الجمعية المغربية للاقتصاد الزراعي

AMAECO

The Moroccan Association of Agricultural Economics (AMAECO)

in partnership with

International Association of Agricultural Economics (IAAE) **&** **United Nations University-World Institute for Development Economics Research (UNU WIDER)**

Climatic constraints play a predominant role in the performance of national agricultures and their capacity to support economic growth and assure food security for the population. With the climate changes and projected inter and intra annual fluctuations, management of the agricultural sector takes a particular dimension including management of risks inherent in the sector and searching for sustainable growth for the sector. Agricultural policies must permit a continual adaption of the processes of agricultural production and a reduction of negative effects of climate change in order to assure food security for the population.

In the face of climate change, the adaptation strategies can generate important development opportunities. Also, governments have need for pertinent evaluations of the impacts of climate change.

Considering the importance of this problem; to permit an exchange of ideas among professional staff, researchers, and specialists in the domain of development; to contribute to a richer understanding of methods and analytical tools ; and to contribute to better preparation of decision making in this domain – the Moroccan Association of Agricultural Economics (AMAEco) in collaboration with the International Association of Agricultural Economics (IAAE) and the World Institute For Development Economics Research of the United Nations University (UNU-WIDER) are organizing an international conference 6-7 December in Rabat, Morocco under the theme:

« Impacts of climate change on agriculture »

Rabat, Morocco December 6-7, 2011

The principal themes proposed are the following::

1. Analysis of the impacts of climate change on agriculture: simulations and projections
2. **Climate change and sustainability of agricultural production systems**
3. **Adaption strategies for agriculture in the face of climate change: systems of production, risks in agriculture, and policies for food security**
4. **Water management in the context of climate change**

http://www.wider.unu.edu/events/past-conferences/2011-conferences-/en_GB/06-12-2011/

Is the "Livestock Revolution" achievable with smallholder farms located in water stressed areas? Lessons from a research intervention project in Morocco.

SRAÏRI Mohamed Taher*
Hassan II Agronomy and Veterinary Institute,
P.O. Box, 6202, Madinate Al Irfane, 10101, Rabat, Morocco. Email: mt.srairi@iav.ac.ma

Abstract
A significant increase in the global demand of animal products is expected in the near future, because of evolving food consumption patterns in emerging countries. To fulfil the needs, a "Livestock Revolution" should occur and it will have to target in priority smallholder farms in developing countries, as they are the main actors in supply chains of milk and meat. To achieve such an increase in milk yield and live weight gain within numerous farms, new tools of intervention have to be tested. In fact, in many developing countries, State services are currently withdrawing from their traditional support to farmers, and therefore innovative methods should be set-up. They will also require a more responsible implication of the stakeholders in supply chains, particularly with well organized farmers' associations. In areas characterized by water stress and climate change, this should be a top priority issue in the agenda of agricultural development institutions. As livestock production involves many processes from water to forage biomass elaboration and dietary rations conceptions, it is generally acknowledged that it necessitates important volumes of water. In this article, an example of an intervention research is presented from the Tadla irrigation scheme (centre of Morocco) as an illustration of intensive cattle production in a context of irrigation in a semi arid region (less than 300 mm of annual rainfall). Results related to follow-ups of water productivity through cattle farming and trials to increase the average milk yield per cow are presented. A reflection on the possibilities to use "virtual water" and on the generalisation of such methods to a whole population of dairy farmers in a supply basin (i.e. an irrigation scheme) is finally developed with its consequences on the economic sustainability of smallholder units. Thus, a capacity building process is urgently required to upgrade farmers' performances. This will induce the adoption of sound on-farm practices, from irrigation systems to soil fertility management and forage biomass production. It will also rely on the continuous design of balanced dietary rations for lactating cows and their impacts on cattle load (number of cattle per ha of forage). Finally, more attention should be paid to the existing farmers' co-operatives, which would constitute crucial operators in disseminating innovation processes to face the challenges of water shortage in cattle production systems.

Keywords: animal production, Morocco, smallholder farms, support to farmers, water productivity

Introduction

The global demand for animal products is expected to increase significantly. For example, according to Thornton (2010), the annual meat consumption *per capita* in developing countries is expected to rise from 18 to 38 kg from 1990 to 2030. This trend is supported by better incomes that will generate changing consumption habits. In emerging countries like China, such a phenomenon is already occurring, as the economic boom coupled to higher rates of urbanization have induced recently a surge in milk and meat consumption (Beghin, 2006). In order to face this growing demand in livestock products, adapted agricultural policies have to be implemented. These policies would also generate opportunities of income to millions of poor smallholder farmers, which are often the main actors in animal products' supply chains. However, such policies must also focus at local levels on the effects of animal production intensification: resources needs, excreta management, value chain, etc. In the one hand, recent food crisis in 2007 and in the beginning of 2011 have clearly demonstrated that the price of feed resources may remain volatile (Gilbert and Morgan, 2010). That might induce higher production costs for farmers who use off-farm feed resources intensively and more food dependency for water deprived countries (Sraïri, 2011). On another hand, there are also increasing concerns about the effects of animal production intensification on the environment, such as nitrate pollution, greenhouse gases emissions, etc. (Tamminga, 2003).

