. From the standpoint of the current situation of the valley's dairy sector, an interrogation arose as to whether this support methodology could better position farmers, diverse in nature, in fulfilling the demand for milk in the area. Finally, given that this particular method does not serve as an aid for decision making *per se*, but rather as a means to stimulate the farmers' thought process with regards to their production system dynamics, the following questions emerged: **How and why does this dairy farm support approach, based on modelling, help farmers reflect on their foreseen projects? What would be the sensitivity of their foreseen production systems to economic and climatic shocks?**

3. Materials and Methods

3.1 The Sample

This study was conducted over the course of 4 months with a total of 10 dairy farmers (Table 1), from 2 districts of the Mantaro Valley, in the department of Junín. The district of Apata, which belongs to the province of Jauja, and the district of Matahuasi, located within the provincial parameters of Concepción, were the focal locations of this research project (Figure 2). Both sites are located on the left bank of the Mantaro River; an area known for its concentration of small and large-scale farmers (Cortijo *et al.*, 2010). The identification of the specific farmers who participated in the experimentation process materialized as the study unfolded. Given that one of the objectives of this project was to test the use of the approach with a large variety of cases, the piloting selection criteria that transpired were herd size and farmers' interest in participating in the study, stemming from interrogations related to the evolution of their farm.

Figure 2: Location of farmers who participated in the study
(Source: Google, 2011; INEI, 2007)

The first farmers who participated in the study were identified at a farmers' association meeting in Matahuasi. During that event, the project was briefly described to the attendees, and it was inquired if anyone in the audience would be interested in participating. It resulted that two farmers manifested enthusiasm in collaborating. Their willingness to take part in the study marked the beginning of the experimentation of the approach. Once the exercise was completed with them, a local dairy in Apata, Monteflor, which collaborated in Cortijo's *et al*. (2010) study, was contacted in an effort to identify further farmers. Given that the initial stage of the study featured farmers with 13 and 25 cows, respectively, it was mentioned that farmers with smaller herds were sought after. As a result, contacts were established with 4 new farmers; 2 of which featured herds of 5 cows and the other 2 farmers both had 8 animals in production. After the methodology was carried out with these farmers, the sample had then covered herd sizes varying between 5 and 25 cows. Consequently, this initiated the search for individuals managing herds smaller and larger than those already explored. Owing to contacts that had been made with various farmers in the area, it was possible to identify three additional farmers, meeting the desired criteria, who expressed interest in participating in the study. The last stage of the project thus featured herds of 3, 4 and 64 cows. Finally, a 10th and ultimate farmer, who helped identify 2 farmers in the sample, was included in the study given that he had asked to take part in the experimentation of the approach, if time allowed. Hence, a farmer with 23 cows came to complete the sample.

Table 1: Overview of the study sample

Farmers (gender)[a]	**Number of cows in production**[b]	**Average milk production (L/cow/day)**	**Collector/processor**	**Location (town)**
F1 (M)	3	8	Bonanza[c]	Apata
F2 (M)	4	12	Gloria and *poronguero*[d]	Apata
F3 (F)	5	9	*Poronguero*	Apata
F4 (F)	5	9	Monteflor[c]	Apata
F5 (F)	8	8	Monteflor and *poronguero*	Apata
F6 (M)	8	11	Monteflor	Maravilca
F7 (F)	13	13	Gloria and *poronguero*	Matahuasi
F8 (M)	23	12.5	Bonanza and *poronguero*	Apata
F9 (F)	25	11.5	Gloria and *poronguero*	Matahuasi
F10 (M)	64	21	Gloria and 4 *porongueros*	Matahuasi

[a]M: male / F: female
[b]Includes dry cows
[c]Small local dairy
[d]Small milk collector who either sells or processes milk

3.2 The Support Approach and its Simulation Tools

The support approach experimented in this study includes the use of three modelling tools developed ultimately in Madagascar (Douhard, 2010). The work carried out in that country led to the creation of three spreadsheet applications. The first, CalculRation, depicted in greater detail in Appendix 2, is designed to simulate milk and meat production tied to a specific ration. The application operates on the basis of the "average lactating cow" found in the herd every month according to the herd's calving dynamics. Given the nature of the production systems explored in this study, only the milk aspect was worked with. The second, CalculFerti, featured in Appendix 3, aims at representing the yield of a specific crop in relation to applied chemical and organic fertilizers. Finally, CLIFS (Crop Livestock Farm Simulator) (Appendix 4) evaluates the techno-economic performances of a particular management strategy at the scale of the entire production system, notably by incorporating the various outputs from the two other spreadsheet applications. The rations from CalculRation and the fertilization strategies from CalculFerti are inserted into CLIFS, from which feed and organic matter balances are established based on the farm's available resources (supply) and demand (rations and fertilizations).

Given that these spreadsheets were conceived in Africa, each application needed to be adapted to a Peruvian context and translated into Spanish before being used in the field. The application requiring the greatest amount of modifications was CalculRation. The version constructed in Madagascar featured the French feeding system, INRA, thus needed to be completely overhauled to function in the American system, NRC, which is used in Peru. In essence, all the formulas used to calculate energy and protein requirements for maintenance, milk production and pregnancy needed to be changed. Moreover, the notion of dry matter intake (DMI) substituted INRA's equivalent, known as *encombrement*. All applied formulas and notions were derived from NRC's 1989 and 2001 editions of Nutrient Requirements of Dairy Cattle. The conversion from the INRA to the NRC system represented the entirety of the equation modifications in CalculRation. All other formulas present in the application that are not specifically tied to a feeding system remained unaltered. Finally, the feed tab in CalculRation was refurbished with feedstuffs, found and utilized in the valley, and their respective nutritional values. With the exception of a couple concentrates, all values were extracted from Laforé's (1999) thesis, which explored the chemical composition of the main feedstuffs distributed to livestock in the Mantaro Valley.

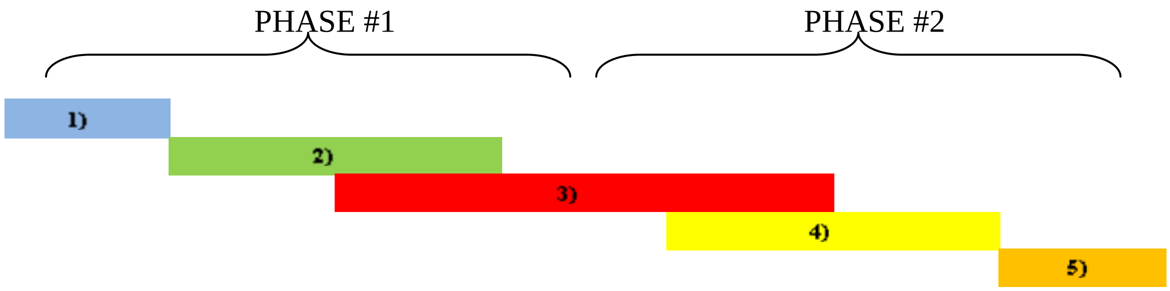
No change was made to any of the equations included in the CalculFerti application. Alterations only related to the types of crops, their respective nutrient extraction values and residue: grain ratios (where applicable), and to the forms of chemical and organic fertilizers used in the valley. Data relating to extraction values was principally retrieved from two main sources. García Bendezú's (2011) thesis, which evaluated the biophysical resource management strategies of the agro-ecosystems in farm communities of the Mantaro Valley, and the IPNI's (International Plant

Nutrition Institute) figures on *Requerimientos nutricionales – Absorción y extracción de macronutrientes y nutrientes secundarios* provided the basis of information required to adapt CalculFerti. A list of additional references used in adapting the spreadsheet applications can be found in Appendix 5.

The equations found in CLIFS were unchanged as well. Necessary adjustments were required in the data tab of the spreadsheet, which features all the inputs (crops, seed, fertilizers, and pesticides) used in the valley's production systems, as well as their prices. Moreover, the appropriate residue: grain ratios (from the adjustments made in CalculFerti) needed to be added in that same tab, enabling the calculation of crop residue amounts available for distribution in the animal rations or for incorporation into farmyard manure. Input types and their prices, in addition to crop yields to be applied in the simulations, were gathered from farmers, agricultural technicians and from locations selling agricultural products.

While the simulation tools were essential components of the support approach, the context in which they were used was particularly important. The work carried out with each individual was an endeavour which unfolded in a series of steps (Figure 3), where certain stages tended to overlap due to the nature of the discussions that materialized. Firstly, before even getting into the heart of this support methodology, its process, its objectives and the general idea behind the simulation tools were clearly explained to the farmer, with the aid of two sketches found in Appendix 6 and Appendix 7. This initial visit with the farmer then featured a series of questions focussed around a questionnaire (Appendix 8). The purpose of this effort was to collect necessary information to depict the production system in terms of its herd and rations, crop rotations and management, irrigation, labour force, input costs, etc. The data collected served as a basis to construct a base scenario, term coined by Douhard (2010), using the three simulation tools. This modelled scheme attempted to best represent the current situation of the farm and foster a better understanding of the production system as a whole. In addition to gathering important data to initiate the modelling process, this first session also served as a time to discuss the farm's history, its structure and actual functioning in an attempt to initiate a dialogue relating to potential projects the farmer had and/or problems he/she was looking to solve.

All depending on the success in constructing the base scenario, the second visit with the farmer went either one of two ways. If all the necessary information was collected in the first session, and if there were no major incoherencies detected while entering the data into the simulation tools, then the second meeting was a time to present the farmer with the initial outputs of the model, depicting the production system. Results were introduced in the form of inputs/outputs and supply/demand in order to make them as tangible as possible for the farmer. At that time, calibrations were made if the farmer estimated that certain results were not representative and/or if a lack of coherence was detected. However, if the construction of the base scenario was not possible with the data gathered in the first visit, the second encounter served as a clarifying meeting during which further inquiries were made in order to pursue the simulation process.



1) Presentation of the approach and data collection
2) Simulations and construction of the base scenario
3) Discussions, simulations and establishment of the reference scenario
4) Discussions, simulations and establishment of the alternative scenarios
5) Comparison of the reference and alternative scenarios
Phase #1: Data collection, construction of the base scenario and beginning of the establishment of the reference scenario
Phase #2: Finalization of the reference scenario, establishment of the alternative scenarios, and comparison of constructed options

Figure 3: Various steps of the support approach

Once a satisfactory representation of the farm was achieved and agreed up upon by the farmer and the facilitator, the construction of a prospective scenario, coined the reference scenario by Douhard (2010), began based on the discussions and reflections raised in the first sessions. The initial steps in building a reference scenario usually commenced with modifications at the unitary level of a particular production process, found in the base scenario. Consequently, a point of entry was most often bringing about changes in CalculRation or CalculFerti, which were then brought back to the scale of the entire farm in CLIFS. For example, if the farmer wished to increase average milk production by feeding more alfalfa, the rations would be modified in CalculRation and then brought over into CLIFS. Inserting the new rations into this application then positioned them according to the resources produced on the farm, i.e. evaluating if a forage deficit would emerge from the modifications. Nonetheless, there were also incidences where changes were made at a greater scale, i.e. a change in herd size or modifications to a crop pattern. Most often such alterations created imbalances, thus it was necessary to make changes in the rations and/or in the choice of fertilizers. Given that the use of the modelling tools in this approach did not aim at optimisation nor were the simulations dynamic, changes brought in one part of the model may have had repercussions on another, which in turn might have modified the initial configuration (example featured in Figure 4). Overall, constructing the reference scenario, a situation closest to the farmer’s aspirations, most often required several tries.

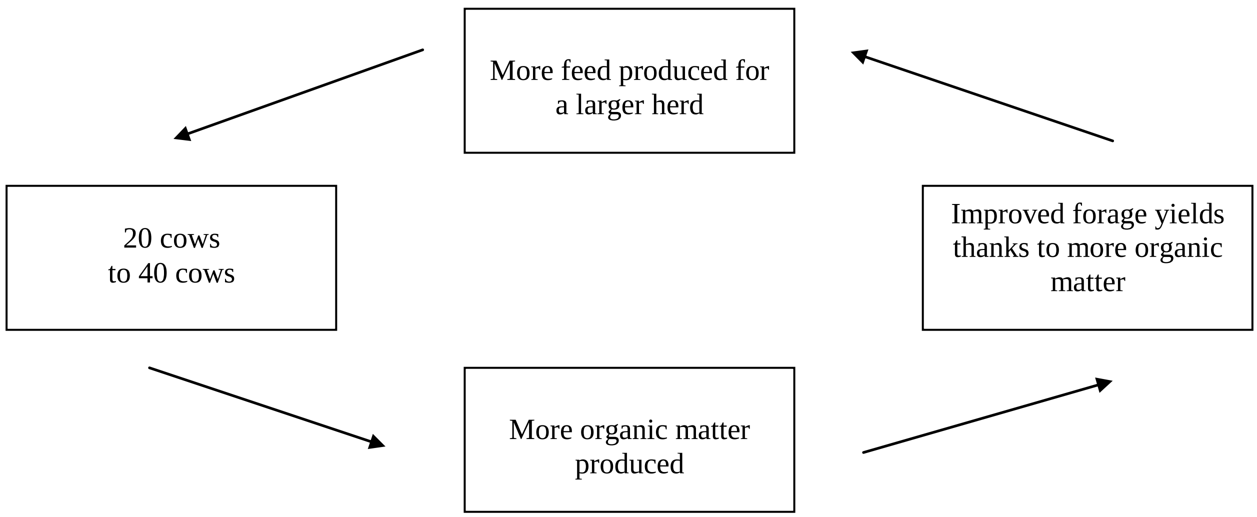


Figure 4: Example of repercussions from a single change in the production system

Once the reference was elaborated, a third visit to the farmer followed. During this time, the reference was presented and discussed. It was particularly important to ensure that the simulation met the farmer's expectations, as it then served as a basis for the next step in the support process: the elaboration of alternative scenarios. Depending on the reactions and comments from the farmer during this third meeting, it occasionally occurred that he/she had his/her own ideas of what should be explored as potential alternatives to the reference scenario. In other instances, possible alternatives to be looked at stemmed from a combination of ideas coming from the facilitator and the farmer. Finally, it also resulted that probable alternatives originated from the facilitator and an agricultural technician from the area.

Based on the ideas and suggestions that materialized during and after the third meeting with the farmer, a series of alternative scenarios were constructed, designed to be comparable to the reference. Once this step was completed, the farmer could then be met with for a fourth time. The objective of this meeting was to present the farmer with the alternative scenarios and evaluate them with the actual reference. Consequently, this stage of the support approach helped the farmer obtain a better perspective of the possibilities in which his/her project could be achieved and fostered greater reflection upon the production system as a whole.

Finally, a fifth and last meeting was conducted with the farmer a couple weeks to a month after the support approach had been completed. The goal of this visit was to evaluate the methodology from the farmer's perspective based on questions found in Appendix 9.

Evaluating *ex-ante* the sensitivity of each farmer's favoured scenario regarding economic and climatic shocks was conducted after the field work since farmers did not express any concern about these issues during the study. A specific methodology was designed, which is described in section 4.4.

3.3 Work Organization

The implementation of the support approach always occurred with only a couple of farmers at once. Working with 2 to 4 farmers at a time favoured a better overall management of the work load. Given that the method required several visits with the farmer and featured countless iterative simulations, it was preferable to focus on a small number of individual cases in a particular period. The first 3 months of the field work were dedicated to adapting the simulation tools and carrying out the methodology with 9 farmers. The last month was devoted to working with the 10^{th} farmer, and conducting the evaluation of the approach, requiring that all farmers be revisited. Finally, upon the request of two farmers who took part in the early stages of the study, another series of scenarios were constructed based on ideas and reflections they developed after their initial journey through the approach.

4. Results

This section aims at presenting the key findings from the experimentation of the support approach and from the sensitivity analysis. First, one farmer's complete journey through the methodology will be portrayed. Secondly, a synthesis of the work carried out with the ten farmers will be put forward. The goal is to highlight the various addressed questions, the different results obtained from the simulations tied to production system performances, and the dynamic of the support approach's implementation. Then, the results from the evaluation will be presented, followed by the results from the sensitivity analysis to economic and climatic shocks.

4.1 Presentation and Analysis of one Case

The purpose of this section is to exhibit the implementation of the support approach, in its entirety, based on the work carried out with one of the farmers from the study. This support methodology is a multifaceted process in which questions, simulations, solutions and discussions materialize, all encompassed within a continual dual-learning process between the farmer and the facilitator. Characterized by a series of on-farm visits and off-farm simulations, this method promotes a discourse wherein the farmers evolve on a series of levels, whether it is regarding the enrichment of their knowledge, the ideas and plans they have for their production system, etc. F8 was selected for this segment for a number of reasons: the diversity of his farming activities, his great interest in the support approach, and for the rich exchanges that materialized through the process between him and the facilitator.

4.1.1 Phase #1 of the Support Approach: Familiarization of the Production System, Construction of the Base Scenario and Development of the Reference Scenario

Background Setting the Stage for the Construction of the Base Scenario

An initial data collection provided a first overview of the production system. F8 farms with his brother: both are university graduates in the agricultural sector. Their farming system features a herd of 23 Holsteins, producing an average of 4500 L annually per head, and a land base of 85 irrigated ha, all of which they own. A portion of this land, 32 ha, is dedicated to forage production, and the 53 others are under various horticultural crops. The forage crops currently include 5 ha of alfalfa, 12 ha of oat-vetch for silage and 15 ha of *choclo* (corn), from which they produce cob-less corn silage. The other crops consist of 35 ha of potatoes, 5 ha producing artichoke, 5 ha sown with broad bean and 5 ha dedicated to peas. Finally, 3 ha are in fallow.

