Biotechnology in Animal Husbandry 37 (1), 27-43, 2021
Publisher: Institute for Animal Husbandry, Belgrade-Zemun

ISSN 1450-9156
UDC 636.034'28
https://doi.org/10.2298/BAH2101027Y

WATER FOOTPRINT OF MILK PRODUCTION SYSTEMS IN SEMI-ARID PLAINS OF NORTH AFRICA

Houari Yerou[1,2], Benamar Belguerbi[2], Abdelkader Homrani[3], Kheloufi Benabdeli[2]

[1]Department of Agriculture Sciences, University of Mascara 29000, Algeria
[2]Laboratory of Geo-sciences and Sustainable Development, University of Mascara. Algeria
[3]Department of Animal Science, University of Mostaganem 27000
Corresponding author: Houari Yerou, houariyerou@gmail.com
Original scientific paper

Abstract: Water resources are becoming scarce and must be preserved. The significant use of water is linked to agriculture in general and to livestock in particular. Very little research in semi-arid regions has been devoted to assessing the contribution of ruminants to water scarcity. This contribution explores the relationships between dairy farming and the various water resources available in an ecosystem with climatic constraints. To meet future food demand while sustainably managing the available land and water resources, dairy farm systems in semi-arid regions must adapt in response to climate and socio-economic change. In this study, we focus on the south Mediterranean region to analyze the key factors influencing water productivity in dairy farming, especially in context characterized by water scarcity. In order to characterize the relationship between dairy cattle breeding and water resources, a monitoring of 40 dairy cattle stables has been carried out in a semi-arid region. The technical and economic parameters of each farm were evaluated: the use of water according to their origins to the production of fodder by source, the contribution of virtual water off the farm, the total fodder biomass, feeding system practiced on the farms and the performances achieved. Analysis of the data indicates that productivity of fodder in dry matter differ between the two systems with values of the order of 12520 to 17188 kg/ha ($p<0.05$) respectively for type extensive and intensive systems. The milk yield per cow did not exceed an average value of 3680 kg (rang 3240 to 4120 kg. The mean gross margin per kilogram of milk was low, not exceeding 0.13€. A significant effect ($p<0.05$) of the value of the water footprint between the two dairy farm systems with an average of around 2.05m^3/kg of milk (range 1.96 to 2.15 respectively for intensive and extensive farms). The contribution of rainfall is estimated at 57% and the rest is represented by the participation of irrigation and virtual water with 18% and 25% respectively. Necessary actions must be taken along the milk production process in order to improve the productivity of water for

forage production and the milk which depends in large part on annual rainfall and to a lesser extent on groundwater.

Keywords: Dairy farms, milk yield, water productivity, water footprint, semi-arid land