In spite of all these risks, in recent years, there have been many attempts to try to convince the international community on the need to intensify animal production worldwide and this has resulted on the call for a “Livestock Revolution” (Delgado, 2003). Such a strategy has to be implemented globally, in a wide variety of environments and it has to avoid copying models which have been adopted in developed countries at the end of World War II, which mainly relied on intensive resources uses (Alary and Faye, 2001). In fact, the “Livestock Revolution” has to be green: producing more and better. One of the main challenges ahead is linked to water uses by the animal production sector. As the water footprint of animal products is almost 10-fold that of vegetal commodities, water availability may constitute a serious threat to increase milk and meat output. This is particularly true in areas with acute water stress, characterized by erratic levels of rainfall and growing threats on groundwater sustainability (Iglesias, 2002). In such contexts, like in the whole Mediterranean Basin, is the “Livestock Revolution” achievable?

In this paper, we try to answer to this specific question by a synthesis of a research program conducted in an irrigated scheme in Morocco. As a first step, the context of the study is presented with a review of the problematic of water productivity through dual purpose cattle (both milk and meat simultaneously) in smallholder farms. Then, a case study relying on 6 smallholder farms is presented. Finally, we investigate opportunities to alleviate water stress in cattle production under irrigation conditions and the means to contribute to increase lactating cows’ milk yield.

Context of the study and methodology

Located in the Western part of North Africa, Morocco is characterized by water stress, because of its limited resources (less than 750 m³ *per capita* annually, under the threshold of 1,000 m³, often considered as a limit for human development). The country already faces water supply problems (Blinda and Thivet, 2009), particularly in the agricultural sector, which is a pillar for the domestic economy, with more than 50% of total jobs. Agriculture is also the main consumer of water with almost 85% of total volumes. As the country has launched recently a massive initiative to increase the productivity of its agriculture (the “Green Morocco Plan”), significant improvements of water use efficiency will have to take place. This might be achieved specially in irrigated areas, which are strategic for the supply of vital commodities such as cereal grains, vegetables, milk, meat, olives, etc. For instance, almost 60% of the country’s milk output comes from the irrigated areas, which represent less than 15% of its arable land. Therefore, the authorities have adopted a strategy which aims to substitute gravity irrigation by drip irrigation at farm level, as they subsidize up to 80% of the investments (Agency of Agricultural Development, 2011).

The Tadla large scale irrigation scheme is located in the east central part of Morocco and covers 100,000 ha (Figure 1). It is characterized by a semi arid climate, as the average annual rainfall is about 310 mm. It represents about 11% of the country’s annual milk output (175,000 metric tons). Milk is produced by almost 17,000 farms (53,000 cows) that rely on alfalfa (about 25,000 ha) as their main irrigated forage. Nearly 80% of these farms belong to smallholders, as they cultivate less than 5 ha of arable land (ORMVAT, 2011).

Studying on farm water productivity through cattle in such a context necessitates a specific methodological approach. There is a need to consider a series of functions of production involved from water volumes used in forage plots to their effective conversion in cattle products (Figure 2). First of all, water volumes and their origins (i.e. rainfall, surface and groundwater) used in forage plots have to be measured throughout the year. Then, the intermediate stage of forage biomass elaboration and the factors that affect it (soil fertility and farmers cropping practices) have to be monitored. Forage biomass has to be measured at each cut. The strategic goals of farmers in dedicating available feed resources to lactating cows and/or to growing calves have also to be specified by a continuous monitoring of the dietary rations used. In fact, under Moroccan conditions, the vast majority of cattle farms are not dairy specialized, as they produce both milk and meat from their herds, simply because calves have a market value which may be negotiated at the contrary of farm gate milk price (Sraïri and Chohin Kuper, 2007).

Figure 1. Situation of the Tadla irrigated scheme (Morocco)

In addition, the proportion of off-farm feed resources used in these dietary rations has to be characterized, as they correspond to imported water consumed elsewhere. This virtual water (Allan, 1998) has to be evaluated and added to actual irrigation and rainfall volumes in order to calculate accurately the total water (real and virtual) productivity of irrigated cattle farming.

Finally, the output of milk and live weight gain has to be measured. Annual milk volumes per farm delivered to the dairy factory were obtained directly from the milk collection cooperatives and added to the amounts consumed within the farms. The milk used by suckler calves was not taken into account as it was considered as an intermediary input processed into live weight gain. The growth performance of calves and heifers was estimated indirectly using body measurements (heart girth) throughout the monitoring period. The following formula linking live weight to heart girth was used (Heinrichs *et al.*, 2007):

$LW = 15.7 + (66.88 \times HG^3)$, where LW is live weight (kg) and HG heart girth (m).

