Increasing irrigation water productivity through supply chain management of agro food products: the case of dairy farming in the Tadla irrigation scheme (Morocco)

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Abstract

Water productivity in agriculture is multi-facetted, difficult to apply beyond a mere physical interpretation of it, and common to a variety of disciplines, each one of them with its own interpretation of the scales of analysis, the objectives of the analysis and the terms of the indicators used. However, if one understands the pitfalls, the water productivity approach can be useful in a given situation – defined by a specific scale of analysis, a specific sub-sector or farming system, a spatial and temporal perimeter – to explore the potential of "improving" the productivity of existing water resources and produce more food per unit of water. In this paper, a cross-analysis of the management of the 100,000 ha Tadla irrigation scheme (Morocco) and the performance of the dairy supply chain, depending on this scheme, is undertaken to explore the possibilities of improving the water productivity through a better coordination in the irrigated dairy supply chain.

Key words: water productivity, supply chain, dairy production, irrigation

1 Introduction

Studying the performance of irrigation systems has a long tradition amongst scholars and practitioners. At the scheme level, this was often done by calculating the benefit-cost ratio or the internal rate of return of the investment consented (Barker *et al.*, 2003). Hydraulic engineers (Israelsen, 1932; Bos and Nugteren, 1974; Molden and Gates, 1992) focused on the efficiency at the canal or field level (conveyance and application efficiency), while agronomists studied the agricultural production at the field level, often expressed as a yield per unit of land. In recent years, attention has shifted towards a more integrated view of irrigation systems. At the same time water has become a focal point in these analyses due to an increasing awareness of water shortage, leading to the international discussion on "water productivity" in agriculture (Kijne *et al.*, 2003).

While the general definition of water productivity would relate to the benefits derived from a use of water (Molden *et al.*, 2003) or to a ratio referring to a unit of output (agricultural production) per unit of input (water) according to Barker *et al.* (2003), Molden *et al.* (2003) show that this definition is scale dependent. For farmers water productivity in agriculture would imply raising crop yields per unit of water; this concept becomes much more complicated at the irrigation system or basin level as one has to take other agricultural or non-agricultural water uses into account with all the inherent difficulties related to the estimation of the value of water, the opportunity costs of inputs, the economic return of various activities, environmental and other externalities and social impacts (Barker *et al.*, 2003). At a regional scale "water saving practices" (lining of canals, introducing drip irrigation) may amount to a simple redistribution of water, or as the authors put it "robbing Peter to pay Paul". This view is partly based on the "neo-classical" irrigation efficiency concept introduced by Seckler *et al.* (2003). This concept as opposed to "classical" irrigation efficiency (conveyance and application efficiency) accounts for return flows, and especially the reuse of groundwater, in a river basin. Indeed, water "losses" in irrigation canals are not necessarily 'used up' from a basin perspective. Bos (2004) proposed the depleted fraction to address this issue.

Kijne *et al.* (2003) caution the audience of their reference book – practitioners and researchers – about the use of the approach on water productivity in agriculture. Interestingly, the book does not provide benchmark values of water productivity. A number of reasons can be advanced for the reticence in comparing situations, sectors and scales. Firstly, Molden *et al.* (2003) urge researchers to clearly define the scale of analysis (plant, field, farm, irrigation system, basin…). The scale addressed will determine not only the processes that need to be studied, but even the definition of water productivity. Similarly, the definition of the concomitant performance indicators depends on the objective of the analysis. Providing technical advice to farmers on irrigation techniques and crop performance will not require the same terms in the numerator nor in the denominator, as compared to evaluating the impact of national water policies.

Secondly, Barker *et al.* (2003) insist on linking water productivity to "other concepts" such as economic efficiency, sustainability and social returns (equity, water rights). In doing so, the authors show the limits of a partial "crop water productivity" approach. Maximising the water productivity may not be economically efficient if the opportunity costs of other factors such as labour are taken into account (Barker *et al.*, 2003).

Thirdly, when the analysis goes beyond the pure physical productivity (yield per unit of water), and addresses economic properties one gets into very tedious process of valuing water, production costs and externalities (Barker *et al.*, 2003), without mentioning the social value of water.

Fourthly, the "production functions" governing the transformation of water into agricultural yields are difficult to establish. In a large review of literature Zwart and Bastiaanssen (2004) investigated the crop water productivity, defined as the marketable crop yield over actual evapotranspiration ET_{act}, for four crops in a large number of situations. The productivity values were shown to vary widely across different situations. For maize, for example, it ranged from 0.22 to 3.99, which is not surprising when considering the poor correlation between ETact and crop yields that was found. Water productivity depends indeed on a variety of factors, ranging from agricultural and irrigation management practices, genetic potential, soils, climate etc. In the case of livestock husbandry this would even be more complicated as the fodder production function would need to be complemented by a production function for the conversion to meat and milk products.

Fifthly, farms in irrigation schemes generally show a considerable "diversity in irrigation and agricultural performance", impacting on the water productivity. In agricultural systems research, this is often addressed by developing a farmer typology, based on the functioning of these farms, the goals and the sociological and family circumstances of the farmers (Brossier and Petit, 1977), in order to understand and explain this diversity and recommend changes in practices adapted to each situation. In such an approach, water productivity would contribute to identifying farm goals and linking farm practices and outputs, rather than being an objective in itself.