Introduction

Global climate change is one of the most serious challenges facing agricultural and animal husbandry in the next decades. The Intergovernmental Panel on Climate Change reported an important global warming trend from 1983 to 2012. This period was the warmest of the last 1400 years in the Northern Hemisphere. By the year 2100, an increase in global surface temperature by 3.7–4.8 °C was predicted (*IPCC, 2014*). As climate change has become a pervasive topic in global agricultural production, especially in dairy cattle breeding. These changes will result in increasingly unfavorable climatic conditions for agricultural and especially livestock production (*IPCC, 2007, Gauly et al., 2013*). The production husbandry systems and agricultural is of vital importance in Mediterranean region, which ensuring food security and contributes significantly to the regions' economy. According to *Kina Stientje and Žiga* (2019), in order to meet future food demand while sustainably managing available land and water resources, irrigated agriculture in semi arid regions needs to adapt as a response to climate and socio-economic change. The climatic conditions in the area are suitable for growing a wide variety of crops, irrigation is essential to maintain consistent yields (*Daccache et al.,* 2014). With around 30% of the cropland being irrigated, it is the largest consumer of freshwater in the Mediterranean region (*FAO, 2016*). Due to high population density and semi-arid climatic conditions, the Mediterranean is among the most water-scarce regions, posing serious constraints on irrigation (*Mekonnen and Hoekstra, 2016; United Nations, 2017*). water availability in the region is decreasing as a consequence of climate change, particularly due to rising temperatures and shifting precipitation patterns (*Giorgi and Lionello, 2008; Grasso and Feola, 2012; Iglesias and Garrote, 2015; Iglesias et al., 2011; IPCC, 2014*). It is estimated that the gross irrigation requirements will face an increase between 4 and 18% if irrigated agriculture does not adapt to these changing conditions (*Fader et al., 2016*). The pressure on freshwater has intensified in recent years not only due to population growth and rising food requirements but also as a cumulative impact of climate change, land cover changes, poor governance in water use, and the development of water diversions (*Sultatna et al., 2014*). At the same pace, livestock production and more specifically dairy production faces great challenges as water use in this sector is also increasing (*Khelil-Afra et al., 2012*). Livestock production, thus, impacts heavily on the world's water supply, representing > 8% of global human water use (*Sharma, 2015; Schlink et al., 2010),* 10 % of global water flows *(Deutsch et al., 2010*), and 29% of agricultural water use (*Mekonnen and Hoekstra, 2010b*). The expansion of global dairy production has a major effect on this trend, and 19% of animal water use is already today related to dairy cattle production (*Mekonnen and Hoekstra, 2010*). However, dairying is an important source of human food and an integral part of agricultural production and the social fabric for more than two thirds of the population especially for smallholders in developing countries (*Doreau et al., 2012*). Water is used in dairy farming for producing feed crops, processing feed, watering the animals, cleaning and disinfecting the barn and equipment, and cooling the milk and the barn. Several studies have investigated water use for drinking, cleaning, and disinfection. The drinking water demand of lactating cows has been investigated by several authors, including *Cardot et al. (2008), Holter and Urban (1992), Meyer et al. (2004), Murphy et al. (1983*). All authors estimated the daily drinking water intake of cows depended on influencing factors such as the milk yield of the cows, live weight, and dry matter content of the feed, dry matter intake, day of the year, rainfall, and temperature. The water scarcity situation worldwide indicates that some areas are extremely water scarce and when it is combined with high milk production, it can be argued that water might be a threat to milk production. To address the problems of water scarcity and intensification, there is a need for research how to increase dairy production without off-setting water resource. The first step is to tackle the situation is to measure water use in dairying. In southern Mediterranean countries, water scarcity is already threatening human development (*Iglesias et al., 2007*). Algeria is exposed to climate change and water scarcity, the impact of which on forage production and technical and economic performance of dairy cattle systems are certain. A similar situation was signaled by (*Schilling et al., 2012; Srairi et al., 2015),* in North Africa where available water resources are heavily exploited, and where climate change may negatively affect the country's economy. According to *Le Gal et al. (2009)* In North Africa, dairy cattle production in semi-arid conditions is a particularly interesting system for such a study, since it implies analyzing a series of on-farm production functions, from water use for growing fodder, to its conversion into feed biomass, and efficiency diets intake by cows. Very few publications are available in the literature to clarify interaction between forage production and dairy production in semiarid ecosystems, mainly from a water use en productivity viewpoint. Such complementarities need to be addressed to assess the relative pressure of both activities on available water resources (rainfall, surface water and groundwater). Estimating water use at the various stages of animal's production and communicating those estimates will help producers and other stakeholders identify hotspots and implement strategies to improve water use efficiency. In this situation improvement in dairy cows productivity efficiency can contribute to reduce the water footprint per unit product. Though the feed production makes up the majority of water use by ruminants, research and development efforts should focus on this area. More research and clarity are needed to examine the validity of assumptions and possible trade-offs between water use by cows and other sustainability indicators. Quantifying the water footprint of anthropogenic activities involving ruminant production is a relatively new field of research where methodologies are still developing. The term “water footprint” was coined in the early 2000s as an indicator of the volume of freshwater used to produce food (milk and meat) or an industrial product (*Hoekstra and Hung, 2002*). Although assessments using the concepts of “virtual water” and “water footprint” suggest that animal products generally have a higher water footprint than plant-based products (*Allan, 1998; Ercin et al., 2012; Mekonnen and Hoekstra, 2012*), there are large discrepancies in the values reported as well as differences in assessment methods. According to *Srairi et al. (2015)* the water productivity of dairy farms becomes a difficult task, for two reasons: the output (milk and meat) tends to vary due to different management practices, with significant difficulties in obtaining accurate on-farm data and these farms are rarely specialized in either milk or meat, suggesting that research methodologies have to deal with both products. In semi-arid contexts, sustainable water use has to be promoted, given the ongoing trend of groundwater depletion (*Wada et al., 2012*). In the case of North Africa’s, increased pressure on groundwater is already threatening the sustainability of many farming systems that depend on it (*Kuper et al., 2015*). The main objective of this study therefore consists in first to estimate the water footprint of dairy farms by considering the volumes of water used their origins (rainfall, irrigation with groundwater) and virtual water, secondarily to evaluate the economic impact of water productivity in dairy farms.