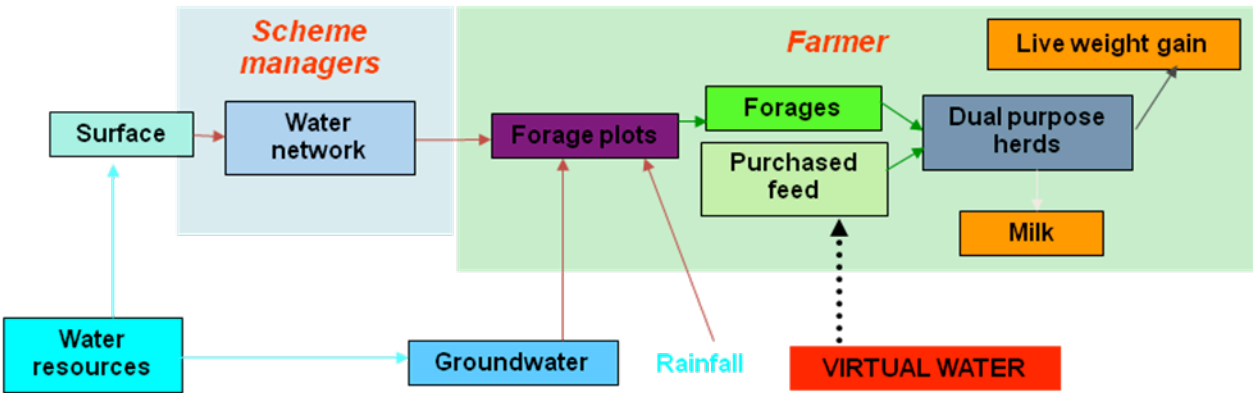

Figure 2. Functions of production involved in water productivity through cattle in irrigated farms

At the end of this process of water productivity assessment through cattle in irrigated farms, an economic evaluation of these functions of production was realized. For that purpose, the economic return from milk volumes delivered to the collection cooperatives by each farm was calculated. The economic value of live

weight gains was estimated from the market price of beef as follows: 2.2 € per kg of calves and steers live weight, 3.1 € per kg of heifer live weight. Then, gross margins per cow and per m^3 of water were calculated. Water productivity was calculated for either milk production or live weight gain (m^3 per kg). Finally, the economic value of water productivity through milk and live weight gain were calculated as the gross margins for these products divided by the total amounts (real + virtual) of water used and expressed in € per m^3.
Following these economic evaluations, an assessment of the margins of improvement was realized. We compared the actual results with optimal performances of fodder and cattle, using a simulator program elaborated for farms in the same irrigated scheme (Le Gal *et al.*, 2009). Some of the possibilities of improvement were tested on the ground, particularly those related to tactical decisions, like the conception of sufficient and balanced dietary rations. The effects of these diets changes on lactating cows' milk yield were assessed. At the end of all these investigations, we try to synthesize their results and assess their consequences on the initial challenge of producing more and better in smallholder cattle farms located in areas with water stress.

Study of water productivity in smallholder irrigated cattle farms

Six smallholder cattle farms were selected for the study. They did not have access to groundwater and therefore they relied on rainfall and on the surface irrigation network managed by a local State agency. During the study year, rainfall did not exceed 210 mm and the irrigation network was affected by frequent water shortages. All the farms delivered their daily milk production to a local dairy factory through a collection cooperative. Their herd varied from 2 to 7 crossbred (local x Holstein) cows with their progeny. The farmers had one of three strategies: they specialized in either dairy production, or in milk and meat production, or in meat production (Table 1). Average arable land covered 3.8 ha (from 1.4 to 6.5 ha), of which 55% was cultivated with irrigated forage (alfalfa, berseem -*Trifolium alexandrinum*- and maize).

Table 1. Main characteristics of the cattle farms surveyed

	1	2	3	4	5	6	Mean
Arable land (ha)	5.0	6.3	6.5	1.4	1.6	1.8	3.8
Alfalfa (ha)	2.0	2.0	2.2	0.8	0.8	1.0	1.8
Berseem (ha)	0.5	0.7	0.4	-	-	-	-
Maize (ha)	0.2	-	-	-	-	-	-
Lactating cows	6.5	7.0	6.4	2.0	2.0	3.0	4.5
Dairy (D), Beef (B) or dual (DB) strategy	BD	BD	BD	D	B	B	-

Irrigation water used to grow alfalfa (an average of 9,730 m^3 per ha) accounted for 82% of the total volume of water, as rainfall was limited during the year of study (2,100 m^3 per ha). Irrigation volumes for berseem, which is supposed to be mainly a rain fed crop, represented about 60.0% of the total water consumed (3,380 m^3 per ha), and 78.5% for maize (4,320 m^3 per ha), which is mainly a summer crop with a short cycle.
Green matter yields were highly variable, particularly for berseem (Table 2). They only represented 66% of the potential production of these crops under Moroccan irrigated conditions (Baya, 1997; Birouk *et al.*, 1997). Many different factors may have limited growth: shortage of water because of the limited quantities delivered by the surface irrigation network and no access to groundwater, crop diseases, soil fertility deficiency, etc. Despite its low cost of irrigation (92 € per ha), maize was the most expensive crop, followed by alfalfa and berseem (respectively 548, 438 and 290 € per ha). Indeed, buying maize seeds, plus fertilization, weed control and harvest requires expensive inputs. Irrigation expenses accounted for 27 (maize), 28 (berseem) and 70% (alfalfa) of the total cost. Alfalfa's high irrigation costs can be explained by its perennial status, which means low annual installation costs, but huge water requirements in summer when biomass production reaches its peak at temperatures frequently exceeding 45°C and with almost no rain at all during more than 5 months (from May to October).