In fine, water productivity in agriculture is multi-facetted, difficult to apply beyond a mere physical interpretation of it, and common to a variety of disciplines, each one of them with its own interpretation of the scales of analysis, the objectives of the analysis and the terms of the indicators used. However, if one understands the pitfalls, the water productivity approach can be useful in a given situation – defined by a specific scale of analysis, a specific sub-sector or farming system, a spatial and temporal perimeter – to explore the potential of improving the productivity of existing water resources and produce more food per unit of water (Kijne *et al.*, 2003). A number of tool kits have been proposed by various authors to assess irrigation and drainage performances depending on the objectives of the analysis and the specific situation analysed (Rao, 1993; Bos *et al.*, 2005). However, fewer research have actually described the implementation of a methodology which supports stakeholders (e.g. scheme managers, farmers) in improving water productivity and irrigation performances (de Nys *et al.*, 2005).

In this paper, a cross-analysis of the management of the Tadla irrigation scheme (Morocco) and the performance of the dairy supply chain linked to this scheme is undertaken to explore the possibilities of improving the water productivity. While water productivity could be improved by reducing the amount of water used through improved irrigation techniques or better agricultural practices, this study focuses on creating more value with available water resources through a better coordination in the irrigated dairy supply chain. This paper presents the first results of an intervention-oriented research project, investigating the dual relationship between irrigation scheme and dairy sub-sector.

Indeed, in semi arid zones irrigation schemes offer interesting opportunities for the agro industry in general as (i) they attenuate climatic fluctuations by ensuring a more constant water supply for the crops that are of interest to these industries, and (ii) they concentrate large quantities of raw material in a relatively compact area. In the case of the dairy supply chain, the performance of dairy farms depends on the regularity and the quality of fodder produced on the irrigation scheme, directly related to the water productivity issue. In Morocco, State policies via the 'milk plan' of 1975 indeed strongly encouraged the milk production in the irrigated areas, because of the relative secure water access for the forage crops (Araba *et al.,* 2001; Sraïri and El Khattabi, 2001). Bourbouze *et al.* (1989) show that 60 % of the green fodder units in Morocco are produced by irrigated agriculture.

Farm revenues depend directly on milk productivity via the yields of fodder and the cattle feeding strategies, including the use of (imported) high value concentrates and the provision of drinking water. But they depend also on the coordination between farmers and other stakeholders in the dairy supply chain (cooperatives, industrial processing plant) in order to organise the milk collection, to implement quality policies and to agree on pricing strategies for the delivered milk. Secondly, the performance of the irrigation scheme in terms of matching irrigation supply and demand but also the water fees collection is tributary to the functioning of the sub-sectors linked to the scheme. Thus, a considerable set of relationships exist between stakeholders linking the irrigation scheme to a set of supply chains starting from the water supplier and finishing with the first raw product buyers (figure 1).

This article shows how dairy farmers, milk cooperatives, the irrigation authority and the dairy enterprise develop antagonist or converging strategies to address the key issues of their supply chain, related to the productivity, the regularity of deliveries and the quality of the milk. The diversity of strategies and practices of farmers is analysed, including their impact on the performance and the functioning of the dairy supply chain. The functioning of the milk cooperatives and the dairy enterprise is discussed to explain the orientations of certain dairy farmers.

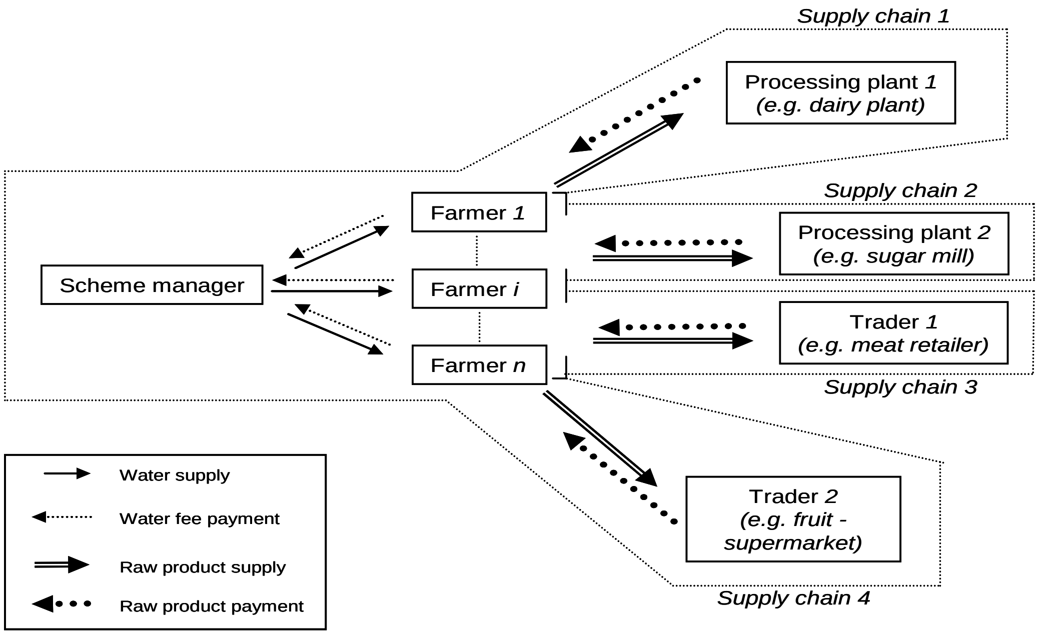

Figure 1. Schematic representation of stakeholders' relationship within supply chains.