Material and Methods

Water footprint in dairy cattle farms was studied in semi rid south-Mediterranean conditions. The dairy farms investigated are located in the center of Mascara town. It covers 12 municipalities, with a total area of 1401 km^2 (27.3% of the total area) and a density of population of 181 hab/km^2. It receives on average 450 mm/year with semi rid climate. It is a rich agricultural plain, known for its rain-fed farming systems (cereals, vineyard and fruit trees). The total number of farms is around of 11624 divided into 3 categories of status. The distribution of farms shows the dominance of private farms in number 8165 farms which represents 70%, with an area of 45568 ha, but the collective farms (EAC) accounted for 16%, with an area of 38157ha, in number 1890 collective farms. As well as EAI (individual farms) number of 1569 exploitation, represent 14%, with an area of 5217 ha (*Yerou et al., 2019*). A benchmark survey of dairy cattle breeders was conducted during 2019 agricultural campaign indicates that all systems selected in this study use groundwater; with 6722 cows 60% of which is Friesian black magpie of total cows and produce 3400 ±1250 kg average milk yield per cow (*Yerou et al., 2019*).

The methodology for monitoring the sample in our study consists of a series of routine visits to 2 types of dairy farming systems, one of the intensive (type I) and the other extensive (type II). The sample followed is made up of 20 dairy farms per type to describe the water use productivity in relation with the milk yield, forages practices, dietary rations and costs of forages and milk in dairy farms. The table1 indicates the characteristics of the sample farms with diverse structural, technical parameters and strategic of use of water in dairy husbandry systems.

Each farm had an average of 14.5 ha of ARL (range = 8.6 to 16.5ha), with an average animal stocking rate of 1.84 UGB/ha of fodder crop (range = 2.1 to 3.06 UGB/ha). Feeding practice in both types of cattle farming systems is shown in Figure 1. The forage calendar of extensive type shows a use of green fodder limited only in spring, a distribution of straw in summer and which continues until the end of winter as well as a very large use of concentrated foods throughout the year. This type of calendar characterizes farms with a milk tendency based on more concentrate. But the forage calendars intensive type illustrates the use of green fodder during a large part of year round; straw is limited to only part of summer and winter. It characterizes milk-oriented farms based on fodder.

Table 1. Average structural and technical's parameters of sample farms (μ ± σ)

Parameters	Symbols	Type 1 (n=20) Intensive	Type 2 (n=20) Extensive
Surface Arable Land use	ARL	16.5 ± 1.94	8.6 ± 1.2
Forage Land (ha)	FL	6 ± 0.75	3 ± 0.73
Sorgho (ha)		1.75 ± 0.19	0.75 ± 0.21
Lucerne (ha)		1. 5 ± 0.17	0.50 ± 0.19
Barley (ha)		2.75 ± 0.15	1.75 ± 0.17
Number of Cows	NCW	12.6 ± 1.66	9.2 ± 1.45
Stocking rate/ ha fodder	UGB/ ha	2.1 ± 0.28	3.06 ± 0.23
Average milk/cow/year	APM	4120 ± 604.6	3240 ± 710.2
Milk concentrates /cow	UFLcc	5.5 ± 0.86	7.6 ± 0.78
Food cost total inputs %	FCT	62.8 ± 9.2	68.7 ± 8.7
Cost 1 liter milk (€)	PCM	0.52 ± 0.07	0.61 ± 0.09
Benefit per cow (€)	BC	881.1±132.6	618.2 ± 129.7

1 DA = 0.090 €. (DA: Dinar Algerian. €: euro).

The practice of fodder crops on the sampled farms is dictated by the availability of irrigation water (rainwater, underground), the modality of use of this water and the costs of milk production. About 41 % of the total arable land was cultivated with rain-fed (oats – *Avena sativa*; barley *Hordium vulgare*) or irrigated forage (Sorgho *Sorghum sp,* lucerne – *Medicago sativa*). In north Africa, dairy cows farms uses also cereal straw, which is considered locally as a strategic fiber resource (*Abdelguerfi et al., 2008; Belhadia, 2016; Yerou et al., 2019*).