Table 2. On farm water uses (m^3/ha) and forage biomass yields (t/ha)

Forage crop	Farms	1	2	3	4	5	6	Mean
Alfalfa	Water used	10,090	12,740	12,350	12,360	13,440	9,990	11,830
	Biomass yield	33.2	38.2	39.9	40.9	40.1	35.0	37.9
Berseem	Water used	4,060	6,440	5,520	-	-	-	5,340
	Biomass yield	23.1	13.3	33.7	-	-	-	23.4
Maize	Water used	5,500	-	-	-	-	-	-
	Biomass yield	25.1	-	-	-	-	-	-

Cattle performances were below their potential, as the average annual milk yield did not exceed 2,170 kg per lactating cow. The average daily gain was 0.66 kg for growing animals. These weak performances can be explained by the limited availability of nutrients to feed cattle due to the high animal load (more than 2.4 lactating cattle with their calves per ha of forage), and low forage production due to the shortage of irrigation water and other agronomic constraints. These weak performances were also induced by the limited use of off-farm feed (only 13% of total energy ingested), because of frequent economic problems in these farms. Growth and lactating performances were also hindered by imbalances in dietary rations. As these were mainly based on legume forages (alfalfa and berseem), and given their protein content, animals often lacked an appropriate supply of net energy. The analysis of feed purchase strategies revealed marked differences among farms. Some of them, like farm F1, used off-farm feed resources to compensate for the lack of on-farm forage crops. Others (farm F5), limited their use of off-farm feed resources for financial reasons.

Consequently the amounts of off-farm feed resources and their corresponding virtual water values revealed considerable variability among farms. On average, a lactating cow consumed the equivalent of 1,276 ± 779 m^3 of virtual water per year, representing some 34% of the total water used by lactating cows through feed consumption. The variability was higher for growing cattle, as each animal was provided with the equivalent of 1,065 ± 950 m^3 of virtual water annually (33% of total water uses).

Total water productivity through milk accounted for an average of 1.8 m^3 per kg of milk considering the calculated volumes of virtual water consumption and the monitored volumes of water used to produce irrigated forage crops (Table 3). The average water productivity for live weight gain was 10.6 m^3 per kg. This value corresponded to some 19.2 m^3 per kg of carcass, considering a mean dressing percentage of 55% for cattle. Both values of water productivity to get 1 kg of milk and meat were almost 70% higher than those referenced by Chapagain and Hoekstra (2004), indicating margins of improvement under Moroccan irrigated smallholder farms conditions.

Table 3. Physical and economic values of water productivity through cattle farming

Farms		1	2	3	4	5	6
Milk	Milk output (kg)	14,820	11,900	13,310	6,800	3,800	4,950
	Total water used (m^3)	31,170	25,950	22,200	7,750	5,740	8,970
	Water productivity (m^3/kg)	2.1	2.2	1.7	1.1	1.5	1.8
	Economic return (€/m^3)	0.02	0.03	0.08	0.14	0.09	0.09
Meat	Live weight gain (kg)	2,100	1,740	1,760	430	712	1,290
	Total water used (m^3)	19,710	22,500	9,980	3,820	6,720	10,800
	Water productivity (m^3/kg)	9.4	12.4	5.6	8.9	9.4	9.4
	Economic return (€/m^3)	0.21	0.14	0.37	0.26	0.24	0.24

The overall economic productivity of water was 0.07 € per m^3 whenever irrigated forage were devoted to milk production and 0.25 € per m^3 for live weight gain. Meat production thus enabled dual purpose cattle farmers to obtain more than three times the margin of milk per m^3 of water. Such a result seems contradictory with the theoretical findings of a better metabolic efficiency of milk versus meat to exploit high quality forage (Vermorel and Coulon, 1998), but it obviously reflects the distribution of actual value in supply chains of cattle products. Nevertheless, farmers maintain their dual purpose cattle farming system as milk and meat production play specific roles in farm management. Milk is compulsory to get

calves (no milk, no calving). It also provides a steady daily income and it allows purchases of feed grain (Sraïri *et al*., 2009), whereas calf crop sales is a strategic source of income to face heavy expenses.
All together, these results emphasize that the expected "Livestock Revolution" may face serious constraints in water deprived areas, due to insufficient resources availability. However, possibilities for intervention exist throughout the sequence of processes involved in the chain of functions of production, from water use efficiency by fodder crops to cattle productivity (milk yield and growth rate). To get a significant improvement in cattle performances within a majority of smallholder farms, the use of adapted support tools has to be tested.