2 Research approach

The results presented in this paper are part of a larger research project involving the Moroccan Agronomic and Veterinary Institute (IAV) Hassan II in Rabat and the French Agricultural Research Centre for International Development (CIRAD) on the analysis of the interlinked dynamics of supply chain management of agro industrial sub-sectors and the management of large-scale irrigation schemes. The supply chain of dairy farming in the Tadla scheme is an excellent case for illustrating these dynamics.

A two-fold objective was assigned to this case study: 1) understand the mechanisms of coordination in the supply chain impacting on the technical and economic performances of the sub-sector and the irrigation scheme; water productivity is one of the items that is addressed, 2) support the stakeholders in improving these technical and economic performances. The research approach is intervention-driven, as formalised by management research conducted in various industrial sectors (Moisdon, 1984; David, 2001). The stakeholders contribute to the definition of the strategic issues to be addressed and the project activities linked to these issues. They review the project results through a steering committee as well as through regular bilateral interactions. The project started in early 2005 and this paper presents the first results of the case study, which are mainly related to the diagnosis of the existing situation.

In order to carry out the diagnosis of the dairy supply chain in the Tadla irrigation scheme, analyses were carried out both at farm and regional levels. At regional level, interviews with selected resource persons allowed the identification of the key issues that stakeholders wanted to address in order to improve the performance of the dairy supply chain. This enabled the formulation of the research questions to be tackled at the supply chain level. At farm level, surveys were conducted in order to firstly describe the diversity of farm strategies and performances, and secondly to model the relationships between these two entities. These models provide a simulation tool to assess different options for improving the dairy performances at both farm and dairy chain levels.

A first series of interviews targeting 30 dairy farms allowed the elaboration of a dairy farm typology based on the farmers' general strategies for cattle feeding and cattle management. Then, a smaller sample of 10 dairy farms was investigated in more detail, focusing on three items: 1) cattle management and milk production (reproduction, calf rearing, drying off…), 2) feeding management, 3) forage system management (water application, crop selection, crop management, yields). All previously identified dairy farm types were represented in this sample. Both the results at farm and regional levels were reported back to all the stakeholders during a one-day workshop (Sraïri *et al.*, 2005). They were discussed and validated, and decisions were made regarding the way forward.

3 Results

3.1 Relations between the irrigation scheme, dairy farmers and the dairy plant

The Tadla irrigation scheme is located 200 km south-east of Casablanca in Morocco. It covers an irrigated area of about 100,000 ha and is managed by the Regional agricultural development authority of the Tadla (ORMVAT). Annually, between 323 (2001/02) and 1003 million m^3 (1991/92) of surface water is diverted to the scheme. In addition, more than 10,000 private tubewells and wells furnish more than 140 million m3 of groundwater at the farm gate according to ORMVAT. The Tadla irrigation scheme is an important producer of agricultural commodities at a national scale (table 1), including milk and meat which account for respectively 18% and 11% of the total national production. Accordingly fodder crops covered 25% of the 118,000 ha cultivated in 2004/2005 (figure 2). It consisted mainly of alfalfa, but some maize (3000 ha) and clover were also grown.

Table 1. Proportion of national production coming from the Tadla irrigation scheme for various agricultural products.

Product	Sugar	Selected seeds	Citrus	Olives	Milk	Meat
%	23	21	13	12	18	11

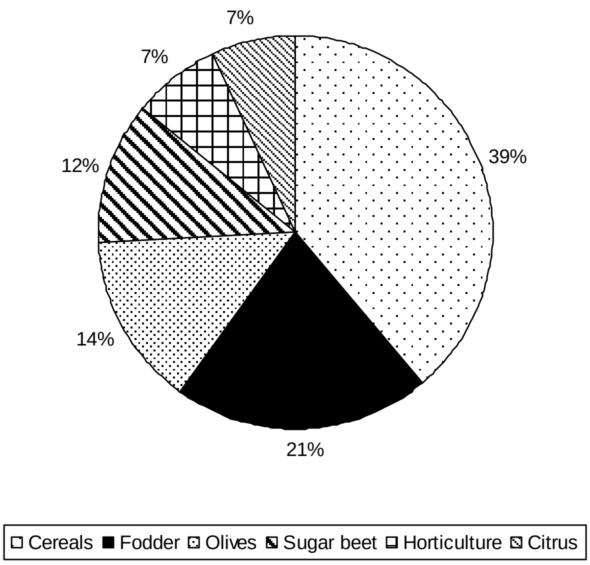

Figure 2. Distribution of crop areas in the Tadla irrigated scheme (source: ORMVAT).

In addition, there is about 165,000 livestock in the scheme, out of which 55,000 constitute the dairy stock, producing an estimated 175 million l of milk per year out of which approximately 114 million l are transformed by the dairy plant located in the zone. This plant belongs to the largest dairy enterprise in Morocco processing annually about 406 million l nation wide (2004 figures). The milk is collected by 84 specialized cooperatives, supplied by more than 17,000 dairy farmers. Each cooperative has between 1-5 collection centres. The majority of these cooperatives (54) are grouped in the Tadla dairy farms association (AET), who defends the breeders' interests, and provides services to the cooperatives that are member of the association (artificial insemination, import of heifers, and supply of concentrates). In addition, ORMVAT provides a technical and administrative support to the milk cooperatives. About 30 technicians are thus at the disposal of these cooperatives.