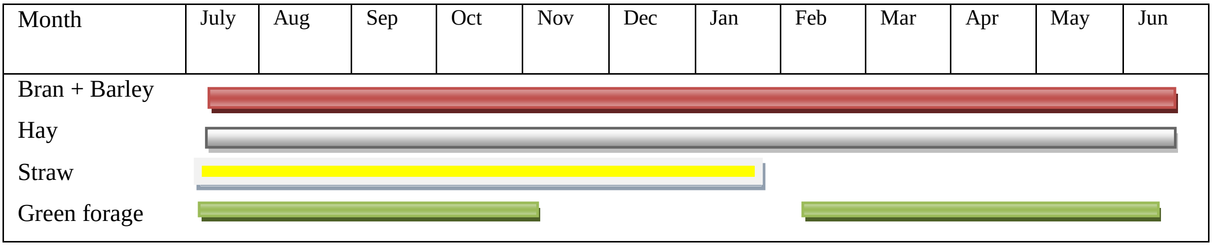

Fig 1. Forage calendar of dairy farms in study region

The parameters measured were water volumes used WU/ha of forage by cultivated species and origin of irrigation (rainfall and groundwater), estimate of forage biomass from irrigated plots and contribution of rations exogenous feeds and the milk yield obtained per systems. The estimation of the volumes of water used by breeders was based on the flow of water from the irrigation wells, the time and frequency of irrigation by irrigated forage plots and by farm. Rainfall data were obtained from the local meteorological station, which was located at a maximum distance of 9 km from farms. The exogenous rations (cereals and bran) were converted into equivalent virtual water according to international standards (*Hoekstra and Chapagain, 2007*) 1 m^3 of water per kilogram of cereals.

The method used to determine the biomass of fodder grown on the farms monitored is inspired by that cited by (*Martin et al., 2005*), which consists to weighing plant samples harvested from each plot within a 1 m^2 quadrat at each harvest. Subsequently, the nutrient value of all forages supplied by this biomass was estimated. The average dry matter (DM) and net energy content of forage crops in the context of north Africa were adopted from *Abdelguerfi et al.* (2008), INRA (2007); for all the fodder identified in the surveyed holdings in the absence of a forage analysis, we refer to other analyzes carried out in Algeria relating to these forages *Kadi et al.* (2007), *Arbouche et al.* (2009). These average nutrient values were used to calculate nutrient yields per hectare in each farm. All of the herds were on "zero grazing" and consumed distributed rations (green, dry and concentrated fodder) according to the forage management specific to each farm. The economic assessment in terms of gross margins for milk production was determined by the difference between income and expenses related to food, veterinary care and other livestock costs. Water productivity of milk production (m^3/kg) and economic water productivity of milk in (€/m^3) were also calculated.

Statistical data processing

A descriptive analysis was performed for the evaluation of averages, standard deviations, minimum and maximum of the various parameters chosen. Then a factor analysis of variance (XL.STAT) was applied to the results according to the model: $Y_{ij} = \mu + \alpha_i + e_{ij}$; Or: Y_{ij} is the explained variable; μ: the general average, α_I : the factor effect and e_{ij}: the residual error of the model. Then, the Student test compared the factors two to two.

Results and Discussion

The objectives of the study were to characterize the use of water in the dairy farming process in semi-arid areas with irrigation possibilities and its impact on water productivity and milk production. The breeding practice within the region is characterized by poorly diversified fodder crops and a contribution of exogenous food resources to the farm which makes the analysis of these systems more complex to determine the productivity of water. According to *Kadi et al.* (2007) and *Ghozlane et al.* (2009), similar situation was reported on dairy farms in a semi-arid climate where the use of concentrates is practiced on all farms to varying degrees. The study sample was explicitly designed to represent the reality of farming in terms of structural parameters in the Mascara semiarid plain where the study was conducted (*Yerou et al., 2019*). From water volumes and their origins to forage biomass Water volumes applied to fodder crops varied widely among farms and were largely determined by irrigation practices.