Support to smallholder cattle farms in increasing lactating cows' milk yield

A simulation tool that takes into account the biophysical terms of production (water requirements for forage production, forage area, calving rates, cattle nutrient requirements for maintenance, growth and lactation) on a dual purpose farm was designed and tested (Le Gal *et al*., 2009).
A simulation was carried out for a 2 ha farm. It showed that replacing crossbred with Holstein cows allowed tripling real water productivity, even with higher annual virtual water expenses. Improved diets were however required to reach the optimal lactation performance of the Holstein breed (5,200 kg of annual milk yield). It means extra purchases of off-farm feed resources which increase the use of virtual water.
Another simulation scenario was based on a partial replacement of alfalfa by drip irrigated maize. It was also coupled with the substitution of crossbred cows by pure Holstein cows. It allowed further improvements in total economic water productivity. Similarly, the second scenario assumed that cattle-feeding techniques were efficient, with appropriate purchases of feed grain and oleoproteaginous feed (particularly with maize silage) at any time of the year. Given the results of these simulations, we chose to test a support program of a continuous monitoring of lactating cows' dietary rations.
For that purpose, five smallholder cattle farms were chosen. They were selected in order to represent the wide range of cattle breeding situations in the region: *i*) specialized dairy farms with pure Holstein cows, *ii*) mixed farming systems (cattle and cash crops) and *iii*) dual-purpose herds (both milk and meat). Each farm was visited twice a month. This schedule enabled the cows' true dietary rations to be compared with their total requirements calculated as the sum of their maintenance and potential production needs. Net energy and protein maintenance requirements were determined in relation with the cows' body weight (Fox *et al*., 1992). The potential energy and protein requirements for milk production were determined using existing models describing variations in daily milk yield during lactation (Wilmink, 1987) and unitary needs to obtain a single kg of milk (Vermorel and Coulon, 1998). These were related to the herds' genetic merit and their average monthly lactation stage (LS), which was calculated as follows:

$$Lactation\_Stage_j = \sum_{k=1}^{m} Lactation\_duration_{k,j} / (Total\_Milked\_Cows_j \cdot 30.4)$$

With:

$Lactation\_Stage_j$ = lactation stage (in months) for month j

$Lactation\_duration_{k,j}$ = number of milking days from calving for cow k and month j

$Total\_Milked\_Cows_j$ = total number of milked cows for month j

In this study, the genetic merit of pure Holstein herds was considered to be 7,000 kg of milk annually, whereas an annual milk yield of 4,000 kg was used for Holstein crosses with local breeds. During each visit, all the components (i.e. forage and concentrates) of the cows' dietary rations were weighed. This implied regular evaluation of forage biomass production using a field quadrate method (Martin *et al*., 2005) throughout the study period. The nutritive contents of the rations were determined using feed composition tables. For concentrates, which were mainly imported, the INRA France table was used (Jarrige, 1988), whereas for local forage crops (alfalfa, berseem and maize) and crop by-products (wheat bran and straw and dehydrated beet pulp), results from Guessous (1991) were used.
At each visit, the correspondence between cows' nutritional requirements and the true ration was evaluated using a simulation tool under Excel® (Table 4). Supplementation was suggested to the farmer

when a gap was detected between the dietary ration and potential net energy, rumen degradable protein or metabolizable protein requirements. These two parameters were related to the protein status of the diet and were determined accordingly to the French system of the PDI - Protéines Digestibles dans l'Intestin -. Calculations assumed that whenever maintenance requirements were fulfilled (i.e. 9.0 Mcal of net energy for a 620 kg Holstein cow and 420 g of proteins - either rumen degradable or metabolizable), the remaining dietary nutrients would be used to cover the effective dairy production, as a single kg of milk requires 0.76 Mcal of net energy and 48 g of proteins (Vérité and Peyraud, 1988). The proposed rations took into account the context of the farm, i.e., the availability of on-farm fodder and the money needed to buy concentrates. The acceptance of the suggested balanced rations was tested by monitoring the herds' total milk yield and noting the farmers' opinions about the nutritional changes that were made. The effects on the profitability of dairy production were also assessed. The gross margin of milk production was determined monthly as the difference between milk income and the costs of inputs used to feed the cows

Table 4. Assessment of dietary rations distributed to lactating cows (part of Excel® application)
(See file Table4.doc)

The initial assessment of lactating cows' dietary rations revealed insufficient and imbalanced supply between energy and rumen degradable protein in all farms. In fact, the main forage used was alfalfa, which provides more protein than energy with respect to the average cow's net energy maintenance requirements. Table 5 shows an example of the dietary rations used in farm F1 for pure Holstein cows with a lactation potential of 27 kg of milk daily and an average body weight of 620 kg at the beginning of the study. This dietary ration is largely representative of the situation observed in the other pure Holstein herds in this study. Its main characteristic is an insufficient supply of DM, which varies between 6 and 8 kg of roughage per cow, whereas a Holstein cow could ingest as much as 15 kg of DM from good quality alfalfa (Castillo *et al*., 2006). And it is unbalanced, as alfalfa and berseem represent the bulk of the initial roughage intake, leading to a relative excess of rumen degradable protein whereas net energy is lacking. The amount of both energy and metabolizable protein supplied were thus insufficient to cover total requirements. For that reason, this dietary ration was not suitable to reach the lactation potential of the herd. Supplementation of the initial ration was proposed. It consisted mainly in adding sources of degradable energy in the diet, and, if possible, in increasing the supply of alfalfa, which is a cheap source of nutrients. Table 5 shows the proposed ration with a balanced supply of nutrients to match the herd's potential production. In 1 month, the supplementation increased the volume of milk per lactating cow in the herd from 11 to 19 kg. The concept of balancing the supply of nutrients in the dietary rations with changes in the herds' potential requirements was maintained in the five herds throughout the study period. Alternative forage such as on-farm reserves of alfalfa hay, berseem and green alfalfa (purchased from neighboring farms) or maize silage, were used during the cold months of December and January when alfalfa stops its growth. The effects of constantly correcting the dietary rations are shown in Figure 3. Farm F1 adopted the strategy straight away and reached a milk yield equal to the potential milk capacity of the herd after three months. The farmer of farm F1 was able to judge the effects of the method on the profitability of the dairy herd (Table 5).