These stakeholders (ORMVAT, farmers, cooperatives and dairy plant) are then linked together within a supply chain starting by the scheme manager supplying water to the dairy farms, the farmers transforming water into fodder and then into milk and meat, the cooperatives collecting and aggregating individual deliveries into larger milk batches, that are finally delivered to the dairy plant by means of 28,000 l tanks (figure 3). This chain includes 4 production functions which impact on water productivity: Pf1 relates to the scheme's efficiency of water distribution; Pf2 is linked to the farmer's ability to efficiently irrigate his fodder crop; Pf3 relates to the way animals transform fodder into milk and meat, in relation with the farmer's feeding practices, including the use of concentrates; Pf4 should impact on the milk price paid to the farmers, and so on the economic valuation of both the surface and groundwater originally used in this chain. The difficult determination of these production functions and the complexity of this supply chain, which involves numerous stakeholders at various stages, illustrate the challenge of assessing water productivity in such a context.

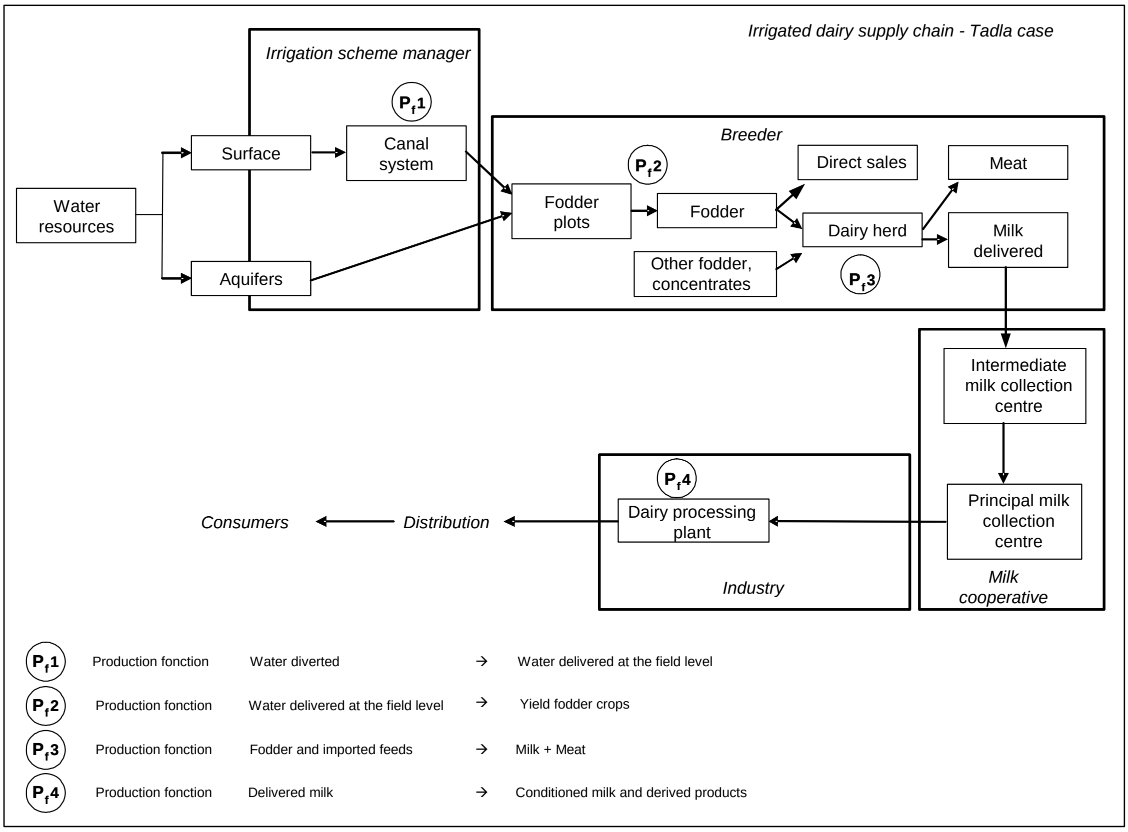

Figure 3. Schematic overview of the irrigated dairy supply chain in the Tadla irrigation scheme.

3.2 How to improve water productivity through a better dairy supply chain management?

The water productivity in an irrigation scheme can be assessed simply by the following equations:

$$WP = \frac{\sum_{y=1}^{z} Ev_y}{V} \qquad (1)$$

Evy: economic value of production y

V: total annual volume of water used in the scheme

z: total amount of productions cultivated in the scheme

$$Ev_y = Q_y \cdot P_y - C_y \qquad (2)$$

$$Q_y = R_y \cdot A_y \qquad (3)$$

Q_y : quantity of production y

R_y : yield of production y

A_y : area allocated to production y

P_y : marketing price of production y

C_y : production costs dedicated to production y

Ev_y may be calculated at the level of the entire scheme by using mean values or at the farm level. The latter case will underline the diversity of farm performances within the scheme. The competition between productions within the scheme is linked to two variables: (i) the water allocation between productions and its impact on the V value, (ii) the cropping pattern and its impact on the Sy values. The dairy chain is a more complicated case, as the fodder production is not directly valued except when it is sold on the market. In that case the water productivity may be calculated as follows:

$$WP_{ap} = \frac{\sum_{j=1}^{n} Ev_j}{\sum_{k=1}^{m} V_k} \qquad (4)$$

WP_{ap}: water productivity of animal products

Ev_j: economic value of animal products (milk, meat) and through the sales of fodder

V_k: amount of water used by fodder crop k.

In the case of animal products, R_y corresponds to quantities of milk and meat produced by animal and A_y to the herd size (classified by animal type).