Their animals are fed with cut alfalfa all year round, corn silage is distributed from May to October, and oat-vetch silage is given from November to April. Despite no concentrates being fed to any of the animals, they do receive a salt and mineral mixture daily. Their animals are permanently stabled, therefore are never brought out to pasture. Given the size of their herd, F8 and his brother have 2 full time employees who work uniquely with the animals. Moreover, they must call upon part time help for all operations tied to their horticultural operation.

Construction of the Base Scenario and Development of the Reference Scenario

Information gathered in the first visit launched the commencement of off-farm simulations aiming to construct the base scenario. Nevertheless, this process was quickly brought to a halt by a number of uncertainties/inconsistencies that arose from an initial data insertion in the spreadsheet applications. Firstly, the stated annual average production of 4500 L/cow was not compatible with the values of the start and peak of lactation: 21 L and 25 L, respectively. These figures rather corresponded to a production level of 5000 L per year. With preliminaries outputs from the modelling tools, the farmer was shown that his asserted rations only covered 80 to 90% of this production objective, which incidentally translated to 4500 L/cow/year. This outcome thus helped validate the declared level of milk production. The annual average yield of 4500 L/cow was thus kept for the following simulations.

Secondly, precisions were required about the average duration of lactation corresponding to the moment of fecund insemination. The farmer declared that his cows are usually in production for 11 months, and then are dry for 2. However, their approximate timing of insemination remained rather unclear. The information provided by the farmer, 2.5, corresponded to the average number of inseminations necessary for the cow to catch, but not the actual time interval in months, between calving and fertilization, which needed to be 4 if the lactation length was 13 months.

This matter is just one example that highlights the importance of properly understanding how the farmer reasons and the necessity of correctly translating the information in order to accurately enter the data into the simulation tools. Given the 13 month cycle, this naturally triggers a one month lag per year with calvings, and offsets the forage demand and supply. The farmer reported that he was going to start synchronizing heats to achieve a 12 month cycle, which would regulate the feed demand according to the supply through the year.

Thirdly, outputs from the applications illustrated that excessive amounts of corn and oat-vetch silage as well as alfalfa were left over throughout the year. The farmer stated that he has yet to experience situations in which there are surpluses of silage, and rarely is there a lot of unutilized alfalfa. These results combined with the reactions from F8 signalled that the yields applied in the simulation were most likely inaccurate. Iterative simulations were thus needed, in which yields were modified, until a balance between supply and demand for feed was achieved.

These detected ambiguities and anomalies required precisions on behalf of the farmer in order to progress with the establishment of the base scenario. Off-farm simulations thus continued, resulting in the emergence of further equivocations. For one, crop yields were 75% lower than regional averages in order to achieve a balance between supply and demand. Moreover, after closer examining the management of the oat-vetch crop, interrogations arose as to why the farmer would produce this forage during the dry season, thanks to irrigation, only to later silage it at the beginning of the rainy season, and feed it throughout the rest of this period of the year.

The seemingly obscure logic behind the oat-vetch management fostered new discussions with F8 about his feeding strategy. It was revealed that this type of silage is harvested and fed in this fashion because there is not enough corn silage to distribute all year round. The supply of corn silage is exhausted at the beginning of the rainy season, thus coincides with the maturity of the oat-vetch crop. In addition to this precision, it was made aware that the farmer prefers to continue feeding silage during this period of the year because it requires less work than feeding exclusively cut green forages, in this case alfalfa, to his permanently stabled animals.

Model outputs served as the basis for discussion to address the yield issue. The use of the forage balance graph in CLIFS (Figure 5), combined with explanations as to how it is constructed, helped reinforce the situation to the farmer: low yields but the persistence of excess biomass. Reflecting on the problem, an important and explanatory piece of information emerged from F8: excess feed was most likely attributed to the fact that more animals were present on the farm the previous year. The farmer’s fattening operation at the north of the country, undisclosed until this point in the course of the approach, transferred animals to the location of his dairy farm. In the wake of a spike in the price of concentrates, some animals were brought to the valley to be fed with forages produced on the farm in an attempt to save money. According to F8, these animals would have consumed the equivalent of 5 ha of oat-vetch, thus bringing the actual area down to 12 ha.

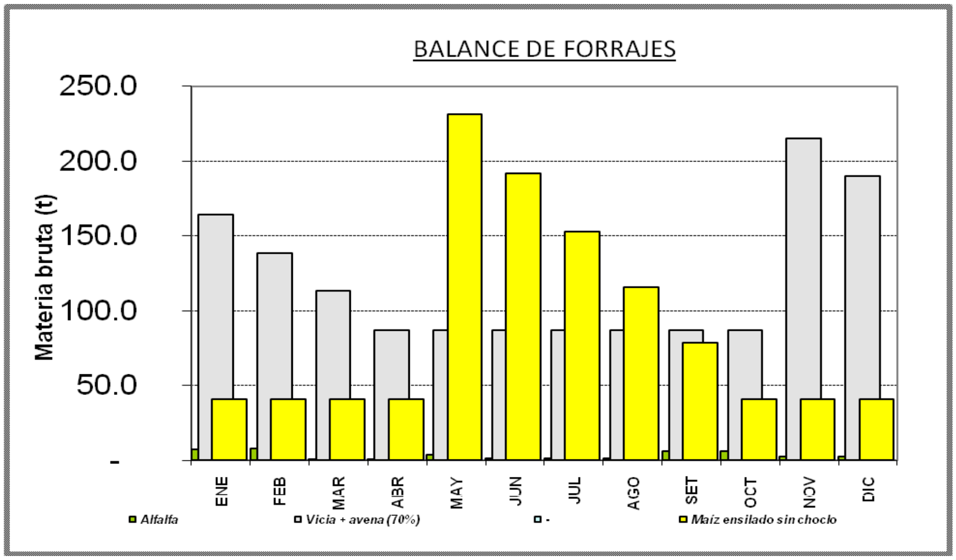


Figure 5: Forage balance graph from CLIFS illustrating the excess of 3 forages present throughout the year

With an adjusted area, another series of iterative simulations were conducted to achieve a certain balance between the demand and supply of this forage. Integrating a yield of 13 t/ha into the model, with a 6 month distribution of this silage in the rations, resulted in a deficit. However, once the yield was augmented to 20 t/ha, a surplus of silage emerged, despite this figure being particularly low compared to other reported yields in the same area. A similar situation materialized for corn silage, where a yield of 18 t/ha was agreed upon with the farmer, despite yields in the area normally hovering around 25 t/ha. In terms of alfalfa, F8 could justify the low yield uncovered in the model by the fact that his fields were in their 4th and 5th year of production. Despite decreased production, there still was an excess of alfalfa present during the rainy season months, for which the farmer also had an explanation. This surplus is always cut and distributed to the heifers, a fact which had not yet been considered in the scheme of things. More immersed in the matter, the farmer also stated the eventuality of his lactating cows being fed more than 18 kg per head daily during that particular time of year.

Though feed surpluses persisted with the figures mentioned above, this overall outcome triggered an enquiry from F8: could a scenario featuring an increase in herd size be constructed to utilize the excess feed? This question actually articulated an anticipated project; the farmer was planning to purchase 10 cows and 30 heifers, aged between 12-24 months, in the months to come. The launched idea for a new scenario immediately reiterated the yield issue: were the seemingly low ones from the base scenario to be kept or should figures from the area be integrated? The farmer ultimately decided upon mean yields from the region. In addition to augmenting the herd, another request was verbalized by the farmer: substituting alfalfa in the rations with a concentrate mixture during the months of July and August, in order to better favour its regrowth during the most critical months of its production. Despite having already conceived a mix, thanks to a spreadsheet tool he developed, the farmer wanted to know the amounts necessary to maintain a level of production of 4500 L/cow/year as well as the economic implications of such a substitution.

In spite of the emergence of projects and questions setting the stage for the construction of a reference scenario, clarifications were necessary before moving on: were the costs and outputs of the horticultural sector to be included in the base and reference scenarios? This immediately sparked a series of interrogations on behalf of the farmer: (i) what yield and price would be assigned to the crops if they can double, for example, from one year to the next?, (ii) would crop residues be considered as inputs to the rations?, (iii) if so, how is it possible to estimate their production?

Yield and price variations were to be managed by utilizing average figures, and crop residues were not going to be factored into the rations because F8 had previously mentioned that they are only distributed once and a while, in a non-scheduled manner. Overall, it was elucidated that no changes to the horticultural crop section would be made from one scenario to another, gross margins would remain identical, and thus noticeable changes would pertain only to the dairy portion of production system.

Agreeing with the precisions, the farmer elicited interest in yet another option to be explored: incorporating residues from one or two crops into the rations in an organized fashion. Discussions around this topic led F8 to decide on integrating broad bean residues in December and those of peas in January. The idea was to see if the utilization of this “free” input could help reduce costs of production, perhaps by necessitating that less oat-vetch be produced, for example. Given the nature of this new request, it was specified that yields for crop residues would therefore be regional figures, which are based on a residue-grain relationship, and that this option could thus represent a potential alternative to the reference scenario.

After an initial insertion of the declared horticultural data into the model, a seemingly high gross margin for the crops emerged. Illustrating to the farmer how this figure was calculated, he also agreed that it was too elevated. This sparked a dialogue around probable causes of this outcome, impelling F8 to ponder a little more on this part of his production system. This process led to the determination that the price and yield for potato were too elevated and should be corrected to portray a more realistic picture. The yield was adjusted to 20 t/ha, down from 40 t/ha, and the price was lowered to 0.45 S/. per kg from the initial set price of 0.70 S/. per kg.

Through the events described above, it is possible to perceive a certain progression of the support approach. Firstly, incorporating the farmer’s data into the simulation tools raised a series of questions, which in part, stressed the importance of fully understanding where the farmer is coming from. A number of the interrogations that emerged eventually guided the discussion towards key management strategies found on the farm; in this case particularly to feeding. As the facilitator and the farmer engaged in a conversation centered around a central element of the production system, there often was the revelation of additional details coupled with further explanations. This enabled the facilitator to better understand and actually learn about how the farmer operates and reasons. As the discussion further evolved, F8 was often driven to draw greater attention to certain matters that in turn, stimulated his thought process. Moreover, this phase characterized by a better understanding of the current situation, for both the farmer and the facilitator, helped enrich the questions and ideas that were to be addressed thereafter. Finally, it is to be noted that the base scenario is not an identical representation of the farm's current situation. This scenario is rather a depiction featuring a number of approximations and simplifications, validated by the farmer, which serves as a basis of comparison for future scenarios.

4.1.2 Phase #2 of the Support Approach: Construction of the Reference Scenario and Creation of the Alternatives

The resolved elements in phase #1 of the approach favoured a last off-farm simulation to finalize the base scenario. Moreover, the questions and requests that arose in the first sessions founded the base for the construction of the reference scenario. A series of off-farm simulations were necessary to produce a potential reference scenario to be discussed with the farmer. The herd was increased according to the specifics set out by F8, and it was discovered that the cows would require 8 kg of the concentrate mix during July and August to substitute the alfalfa eliminated from the rations (Figure 6). With crops surfaces identical to those in the base, but with regional yields, an alfalfa deficit materialized between January and June and during November and December (Figure 7).

This forage shortage fuelled another simulation in which rations were modified, principally based on the availability of alfalfa in each month, and then complemented with either oat-vetch or corn silage, depending on the time of year. Despite such adjustments, the reduced availability of alfalfa in June, September and October, coupled with a decreasing supply of corn silage, required that more concentrates be distributed in the rations to maintain the level of milk production (Figure 8). Finally given the demand in relation to the supply of corn silage, this forage was exhausted before the end of October, thus requiring 46 t be purchased to make up for the shortage that materialized (Figure 9).

Raciones vacas en lactación (kg MV/vaca/día)												
Alimentos	Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Septiembre	Octubre	Noviembre	Deciembre
Alfalfa	30	30	30	30	20	20	0	0	20	20	30	30
Vicia + avena (70%)	12.0	12.0	12	13							12.0	12.0
Maíz ensilado sin choclo					33.00	35	36	36	33	33		
-												
-												
-												
Concentrados (kg/vaca en lactación/día)							8	8				

Figure 6: Rations with alfalfa substituted by a concentrate mixture in July and August, complemented by corn silage

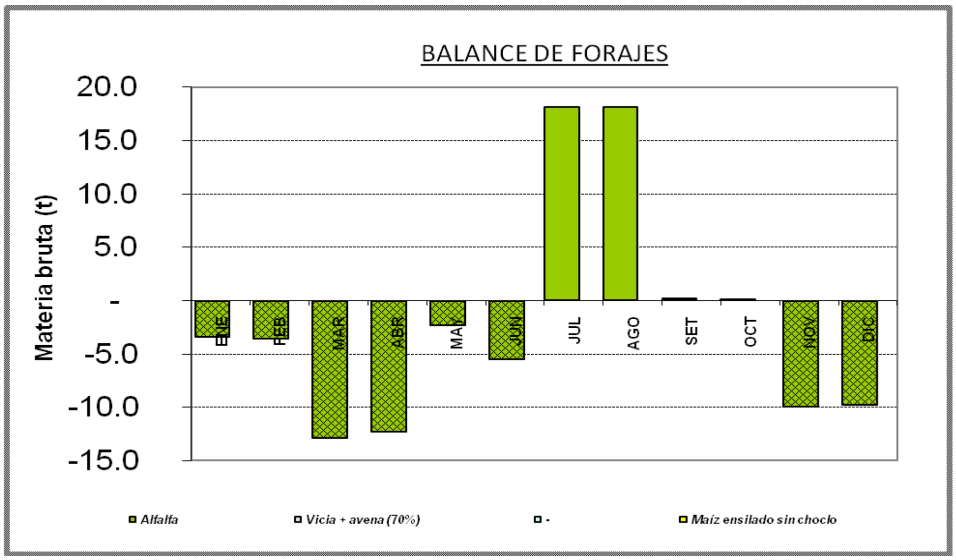


Figure 7: Forage balance graph from CLIFS illustrating the alfalfa deficit

For the purpose of highlighting the alfalfa deficit, both oat-vetch and corn silage were taken out of the figure.

Raciones vacas en lactación (kg MV/vaca/día)												
Alimentos	Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Septiembre	Octubre	Noviembre	Deciembre
Alfalfa	25	25	16	17	17	14	0	0	20	20	19	19
Vicia + avena (70%)	17.0	17.0	26	26							34.0	34.0
Maíz ensilado sin choclo					33.00	35	36	36	11	0		
-												
-												
-												
Concentrados (kg/vaca en lactación/día)						2	8	8	7	9		

Figure 8: Modified rations from those in Figure 6; constructed on the basis of alfalfa availability

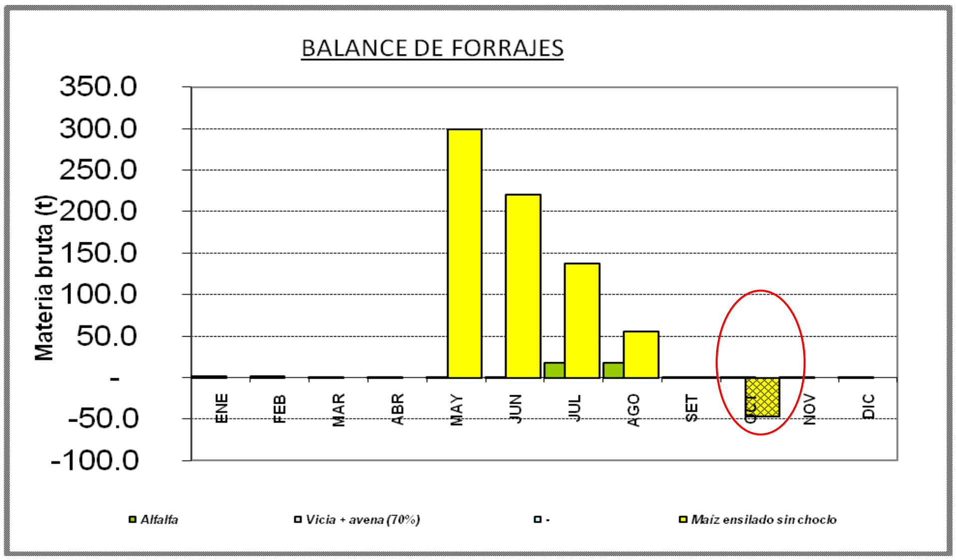


Figure 9: Forage balance graph from CLIFS illustrating the corn silage deficit that materialized when rations were modified[3]

Both outcomes, the purchase of an 8 month alfalfa deficit or the addition of extra concentrates combined with bought corn silage, were conserved as a basis for discussion with F8. The first topic to be addressed with him pertained to the regional yields applied in these scenarios. All but one was approved. The farmer was uncomfortable assigning 80 t/ha to oat-vetch; he thought 60 t/ha was more adequate. Secondly, with the help of the forage balance graphs (an example featured in Figure 10)[4] , both scenarios were illustrated. F8 was astonished by the amounts of unutilized oat-vetch silage that appeared in these figures. This triggered a discussion as to how he would manage this surplus: (i) sell it?, (ii) distribute it in the rations all year round?, (iii) cultivate a smaller area of oat-vetch? His immediate reaction was that with an adjusted yield,

[3] For the purpose of highlighting the corn silage deficit, oat-vetch silage was taken out of the figure.

