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Abstract. In the Maghreb countries, because of structural drought, recent livestock production policies have relied heavily on irrigation. This aimed to secure animal protein supply by using water to grow fodder. Such choices have led many smallholder farms to rear cattle in typical dual purpose (both milk and meat) systems. In such a situation of fragmented supply, the usual tools available in developed countries to assess livestock production sustainability may not be adapted therefore, innovative methods have to be implemented. For that purpose, an array of indicators might be used, including economic profitability and water productivity through cattle and milk quality. All together, these parameters can be used to analyse beef supply chains in an eventful context.

Keywords. Irrigation – Livestock sustainability – Profitability – Water productivity.

Évaluation de la durabilité de l'élevage dans les périmètres irrigués du Maghreb

Résumé. *Dans les pays du Maghreb, en raison de sécheresses récurrentes, les politiques récentes de promotion de l'élevage ont été basées sur l'irrigation. Cela a visé la sécurisation de l'approvisionnement de la population en protéines animales par la programmation de soles fourragères irriguées. Il en est résulté de très nombreux élevages bovins de petite taille, le plus souvent à finalité mixte : lait et viande simultanément. Dans cette situation, l'offre en produits bovins est atomisée, et les outils traditionnels issus des pays développés pour évaluer la durabilité des systèmes d'élevage bovin risquent de ne pas être adaptés. Aussi, des méthodes innovantes doivent-elles être mises au point. Celles-ci pourraient ainsi reposer sur une gamme d'indicateurs comme la rentabilité des élevages, la valorisation de l'eau et la qualité du lait. Au final, de tels paramètres permettent d'analyser les chaînes d'approvisionnement en produits bovins, dans un contexte mouvementé.*

Mots-clés. *Durabilité de l'élevage – Irrigation – Maghreb – Rentabilité – Valorisation de l'eau.*

I – Introduction

There are growing concerns about the expansion of the demand in meat and milk worldwide, which may necessitate a "Livestock Revolution" (Delgado, 2003). Therefore, animal production systems are facing important challenges with regard to their sustainability, particularly in a context of climate change (Thornton *et al.*, 2009). In industrialised countries, this has led to the implementation of adapted legislations to assess the sustainability of animal production systems and their impacts on physical environments (Bocquier and González García, 2010). It has particularly affected dairy cattle production as farmers are getting extremely aware of environmental matters and adopt consequent farming practices (manure management, proper use of fertilisers, etc.) to avoid penalties (Anderson and Magdoff, 2000). Such developments seem however far from the evolution of dairy cattle systems in many developing countries, where their sustainability indicators are still rarely assessed. In fact, in these regions milk production is mainly achieved by a vast majority of smallholder farms, which have to deal with increasing State services disengagement. Therefore, the environmental impacts of their livestock production are somewhat unknown. In the specific context of North African countries, with limited water availability (less than 1,000 cubic meters per capita per year) and increasing climatic uncertainty, intensive livestock production systems rely on irrigated fodder. It has led to the adoption of large scheme irrigation policies to sustain intensive cattle production in order to secure the supply of milk. In such systems, scarce information is available about cattle sustainability and its perception by farmers. This is why specific tools related to the assessment of irrigated cattle production under smallholder conditions have to be elaborated. In this paper, the specific case of dairy cattle in the Tadla scheme (Morocco) is reviewed. Studies related to water productivity through cattle production are then presented. Implications on possibilities to improve farms' economic performances and sustainability are finally discussed.

II – Materials and methods

A series of controls of smallholder cattle farms was adopted in the Tadla irrigated scheme, Centre East of Morocco. This region of 105,000 irrigated ha accounts for 16% of the annual domestic milk output. Raw milk is produced by some 17,000 cattle farms, which mainly rely on alfalfa (25,000 ha). Around 55,000 lactating cows of diverse genetic merits produce 150,000 tons of milk annually: less than 25% are of local breeds, almost 75% are either pure Holstein or crosses with local breeds. Nearly all the milk comes from smallholder dual purpose (both milk and meat) farms, as 80% of them cover less than 5 ha of arable land (ORMVAT, 2010). This region is characterised by a semi-arid climate (only 300 mm of average annual rainfall), and therefore the issue of water productivity through agriculture is vital for the future of that sector. Moreover, growing pressure on groundwater resources has implied unsustainable rhythms of depletion which may threaten agricultural activities in North African irrigated schemes (Iglesias *et al.*, 2007). The study of water productivity through milk and meat is quite complicated in smallholder units, as it necessitates an on-farm analysis of a chain of functions of production: (i) from water uses and their diverse sources (rainfall, groundwater, irrigation network) to forage biomass production; and (ii) from forage and its complementation with extra farm feed resources to cattle products, whether live weight gain or milk.