These equations underline the various ways to improve water productivity through a better dairy supply chain management. A first common direction consists in reducing the water quantity used, either by improving the distribution and application efficiency or by selecting fodder crops with lower water requirements. Various practical actions may be carried out to achieve these objectives: at the scheme level by reallocating water to low consumer crops or by investing in infrastructures which decrease conveyance losses; at the farm level by changing both crop selection and irrigation practices. These changes may even pave the way for original solutions, for example by advocating deficit irrigation (Zwart and Bastiaanssen, 2004) or by considering that water lost in canal systems may be more productive elsewhere (Seckler *et al.*, 2003).

The second direction consists in improving the dairy supply chain management in order to increase its economic value, both at the farm and industrial levels. Four options may be considered: Firstly, various measures are possible to enhance the attractiveness of the dairy supply chain with respect to other crops or sub-sectors: price strategies for agricultural inputs and commodities, contracts providing a certain security to various parties, credit facilities, technical support, and provision of inputs. Secondly, guaranties could be provided to farmers regarding the purchase of their milk, thus encouraging them to produce more and to deliver preferentially to the plant. Thirdly, the deliveries throughout the year could be regulated to better match the consumers' demand, for example through differentiated price mechanisms. Fourthly, measures could be implemented to increase the quality of raw milk which leads to better valued processed outputs.

In that respect the interviews carried out with the Tadla stakeholders and the general discussion conducted during the workshop showed that the dairy supply chain is currently facing three strategic issues: 1) how to increase the milk production by improving the productivity of cows which is presently around 3,000 l/cow/year, 2) how to reduce the seasonality (highest daily delivery divided by the lowest daily delivery) of milk deliveries from 1.9 to 1.6, 3) how to improve the hygienic (total germs) as well as the intrinsic quality (protein, fat substance) of the milk delivered to the plant? A general convention was signed in 2003 between the Regional agricultural development authority and the principal dairy enterprise of the area, fixing quantitative objectives on the volumes and the quality of the milk delivered.

The chain analysis showed that stakeholders face many problems in achieving these objectives. The cows' productivity remains quite low despite the importation of genetically improved animals from Europe. Both this performance and the production seasonality are linked to the way farmers manage their feeding system, particularly the fodder crops, in coordination with the cows' reproduction on the one hand, the irrigation management on the other hand. Moreover the milk production cannot be dissociated from the meat production. How do farmers select their production orientations? How do the balance between marketing prices of milk, meat and fodder as well as the respective economic function of each output impact on the milk quantities delivered to the dairy plant?

The management of the milk quality raises other constraints. The dairy plant analyses milk batches provided by the cooperatives and pays premiums linked to their intrinsic quality. These premiums remain at the cooperative level as there is no individual analysis, except for milk acidity and density. Some cooperatives may redistribute these extra funds by offering specific services to their members, such as social insurance or the pilgrimage to Mecca. Some quality-targeted actions are also implemented, such as establishing collection centres closer to the dairy farms, encouraging the use of aluminium rather than plastic pots or collecting milk twice a day. But the average quality remains quite uncertain, due both to the lack of direct incentive from the plant to the individual farmers and the cooperatives' diverse contribution to the quality management process.

The research and intervention program aims at solving these various strategic issues. The first step consists in investigating the dairy farm diversity and to model it by designing a farm typology.

3.3 Modelling farm diversity: a typology of dairy farms

The dairy farm typology was developed on the basis of farmer strategies following the agricultural systems research approach as mentioned in the introduction. In doing so, one tries to understand and explain the diversity in the dairy performance and explore 1) the potential for changing practices in order to improve this performance and 2) the impact of these changes on the supply chain performance. The conceptual framework for the dairy farm typology in the Tadla irrigation scheme is presented in figure 4. It helps to identify four dairy farm types, based on the relative importance of the livestock unit in the overall farming strategy.

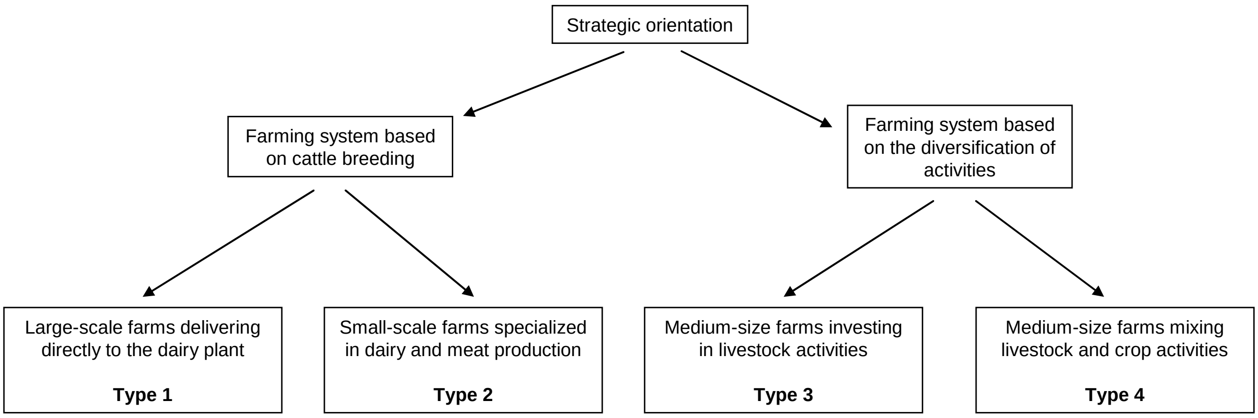

Figure 4. Conceptual framework of the dairy farm typology in the Tadla irrigation scheme.