Table 5. Changes in the daily gross margin per cow and milk production cost during farm monitoring

	F1	F2	F3	F4	F5
IGM_0 (€/day)	- 0.4	- 2.2	- 1.5	- 0.3	- 1.0
AGC (€/day)	0.3 /0. 8	0.2 / 0.7	0.4 / 3.0	0.04 / 0.8	- 0.6 / - 1.0
IPC_0 (€/kg)	0.34	0.31	0.41	0.34	0.46
APC_a (€/kg)	0.17	0.22	0.27	0.23	0.41

IGM_0 : Initial gross margin per cow
AGC : Average gross margin per cow after calculation of balanced dietary ration
IPC_0 : Initial production cost of a kg of milk
APC_a : Average production cost of a kg of milk after calculation of balanced dietary rations

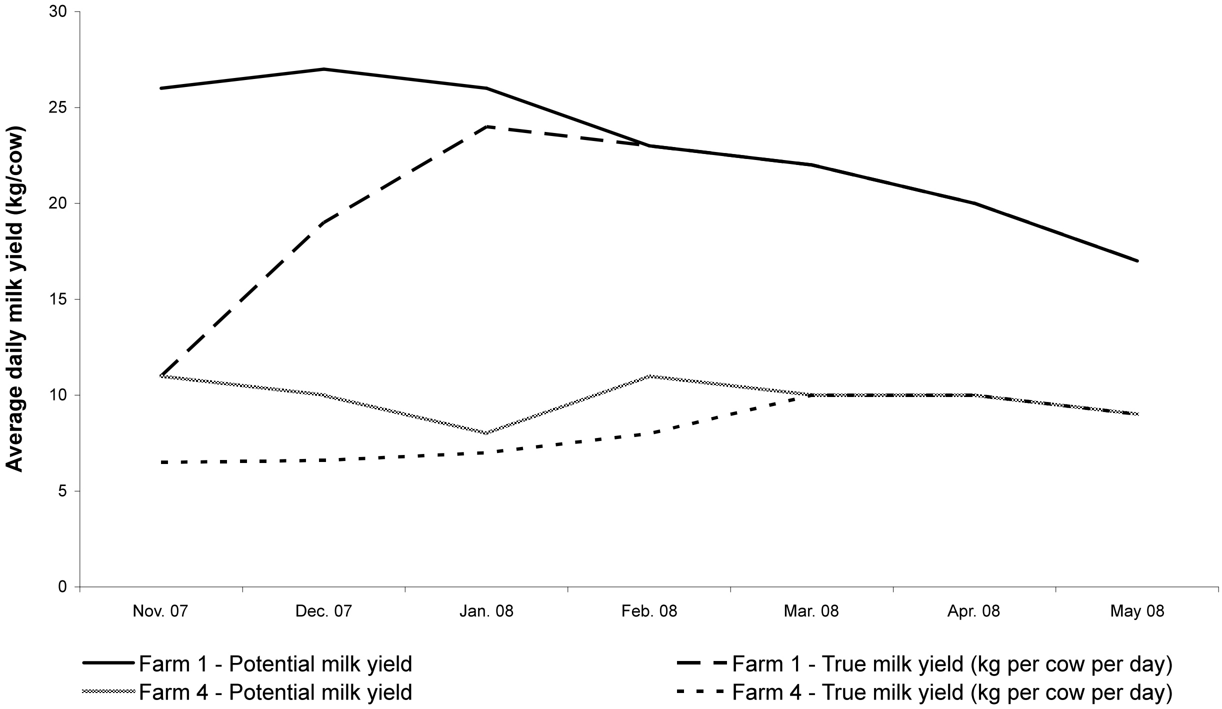

Figure 3. Effect of the diet support programme on the average milk yield per cow for purebred Holstein cows (Farm 1) and cross bred cows (Farm 4)

Similar results were obtained by the two other dairy specialized farms, F2 and F3. All three farmers were able to purchase alfalfa from neighboring farms, as this roughage provided nutrients (energy and proteins) that were cheaper than those available in purchased concentrates. The support process was also successful in farm F4 with crossbred cows, but it took more than 5 months to reach its potential milk yield (Figure 3). This result highlights the quicker response of purebred Holstein cows to improved rations than that of crossbred cows. This can be explained by their better milking ability which allows them to convert nutrients in the diet into milk more efficiently than other cattle breeds (Delaby *et al.*, 2009). Increasing milk yield to reach the genetic and physiological potential allowed milk production costs to be reduced below the farm gate milk price (0.27 €/kg), making this activity profitable before calf crop sales. However, the method failed within farm F5, as the farmer did not agree to change his feeding practices, because he preferred to maintain a balance between milk and meat production rather than increasing the milk yield of lactating cows. In his case, the gross margin of milk production remained negative throughout the study period and livestock profitability came mainly from cattle sales.