[4] Both outcomes featured similar surpluses of oat-vetch silage, which is why only one of the two forage balance graphs is present.

there would undoubtedly be less excess generated. Furthermore, he considered distributing this silage throughout the year a good suggestion. Agreeing to change the rations, it was thus necessary to inquire whether concentrates, particularly in July and August, should still be factored in. The farmer suddenly had a change of heart and considered it worthwhile to better utilize resources produced on the farm rather than purchasing inputs.

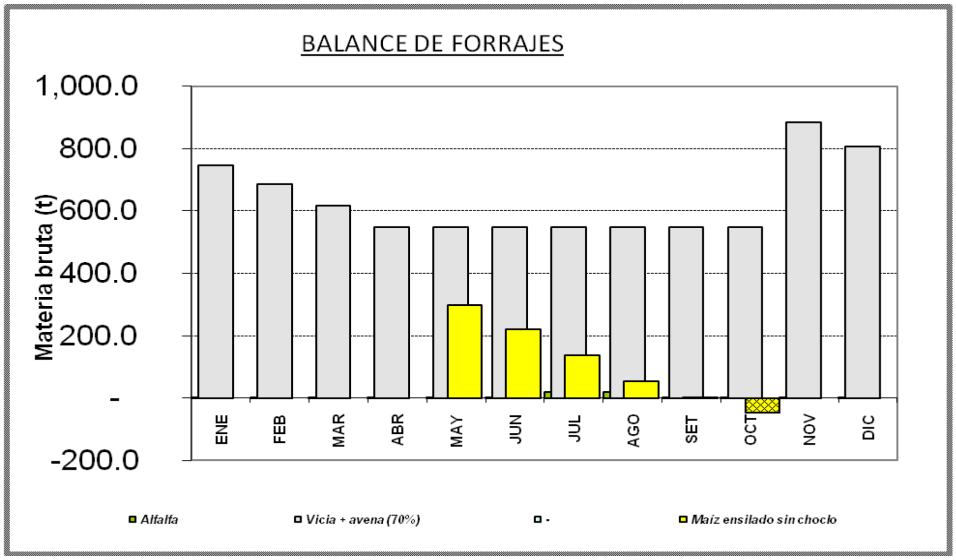


Figure 10: Forage balance graph from CLIFS highlighting the oat-vetch silage surplus in the second outcome

Finally, two last points needed to be addressed before continuing with the construction of the reference scenario. First, what did F8 think about the additional work load induced by a larger herd? After a moment of reflection, he considered that indeed an extra full time employee would be necessary, thus should be factored into the reference and alternative scenarios. Second, more for the sake of better understanding on behalf of the facilitator, the farmer was questioned about his veterinary costs. At this stage of the support approach, the costs appeared disproportionately low considering the new number of animals. It was discovered that the costs declared during the initial data collection represented inputs only. The farmer reported that he rarely calls upon a veterinary's services as he carries out most of the procedures himself.

The issues discussed in the first half of phase #2 illustrate, in part, the intricacy of elaborating a reference scenario. As with the construction of the base scenario, a number of ambiguities needed to be addressed before the process could continue. Furthermore, it is possible to note how through the questions and results that emerged, the farmer's perspective on things altered. Depending on how the approach unfolds, the farmer may be brought to rethink things, dropping one idea for another, and realizing that perhaps more advantageous strategies exist. Oscillating between ideas, whether it is back to an original position or towards new ideas, which occurs as results are assessed, is also encompassed in the farmer's learning process fuelled by the approach. Finally, the latter highlighted how the farmer was impelled to consider a very important issue in any agricultural project: labour requirements.

The refinement of a number of details launched another series of off-farm simulations, in which more interrogations arose. Excess feed persisted in the simulated outcomes: 146 t of corn silage and 74 t of oat-vetch silage. These results prevented the wrapping up of the reference scenario. Further input from F8 was required to clarify what he foresaw doing with the surplus: (i) sell it?, (ii) aim for an increased average milk production?, (iii) include more cows in production (to simulate the near future when the 30 heifers will have matured into cows)? The farmer reported not wanting to increase average production, as compelling cows to produce at superior levels at high altitudes (the farm is situated at approx. 3200 m.a.s.l.) can lead to altitude sickness and potentially death. Conversely, exploring the implications of a herd composed of 63 cows[5] in production was of great interest to him. This led to a reconfiguration of the reference scenario. Clearly the issue of surplus feed would be resolved, however a herd tripled in size fuelled more questions for the farmer. How would he plan on meeting the increased demand for feed: purchase more forages, or devote more of his land base to forage production? Moreover, if the latter was the preferred option, which horticultural crop(s) would he be willing to give up? His immediate reaction was that he would convert land and renounce whatever crop was the least profitable. These answers nevertheless drove further questioning. If broad bean and/or peas proved to be the less favourable economically, would he be willing to give up exploring the option of incorporating crop residues in his rations? Holding to that request as an alternative scenario, the farmer decided it was better to give up a few hectares currently in potato production.

These modifications meant that a final series of off-farm simulations were needed to finalize the reference and alternative scenarios. In F8's case, the elaboration of the reference and alternative scenarios occurred in parallel; however this nature of events is not always the case. The reference scenario essentially featured a reallocation of land already in forage production, where a couple hectares of *choclo* were given up. Moreover, it was necessary to convert a few hectares of potato into forages to produce sufficient feed. However, given the nature of this reorganization, less *choclo* would be produced and sold, meaning less income could be captured from this remunerative crop. Therefore, alternative #1 featured the same area of *choclo* as in the base to insure that maximum potential revenue could be generated, but required that a greater number of hectares in potato be converted. Finally, alternative #2 featured the incorporation of crop residues in the rations, kept the same amount of *choclo* production, and ultimately less potato was removed from the production system as the residues compensated for other forage crops, meaning less land needed to be converted overall (Table 2).

[5] This new herd size is the result of the 23 cows he has, in addition to the 10 cows he is already planning on buying and the 30 heifers, also an anticipated purchase, matured into cows.

F8's initial inclination was toward the scenario with the greatest economic return, which was the simulation featuring the incorporation of crop residues in the rations. However, reflecting on the options a little more, he expressed that it would be preferable to go ahead with alternative #1 given that he could benefit from maximum potential revenue stemming from *choclo* production and not have to worry whether yields from broad bean and peas were going to be decent. He restated that crop residue yields are extremely variable year after year, notably due to climate. Nevertheless, he said he was glad that the option of incorporating residues was explored, but that it would not be his first choice of as a feeding strategy.

Table 2: Configuration and performance indicators of the constructed options

	Reference	Alternative #1	Alternative #2
Average milk production (L/cow/day)	12.8	12.7	12.8
Commercialized production (L/cow/year)	4007	3976	4016
Number of ha in alfalfa (55 t/ha)	16 (+11)[a]	16 (+11)	16 (+11)
Number of ha in oat-vetch (60 t/ha)	13 (+1)	12	10 (-2)
Number of ha in *choclo* (25 t/ha cob-less corn silage)	14 (-1)	17 (+2)	17.5 (+2.5)
Number of ha taken out of potato production	11	13	11.5
Dairy gross margin (S/.)	244 682	242 474	245 372
Return on dairy investment	4.7	4.7	4.8
Crop gross margin (S/.)	607 435	655 965	665 296
Return on crop investment	1.4	1.5	1.5
Farm net margin (S/.)	713 217	759 539	771 768

[a]The figures in parenthesis note the change in forage area from the base scenario.

Overall, the completion of the support approach with this farmer required 7 separate visits, all within a relatively short time frame in the interest of keeping F8 well engaged in the process. However, it is to be noted that every farmer's situation is unique, thus the number of meetings ultimately varies. Through the elements discussed in the last half of phase #2, the convolution in creating a reference scenario and potential alternatives is further underlined. Again, the farmer was brought to consider various issues, which in turn contributed in refining a development project in line with his aspirations and fitting to his production system.

4.2 A Diversity of Farmers, a Number of Different Projects/Questions, a Variety of Solutions

The farmers that took part in this study were diverse, whether in the size of their operation or level of production (Table 1). Additional details pertaining to their current situation can be found in Appendix 10. Overall, their distinct nature was reflected in the series of different projects uncovered in this study, which ultimately were categorized into 4 main types (Table 3).

Table 3: Description of main project types encountered in the study

Project type	Description
A	Increase herd size and increase average milk production
B	Increase average milk production
C	Increase herd size
D (Post-approach)[a]	Decrease herd size (maintaining already increased average milk production or further elevating this level from the finalized scenario)

[a]Projects that were explored based on the demand of famers, once an initial complete journey through the support approach was completed with them.

Increasing milk production was the leading theme emerging from these various types of projects, where greater milk volumes could be attributed to ameliorating the cow's productivity and augmenting the number of animals, or to either facets in isolation. Despite a seemingly homogenous objective from the part of the farmers, their envisaged approach to this particular goal proved to be quite different from one farmer to another, perceivable in Table 4. In addition to the distinct nature of foreseen plans encompassed under one same project type, several solutions were constructed to provide various options to fulfil a particular endeavour.

Table 4: Support approach details specific to each studied case

Farmers	Number of visits	Number of finalized alternative scenarios	Project type	Project description
F1	5	3	A	Expand herd to 30 cows within next 2 years, and increase average production to 15 L/cow/day
F2	4	3	A	Expand herd to 10 cows, renovate barn to keep animals permanently stabled, and increase average production to 15 L/cow/day
F3	4	2	B	Increase average production to 15 L/cow/day by adding concentrates to the rations
F4	5	3	A	Build herd back to 10 cows, increase average production to 20 L/cow/day all while being self-sufficient in forage production
F5	5	4[a]	B & D	1) Increase average production to 11.5 L/cow/day, without purchasing green forages and by including personally configured concentrate mix to rations 2) Downsize herd to 5 cows while maintaining increased average production
F6	4	2	B	Increase average production to 17 L/cow/day while integrating *chala picada con choclo y melaza*[c] into the rations all year round
F7	4	3	C	Increase herd size to a number of head that can be supported by owned green forage land base
F8	7	2	C	Add 10 cows and 30 heifers (12-24 months) to the herd to have 63 cows in production in the near future all while maintaining current average production
F9	7	7[b]	B &D	1) Increase average production without significantly increasing costs 2) Downsize herd to 20 cows while increasing average production to 16 L/cow/day, sustained by a new feeding strategy of cut green forages and concentrates
F10	4	6	C	Convert herd to Jerseys and explore the possibility of maintaining 100 cows at current level of average production with owned land base

[a]Includes one post-approach scenario
[b]Includes three post-approach scenarios, and two post-approach semi-alternatives (exploring further ration options to meet the new production objective, but elements from these simulations were not brought back to the farm level in CLIFS)
[c]Chopped corn stalks, with the cob, combined with molasses

4.2.1 Project Types and Various Options Explored

4.2.1.1 Project Type A

Two prevailing paths were uncovered in this category. The first case (F1) consisted of a significant herd size increase, 3 to 30 fostered by the purchase of animals, coupled with a jump in average milk production from 8 to 15 L/cow/day. The young farmer foresaw brining about such drastic changes in a very near future. Equipped with the necessary infrastructure to accommodate a herd of this size, the missing details pertained to feed and land. The heart of the F1's questioning was with regards to the land base required to produce ample amounts of forages to sustain that quantity of animals, producing at that level of average production. Through the approach, various options were explored around a feeding strategy featuring A+RG+C (an association of alfalfa, ryegrass and clover) and oat-vetch silage, complemented by liquid whey and/or concentrates.

Two farmers (F2 and F4) were found to have objectives with similar envisaged means to achieve them, in the second prevailing path. In essence, they both foresaw a herd increase, of 6 and 5 respectively, by keeping more offspring, with an augmented average production between 15 and 20 L/cow/day, while stressing the importance of being completely self-sufficient in forage production. The evolution of the approach with each farmer led to the elaboration of options featuring a similar feeding strategy centered around the distribution of A+RG+C and *chala*, combined with varying amounts and types of concentrates.

When all constructed options were finally presented and discussed with the farmers, the economic favourability of one alternative over the others was most often the factor carrying the most weight. Nonetheless, their appreciation of a scenario over another also encompassed the opportunity of generating additional income through the incorporation of *choclo* to the crop pattern, for example, or not having to rely on any purchased feedstuffs. A common reaction to all scenarios was the realization that supporting increased milk production was a laborious endeavour, and not only because more animals were in the picture. Their current practices make ample feed available most often only during daylight hours. Therefore, the necessity of ensuring that important quantities of forages are accessible to the animals in the evening and night as well was explained. If the cows were to pasture during the day, this would require that significant amounts of forages be cut and carried back to the barn daily. For F1, it was determined that 4 employees would be necessary to manage the increased work load. In F2's situation, it was mentioned that his son would assist with the additional work. Finally for F4, she reported that she would have to hire someone. In all cases, the necessary infrastructure was already in place to accommodate their foreseen herd expansion.

4.2.1.2 Project Type B

Three main ways aiming to only augment average production were discovered. Despite different desired levels of increased average production and dissimilar herd sizes, two farmers (F3 and F5) envisaged attaining their objective principally through the addition of concentrates to their rations. The constructed scenarios in both cases rendered feeding strategies featuring A+RG+C and *chala*. However, their use of concentrates differed; while F3 was willing to incorporate 1 to 2 different supplements in her rations, F5 was curious to explore the implications of integrating her own preconceived concentrate mixture.

The second uncovered strategy to increase average production featured rations centered around A+RG+C and *chala*, like in the situations described above. However, the major difference in this case (F9) was that augmenting milk production with such rations was the result of a re-organization of resources already present on the farm. Unlike in the previously described cases where additional land needed to be included into the production system in order to produce enough forages, the scenarios elaborated with this farmer explored making changes to the crop pattern (Figure 11). This contributed to increasing the availability of nutrient-rich green forages, which were maximally used in the rations, helping to reduce the amount of distributed *chala*.

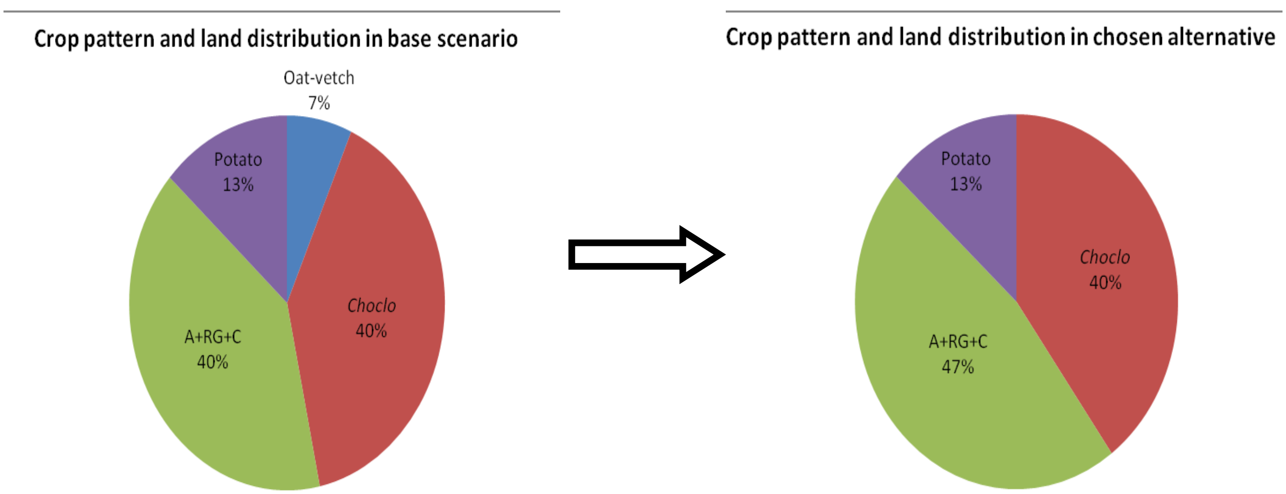


Figure 11: Change in crop pattern and land distribution in F9

The third envisaged method to increase average production was very different from the first two; it entailed the implementation of a feeding strategy observed from another dairy producing region of Peru. F6 wanted to completely re-configure his rations by feeding *chala picada con choclo y melaza*, in combination with alfalfa all year round. Having seen cows respond well to such rations on the Peruvian coast, the farmer was inspired to test that same strategy on his farm. Despite having a concrete idea in mind, and a recently purchased chopper to feed *chala* in this manner, questions remained with regards to actual feed and land requirements necessary to sustain a herd at this new level of average production (17 L/cow/day).

As in the cases presented in type A, economic favourability and the possibility of generating supplementary income, principally through the sale of *choclo*, were factors inciting farmers to prefer one option over another. Moreover, the prospect of being completely self-sufficient in forage production was also an appreciated aspect. For F9, her inclination to a particular scenario stemmed from a sense of familiarity. She felt more comfortable managing one forage association over another. By chance, this option was also the most profitable. Finally, there were similar reactions from F3 and F5 regarding the work load induced with feeding important quantities of forages to sustain an augmented level of average production. They determined that hiring someone would most likely be necessary.

It is important to mention that, in the cases presented in type A, like in type B, farmers were reminded that while adequate feeding is the basis for ameliorated milk production, this outcome is associated with a number of factors. Animal health, heat management, genetics, etc. are all important issues to be considered when striving for improved animal productivity.