A sample of six cattle farms representative of the overall population was chosen (Table 1). They reflected the diversity of cattle systems in the region: (i) very few specialised dairy farms; (ii) a majority of mixed farming systems (cattle and cash crops); and (iii) some dual-purpose herds (milk and meat). Farming practices were characterized during the agricultural campaign from September 2007 to August 2008. Irrigation water volumes destined to produce forage (mainly alfalfa and berseem – *Trifolium alexandrinum*) were measured. Biomass from forage plots was weighted. Variations in the dietary rations of the different groups of cattle (lactating cows and growing calves) were characterised throughout the year. Finally, cattle products (milk and meat) outputs were determined by the follow-up of milk delivered to collection co-operatives and by regular weighting of live animals (both cows and their calf crop). The economic performances of farms were also assessed and that allowed characterising the profitability of water productivity (€/m^3) through milk and meat (live weight gain).

Table 1. Characteristics of the sample study farms in the Tadla irrigated scheme

Farms	1	2	3	4	5	6
Arable land (ha)	5.0	6.3	6.5	1.4	1.6	1.8
Total fodder crops area (ha)	2.7	3.4	2.6	0.8	0.8	1.0
Alfalfa (ha)	2.0	2.0	2.2	0.8	0.8	1.0
Berseem (ha)	0.5	0.7	0.4	-	-	-
Maize (ha)	0.2	-	-	-	-	-
Barley (ha)	-	0.6	-	-	-	-
Herd characteristics						
Lactating cows	6.5	7.0	6.4	2.0	2.0	3.0
Growing cattle	5	7	6	2	2	3
Dairy (D), beef (B) or dual (BD) strategy	BD	BD	BD	D	B	B

Such a protocol allowed characterising the variability of water productivity through cattle products (milk and meat) and its determining factors. A further reflection on the intervention possibilities to enhance smallholder irrigated cattle farms' performances was adopted. It consisted in presenting to farmers a model which would allow them designing farming systems for increased water productivity through the adoption of sound strategies: change in the forage system or substitution of crossbred cattle by purebred dairy cows.

III – Results and discussion

Results show that the overall performances of cattle production were highly variable (Table 2). For instance, mean annual milk yield per cow was only 2,170 kg, and it varied from 1,650 to 3,400 kg. Indeed, from irrigated fodder to cattle products, evident drawbacks appear, due to inappropriate farming practices and insufficient water availability, particularly in a dry year (less than 250 mm of rainfall). In fact, all farms adopted gravity irrigation which means important amounts of water lost by leaching (up to 40% of irrigation volumes). Furthermore, cattle load was heavy (more than 2.6 cattle per ha of forage) resulting in limited nutrients for cattle. As alfalfa was the main forage in all farms, it was hardly supplemented by an adequate energy feed, implying that cattle dietary rations were unbalanced. As a consequence, the average profitability of the dairy activity is weak (less than 230 € per cow including the value of calves), because the cost of production of milk is often higher than farm gate milk price. In fact, only calf crop sales allow farmers to reach the economic equilibrium. Therefore, live animals sales constitute a strategic income for farms, whereas milk allows a steady cash flow to face daily expenses. These trends result on a highly improvable water productivity through cattle: almost 1.8 m^3 (from 1.1 to 2.2 m^3) per kg of raw milk and 10.5 m^3 (from 5.6 to 12.9 m^3) per kg of live weight cattle. These results appear however to be close to international standards expressing the water footprint of a single kg of milk and beef (Chapagain and Hoekstra, 2004). Such results imply that urgent measures are needed to ensure the competitiveness of dairying with irrigated fodder in Morocco with regard to other agricultural (fruits, vegetables, etc.) or non agricultural (tourism or industry) activities, in a context of growing water shortage. Therefore, interventions to enhance the performances of dairy producers, mainly the vast majority of smallholder units, would be fruitful (Le Gal *et al.*, 2009).

Table 2. Technical performances of irrigated cattle farms: from water productivity to profitability

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 through milk (m^3/kg of milk)	2.1	2.2	1.7	1.1	1.5	1.8
Water economic productivity (€/m^3)	0.02	0.03	0.08	0.14	0.09	0.09
Meat						
Total live weight gain (kg)	2,100	1,740	1,770	430	710	1,290
Total water used (m^3)	19,710	22,500	9,980	3,820	6,720	10,800
Water productivity through meat (m^3/kg of milk)	9.4	12.9	5.6	8.9	9.4	8.4
Water economic productivity (€/m^3)	0.21	0.14	0.37	0.26	0.24	0.24
Water economic productivity through cattle (€/m^3)	0.09	0.09	0.08	0.17	0.18	0.17