The results of monitoring the two types of farming indicate that the total water use for summer fodder (Sorghum and Lucerne), was (4350; 4160) and (3150; 3050) m^3/ha respectively for in types I and II. A comparison of the irrigation practice between the two types of dairy farms indicates a variation of around 27% (7320 to 10160 m^3/ha) in favor of type I. The maximum value was recorded on Type I (intensive system), which was the only one equipped with drip irrigation. According to the precipitation recorded during our monitoring, water consumption for oats is relatively constant with an average value of 3740 and 2950 m^3 / ha respectively for the intensive and extensive systems. The productivity of fodder in dry matter differ between the two systems with values of the order of 12520 to 17188 kg/ha respectively for type II and I. This difference is due to the mode of management of the fodder crops and the volume of irrigation water applied, in the same way a relative shift of the vegetative cycles was observed within the dairy farms. Our assessment of water productivity based on the contribution of rainfall, the possibility of irrigation and the share of virtual water, indicates the existence of variability in the water used between dairy farms. The water productivity of the various cultivated forages presents a variation between farms of the order of 0.84 and 1.04 m^3/kg DM) respectively for the intensive and extensive system (Table 2). The results obtained are slightly higher than those reported by *Srairi (2009*) and *Bouazzama et al*. (2012) under irrigated conditions in Morocco (0.33 to 0.54 and 0.33 to 0.54 m^3/ kg DM).

Our results on the yield of DM from Lucerne are poor (4960 kg of DM/ha) compared to those obtained by (*Sraïri et al., 2009*) of the order of 9190 kg/ha and 6820 kg of DM/ha in a semiarid irrigated region of Morocco. This can be explained by the rainfall regime of each zone. For the water productivity of this species (0.76 m^3/kg DM) was lower than that reported by *Srairi et al. (2009), Montazar and Sadeghi (2008*).

Table 2. Water productivity of fodder in the study farms

	Type I Intensive system			Type II Extensive system		
Parameters	WU m^3/ha	DMY kg/ha	WPDM m^3/kg	WU m^3/ha	DMY kg/ha	WPDM m^3/kg
Sorghum	4350^{a}	3260^{a}	1.33^{a}	3150^{b}	1460^{b}	2.15^{b}
Lucerne	4160^{a}	5458^{a}	0.76^{a}	3050^{b}	4460^{b}	0.68^{b}
Barley green	1650^{a}	2600^{a}	0.63^{a}	1120^{a}	1850^{a}	0.60^{a}

a, b, means for each parameter with different letters across a row are significantly different $p<0.05$

For all the parameters characterizing the use of water, the oat crop had a relatively homogeneous use of water and a yield of DM per hectare quite similar between farms. This is explained by the technical mastery of the cultivation of this species in the northern Mediterranean production systems. With regard to the other fodder species requiring water, the technical route remains poorly controlled, which significantly affects yields by crop and exploitation within the same agro-ecological zone. In addition, profitability of using irrigation is affected by other factors relating to the mastery of the cultivation techniques of the fodder used. Similar trend results have been reported in the semi-arid North African zone with regard to the use of irrigation water (*Sraïri et al., 2009; 2016*). According to the same source, precipitation in semi-arid regions significantly affects the extent of irrigation use with an interval of the order of 82% to 87.9% of the total amount of water used to irrigate fodder crops, which implies great pressure on the groundwater of crops in regions with a semi-arid climate. In their work on dairy farming, *Meul et al. (2012)* in temperate zones indicate that the development of intensive fodder systems based on the irrigated fodder in this case maize plagues groundwater.

Relationship between distributed off-farm exogenous ration and milk performance

Monitoring the consumption of rations distributed on dairy farms indicated seasonal variability, with a peak achieved in spring (March to May), followed by regression until the end of winter. This observation is linked to the availability of green according to the forage calendar practiced by dairy farms and the participation of exogenous distributors, which is strongly linked to the prices of the concentrated foods purchased. In addition, the quantities of DM ingested did not cover the optimal needs of the cows mainly due to the average rate of the animal load practiced 1.84 UGB/ha and the variability of the fodder yield in green realized in the semiarid conditions. The characterization of the distributed rations reveals a quantitative and qualitative imbalance of the rations which affects the efficiency of transformation of the rations into milk. The participation of the rations ingested by the dairy herds reveals that the contributions of the rations are deficient in DM. moreover, the food balance of the distributed ration is unbalanced, causing the fall in dairy performance of cows. This deficit necessitates the use of quality concentrate supplements to correct food rations. Similar observations have been reported by (*Moran, 2013; Sraïri et al., 2015*), who recommend the need to generalize the formulation of complementary feeds within dairy farms to increase milk production.

Water use productivity and profitability margin for dairy cows

In terms of feeding practice strategies, breeders always seek to reduce food production costs, by reducing the quantities of concentrates distributed during periods of green availability. This leads to a reduction in milk production per cow, although the breed exploited allows production of around 20 Kg/day under semi-arid breeding conditions. The decline in dairy performance continues during the summer period. The milk yield per cow did not exceed an average value of 3680 kg (rang 3240 to 4120 kg) (Table 3). The mean gross margin per kilogram of milk was low, not exceeding 0.13 euro.