4.2.1.3 Project Type C

Two distinct anticipated paths to herd expansion were uncovered. Despite herd augmentations of different magnitudes, and very dissimilar farming systems, both in size and activities, two farmers (F7 and F8) eventually foresaw supporting more animals thanks to a reorganization of crops produced on their land base, to optimize forage production. F7 knew she wanted to milk more cows; however was uncertain of just how many more animals could be supported by the land she currently had in RG+O (an association of ryegrass and orchardgrass) in order to maintain self-sufficiency in this crop's production. Alternatively, F8 already had a preconceived idea of how many more animals he wanted to add.

The third farmer (F10) had a completely different vision. He wished to eventually convert his entire herd, primarily composed of Holsteins in addition to a couple of Brown Swiss, to Jerseys, all while almost doubling the number of animals, and keeping the same land base with an unaltered crop rotation. He expressed that the advantage of having Jerseys is that they consume 20% less feed than Holsteins while producing comparable volumes of milk (up to a certain level of average production).

Once again, optimal economic outcome was an important factor leading farmers to be more inclined to one situation over another. Nonetheless, farmers associated with this project type were the first to not necessarily consider the most profitable option as the most advantageous one for them. For F8, it was an aspect of certainty and security that made him more attracted to a particular solution. For F10, it was the convenience facet that drew his attention more to one alternative over the others. He decided to forego his expansion to 100 cows and opted for a herd of 84 head instead. Even though the farm net margin was greater with 100 Jerseys, he considered that the magnitude of the margin was not large enough to compensate for the "headache" of having a herd of this size. With 100 cows, he would have to rent an additional 15.5 ha, in various locations, as there are few available plots situated close to one another. This would ultimately require additional management and create a lot more work.

4.2.1.4 Project Type D

Coincidentally, the two farmers (F5 and F9), who solicited further assistance once an initial complete journey through the approach was carried out, wanted to explore the same type of project: decrease the size of their herd. In the case of F5, this idea was essentially fuelled by the results of the simulations tied to her initial project. Having gone over the various options, she realized that perhaps it would be more feasible, in a close future, to improve the productivity of her cows with a smaller herd. These reflections led her to inquire about the possibility of running a simulation, featuring the exact same characteristics as those found in her preferred scenario from the options built in project type B, but with fewer cows.

F9's desire to explore the implications of administrating a smaller herd emerged from overall reflections the support approach led her to have with respect to her production system as a whole. Almost two months after the initial exercise was completed, she requested that a new series of scenarios be constructed. Not only did she want to factor in fewer cows, she also wanted to increase the level of average production and explore a completely different feeding strategy: exclusively cut green forages complemented by a mixture of concentrates.

Ultimately, both farmers were more inclined to the option of reducing the size of their herd as opposed to keeping the number of animals present in their former scenarios. Moreover, for F9 who wished to explore an entirely new feeding approach, her inclination to one alternative over the others was related to an issue of convenience. Even though the farm net margin was lower, she considered it more convenient to feed more concentrates in certain months of the year rather than having to rely on purchased forages.

4.2.2 Various Options: Different Impacts and Performances

4.2.2.1 The Driving Forces Behind the Variations in Revenue

Despite all striving to increase volumes of produced milk, every farmer foresaw doing so in a different manner, which ultimately led to the creation of a wide range of potential options. Even within the same project type, no two chosen paths were similar as they led to different production system configurations, while varying in the level of impact on the farmer's current situation. The effect a particular strategy has on a production system can be perceived notably in the farmer's revenue. While all farmers explored strategies that ameliorated their earnings, there was great variation in revenue across the sample and even within a same project type. This variability is a phenomenon that can be explained in part by the fact that every explored strategy features a certain number of variables, which are more or less influential on revenue as a whole. The principle variables identified in this study include:

-*The nature of the farmer's initial situation (negative revenue).* Four farmers (F1, F3, F5 and F6) are experiencing negative returns in their current situation. This state of affairs is related to a number of factors, notably low milk production and a heavy reliance on bought forages. Nonetheless, all farmers in this position have additional sources of revenue, either from another area of their production system or from an off-farm source. Despite negative returns, the farmers report still valuing this activity for its complementarity to other facets of their production system and for the stability and regularity of income it provides. Therefore, given that the simulated situation is radically different from the initial one, it allows the dairy sector of the farm, which was unprofitable until now, to generate positive returns.

-*The nature of the anticipated plan of action (herd expansion and/or increase in average milk production per cow).* With the exception of strategies found in project type D, all others aim for an increase in herd size and/or in average milk production per cow. The augmentation in revenue is thus proportional to the foreseen increase in herd size or in the level of average production per cow.

-*Autonomy in forage production vs. purchasing inputs.* A number of the farmers, thanks to their explored strategy, are able to ameliorate their forage autonomy; either going from situations of heavy reliance on bought forages to ones of partial or complete self-sufficiency in feed production, or simply improving their level of autonomy without necessarily having been greatly dependent on purchased forages. As a result, this improvement may prove to be the driving force behind the farmer's increase in revenue.

To best depict the level of influence these variables can have on revenue when combined together within an explored strategy, a comparison is made among the farmers in project type A and B, found in Figure 12 and Figure 13.

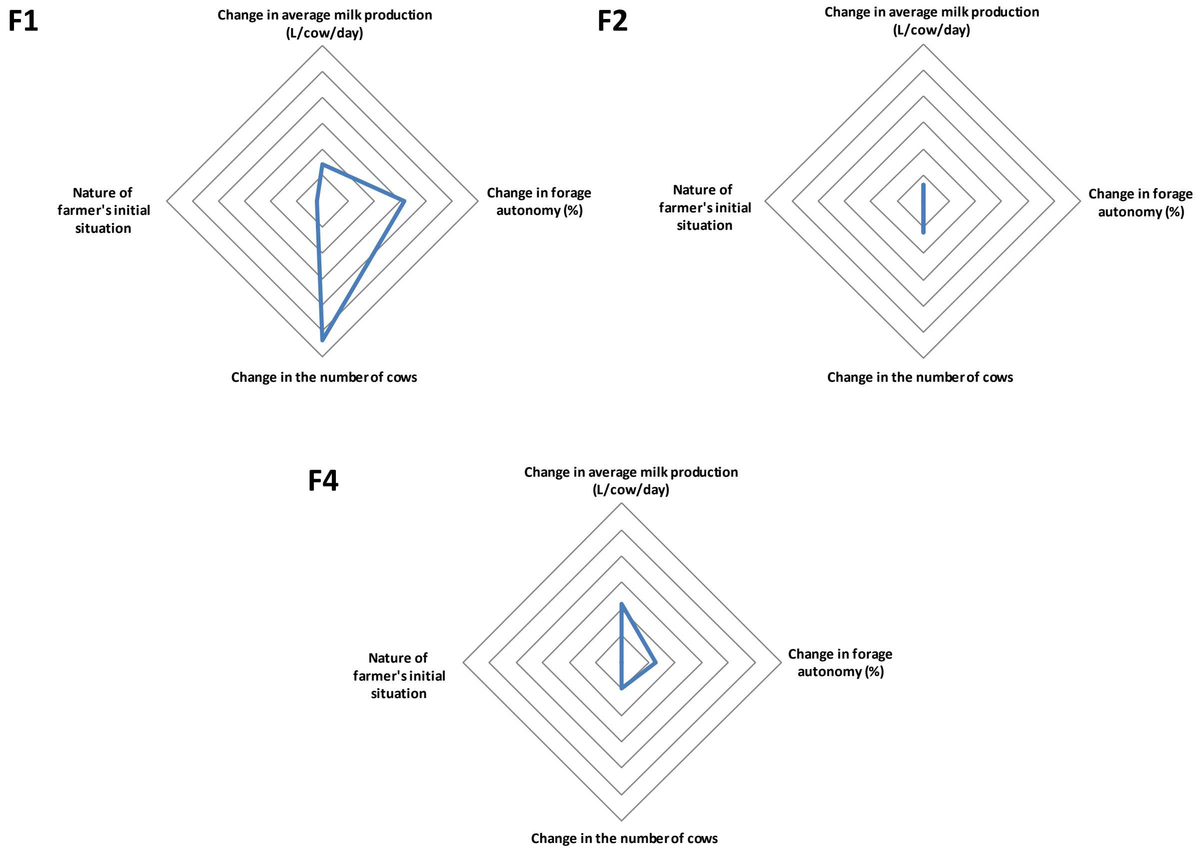


Figure 12: Influence of different variables on farmers' revenue in project type A
All variables of change represent the difference between the initial and simulated situation. The nature of the farmer's initial situation corresponds to the level of negative returns if the farmer is in an unprofitable position. The same scale was used for all the cases within the project type.

- F1: Despite increasing average milk production per cow and experiencing slight negative returns in his initial situation, the variables most influential on his change in revenue appear to be improved forage autonomy (an increase by 53% making him totally self-sufficient in feed production) and a significant increase in herd size (3 to 30 cows);

- F2: This farmer is completely self-sufficient in forage production and is currently generating positive returns; therefore the variable that seems to be principally driving his change in revenue is his herd expansion from 4 to 10 cows;

- F4: Despite going from 5 to 10 cows, becoming completely autonomous in forage production (going from 78% self-sufficiency to 100%) and aiming for an augmentation in average production of 11 L/cow/day, are the 2 factors that seem to carry the most weight in improving her revenue.

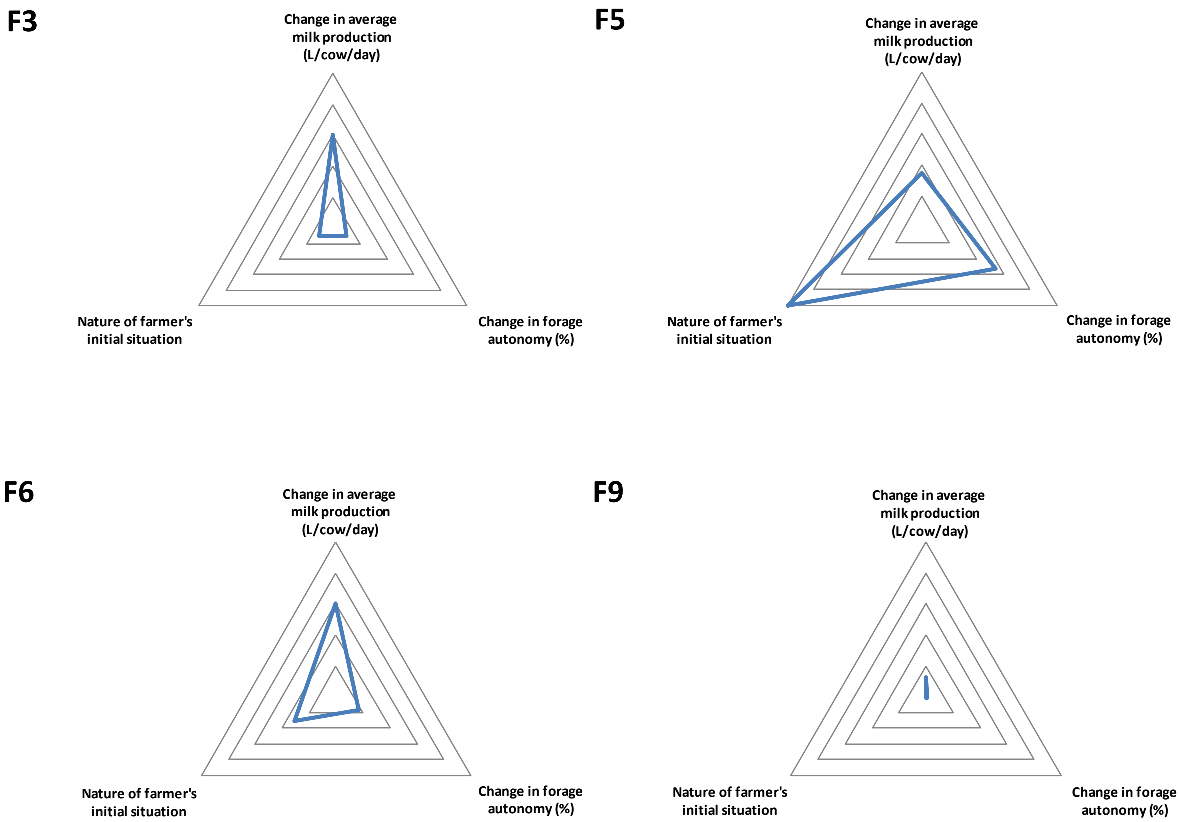


Figure 13: Influence of different variables on farmers' revenue in project type B
The same details from Figure 12 apply here.

- F3 and F6: In spite of currently generating negative returns and improving their forage autonomy with their explored strategy (by 10% and 17%, respectively), their anticipated augmentation in average production of 6 L/cow/day proves to be the variable with most influence on their revenue change;

- F5: Among the 4 farmers presently in unprofitable situations, this farmer is in the most unfavourable position. This reality combined with a 54% improvement in forage autonomy appear to be the variables with the most precedence over her anticipated 3.5 L/cow/day augmentation in average production, when looking at her change in revenue;

- F9: This farmer is currently generating positive returns and is already completely self-sufficient in forage production; therefore the only variable really influencing her change in revenue is the augmented average production of 1 L/cow/day.

The farmers in project type C and D are not presented here graphically. Though their strategies also involved a combination of variables, it was principally one same variable that had the most influence on revenue: a change in the number of cows. Nevertheless, F9's alteration in herd size (going from 25 to 20 cows) appeared similarly as influential on revenue as her 3.5 L/cow/day increase in average production.

4.2.2.2 Commonalities Amongst the Variability

While the section above illustrates how farmers in a same project type will have their revenue vary according to the influence of one or several variables, the explored strategies across the sample reveal that, despite the diversity and variability, certain trends can be put forward. In other words, in spite of choosing different plans of action, the farmers do manage to achieve common finalities.

- *A common trend towards intensification*

This is first observable when looking at land utilisation and feeding strategies explored by the farmers. From the processes featured in Figure 14, it is possible to note that despite the different considered paths, all farmers are able to achieve an intensification of their forage land base. Here, intensification refers to the ability to produce more milk per hectare of forages, going from the farmers' initial situation to their anticipated plan of action. F1 and F5 have been omitted from this figure due to the fact that they follow a strategy based on a heavy reliance of purchased forages and practically negligible forage surfaces in their present situation: this severely distorted actual milk production per unit area.

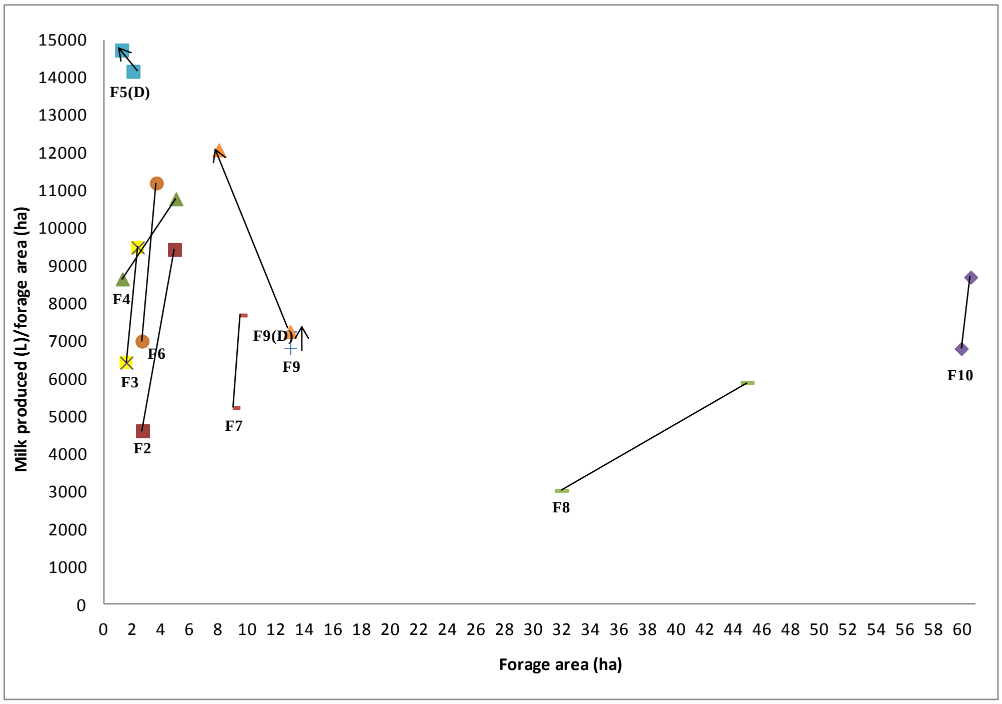


Figure 14: Degree of intensification and/or expansion of forage area

From the 10 situations depicted above, 3 trends pertaining to intensification can be noted:

-*Intensification and expansion of forage areas*. Seven farmers appeared to be striving to produce more energy and protein-rich biomass per hectare, all while augmenting their land base. Four sub-cases were encountered leading to increased milk production per hectare:

- Slight increase in forage surfaces combined with the addition of concentrates to the rations (F2, F3, F4 and F6);
- Change of forage crop from *chala* production to RG+O (F7);
- Change of breed, from Holsteins to Jerseys (F10);
- Significant increase in forage surfaces due to the absence of concentrates in the rations (F8).

-*Intensification of forage areas*. This strategy concerns only one farmer (F9), who converted a section of her land producing oat-vetch into more nutrient-rich forages (A+RG+C) without expanding her forage area.

-*Intensification of forage surfaces coupled with a decrease in area.* Both cases (F5 and F9) stemmed from tactics found in project type D. Managing to increase milk production per hectare in addition to reducing forage areas was particularly made possible by the fact that concentrate mixtures, as opposed to the inclusion of 1 or 2 supplements in the cases mentioned above, where integrated into the rations (example featured in Figure 15).