The results of this intervention research showed a reliable impact of a support process on the average milk yield per cow and the profitability of dairy production in smallholder farms. They also demonstrate that such a structure of production which relies on an fragmented offer (numerous small farms with a limited number of cows) may be compatible with industrial dairy supply chains in emerging countries, as long as they can benefit from some support and from input supply services (Arriaga-Jordan *et al.*, 2002). But the milk supplies required by industrial dairy plants as well as the expected regional impact of dairy production on poverty alleviation imply that a large proportion of farmers must be reached if the existing situation is to be significantly improved (Bayemi *et al.*, 2009). This study also revealed certain limits of such an approach. It was conducted on a very small sample of farms and was based on labor-intensive interventions: bi-monthly visits, direct measurement of critical variables that are rarely estimated by smallholder farmers, such as forage productivity, good knowledge of the farms visited, use of a simulation tool in a one-to-one relationship between researchers and farmers.

In Morocco, as in many other developing countries, State withdrawal from extension activities means that the generalization of such an experiment to a vast majority of cattle farms would involve dairy collecting cooperatives managed by the farmers themselves. This may also be achieved with the support of the dairy industry, as the latter urgently requires higher flows of good quality milk. The milk collection cooperatives already provide inputs such as feed concentrates and they could also recruit technicians to provide advice to their members based on a fee collected on each kg of milk delivered. Similar experiments have been conducted in West Africa with cotton-based farms and showed the importance of taking into account the different components of an advice institution in agriculture (governance, funding, training, advice methodology, advice tools) (Faure and Kleene, 2004). Such institutions should facilitate the design of suitable advice tools and the collection of local references on dairy and fodder production which are needed to provide efficient support to local dairy farmers (Pacheco, 2006). The institutions should focus their support activities on farmers who wish to improve their milk yield like the specialized farms in our sample, since some farmers prefer to diversify their income by combining dairy production with other products such as meat or crops.

Conclusion

This series of investigation on water productivity through cattle in irrigated smallholder farms located in semi arid areas and on the means to improve it have revealed the complexity of such issues. The results indicate that water shortages constitute a serious threat to the increase of cattle productivity in water stressed areas, and therefore it could hamper the achievement of a "Livestock Revolution". This might be even worsened by the expected climate changes. However, the existence of a wide range of farms' strategic goals and their effective farming practices imply interesting possibilities of intervention. Testing a close monitoring of lactating cows' dietary rations and their frequent adjustment to cows' potential milk yield has demonstrated that milk yield may be easily increased with the existing resources. That has also induced significant improvements in farms profitability, which may facilitate convicting other farmers to adopt the support program. All these achievements suggest real possibilities of improving the water productivity through cattle. Another mean to increase cattle performances with the same amount of irrigation water would be to design new forage systems, based on alternative crops, such as drip irrigated maize instead of alfalfa, if necessary attendant measures (balanced rations, control of pesticides residues in groundwater, etc.) are adopted. It can also be mentioned that an intervention on milk quality may also bear significant advances in the economic return per m^3 of water, as the current situation is characterized by raw milk batches generally of poor hygienic standards. All the improvements that are suggested in this study require however a close intervention in numerous farms, which will have to be convinced of the utility of such approaches. Moreover, the cost of such interventions and the nature of the partnership that will lead them (farmers' association, private operators, State services, etc.) have to be specified to get the expected improvements effective at a large scale (i.e. the whole dairy basin with some 17,000 farms). At a time of State agricultural services withdrawal from the extension activities, and because of the current soaring prices of food in international markets, ensuring the resilience of smallholder irrigated farms in Morocco is a crucial task. In order to ensure the supply of animal products (milk and meat) for rapidly growing cities, more attention and means should be devoted to the question of sustainable water uses in cattle smallholder irrigated farms. Otherwise, their resilience might be at risk with important social disturbances, such as rural exodus and illegal migration.

References

Agency of Agricultural Development (Morocco), 2011. The Green Morocco Plan. http://www.ada.gov.ma/en/Plan_Maroc_Vert/plan-maroc-vert.php

Alary, V. and Faye, B., 2001. Stakes of animal production in Southern countries. INRA Productions Animales, 14, 3–13.

Allan, J.A., 1998. Virtual water: a strategic resource - global solutions to regional deficits. Groundwater, 36, 545–546.