The four dairy farm types are presented in more detail in table 2.

Table 2. Presentation of the dairy farm typology in the Tadla irrigation scheme.

Type 1: Investment of capital in a dairy unit - Dairy herd of 20 or more - Diversified forage system (maize ensilage) not limited by the surface area - Direct delivery to the dairy plant - Salaried employees - 3 000 to 5 000 l/year delivered per cow	Type 3: Increasing cattle herd in a diversified farming system - 10 to 20 ha of surface area - 3 to 6 ha of forage crops - Investments in stables and equipment - 8 milk cows and aiming to increase this number - 2500 to 3000 l/year delivered per cow
Type 2: Intensive cattle farming with a limited surface area - All farm land (~ 2 ha) produces forage crops (alfalfa) - Investments in stables and sometimes milking machines - Dairy herd from 5 to 10 - 2 500 to 5 000 l/year delivered per cow	Type 4: Cattle farm dedicated to a diversified farming system - 7 ha of surface area out of which 15 % consists of forage crops - Herd of local race, adapted to feed restrictions - Recycling of all by-products of different crops - Milk ensures the cash flow for the different crop expenses - 1 500 to 2 000 l/year delivered per cow.

While the first farmer type impresses during a first visit for the importance of the investments committed and the number of cattle present, its relative performance seems limited by a lack of technical command of the unit. The owner has often another professional background; the routine supervision is delegated to a farm manager. In addition, one can question the profitability of the enterprise, depending for example on the price fluctuations of feeds. However, the farmers of this category have sufficient capital for further investments, including human resources, to improve the dairy productivity, while better managing the expenditure linked to their livestock unit.

The second farmer type is a good technical breeder who clearly focuses on dairy production, while making the best of considerable limitations in terms of surface area. This reduces significantly the scope for growing forage crops. The diversity of the milk productivity is considerable and for many farmers of this type gains are to be made through a better command of the fodder production as well as the rationing of the feeds, including the purchase of imported feeds. In terms of development perspectives, the future lies probably either with an increase in surface area by the purchase or rent of additional land, or with an off-land orientation, relying more on the purchase of imported feeds.

The third farmer type has a diversified farming system with sufficient land. The livestock unit is an important complementary activity for the farm. There are several factors explaining a limited milk productivity of the herd: 1) the genetic material of the cows (mixed breed), 2) the competition of milk production with other livestock activities such as fattening, 3) the competition of forage crops with other plant productions leading in some years to a lack of feeds. This farmer type is willing to purchase additional dairy cows, which would not lead to an improvement in milk productivity. In order to increase this productivity, a change in plant production strategies (abandoning industrial or market crops in favour of fodder) and a genetic improvement of the herd through the import of purebred heifers and further selection will be necessary. A choice will have to be made on a specialisation in milk production with respect to other breeding activities such as fattening.

It is not by chance that the fourth farmer type is the last category of the dairy farm typology. A limited capital, a local breed cow, and a low priority in growing fodder crops, makes this type a very poor performer in terms of milk productivity. However, from a farmer point of view, the livestock unit can be profitable with little expenditure (use of by-products, little investment in genetic material). In terms of development perspectives, this type could be inclined to continue in the same way or, if sufficient incentives will be provided (exclusion of low performers from the industrial supply chain or a more enticing price policy) could convert to the third farm type by investing in the milk production.

Despite the fact that this typology was established on a small sample it provides a valuable view of the farm diversity within the Tadla scheme and the local dairy supply chain. Potentialities as well as constraints linked to milk production differ greatly from one case to another, as should be their contribution in improving both the dairy chain performances and the productivity of water used for fodder crops. Several actions have now to be carried out in order to assess these contributions:

- Linking the dairy farm typology to irrigation management practices of forage crops. For example there is evidence on the wide diversity in the attention given by farmers to the alfalfa production (Kuper *et al.*, 2003). This is expressed in the quantity of fertilizer applied to the crop as well as to the amount of irrigation water provided (figure 5). Farmers that have access to both surface water (state managed canal system) and groundwater through private wells provide on average 90 % (18,350 m^3) of the theoretical requirements. Those who only have access to surface water provide only 40 % of the requirements, amounting to 8 750 against 20 700 m^3.