Because of numerous drawbacks in cattle farms, possibilities of intervention were designed. A first one consisted in simulating changes in farmers' systems and assessing their impacts on water productivity. The improvements could come from the sequence of processes involved. Therefore a simulation tool which takes into account the biophysical terms of production in smallholder farms was designed and tested. Simulations were carried out for a typical smallholder farm of 2 ha, mainly specialised in dairy production (1.9 ha of forage). This virtual farm raises 2 cows. The simulation considered three different strategies:

(i) an initial situation with 1.4 ha of alfalfa, 0.5 ha of barley and 2 crossbred cows of a weak annual milk yield (2,820 kg);

(ii) a first change which consists in substituting the crossbred cows by purebred Holstein cows which will have to be fed correctly to reach an optimal annual milk yield of 5,000 kg. No change is planned in the forage area;

(iii) a second change which is also built on substitution of the 2 crossbred cows by pure Holsteins and a partial substitution of alfalfa by maize with drip irrigation.

Results of the simulations showed that significant improvements in water productivity through cattle production may be achieved, by an increase in milk yield and a more efficient use of water to irrigate forage. A single cubic meter of water may generate almost three times more economic value as it used to create (Table 3), but that will require the adoption of good management practices in farms, from irrigation and cropping to livestock feeding.

Table 3. Water productivity through cattle with simulations using two alternative scenarios

	Initial situation	**Scenario 1†**	**Scenario 2††**
Land under forage (ha)			
Alfalfa	1.4	1.4	0.8
Barley	0.5	0.5	0.3
Maize	-	-	0.8
Cattle herd			
Number of lactating cows	2	2	2
Milk yield per cow (kg/year)	2,820	5,040	5,240
On-farm water use (m^3/year)	38,500	37,500	25,850
Livestock products (€/cow.year)			
milk	707	1,326	1,316
liveweight gain	893	1,250	1,250
total	1,600	2,576	2,566
Annual gross margin per cow (€)	853	1,312	2,156
Real water economic productivity (€/m^3)	0.04	0.07	0.17

†Scenario 1: milk productivity – same forage crops but with replacement of crossbred lactating cows by purebred Holstein cows fed according to their production potential.

††Scenario 2: water saving – partial substitution of alfalfa by maize, and replacement of crossbred lactating cows by purebred Holstein cows.

A further reflection on the improvement of cattle farms' profitability was also developed. It appeared that a significant increase in farmers' income may occur with an adapted payment of milk at its actual quality. In fact, in supply chains with numerous farms which deliver limited amounts of milk daily, it is quite impossible to assess the chemical (fat and protein) and hygienic quality (microbial load) of each batch. Therefore in such chains with a fragmented offer, farmers are paid only on the volumes delivered, and collective milk from numerous farms which deliver their output at the same collection co-operative is considered as a single sample. This collective sample may eventually be assessed by milk processors for its quality, but such a system of payment does not create any incentive to improve milk quality, and farmers' efforts to enhance their incomes though milk quality are hampered. This means that further negotiations implying all the stakeholders (farmers, milk collectors and dairy processors) are needed to try to define a frame of milk payment at its quality. That may involve controls of farming practices (feeding, hygiene, genetic type of lactating cows, etc.) at farm level (Sraïri *et al.*, 2009).

IV – Conclusions

The current conditions of cattle production in large scale irrigation schemes in Morocco show that this activity is characterised by numerous drawbacks. In fact, from fodder production to cattle feeding, many improper farming practices (gravity irrigation, non adapted forage fertilisation, insufficient and imbalanced dietary rations, etc.) result in low animal performances and reduced income for farmers. Thus, water productivity through cattle farming has a lot of room for improvement. All together, such characteristics imply that the perceptions of sustainability by cattle farmers are primarily linked to their economic performances and the resilience of their activities in a context of limited water availability. In fact, all the North African countries are facing growing challenges to manage water shortage and to increase food production. Therefore, in irrigated schemes, a marked interest will have to focus on the issue of water productivity through cattle farming to improve its competitiveness and ensure its sustainability. This should be a high priority item on the agenda of the agricultural authorities, at a time where ambitious policies are set-up to boost the domestic food production. The results presented in this paper emphasise on the importance of a proximate intervention in numerous smallholder farms, which constitute the immense majority of farms. Adapted technical support from forage production to cattle balanced feeding should be tested in some farms to demonstrate the feasibility of such an intervention, as a way to improve farms' economic results and adaptation to water shortage. The reflection on an alternative system to remunerate milk quality may also constitute a way to improve farmers' incomes. All these interventions may require functional farmers' organisations and relationship of confidence between farmers and technical advisers. Furthermore, such interventions also require operational private extension actors, at a time where State services are withdrawing from the agricultural support.

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