Raciones vacas en lactación (kg MV/vaca/día)

Alimentos	Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Septiembre	Octubre	Noviembre	Deciembre
Alfalfa	25	25	25	24	24	19	15	15	24	24	24	24
Rye grass ingles	19	19	18	19	18	12	9	9	17	18	19	20
-												
-												
-												
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Concentrados (kg/vaca en lactación/día)	3	3	3	3	3	5	7	7	3	3	3	3

Figure 15: F9's rations complemented by a concentrate mixture (80% wheat bran, 12% barley, 4% soybean meal, 4% corn)

- *Altering costs of milk production*

Since milk prices vary between 0.9 – 1.2 S/. per litre according to the collector, farmers' initial situations are quite sensitive to economic shocks. Indeed, three of them (F4, F5, F8) produce at a loss, while four other ones (F1, F2, F6, F10) show costs close to milk prices (Figure 16). The explored strategies yield a common finality in the altering effect they have on these initial costs of production, with two main perceivable tendencies.

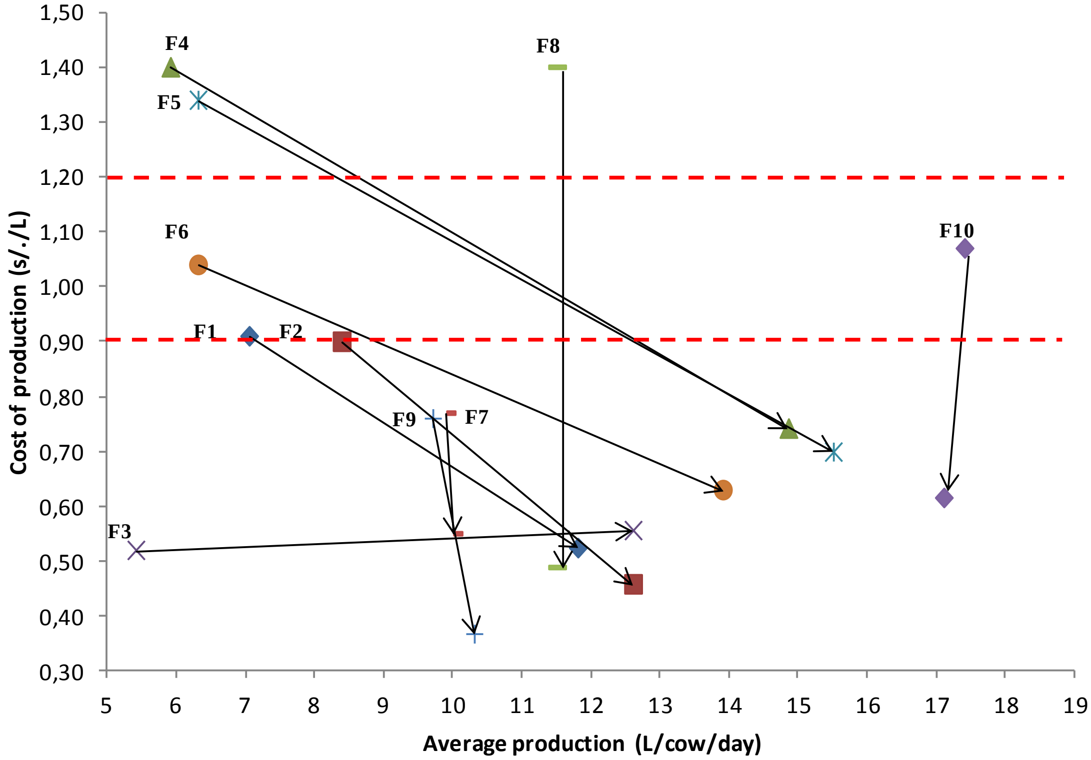

Figure 16: Variation in the costs of production and comparison with milk prices (red dot line) across the different strategies

-*Overall decrease in the costs of production.* Nine of the depicted strategies led to a reduction in the costs of production. Nevertheless, three cases featured decreases less marked than the others attributed to:

- Better utilization of forages already produced on the farm thanks to a slight increase in herd size (F7 and F10) (represents only a small change from their initial situation);

- Partial substitution of *chala* in the rations thanks to a better utilization of green forages already produced on the farm, fostering a slight increase in average production (F9) (represents only a very little change from her initial situation);

F3 experienced an increase in costs of production from her initial situation to her explored strategy as she went from feeding no concentrates to incorporating some in her rations. Moreover, her new strategy featured *choclo* production; a crop currently not present in her crop pattern. Nonetheless, the elevation in costs proved to be greatly diluted in the end by the increase in revenue associated with enhanced milk production.

-*Homogenization in the costs of production.* The farmers' initial situations had them producing milk anywhere from 0.52 to 1.4 S/. per litre. Conversely, the explored strategies narrowed the gap in production costs: 0.55 to 0.95 S/. per litre. This result tends to prove that the tested options appear to converge.

By intensifying dairy production systems, the decrease and homogenization of costs lead to a much better economic situation for all of the farmers. This result shows that (i) ways of enhancing dairy production resilience against variability of milk price exist and (ii) the support approach provides some evaluation of each farm capacity to react to lower prices. Section 4.4 develops this sensitivity analysis in relation with availability of irrigation water.

4.2.3 The Dynamic of the Support Approach's Implementation

As revealed in various instances until now, it is possible to note that the carrying out of the support approach differs from one farmer to another. Whether it is in the number of visits or constructed scenarios or with regards to the questions and discussions that materialize through the process, no two cases are the same. Despite the distinct experiences, four main paths the approach brought the farmers to take in relation to the evolution of their thought process were observed:

-*The farmers have specific ideas right from the start of the exercise* (F1, F7 and F10). They knew from the beginning that they wanted to expand to 30 cows, or implement a particular feeding strategy like *chala picada con choclo y melaza*, or even convert the entire herd to Jerseys. With a concrete idea in mind, the support approach thus served as an exploratory tool to examine various elements pertaining to their objective, to ultimately better position the project and facilitate its potential implementation.

-*The farmers, at the start of the exercise, have rather vague ideas regarding an evolutionary plan of action for their farm* (F2, F3, F7 and F8). However, as the support approach unfolded, they began to develop concrete thoughts; requesting that specific aspects be explored. Once a reference scenario was established, their inspiration carried them to even propose that particular alternatives be simulated.

-*The farmers have no real idea at the start of the support approach* (F9). What she had in mind was rather a concept, i.e. increase milk production without significantly augmenting costs of production. Therefore, the initial simulations were initiatives stemming from the facilitator's observations and ideas. However, once a first series of results were presented, this seemingly triggered her thought process, which from that point on proved to be very active. Suddenly, F9 was eager to explore a number of different elements. Overall, she turned out to be the farmer with the most ideas, and even requested that further simulations be carried out after an initial journey through the approach was completed.

-*The farmers have a general idea at the start of the support approach but their reflections do not materialize into concrete aspects to be further explored* (F4 and F5). In this situation, the facilitator played a bigger role in the development of new alternatives to be simulated. Despite the facilitator's greater level of contribution in F5's the initial journey through the approach, this did not prevent her from developing additional ideas. Having reflected on the results from a first participation in the exercise, she requested that further simulations be carried out.

4.3 The Support Approach as Viewed by the Farmer

A key portion of this study consisted of carrying out a post-support approach evaluation with the farmers. The purpose was multifaceted; it aimed at obtaining an overview of where the farmers stood before taking part in the exercise, at sensing how such an approach benefited them or not, at comparing this type of support with others they have received, and finally at assessing a potential transfer of this methodology to agricultural professionals in the area.

4.3.1 Factors Inhibiting the Farmers from Implementing their Foreseen Projects

A number of obstacles were uncovered, preventing the farmers from putting their ideas into action thus far. The dominating impediment proved to be a lack of financial means to make the necessary investments. Money as the greatest limiting factor stemmed from four main causes: children in school (F3 and F4), several families being supported from one farm income (F9), high interest rates discouraging the taking out of a loan (F9), and production system expenses, principally purchased feed, accounting for just about all earning (F5). Also related to money, were the farmers who had not yet gone through with their project because they were saving up to now. Earnings were being put aside to purchase animals (F1 and F8) and to progressively become more mechanized to better facilitate the adoption of a new feeding strategy (F6).

Labour also was a limiting factor (F2 and F3). The scarcity and elevated price for hired labour in the area meant that both farmers had to postpone their project until their eldest child was going to finish school.

Lack of land and knowledge were obstacles for F7. For the last few years she has been progressively purchasing land to support more animals. Moreover, it is only as of late that she and her siblings felt that they had received enough training to successfully manage a larger herd.

4.3.2 Discussing Farming Ideas with Other Stakeholders

It was discovered that discussing and sharing ideas with others is not a common practice in the Peruvian farming community. Also in reference to keeping plans and projects personal, other farmers mentioned that this is the result of a lack of time to engage in constructive conversation with neighbour farmers, or that there simply are no agricultural professionals available with whom to do so. Consequently, three farmers (F1, F4 and F5) said that they had never discussed their projects with anyone. Moreover, to this effect, five farmers reported only having talked about their plans with immediate family. Exceptions to the rule were F3 and F6 who had the opportunity to exchange inspirations with an agricultural technician and a professor, respectively.

4.3.3 Evaluating the Support Approach from the Farmers' Project Perspectives

Central issues explored were how this methodology aided or not the farmers in advancing their ideas, how they perceived the various simulations that were presented, and what they might have learned through the support process. The prevalent sentiment was that the constructed scenarios were realistic and tangible. Several farmers mentioned that having the simulations integrate their personal data greatly enhanced the realism of the elaborated options. Another widespread reaction was a feeling of greater enlightenment with respect to quantifying the various components of rations to meet their specific production objective. This quantification support also applied for the amounts of land necessary to produce sufficient feed throughout the year.
A number of more individual enlightenments were also reported. F9 said she acquired vital knowledge, through the comparison of rations in the scenarios, on the importance of feeding high rather than low energetic feedstuffs, all while saturating the cow's dry matter intake. Furthermore, she stated that the simulations helped her better identify areas where potential improvements could be made. F6 expressed that the results from the approach taught him that there are several ways to go about a project, which notably include re-organizing and better utilizing already available resources. Finally, F8 claimed that despite not learning anything new *per se*, going through the support approach helped him refresh a number of concepts and theories that he was taught in the past. Furthermore, he said that participating in this exercise allowed him to break from his hectic schedule and actually think, in depth, about important facets of his production system.

Another all-encompassing response was that the support approach provided great perspective. Common remarks included feeling a lot more confident and now having a sense of direction in which to progress into the future. Three farmers (F2, F7 and F10) added that, had they not gone through the approach, they most likely would have gone ahead anyway with their project, but in a rather haphazardly fashion. F2 also reported that the simulations confirmed the feasibility of his anticipated venture. F9 highlighted that the various scenarios were particularly interesting as they gave her a better idea of the economic consequences of different technical choices. Lastly, F10 reported that the approach brought him to realize that his initial plan might have been too ambitious and unpractical. The results from the simulations thus helped him re-scale his project and find a more tangible way to carry out his idea.

From the variety of options presented, the most common foreseen path to implement change was using various elements from the array of simulations, rather than implementing a specific scenario. This response was particularly linked to the inevitability of certain farmers gradually progressing towards their objective due to financial constraints, for example. Alternatively, there were others who had a clear plan of action: immediately purchasing animals (F1 and F8), invoking changes to the management of their herd by keeping more offspring (F2 and F7) or by breeding with different genetics (F10).

4.3.4 Comparing the Support Approach with Other Methodologies

Six farmers (F3, F4, F5, F6, F7 and F9) had previously attended what they referred to as "traditional training sessions", consisting of a presentation given by an agricultural professional in front of a group of farmers. Consequently, this was their main base for comparison. The prevailing comment was that these forms of training are far too theoretical and that the support approach represents a much more practical form of intervention. Many stated that the information provided during the traditional sessions is often hard to grasp, and therefore difficult to put into practice. Conversely, the issues discussed and the presented results in this study's methodology were more comprehensible and applied. F8 said that this approach promotes a much more holistic focus, impelling the farmers to bear in mind a variety of issues related to their production system simultaneously, rather than considering a specific theme in isolation, as is often done in many traditional training sessions.

Widely appreciated were the constructive, one-on-one, discussions fostered by the support approach; reported as non-existent in training sessions. F5 stated how, often during these meetings, farmers are ashamed to ask questions in front of a large group. She said that the individual interaction promoted through the approach dissolves the shyness and puts the farmer at ease to inquire about issues. F3 added that the nature of discussions that materialize in the approach also helps reinforce the knowledge that transpires from the various explored topics. In her opinion, the context in which the approach takes place is very conducive to learning. Further appreciation pertained to convenience. Three farmers (F6, F7 and F8) thought that having someone visit them at their farm, at an accommodating hour, enabled them to save time. Finally, several highlighted that is methodology is a very personalized form of support.

Only one comment was made for possible improvements to the support approach. F8 said he would have liked for the process to have gone on longer to foster more time for discussion. Finally, he commented how both methodologies, i.e. traditional training sessions and the support approach, are ultimately complementary. According to him, the technical bases thought in the training sessions foster a foundation of knowledge, which can then be better put to use in the constructed options from the approach.

4.3.5 Extending the Support Approach to a Greater Farming Population

All farmers in the study reported that others in the area could gain from the support approach. Nevertheless, two participants had specific comments pertaining to this issue. F8 thought that this methodology could be particularly beneficial to farmers in the area, given that has been a recent trend in which horticultural production is progressively being replaced by dairy. Farmers new to the field of milk production could particularly benefit, given their inexperience in managing the offer and demand aspects tied to this agricultural activity. According to F10, only a selective group of farmers could profit from this methodology: farmers who have been producing milk for many years, and who will pursue this activity regardless of the fate of the price for milk. He expressed that farmers new to the field, which most likely will give up the activity as fast as they got into it if the price for milk drops, are not in a position to project themselves into the future: "*Someone who has just learned to swim is just looking to stay afloat, not swimming laps*."

Despite thinking that the approach should be disseminated, the farmers had no idea who could be in a position to do so. This reaction was essentially fuelled by the reality that the only professionals who interact with farmers in the area on a regular basis are veterinarians and animals technicians, who come to the farm to administer a specific paid service and leave. The overall comment was that these individuals are only concerned with getting paid and have no real interest in the amelioration of farms in the valley. In spite of this preliminary answer, some suggestions were put forward. Five farmers (F3, F5, F6, F8 and F9) thought that the ideal situation would be having a technician employed by a NGO (non-profit organization) work with the support approach. F5 even went on to add that the technician in question should be a woman. F2 and F7 said a professional from the Ministry of Agriculture would be best, as this type of personnel is educated and funded. F4 stated that her farmers' association should have a technician working with this tool. Lastly, F1 and F10 said that university students in the last year of their agricultural degree should use this approach with farmers as a part of an internship.

The reported advantage of having a NGO or the government implement the support approach is that the governing body would cover the expenses of putting the methodology into action. If students were to work with the approach, the service would ultimately be free. As for having a technician outsourced by a farmers' association, F4, who suggested the idea, was unsure how this undertaking could be financed. It was suggested that perhaps farmers could contribute a small amount to a collective fund to pay for a professional. Despite thinking it was a good idea, she said that she did not have much faith in this proposal as Peruvian farmers are often reluctant to gather with others for a common good.

Finally, using the support approach as a collective group exercise was considered a difficult undertaking by all the farmers in this study. The prevailing remark was that every farmer works within a distinct context and thus faces very different realities. Nevertheless, F9 said maybe working within a group setting could be done for the purpose of feed training, with the use of the CalculRation application.

Overall, there was a very positive sentiment from behalf of the farmers towards the support approach. While this may hold true, the outcome of the evaluation is not sheltered from potential bias, particularly given that the assessment was conducted with the farmer by the facilitator. Furthermore, despite there being no real areas for improvement voiced by the participants, this does not suggest that there is no room for amelioration.

4.4 Exploring sensitivity of farming systems to water availability

Irrigation remains the best way for the farmers to feed regularly their cows and achieve their production objectives. The study conducted by Cortijo et al. (2010) showed that farmers were concerned by decreasing water availability at plot level. But the reasons for such constraint were not investigated, from depletion of upstream water linked to climatic change to increasing water demands not covered by schemes' distribution system. Moreover, it was shown that the water costs paid by farmers were quite low compared with other expenses, creating some confusion between the physical availability and the economic value of the resource. Indeed, the farmers involved in the current support process did not raise any issue regarding how economic and climatic shocks could impact their projects, probably because shocks would originate from elements they do not control, such as national and international markets for the prices of dairy products, or water management at basin and scheme levels for the water resource.

However, these risks are still real, and the support approach experimented in this study provides a way to evaluate *ex-ante* their potential impacts on dairy farms performances. This sensitivity analysis was conducted after the 2011 field work ended, in order to provide some elements that will be discussed in future workshops in the Mantaro Valley. The methodology was based on the scenarios simulated with the 10 farms by estimating the impacts of 10 and 20% decrease of water availability on milk production at farm level. Since we did not know the water consumption per fodder crop and per farm, we considered a linear regression between water consumption and fodder yields.