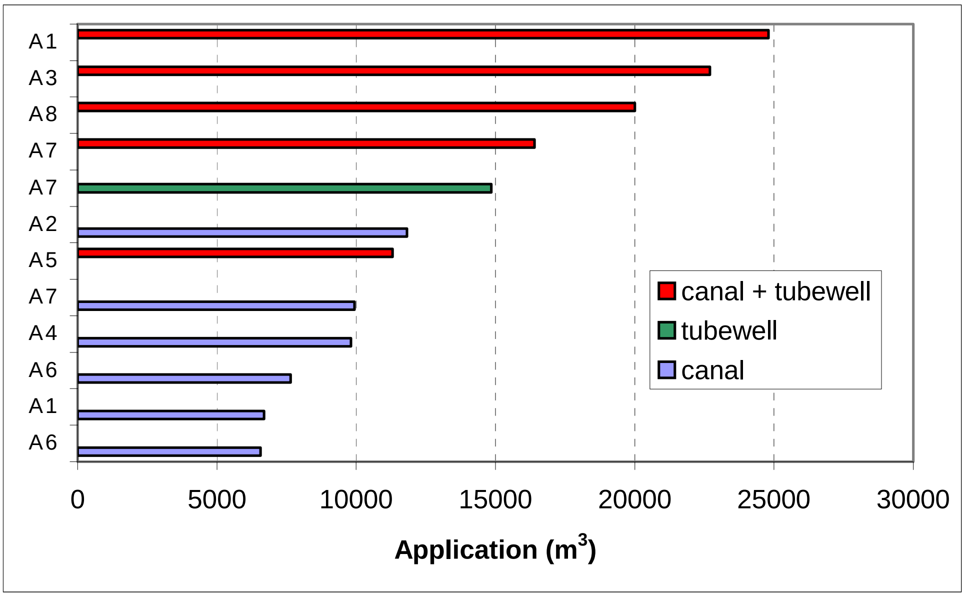

Figure 5. Annual water application (m^3/ha) of alfalfa crops differentiated by the farmer's access to irrigation supplies (canal + tubewell, tubewell or canal only), source: Kuper *et al.* (2003).

- It is interesting to analyse the specific cases of farmers A2, A5 and A7. Farmer A2 has only access to surface water, but manages to give 35% more water than other farmers in his case. This is due to an arrangement with his brothers who have installed a tubewell, to the installation cost of which he has contributed but which cannot irrigate his lands. In return, these brothers give farmer A2 their shares in surface water. Farmer A5, who has managed to install a tubewell in association with another farmer, faces cash flow problems, which hamper the tubewell operations (purchase of diesel). This problem is imputed by the farmer to the fact that he has no revenues from family living in Europe. Emigration revenues are indeed considered crucial not only in the installation of tubewells, but also for their functioning. Farmer A7 irrigates some plots at a certain distance from his tubewell resulting in considerable water losses. Even though he can operate his tubewell whenever he wants, he applies less water than other farmers in his case because of the pumping costs related to the losses.

- Assessing the relative weight of these four farmer types in the Tadla irrigation scheme among the 17 000 breeders, in order to evaluate the cumulative impact of changes conducted in one or more types at the chain level. Crossing this analysis with existing databases managed by the supply chain stakeholders may provide a better idea of this relative weight, but may also provide evidence for other hitherto fore not identified farmer types.

- Designing simulation models per farm type that take into account the relationships between the various constraining factors and milk productivity. These models will allow a better diagnosis of the impact of these factors on the performances of each farm type. Used at the chain level jointly with the relative weight per type, they will provide a quantitative assessment of these impacts on the total production and its annual seasonality. These models are currently developed using a spreadsheet approach, but may be developed using a computational platform allowing a more dynamic modelling of alternative scenarios.

4 The way forward

Several research proposals were discussed with the stakeholders during a one-day seminar in May 2005 in order to agree on the way forward after the first phase of the study, (Sraïri *et al.*, 2005). These proposals were based on the following principles and objectives:

- They will favour the cooperation of stakeholders rather than focusing on existing tensions related to some aspects of the dairy supply chain (milk prices, for example);

- They aim at increasing the total value created by the supply chain;

- They are intervention-driven, focusing on concrete questions that can be improved through technical or organizational innovations;
- They will develop tools and methods that can cover the largest possible number of breeders, while taking into account their diversity.

It was further agreed that the proposals should target first and foremost the level of the cooperatives and cattle breeders, where the three strategic issues described in section 3.2 should be preferentially addressed. Indeed, while the productivity of the dairy herds and the milk quality are directly managed at the farm level, the cooperatives play a critical role in the supply chain. They collect and store the raw milk product, checking its acidity and its density, redistribute the created value, and supply farmers with various support services (purchase of concentrates and other feeds, veterinary services, etc.). In addition, they often have a prestigious social function in the local society as they may offer social services to members (school bus, ambulance, medical insurance, etc.).

The proposed actions are based on the three strategic issues identified by the stakeholders (improve the productivity of dairy cattle, reduce the seasonality of deliveries, improve the milk quality). They attempt to answer four main issues:

- How to support breeders in designing and managing diversified feeding systems?

This question is not limited to feed rationing but addresses all three strategic issues. The proposal aims firstly at designing and testing a support method for breeders on the management of forage systems. Various aspects will be addressed, related to animal husbandry (production, storage, feeding and performance levels), hydraulics (water saving, water productivity), and economics (production costs of milk). In that respect, the relationship between the performances of dairy herds, the management of feed systems and the water productivity will be analysed and modelled for the various types of farms proposed in section 3.3, while quantifying the impacts on the viability of these farms. Previous works on water productivity in the Tadla give some ideas about the values obtained, although livestock was not included in the analyses (Hellegers and Perry, 2005 forthcoming) Secondly, it aims at integrating this method in the advisory services proposed by the different stakeholders via the milk cooperatives.

- How to manage the milk quality from the farm to the cooperative level?

Quality is a key parameter for the performance of the supply chain. It governs the value of the raw material (rejection of batches below standard) and of the final processed products (specific uses like UHT milk). The consumers' expectations towards dairy products will lead to pressures on the dairy supply chain. The fact that cooperatives aggregate the deliveries of hundreds of small-scale dairy farms complicates the quality management, as the dairy plant is only aware of the combined quality at the cooperative level. Indeed, cooperatives are paid according to their aggregated performances in terms of production and quality. Therefore, this part addresses the design and testing of support systems promoting the improvement of the milk quality in a typical context of indirect relationship between the primary producer and the industrial process unit. The development of these support systems will be based on an analysis of the quality perception by the various stakeholders, their management practices, and the impact of these practices on the milk quality.