Arriaga-Jordan, M., Albarran-Portillo, B., Espinoza-Ortega, A., Garcia-Martinez, A. and Castelan-Ortega, O.A., 2002. On-farm comparison of feeding strategies based on forages for small-scale dairy production systems in the highlands of central Mexico, Experimental Agriculture, 38, 375–388.
Baya, B., 1997. Maïs fourrager (*Zea mays*). In: G. Jaritz and M. Bounejmate (eds), Production et utilisation des cultures fourragères au Maroc, (INRA Éditions, Rabat, Morocco), 244–253.
Bayemi, P. H., Webb, E. C., Ndambi, A., Ntam, F. and Chinda, V., 2009. Impact of management interventions on smallholder dairy farms of the western highlands of Cameroon, Tropical Animal Health and Production, 41, 907–912.
Beghin, J.C., 2006. Evolving dairy markets in Asia: recent findings and implications, Food Policy, 31, 195–200
Birouk, A, Bouizgaren, A. and Baya, B., 1997. Luzerne (*Medicago sativa*). In: G. Jaritz and M. Bounejmate (eds), Production et utilisation des cultures fourragères au Maroc, (INRA Éditions, Rabat, Morocco), 129–136.
Blinda, M. and Thivet, G, 2009. Ressources et demandes en eau en Méditerranée : situation et perspectives. Sécheresse, 20, 9–16.
Chapagain AK, Hoekstra AY. 2004. Water Footprints of Nations. Value of Water Research Report Series No. 16, UNESCO-IHE, Delft, The Netherlands, http://www.unesco-ihe.org/Project-activities/Project-database/Virtual-Water-Trade-Research-Programme/Chapagain-A.K.-HoekstraA.Y.-2004-.-Water-footprints-of-nations-Volume-1-Main-Report-Value-of-Water-Research-Series-No.-16-UNESCO-IHE
Castillo, A.R., Taverna, A.M., Páez, R.R., Cuatrin, A., Colombatto, D., Bargo, F., García, M.S., García, P.T., Chavez, M., Beaulieu, A.D. and Drackley, J.K., 2006. Fatty acid composition of milk from dairy cows fed fresh alfalfa diets, Animal Feed Science and Technology, 131, 241–254.
Delaby, L., Faverdin, P., Michel, G., Disenhaus, C. and Peyraud, J.L., 2009. Effect of feeding strategies on performances and their evolution during lactation of Holstein and Normande dairy cows, Animal, 3, 891–905.
Delgado, C.L., 2003. Rising consumption of meat and milk in developing countries has created a new food revolution. Journal of Nutrition, 133, 3907S–3910S.
Faure, G. and Kleene, P., 2004. Lessons from new experiences in extension in West Africa: management advice for family farms and farmers' governance, The Journal of Agricultural Extension and Education, 10, 37–49.
Fox, D.G., Sniffen, C.J., O'Connor, J.D., Russell, J.B. and Van Soest, P.J., 1992. A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy, Journal of Animal Science, 70, 3578–3596.
Gilbert, C.L. and Morgan, C.W., 2010. Food price volatility, Philosophical Transactions of the Royal Society B, 365, 3023–3034.
Guessous, F., 1991. Production fourragère et systèmes animaux, (Actes Éditions, Rabat, Morocco).
Heinrichs AJ, Erb HN, Rogers GW, Cooper JB, Jones CM. 2007. Variability in Holstein heifer heart-girth measurements and comparison of prediction equations for live weight. Preventive Veterinary Medicine 78, 333–338.
Iglesias A, Garrote L, Flores F, Moneo M. 2007. Challenges to manage the risk of water scarcity and climate change in the Mediterranean. Water Resources Management 21, 775–788.
Jarrige, R., 1988. Table des valeurs nutritionnelles des aliments. In : R. Jarrige (ed), Alimentation des bovins, ovins et caprins, (INRA Éditions, Paris, France), 351–443.
Le Gal, P.-Y., Kuper, M., Moulin, C.-H., Sraïri, M.T. and Rhouma, A., 2009. Linking water saving and productivity to agro-food supply chains: a synthesis from two North African cases. Irrigation and Drainage, 58, S320–S333.
Martin, R.C., Astatkie, T., Cooper, J.M. and Fredeen, A.H., 2005. A comparison of methods used to determine biomass on naturalized swards, Journal of Agronomy and Crop Science, 191, 152–160.
ORMVAT (Regional Office of the Agricultural Development in the Tadla), 2011. Technical achievements of the Regional Office of Agricultural Development in the Tadla region, Fquih Ben Salah, Morocco. http://ormvatadla.com/site/
Pacheco, F., 2006. Dairy production systems in the Entre Douro e Minho region. Remarks about a technical support to farmers, Options Méditerranéennes Series A, 70, 179–185.

Sraïri, M.T., 2011. Le développement de l'élevage au Maroc : succès relatifs et dépendance alimentaire. Le Courrier de l'Environnement de l'INRA, 60, 91–101.
Sraïri, M.T. and Chohin Kuper, A., 2007. Conséquences de la libéralisation des marchés sur les opérateurs de la filière laitière au Maroc, Revue d'Élevage et de Médecine vétérinaire des Pays tropicaux, 60, 177–187.
Sraïri, M.T., Kiade, N., Lyoubi, R., Messad, S. and Faye, B., 2009. A comparison of dairy cattle systems in an irrigated perimeter and a suburban region: case study from Morocco, Tropical Animal Health and Production, 41, 835–843.
Tamminga, S., 2003. Pollution due to nutrient losses and its control in European animal production. Livestock Production Science, 84, 101–111.
Thornton, P.K., 2010. Livestock production: recent trends, future prospects, Philosophical Transactions of the Royal Society B, 365, 2853–2867.
Vérité, R. and Peyraud, J.L., 1988. Nutrition azotée. In: R. Jarrige (ed), Alimentation des bovins, ovins et caprins, (INRA Éditions, Paris, France), 75–93
Vermorel, M. and Coulon, J.B., 1998. Comparison of the National Research Council energy system for lactating cows with four European systems, Journal of Dairy Science, 81, 846–855.
Wilmink, J.B.M., 1987. Adjustment of test-day milk, fat and protein yield for age, season and stage of lactation, Livestock Production Science, 16, 335–348.