Simulations were conducted on the scenarios considered by farmers as the most adapted to their future projects (see Appendix 11 for detailed description of scenarios and simulation results). In each case the following methodology was applied:

. Application of a 10% or 20% decrease to fodder crop yields found in the scenario;
. Calculation of the monthly diets applied to lactating cows which balance fodder supplies;
. Calculation of the average daily milk production of the lactating herd per month
. Calculation of the total annual milk production
. Calculation of the annual milk production costs

All the others variables remained similar to the initial scenario, except fertilization costs that were reduced respectively by 10% and 20%. For instance both amounts and prices of concentrates are not modified. Thus simulations estimate the direct effect of a water supply reduction on farm performances, before any sort of adaptation by farmers such as change of fodder crops, feed diets or herd size.

Figure 17 shows the impacts of 10% and 20% reduction of water availability on milk production and milk production costs for the ten farms studied. These results highlight that:

. A 10% reduction would have minor consequences on a majority of farms, since their milk production is reduced in a range of 0-5%. F1 is the only farm significantly impacted.

. A 20% reduction of water availability leads to less than 10% reduction of milk production for seven farms. Three farms (F1, F5, F8) show impacts between 16% and 38%. The three of them are characterized by very low fodder surplus during the dry season in the project scenario, plus the absence of concentrate use for F1 and F8 which rely only on their own fodder production.

. Herd size and cow milk yields do not impact farm results in one way or another. For instance F10 shows results close to F6, which is structurally opposite.

. Milk production costs increase in every case due to the reduction of water availability. But they remain below the current milk prices paid by dairies and cheese processors. The highest production costs are attained by farms which rely heavily on concentrate purchases (F4 and F5).

These results show that intensifying dairy production in the context of the Mantaro Valley is still a profitable farming strategy, even in case of economic and environmental shocks. But it must not hinder the fact that each farm remains a particular case, which will be differently impacted by these shocks according to its own leeway in balancing fodder selection and productivity with dairy herd size and feed demand. In that respect, the support approach tested here provides a mean to better evaluate *ex-ante* the various options to adjust a project and its implementation to physical and economic hazards.

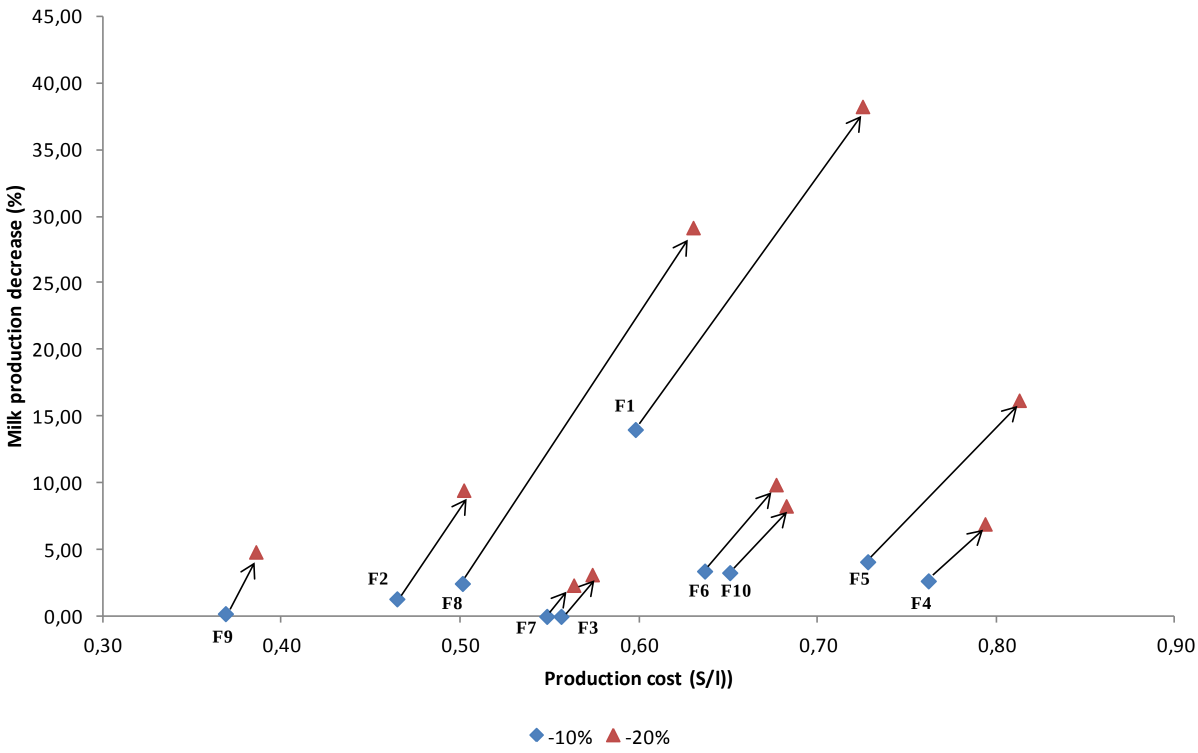

Figure 17: Simulated variations of milk production costs and milk production per farm following a 10% and 20% reduction of irrigation water availability

5. Discussion

5.1 A Catalyst for Reflection…

The various results generated in this study highlight that this dairy farm support approach, based on modelling tools, does in fact encourage reflection on behalf of the farmer. This outcome, the essence of the approach's purpose, materializes due to a number of elements comprising the methodology in itself and also thanks to several of its derivatives. For one, this method relies heavily on the participation of the farmer; this by its very nature is conducive in stimulating one's thought process. Secondly, the various outputs from the simulation tools, produced in every major step of the approach, are also a catalyst for thinking. While the farmers have questions prior to the start of the exercise, being presented with results as the methodology unfolds, impels them to carry their ideas further or even to come up with entirely new ones. Undoubtedly, this phenomenon is also intimately related to the discussions that arise throughout the process. As in the study conducted by Bernard (2010), the kinds of results generated here by the simulation tools provided trends for a particular project. This makes it feasible to assess and contrast various alternatives, and ultimately orients the discussion on various elements of a production system. Consequently, this triggers farmers to consider different facets of their operation; promoting the evolution of their thoughts.

As depicted in the detailed presentation of one case, the farmer was led to reflect on a wide range of aspects. While his attention was brought to a number of very specific points, he did also progress through a number of different ideas, which exercised his prospective thinking. The farmer went from only considering a herd increase of 10 cows and 30 heifers and substituting alfalfa with concentrates during a specific time of the year, to envisaging feeding oat-vetch silage all year round, abandoning the idea of supplements all together, potentially incorporating crop residues to the rations, and factoring in 63 cows. This illustrates how, aided by the various steps of the approach and by its derivatives, the farmer better solidified an evolutionary plan through his own thought process.

The context, in which the support approach unfolds, essentially consists of a continuous discourse between the farmer and the facilitator, where ideas tend to build on each other. The farmer will have an initial question or idea, which gets the facilitator thinking and bringing various elements forward that, in turn, broaden the farmer's scope of reflection. Moreover, this phenomenon can also contribute in inciting farmers to develop a more holistic outlook on the various components of their production system. Because the approach directly and indirectly addresses the consequences of carrying out a particular endeavour, it helps to accustom farmers in considering a wide range of elements before going ahead with something. This can thus assist in the successful implementation of production system advancements in the future, and it may ultimately reinforce their planning and anticipation capacities. Finally, participating in this type of approach also brings farmers, in certain cases, to realize the importance of various managerial activities on the farm. A number of the study's participants reported that having gone through this methodology considerably reinforced the value of adequately documenting inputs and outputs, on a regular basis.

5.2 …Amidst a Sea of Diversity

Cortijo's *et al.* (2010) typology and the characteristics of participants in this study have contributed in illustrating the diversity of farmers present in the Mantaro Valley. While their nature has proven to be distinct, the heterogeneity in their foreseen approach to increasing milk production has also been highlighted. The various elaborated scenarios across the sample also emphasized how farmers' situations were highly individualized. Every set of constructed options was greatly tailored and was designed to be adaptable to a particular farmer's case. The level of customization further transpired through the range of impacts and performances the established solutions had the farmers' initial situation. Furthermore, the variability in revenue notably illustrated how farmers work with different combinations of variables in their foreseen strategy.

Diversity was further highlighted in the different paths the support approach brought the farmers to take in relation to the evolution of their thought process. While this outcome can ultimately be tied to the fact that no two individuals think alike, there may also be other factors influencing the degree of reflection experienced by the farmers. Naturally, education may have played a part. Another possible affecting factor is flexibility. Farmers in favourable economic situations may feel like great potential lies ahead, thus leading them to develop many ideas. Nevertheless, there was no detectable relationship between perceived farmer flexibility and the extent of thought development; there were farmers in this study who were in seemingly more restrictive situations and appeared equally as inspired as their better-off counterparts.

The uniqueness of every farmer was also underlined by the participants themselves. This issue was accentuated when the farmers were inquired about the feasibility and interest of working with the support approach in a group setting. All participants responded that it would be difficult to do so because every farmer's situation is different.

Finally, the positive response towards the support approach from a diverse array of farmers helped demonstrate the flexibility of the methodology and its tools. It was noted that, small-scale like larger-scale farmers, operating within different contexts, were brought to reflect on their projects. Regardless of their level of education, their available resources, etc., it was possible to perceive a progression of their ideas through the approach. This outcome illustrated that this method and its modelling tools are suitable for different types of dairy farms and for addressing the distinct nature of farmers' inquiries.

5.3 Broadening the Support Approach's Horizons

The constructive reaction towards the approach uncovered in the evaluation provided an indication that there may be demand for this type of agricultural support by other dairy farmers in the Mantaro Valley. Nevertheless, this study suggests that, at the moment, there is no clear perspective as to what entity present in the region could manage and implement this approach. It became apparent that the private sector is highly present and assumes most of the interactions with farmers, selling inputs and administering paid services. Given the current situation, it is difficult to foresee a possible transfer of the methodology to a non-private organization.

While no concrete bodies were identified, one suggestion from a couple of farmers, later reiterated by a professor from UNALM, could potentially be an avenue to explore: handing over the support approach to university students studying agriculture. The idea would be to offer working with the approach as an internship option for students in their graduating year. There are several foreseeable advantages to this endeavour. Firstly, students are a continuously available and free resource. This helps guarantee a sustained presence in the farming community. Secondly, this activity would provide students with the chance to put into practice all the knowledge they gained through their curriculum, in addition to acquiring vital skills necessary to their future profession, particularly communication and research abilities. Thirdly, it was mentioned that often agricultural education at the university level in Peru is far too theoretical and disconnected from actual realities found at the farm level. Working hand in hand with farmers could give students the opportunity to obtain some imperative field experience. Finally, it was expressed that this experience could help students broaden their agricultural knowledge base, given the degree of specialization they find themselves in, early on in their academic career. In Peru, unlike many places around the world where agricultural engineers follow a very interdisciplinary curriculum, students are trained as zootechnicians or as what they refer to as agronomists, who only dedicate their efforts to plants and soils. As a result, students graduate with limited knowledge pertaining to fields intimately related to their own. Therefore, coupling an animal specialist with a person trained in crop and soil science for the implementation of the approach could contribute in bridging disciplines, and ultimately in shaping better future agricultural professionals.

Evidently, having students work with the support approach in the field implies that a certain level of preparation be carried out beforehand. Students would need to be trained on how to use the simulation tools and made aware of all the steps making up the methodology. This also supposes that the spreadsheet applications made available to them are overhauled versions of the ones that were used in this study.

While this study was unable to clearly identify an entity that could pursue this type of agricultural support in the Mantaro Valley, a research project aiming to analyze the agricultural service provider system in the region is scheduled to be carried out next by the CIRAD and UNALM. This study is expected to provide greater insight on the advisory services, which will potentially contribute in uncovering an organization suitable for extending the support approach to a greater farming population in the valley.

5.4 Limitations, Potential Improvements and Perspectives

As illustrated in this study, the implementation of the support approach is a lengthy endeavour, requiring a series of visits with the farmer and numerous iterative simulations to construct scenarios. As mentioned in Douhard (2010), putting the approach into practice by professionals outside of an experimental context is not without its complications. Support approach training, the duration of the process and logistical costs, notably tied to travel and computer equipment, are all factors that may limit the dissemination of this methodology in agricultural advisory entities. Other obstacles related to this approach pertain to data availability. Discussed in Le Gal *et al.* (2011), despite the relative simplicity of the input variables of the simulation tools, the availability of on-farm data was also an issue in the studied cases. Some farmers collect little or no information on their activities; therefore stated values were sometimes aberrant. As a result, this may extend the overall length of the approach given that more efforts are needed through iterative simulations and research to adequately establish a base scenario: the basis upon which further modelling takes place. Finally, estimating agricultural productivity may prove to be a delicate process. For milk production, this is made easier given that productivity is, in large part, associated with a ration. As denoted in F8's case, adjusting yield can be done effortlessly. However, modifying this variable says nothing about differences with regional averages, nor does it encompass any agronomic links between agricultural practices, the environment and yield. These are in fact complex processes, and the support approach is only in a position to point out the sensitivity of the simulated results. In the end, it is up to the farmers to decide what appears to be most realistic for their situation. Nevertheless, this supposes that they have a yield reference in mind, which is not always the case.

A number of changes need to be brought to the spreadsheet applications if transferring these tools is foreseen in the future. Ideally, the spreadsheets will pave the way to the construction of a more generic tool, which is easy to use and to calibrate. Given that there are currently three separate tools, using them collectively for the elaboration of a particular scenario makes for a lot of cumbersome manipulations, to which great attention must be brought to avoid the emergence of potential error. This suggests that they should be integrated into one working entity, all while keeping the flexibility of CalculRation to be used independently for the purpose of group feed training, for example. There are also a number of more explicit details to be addressed. Firstly, CalculFerti should be improved as at the moment its functioning and generated outputs are far too unrefined. One important element not accounted for in this tool is the nitrogen fixation capacity of legumes. Moreover, soil type has been left out of the equation. These two elements can prove to be very influential when determining a fertilization strategy which covers the nutrient exports of a particular crop. Secondly, the generic tool should distinguish horticultural crop production from that of forages, which are destined for the dairy portion of the farm. Currently in CLIFS, all crops are amassed together, making it tedious to determine the economic performance of either sector. Thirdly, the input section associated with crop production, designed to calculate a cost per hectare for the cultivation of a specific crop, should be able to accommodate more than 3 entries for fertilizer types and more than 4 entries for pesticides. Certain cases that were worked with during this study proved to be far more input intensive than the agricultural systems found in Madagascar upon which the simulation tools were constructed. Lastly, all costs associated with the herd (e.g. veterinary and insemination expenditures) should be automatically modified the moment there is a change in the number of animals found within the production system. When numerous simulations are conducted exploring various herd sizes, it is a lengthy process to ensure that all figures have been adjusted.

Finally, in addition to fostering reflection on behalf of the farmer, this study also suggests that this support approach does hold the potential in aiding farmers increase their milk production. Though this research did not feature a monitoring component, to examine change brought about at the farm level in relation to the support provided to the farmer, the essence of many simulations in this work was similar to that of the ones carried out in the Moroccan study (Sraïri *et al.*, 2011), which proved to have a positive impact on milk production.

Their use of simulation tools permitted a balancing of rations to improve milk productivity according to the cow's potential, while factoring in the demand and supply of feed found on the farm. As a result, they were able to demonstrate how milk production could be rapidly improved by balanced dietary rations that permitted the average milk yield of lactating cows to be attained, while optimising feed costs and decreasing milk production costs. Despite the current study not being able to carry out any measurements on ameliorated milk production, it did demonstrate how targeting different feeding strategies did lead to a decrease in production costs, like the explored options in Sraïri *et al.* (2011).

The Moroccan study's assessment of the rapid and reliable impact their support process had on the profitability of dairy production, led the authors to conclude that small-scale production structures are compatible with industrial dairy supply chains in emerging and developing countries. This thus suggests that the implementation of the support approach in the Mantaro Valley holds the potential in better positioning farmers to fulfil the demand for milk in the area, which may ultimately contribute to the development and prospering of the region as a whole.
Nevertheless, assessing the value of a support methodology, like the one in this study, on the decisions actually taken by farmers is a difficult endeavour. Reasons for this include a lack of temporal retrospect, the emergence of change in the farm's environment or within the production system's internal dynamic, family matters, and status quo in absence of profitable and realistic scenarios.

5.5 Lessons regarding sensitivity of dairy production to economic and climatic shocks

The Peruvian dairy sector is dynamic due to a growing demand of dairy products from urban population. The Mantaro Valley participates to that dynamic based on its network of industrial dairies, both local and national (Gloria) and local cheese processors. Milk prices obtained by farmers seem currently high enough to absorb some reduction of milk production due to an eventual decrease of water availability.

Nevertheless farms are differently impacted by water reduction. In that respect strategies based on fodder autonomy would be more sensitive than strategies involving higher use of concentrates produced outside farms and even the valley. Indeed, these purchases correspond to 'virtual' water imported from the places where concentrates are produced (Hoekstra and Chapagain, 2007). Thus their impact on the water balance may be positive locally but negative globally. Moreover concentrate purchases increase local milk production costs and thus, farm sensitivity to economic shocks.

Reducing sensitivity of dairy farms to such economic and environmental shocks could push farmers in redesigning their production system, for instance by selecting less water demanding fodder crops or by downsizing their herd while maintaining high cow yields. In that respect, the support approach tested in that study would provide new insights that farmers could use in their reflections. But it requires that agronomic references linking water requirements to fodder yields are available, which is not the case currently (E. Flores, Unalm, personal comm.).