- How to support cooperatives in implementing methods to achieve higher performances in dairy cattle productivity, the seasonality of deliveries and milk quality?

The functioning of the cooperatives' affects directly the supply chain performances, due to their role as an interface between the primary producers and the dairy plant. This part will focus on the tools cooperatives use in managing their functions. It will then design and test innovative tools that can improve those performances. Three ideas will be explored:

1. coordinating production scheduling of individual breeders in order to reduce the seasonality of deliveries at the cooperative level;
2. designing incentives stimulating farmers to increase their focus on quality, for example by modifying the current redistribution of quality premiums paid by the dairy plant;
3. improving information systems used by cooperatives for managing their various activities.

- How to match the canal water supply to changing water demands related to the operation of various supply chains linked to the irrigation scheme?

Since the liberalisation of crop choice in the 1980s and the development of groundwater pumping through private tubewells, the cropping patterns in the Tadla irrigation scheme have considerably changed: alfalfa went up from 10,000 to almost 25,000 ha in less than 15 years, while cotton disappeared and the surface area of sugar beet diminished significantly. Meanwhile, farmers have switched from gravity to drip irrigation on thousands of hectares in a context of surface water restrictions. These changes in cropping patterns modify the equilibrium between supply and demand of water at the scheme level and entail new management challenges. This study aims at defining new management rules, based on the analysis of various scenarios regarding both water supply and demand (cropping patterns, use of groundwater, irrigation methods). A simulation tool developed for a number of irrigation schemes in the north-east of Brasil (De Nys, 2004; Ana, 2005) will be adapted and tested for the Tadla case.

Beyond the Tadla scheme this research aims at developing 'generic' methods and tools for improving the value created by irrigated supply chains and thus irrigation water productivity that could be of interest for other cases. The expected specific outputs of the research relate to: (1) knowledge on both the quality management throughout the dairy supply chain and the design and management of feeding systems under various constraints (water, land, capital), (2) management (information systems, databases) and simulation tools (design of forage systems, redistribution of quality premiums), and 3) advisory services to cooperatives and breeders.

5 Conclusions

Assessing the water productivity is complex because of the numerous parameters affecting its calculation and value. The ways irrigated agricultural products are processed and marketed play a significant role in contributing to this productivity, affecting directly farmers' income per cubic meter of water used. As such, improving the technical, economic and organisational performances of agro-food supply chains located on irrigated schemes seems a valuable direction to follow. It means (1) pinpointing the critical supply chains driving the water consumption at the scheme level, (2) analysing their potential capacity for improvement and (3) working with the various stakeholders involved in these chains.

The dairy chain studied in the Tadla scheme illustrates this statement. It deals with about 50% of the farmers and covers 30% of the irrigated area. The milk productivity of dairy farms is quite low despite the various technical supports they receive. De facto farmers, dairy cooperatives and the dairy plant have different responsibilities in the chain and they need to coordinate their decisions. But their objectives in term of dairy and water productivity do not necessarily match. The dairy plant may aim at increasing the milk productivity while keeping, or even reducing, the number of dairy farmers and cows. The scheme manager may endorse this strategy, as this may improve the water productivity as shown by Toulmin (1995) and Sonder *et al.* (2003). Although these two stakeholders occupy a prominent role in the water and dairy supply chain, they have to take into account the farmers' orientations.

These farmers might prefer to market fodder or to produce meat rather than milk depending on their relative prices (or even switch to other crops). Besides, milk and meat production fill complementary functions in the farm, as milk provides cash-flow (payment every two weeks) while meat allows saving up for future investments or important expenses (water bill, social expenses). The strategic balance between productions will depend mainly on the farm type - for example Type 2 may prefer raising calves and heifers than producing milk *per se* - while both operational and tactical decisions will be made according to the context farmers are currently facing. All these decisions will directly impact on the water productivity through the various production functions (water to fodder, fodder to milk or meat). Moreover indirect parameters may play an important role as well, such as the services provided by the milk cooperatives to their permanent milk suppliers or problems in the banking system, encouraging the use of cattle to put away savings. The production of manure contributing to the soil fertility is another factor taken into account by farmers.

Therefore, analysing the dairy sector in relation to the water productivity may follow several research orientations. A supply chain viewpoint will focus on linking the milk price to the prices of other agricultural outputs in the area, including meat and fodder. But the chain strategy and ultimately its pricing system may vary, should it look for excluding non-competitive breeders with dissuasive price levels because of their low productivity or their poor milk quality, or for attracting new suppliers. In that case prices need to be attractive, as several supply chains operate in the irrigation scheme and they fiercely compete for the scarce water, land, labour and capital resources of the Tadla (Cances, 2005).

From a farmer's viewpoint the water productivity issue cannot be restricted to the milk production. The various uses of fodder crops and the economic value of their combination have to be considered. They will depend on the prices of agricultural products (milk, meat, fodder) and the economic situation of the farm (pressure on cash-flow, savings objective), but also the amount of water they utilize and the outputs favoured by the farmer.

A third research orientation has been selected to overcome these various difficulties to assess water productivity. It consists of taking into account the strategies and perceptions of the various stakeholders of the supply chain and involving them in a joint reflection on their common future. For the next three years this prospective process will focus on improving both the supply chain organisation and the stakeholders' coordination processes, as key determinants of the dairy and water productivity.

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