Enhancing the dairy sector resilience against external shocks is not only a farmer issue but should involve others stakeholders in a “supply chain” perspective which include irrigation schema managers, farmers and dairy processors (Le Gal *et al.*, 2009). Whatever the reason for reduction of water availability at plot/farm level, changes in water management could include actions involving both farmers, whom irrigation practices could move to water saving technologies such as drip and sprinkler irrigation, and scheme manager for improving efficiency of water distribution. These aspects were not included in the current project but are instrumental to improve water value jointly with evolving interactions between farmers and dairy processors). Indeed, these interactions condition the economic value produced by the chain and to be shared between farmers and processors (Hugos, 2003), and the way it is shared based on the payment system applied to farmers.

The current project takes into account this second aspect by focusing on milk quality management from cows to dairy processing unit, viewed as a way to improve economic value of local production. During the second year of the project, relationship between farmers and processors on one hand, between farmers’ practices and milk quality on the other hand, will be investigated by Eduardo Fuentes, PhD student registered in Montpellier SupAgro and supervised by P.Y. Le Gal (Fuentes, 2011). During the second year of this PhD and after the completion of the World Bank project, this analytical work will be extended to the evaluation of various payment systems including quality based components.

6. Conclusion

This study has illustrated that amidst a group of farmers with a seemingly homogeneous goal, increasing volumes of produced milk, the envisaged ways of reaching this objective are dissimilar. This reflects the diverse nature of farmers’ questions and foreseen projects, which ultimately justifies a need for individualized agricultural advising. The chosen methodology that was experimented, a dairy farm support approach based on the use of modelling tools, has proven to be a considerably personalized form of intervention with farmers.

Beyond providing tailored support, it was demonstrated that this approach enables farmers to reflect on the dynamics of their production system and on envisaged evolutionary plans for their farm. The “how” and “why” of this phenomenon are encompassed in an amalgamation of factors. Contributing attributes include the highly participative nature of the approach, tangible simulation outputs, the assessment and comparison of various alternatives, the acquirement of knowledge and the constructive discussions, between the facilitator and the farmer, that materialize as the support approach unfolds.

While broadening farmers’ perspectives and fostering the development of their anticipation and planning capacities, this support approach and its tools exhibit flexibility as they proved to be suitable for different types of dairy farms and for addressing the distinct nature of farmers’ inquiries. Its adaptability to a variety of situations and the positive response from behalf of the farmers in this study, suggest that the approach could benefit a larger farming community. However, the success of such an undertaking entails that the simulation applications be overhauled into a more generic and ergonomic tool and that an agricultural advisory entity is identified in the region, that could guarantee a sustained implementation of the methodology.

Aiding farmers cultivate prospective thinking through the support approach may ultimately further a number of positive impacts. Sensitivity of the projects explored by farmers to economic and climatic shocks, still low in the current context, can be assessed and some options favoured or abandoned. While this can contribute to the successful materialization of evolutionary projects at the farm level, which may assist farmers in improving their standard of living, benefits can possibly transpire to a regional level. Better positioning farmers to actively participate in the area’s dairy sector fundamentally promotes growth and helps ensure that the rising demand for milk is fulfilled. Nevertheless, this support approach may represent only one factor among others to achieve the latter, which will also require that the relationship between farmers and collectors be explored: next step in the project funded by the World Bank.

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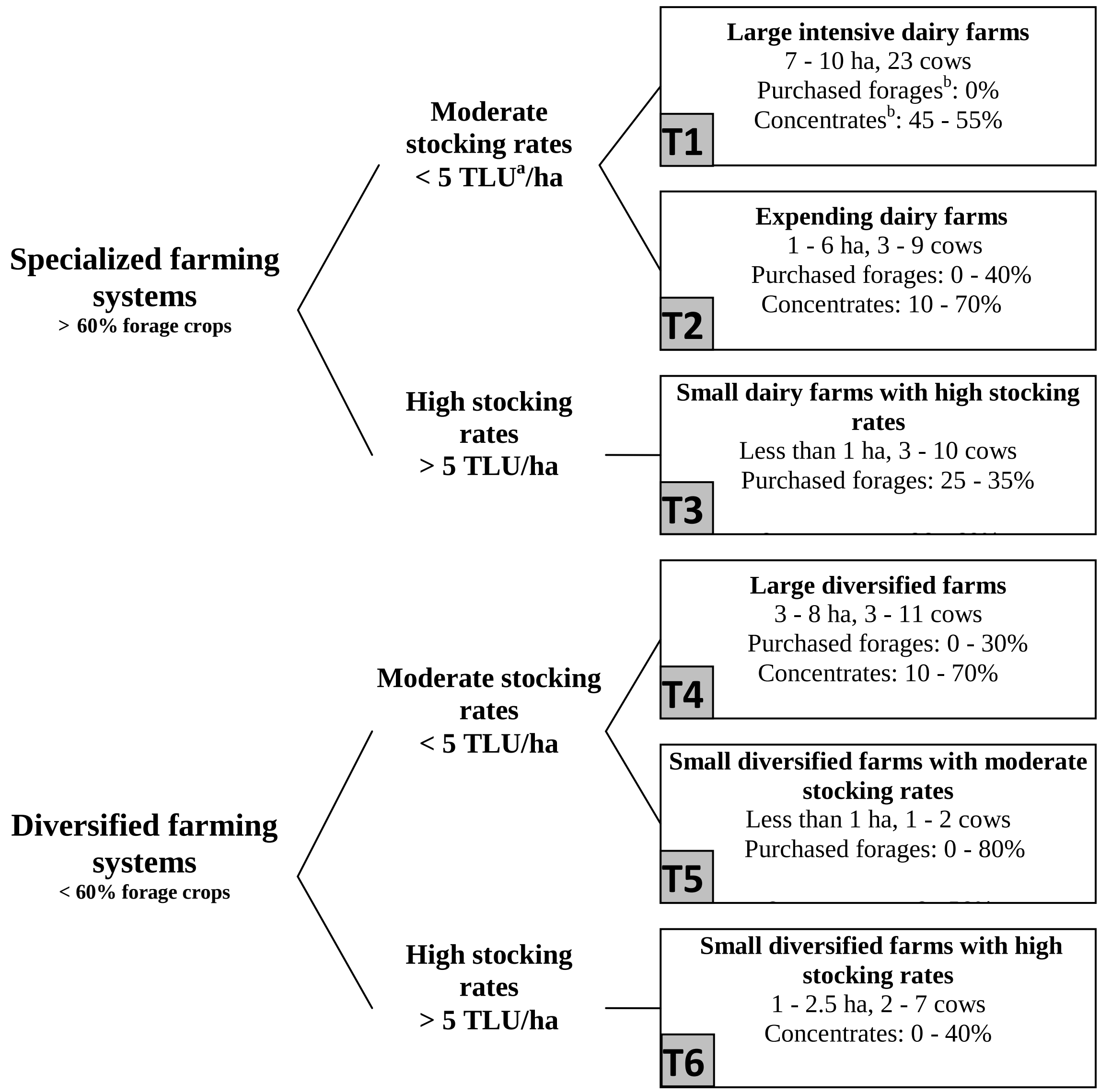
Appendix 1 — Typology of Dairy Farms Found in the Mantaro Valley (Based on and Adapted from Cortijo *et al.* (2010))



[a]TLU: Tropical Livestock Unit
[b]Percentage of intermediate consumption

Appendix 2 — CalculRation Details

CalculRation calculates an estimate of an individual animal's production in relation to an objective. The user defines the production goal in terms of litres of milk per day. The application also characterizes the animal according to weight and to calving distribution, from which it calculates milk production of an average cow. The calculation of the production allowed by the ration is based on the NRC feeding system which factors in notions of DMI (dry matter intake), energy and protein. For the animals in production, the user composes a ration which can accommodate up to 6 different forages and 3 different concentrates and/or mixtures. A mixture can be created in another tab where, based on its constituents and proportions, the nutritional value for the overall mix is calculated, which in turn can be incorporated into the ration. Incidentally, the requirements for vitamins and minerals are not taken into account in the ration formulation. In essence, the user defines the ration through trial and error in an attempt to find a balance between the objective and the production limited by the energy and protein content of the feedstuffs. The user may also test a range of possible solutions according to feed availability (Douhard, 2010).

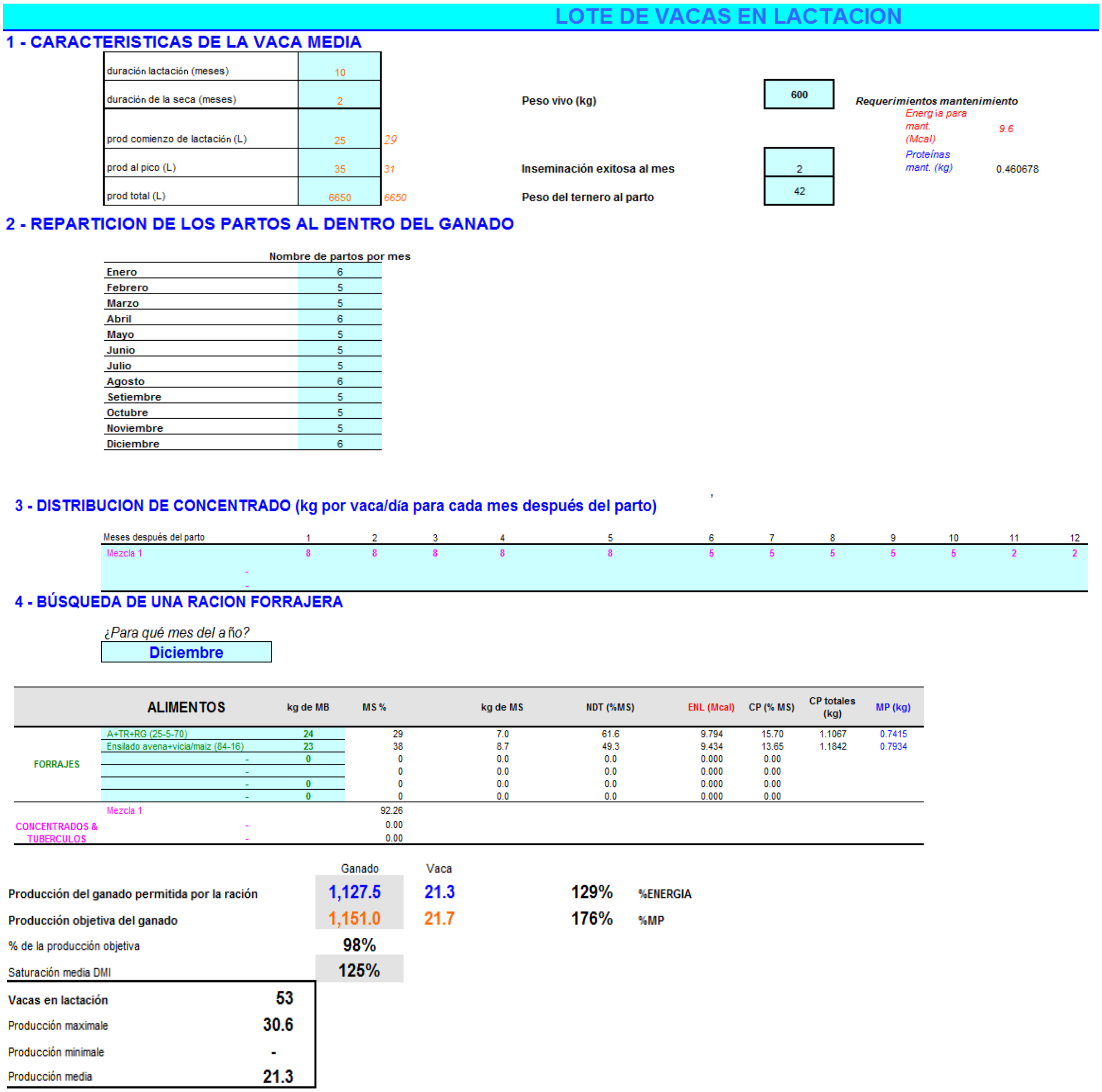


Figure 1: Main tab in CalculRation where variables are inserted in order to determine the milk production permitted by a particular ration

Appendix 3 — CalculFerti Details

CalculFerti is a tool designed to uncover a fertilization strategy that covers the mineral exports of crops. The user defines the yield objective in terms of raw material per hectare while specifying the portion of crop residues exported from the plots. CalculFerti then calculates the quantities of nitrogen, phosphorous and potassium that are theoretically exported. The user then tries to balance the exports by trial and error with quantities of fertilizers chosen to be applied.

The fertilization strategy may feature up to 5 different fertilizers selected from a list which features their N, P, K values in kg/t. Amongst the fertilizer possibilities, 3 may be manures specified by the user. CalculFerti also includes a tab in which it is possible to define a specific manure based on its straw and dung (fresh or dried) composition. Multiple equilibrium solutions are possible, especially since it is sometimes necessary to tolerate a certain level of surplus to cover the exportation of all 3 minerals (Douhard, 2010).

Cultivo 1	Papa				
Rendamiento (t/ha)	20.0				
Pajas	NON	% exportadas	100%	en t/ha	0.0000
Cultivo 2	-				
Rendamiento (t/ha)					
Pajas	NON	% exportadas		en t/ha	0

2- FERTILIZACION

Fertilizantes	Cantidades (kg/ha	(o carritos**/ha)	N (kg/t)	N (kg/ha)	P (kg/t)	P (kg/ha)	K (kg/t)	K (kg/ha)
Deyecciones desecadas de vacas (guano)	2,000		19	38	34	68	33	66
18-46-0	-		180	0	460	0	0	0
46-0-0	100		460	46	0	0	0	0
Abono 17-9-25	175		17	3	90	16	250	44
-			0	0	0	0	0	0
Total oferta (kg/ha)				87		84		110
Demanda (kg/ha)				70		14		108
BALANCE (kg/ha)				17		70		2
				124%		598%		102%

Figure 2: Illustration of potential outputs of a particular fertilization strategy based on a crop and its yield in CalculFerti

Appendix 4 — CLIFS Details

The CLIFS application runs on a monthly basis, and generates a simulation featuring the technical and economic results for the farm's operations for one year.

CLIFS essentially regroups on-farm production and demand and establishes a balance of resources: fodder for the herd by feed type and fertilizers by type (organic and chemical). For each balance, the dynamic between supply and demand dictates the level of necessary purchases, ultimately determining the farm's expenditures. Moreover, the application determines the level of income stemming from milk and crop production, which is then combined with the costs of production to determine the farm's revenue.

The simulation procedure in CLIFS is the following:

-The user enters in the "Farm resources" tab all the structural characteristics of the operation for further calculations (e.g. area of agricultural land, livestock buildings with or without a roof, storage infrastructure for manure) and the choice of resource uses (e.g. type and volume of sold products, type of feed and fertilizer purchased).

-In the "Herd" tab, the user goes on to define the composition of the livestock unit (number of dairy cows), calving distribution, and the number of sold and purchased animals.

-In the "Crop and agricultural land" tab, the characteristics of crop pattern present on the farm are entered (e.g. areas, yields and fertilization strategies defined in CalculFerti, the percentage of harvested crop residues, and quantities of seed and pesticides used).

-In the "Rations" tab, the rations established in CalculRation are inserted.

CLIFS then generates an economic summary where the balance between all the supplies and demands are calculated to evaluate the level of expenditures, which is then subtracted from money entries associated with volumes of sold milk and crops (Douhard, 2010).

Appendix 5 — Additional References Used in Adapting the Spreadsheet Applications

CalculRation:

Muirhead, S. (ed.), Lundeen, T. (ed.), 2001. Feedstuffs Reference Issue and Buyers Guide. Vol. 73, No. 29. Minnetonka, Minn., Miller Publishing Co., 220 p.

Zegarra Paredes, J., 2008. Valoración químico nutricional de recursos alimenticios, conocimiento base para mejorar la competitividad y la sustentabilidad de la ganadería bovina del sur peruano. Universidad Católica de Santa María de Arequipa, [online] http://www.incagro.gob.pe/documentos/ECI2010/08%20ValoracionAlimentosGanaderia.pdf

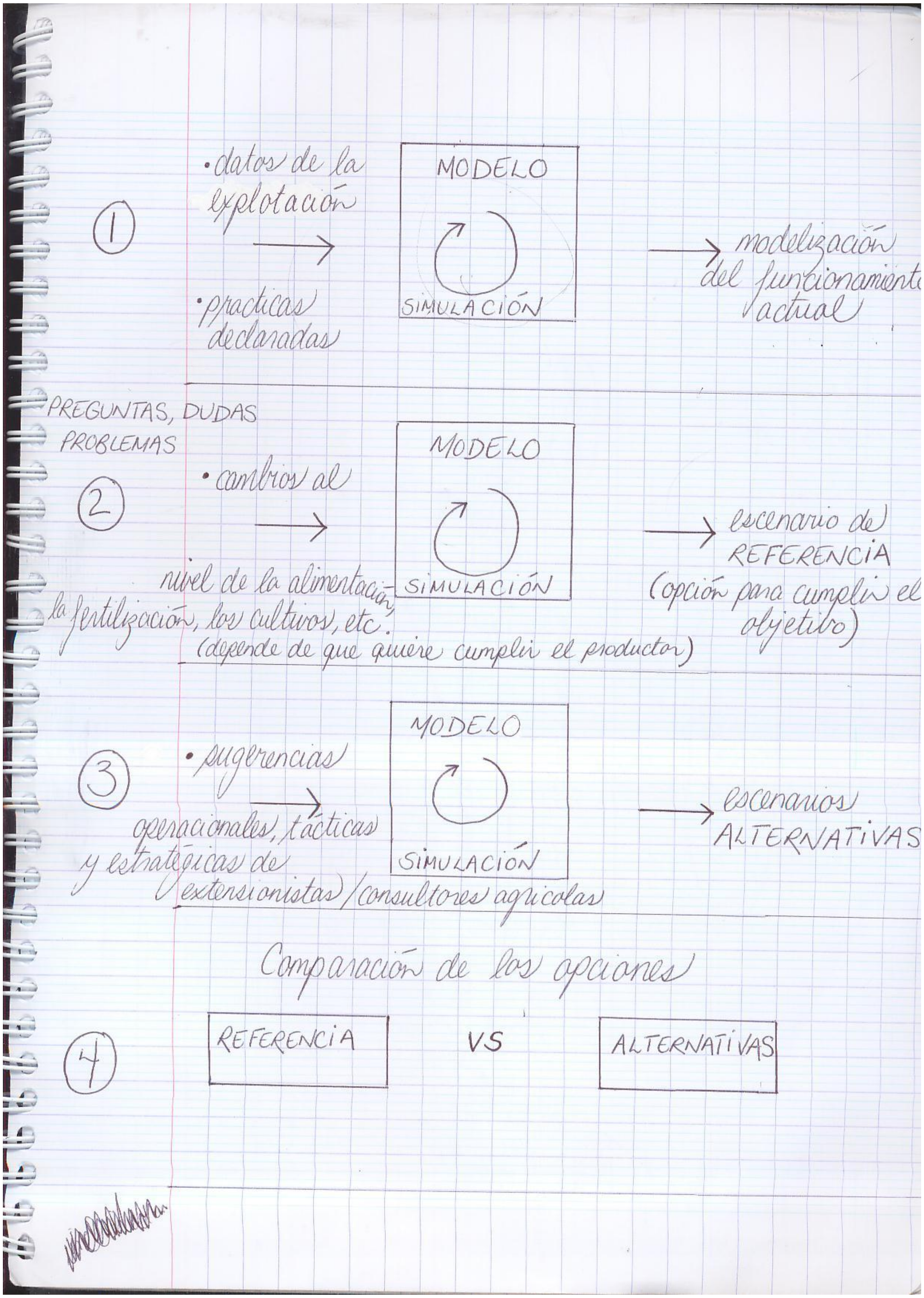
CalculFerti:

Pettygrove, G.S., Bay, I., 2009. Crop Nutrient Harvest Removal. University of California Cooperative Extension Manure Technical Bulletin Series, [online] http://groups.ucanr.org/manuremanagement/files/74636.pdf

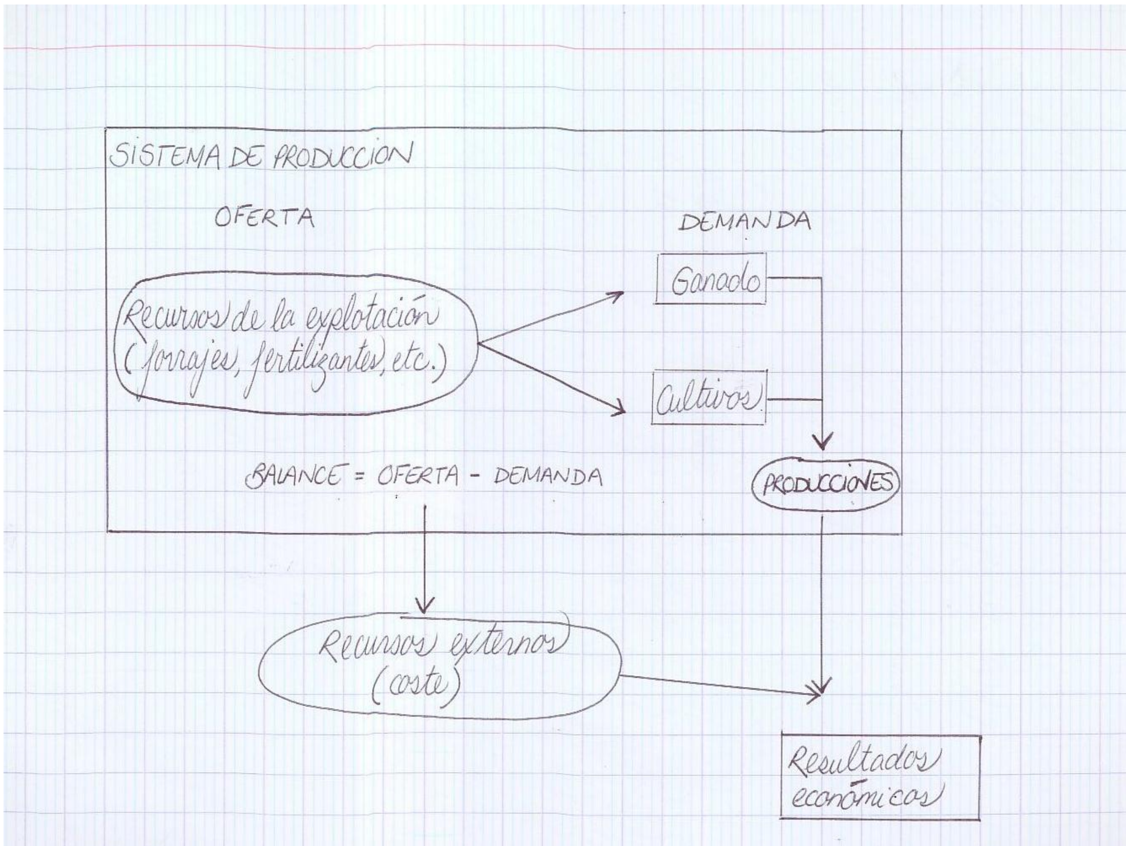
Rodríguez Góngora, A., 2009. Comparativo de 3 niveles de fertilización y extracción de nutrientes en alcachofa (*Cynara scolymus* L.) CV. lorca en condiciones de San Juan de Yanamudo (Valle del Mantaro). Tesis para optar el grade de Magister Scientiae, Lima, Peru, Universidad Nacional Agraria La Molina, 77 p.

Universidad Nacional Agraria La Molina (UNALM), 2000. Programa de Hortalizas – Anexo 8 Composición aproximada típica de algunas fuentes de materia orgánica y fertilizantes de origen natural, [online] http://www.lamolina.edu.pe/investigacion/programa/hortalizas/pdf/12-p130%20a%20p141%20(Anexos%204%20al%2013).pdf

Appendix 6 — Sketch #1 Illustrating the Major Steps of the Process



Appendix 7 — Sketch #2 Illustrating the General Idea of How the Various Elements of the Production System are Managed in CLIFS



Appendix 8 — Questionnaire

Cuestionario Valle del Mantaro 2011

Información general

Fecha:

Comité irrigación:

Nombre:

Acopiador/procesador:

Localización:

Superficie agrícola útil (ha):

Un poco de historia

Esquema de la explotación

Ganado

Características de la vaca media

duración lactación (meses)	
duración de la seca (meses)	
Producción comienzo de lactación (L)	
Producción al pico (L)	

Peso vivo (kg)	
Inseminación exitosa al mes (1, 2,…)	
Peso del ternero al parto	
Producción por medio/vaca/día	

Repartición de los partos

	Nombre de partos por mes
Enero	
Febrero	
Marzo	
Abril	
Mayo	
Junio	
Julio	
Agosto	
Setiembre	
Octubre	
Noviembre	
Diciembre	

Efectivo del ganado al 1 de enero

12-24 meses	
> 24 meses (no las vacas en producción)	

Terneros

Edad de los terneros al destete	
Edad de los terneros a la entrada al ganado	

Informaciones varias

Costos veterinarios por medios (vaca/año)				
Costo de la mano de obra temporal ganadería				
Costo alquiler toro o inseminación (por año)				
Precios de la leche	Precio y meses		Precio y meses	
Autoconsumo de la leche (L/día)				
Alimentación de leche de la madre (ternero) (L/día)	1° mes	2° mes	3° mes	4° mes

Engorde

Nb. animales	**Categoría (edad)**	**Apuesta al engorde (mes)**	**Nb. De meses**	**Peso inicial**	**Peso a la venta**	**Precio (S/./ kg vivo)**

Venta de animales flacos

Nb. animales vendidos	**Categoría (edad)**	**Mes de la venta**	**Precio**

Raciones de las vacas en producción (kg MV/vaca/día)

Alimentos	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**

Meses después parto / **Concentrados (kg/vaca/día)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

Tiempo pasado en edificio (horas/día)	
Tipo de estiércol recogido (fresco/seco)	

Raciones de base de los otros animales

Alimentos/ concentrados	**ENE**	**FEB**	**MAR**	**ABR**	**MAY**	**JUN**	**JUL**	**AGO**	**SET**	**OCT**	**NOV**	**DIC**

Tiempo pasado en edificio (horas/día)	

Tipo de estiércol	

Cultivos forrajeros

Cultivo:				**Stock:** sí / no				**Nivel del stock: (kg)**		**Mes:**		
Superficie (ha)												
Rendimiento (t/ha/año)												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nivel de producción (%)												

Cultivo:				**Stock:** sí / no				**Nivel del stock: (kg)**		**Mes:**		
Superficie (ha)												
Rendimiento (t/ha/año)												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nivel de producción (%)												

Cultivo:				**Stock:** sí / no				**Nivel del stock: (kg)**		**Mes:**		
Superficie (ha)												
Rendimiento (t/ha/año)												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nivel de producción (%)												

Recursos de la explotación

Cultivos alimentarios y comerciales

Cultivos	Rendimiento (t/ha)	Superficie (ha)	Venta (t de la cosecha)

Compras de recursos alimentarios no producidos sobre la explotación

Concentrados y tubérculos	Forrajes
Sal mineral (kg/año por el ganado)	

	Nombre alimento compuesto #1	Nombre alimento compuesto #2	Nombre alimento compuesto #3
Ingredientes para los alimentos compuestos			
	kg de MB/100 kg de MB del alimento 1	kg de MB/100 kg de MB del alimento 2	kg de MB/100 kg de MB del alimento 3

Fertilizantes comprados

Informaciones varias

Nombre de fosa de purín	
Capacidad de almacenamiento de la fosa (t de estiércol fresco)	
Estiércol en la fosa	
Limpia(s) de la fosa por año	
Parque por ganado sin techo (sí o no)	
Parque/edificio con techo (sí o no)	

Economía de la explotación

Gastos de la mano de obra y material

Remuneración de la mano de obra permanente	
Reembolso de la anualidad	
Tasa de interés del préstamo	
Consumo de combustible (S/./año)	
Mantenimiento de los edificios (S/./año)	
Costo de la irrigación por año	

Gastos diversos

Compra de animales (nombre y precio)	
Suma anual de gastos atados a la compra de material	
Compra de tierras	
Compra de pajas estiércol	
Compras diversas otra que para la ganadería y los cultivos	

Ventas diversas excepto ganadería y cultivos

Situaciones de cultivos

Cultivo	
% de pajas cosechadas	
Fertilizantes (cantidad/ha)	
Pesticidas, herbicidas (cantidad/ha)	
Semilla (cantidad/ha)	
Mecanización (carburante, alquileres, preparación del suelo, etc.)	
Mano de obra temporal	
Alquileres de tierras	

Cultivo	
% de pajas cosechadas	
Fertilizantes (cantidad/ha)	
Pesticidas, herbicidas (cantidad/ha)	
Semilla (cantidad/ha)	
Mecanización (carburante, alquileres, etc.)	
Mano de obra temporal	
Alquileres de tierras	

Cultivo	
% de pajas cosechadas	
Fertilizantes (cantidad/ha)	
Pesticidas, herbicidas (cantidad/ha)	
Semilla (cantidad/ha)	
Mecanización (carburante, alquileres, etc.)	
Mano de obra temporal	
Alquileres de tierras	

Appendix 9 — Support Approach Evaluation (Semi-Structured Interview Guide)

Starting from the basis of a farmer who has evolutionary ideas/projects for his/her production system;

1. Why has the farmer not implemented his/her project yet? What have been the obstacles, the difficulties, the restrictions that have prevented the farmer from bring about change to his/her farm?
   - A lack of financial means, i.e. a treasury problem?
   - A lack of knowledge?
   - A timing issue?
   - Other

2. Has the farmer discussed his/her project with someone in the past? If so, with who?
   - Family?
   - Neighbours/fellow farmers?
   - Agricultural technicians?
   - Veterinarians?
   - Other

Getting into details directly related to the support approach;

3. How has the support approach helped him/her advance in his/her ideas?
   - The degree of realism pertaining to the simulated ideas?
   - How does the farmer foresee bringing about change now that he/she has been presented with a series of scenarios?
   - Does the farmer have a better perspective with regards to what is or is not possible?

4. Were there specific points of knowledge acquired through the process?
   - With regards to rations?
   - Related to forage crops?
   - Other

5. Compared to other types of agricultural support offered in the region, how does this approach differ?

6. Are there any aspects of the support approach that can be improved?

7. Could other farmers in the area benefit from this type of support? If so, who could potentially adopt this approach and extend it to a greater farming population, and how could such an undertaking be financed?

8. Should this support approach be used as a collective group exercise?

Appendix 10 — Details on Farmers' Current Situation

Farmers	Land owned (ha)	Land rented (ha)	Green forages feeding strategy	Ration composition	Purchased concentrates	Purchased salt and minerals	Purchased forages	Horticultural crops
F1	0	0.33	C&C[a]	A+RG+C[c] CS[d]	NO	YES	YES (A+RG+C, CS)	NO
F2	3	0	P[b] + C&C	A+RG+C *chala*	YES (WB[j])	YES	NO	YES (PC[n])
F3	0	1.5	P	A+RG+C *chala* S[e]	NO	NO	YES (A+RG+C, *chala*, S)	YES (PC)
F4	0	1.5	P + C&C	A+RG+C *chala* S	YES (WB)	YES	YES (*chala*, S)	YES (PC + FS[o])
F5	0.7	0	P	A+RG+C *chala*	YES (WB)	YES	YES (A+RG+C, *chala*)	YES (PC)
F6	1.73	0.9	P	A/RG+C *chala*	YES (WB)	YES	YES RG+C[m]	YES (PC + FS)

F7	10.5	0	P	RG+O[f] S	YES (WB, CP[k])	YES	NO	YES (PC + FS)
F8	85	0	C&C	A CS OVS[g]	NO	YES	NO	YES (FS)
F9	11 + 20 (at 3700 m.a.s.l.) seldom used)	4	P + C&C	A+RG+C *chala* CS OV[h] S	YES (WB, CP)	YES	YES (S)	YES (PC + FS)
F10	60	0	P + C&C	A+RG OVCS[i]	YES (Mixture[l])	YES	NO	YES (FS)

[a]C&C: cut and carry for green forages
[b]P: pasture
[c]A+RG+C: association of alfalfa, ryegrass and clover
[d]CS: cob-less corn silage
[e]S: straw
[f]RG+O: association of ryegrass and orchardgrass
[g]OVS: oat-vetch silage
[h]OV: oat-vetch fed as cut green forages
[i]OVCS: oat-vetch-cob-less corn silage (85% -15%)
[j]WB: wheat bran
[k]CP: cotton pulp
[l]Mixture: 44% wheat bran, 20% corn, 12% soybean meal, 12% cotton pulp, 12% barley
[m]RG+O: association of ryegrass and orchardgrass
[n]PC: personal consumption
[o]FS: for sale

Appendix 11— Impacts of water depletion (-10% and -20%) on annual milk production (l) and milk production costs (S/l, in brackets) of the ten studied farms.

	Scenario description	Potential	Initial	Water -10%	Water -20%
F1	30 cows (4750 l/cow) 9 ha : A+T+RG 5.8 ha : O + V Concentrates : No	143000	130000 (0.52)	114000 (0.60)	94000 (0.72)
F2	10 cows (4750 l/cow) 4 ha : A+TR+RG 0.9 ha : Maize (chala) Concentrates : Yes	47500	46200 (0.46)	45600 (0.46)	42200 (0.50)
F3	5 cows (4750 l/cow) 2 ha : A+TR+RG Concentrates : Yes	23800	23000 (0.56)	23000 (0.56)	22300 (0.57)
F4	10 cows (6000 l/cow) 3,5 ha : A+TR+RG 1,5 ha : Maize (chala) Concentrates : Yes	60000	53900 (0.74)	52500 (0.76)	50400 (0.79)
F5	5 cows (3600 l/cow) 2 ha : A+TR+RG Concentrates : Yes	28800	28320 (0.70)	27000 (0.73)	24000 (0.81)
F6	8 cows (5100 l/cow) 1.8 ha : A 1.8 ha : Maize (choclo) Concentrates : Yes	40800	40600 (0.63)	38800 (0.65)	36500 (0.68)
F7	20 cows (3800 l/cow) 6 ha : RG+ dactylis 4 ha : Maize (chala) Concentrates : Yes	76000	73000 (0.55)	72300 (0.55)	69400 (0.56)
F8	63 cows (4500 l/cow) 16 ha : A 12 ha : O + V 17 ha : Maíze (silage) Concentrates : No	284000	265000 (0.49)	244000 (0.50)	182000 (0.63)
F9	25 cows (3800 l/cow) 7 ha : A+TR+RG 6 ha : Maize (chala) Concentrates : Yes	95000	94100 (0.37)	92100 (0.37)	86300 (0.39)
F10	84 cows (6650 l/cow) 20 ha : A + RG 24 ha : O + V 13 ha : Maize (silage) Concentrates : Yes	559000	527000 (0.62)	503000 (0.64)	467000 (0.68)

A : Alfalfa C : Clover RG : Ray-Grass O : Oat V : Vetch
RS : rainy season DS : dry season