Table 3. Virtual water use and cattle performance variability among farms

Parameters	Systems types		
	Intensive	Extensive	Average
Total WU off-farm feed uses (kg)	3780 [a]	4970 [b]	4375
Virtual water for lactation (m^3/cow)	1220 [a]	1090[b]	1155
Average milk (kg/cow per year)	4120 [a]	3240 [b]	3680
Milk profitability margin (€ / kg)	0.15 [a]	0.12 [b]	0.13

a, b, means for each parameter with different letters across a row are significantly different $p<0.05$

In system Type I, which had the highest average annual milk yield per cow, the economic results from the herd were the highest compared at systems type II with lowest average milk yield per cow.

The estimate of the value of the water footprint at the dairy farm level indicates an average of the order of 2.05 m^3/kg of milk (with a margin varying from 1.96 to

2.15). The contribution of rainfall is estimated at 57% the rest is represented by the participation of irrigation and Virtual water with 18% and 25% respectively. This trend indirectly affects purchases of exogenous fodder resources on the farm. The results obtained in this study indicate a variation between dairy farms in terms of the percentage of dependence on rainfed crops to produce rougher fodder intended to feed their dairy herd. Economic productivity based solely on irrigation water revealed that to produce fodder for dairy barns, the use of 1 m^3 of irrigation water generates an average gross margin of around 0.17 €. Our results agree with those indicated by (*Armstrong, 2004; Sultana et al., 2014; Sraïri et al*., 2015) which report the existence of a variation between dairy farms due to the management practices of all production functions for water and livestock products.

Table 4. Water productivity characteristics in milk, in the study farms

Parameters	Systems types	
	Intensive	Extensive
Total WU per kg of milk (m^3)	2.15 ^{a}	1.96 ^{b}
Costs of total WU in milk (€ / m^3)	0.08 ^{a}	0.06^b
Costs of irrigation WU in milk (€ /m^3)	0.15 ^{a}	0.20 ^{b}

a, b, means for each parameter with different letters across a row are significantly different $p<0.05$

The extensive system is the least efficient in terms of water productivity and the highest stocking rate, which considerably affects food autonomy. Moreover, within this system, poor practice in the management of fodder crops generates low water productivity in irrigated forages. Conversely, the intensive system was the most efficient in terms of milk water productivity with a lower storage rate and better performance in the productivity of water from forage crops. The comparison between the two farming systems in semi-arid region indicates that the system (type I) is characterized by greater food autonomy, allowing it to achieve good performance compared to the average of the sample studied and have the highest economic costs. The best results have been observed for the intensive system, which stands out for its good practice along the process chain, from irrigation management to farming. Intensive farming is the most specialized in milk production which is considered a strategic activity within the agricultural production system applied in the semi-arid zone. On a global scale, dairy farming systems seek to achieve food self-sufficiency to improve the gross margin per dairy barn. The scientific work of (*Val-Arreola et al., 2006; Lebacq et al., 2013; Gaudino et al., 2014; Srairi et al., 2015*) indicate that the farms with the best agro-environmental indicators and optimal management fodder resources.

This thematic contribution converges with the directions of recent research indicating the urgency of adding value to green water rather than blue water in order to solve the problem of food security in the 21st century (*Rockström et al., 2009*). Overall, the results obtained reveal that within dairy farms in a semi-arid climate the need to assess the contribution of the various water sources integrated into the milk production process. The analysis carried out confirms the limited pressure of dairy cattle farming on groundwater, due to its dependence on rainfall and the regulation possibilities enabled by virtual water (exogenous food on the farm). In addition, pastoralists should improve forage autonomy through good control of fodder crops and off-farm food stocks, to support the sustainability of their livestock in the face of climate change affecting the semi-arid regions of North Africa. Finally, this study was carried out on farms practicing a polyculture production and dairy cattle farming system. Following the establishment of dairy cattle farming in an arid Saharan environment and due to the nonexistence of a national benchmark in terms of the use of groundwater irrigation water and its productivity in production systems in regions with climatic constraints, this contribution could help the country's authorities to better choose the irrigated perimeters and to develop non-renewable water resources in a sustainable manner in this Saharan ecosystem.

Conclusion

The study describes on the one hand, the relationship between milk production in dairy cattle stalls and the use of different water resources and on the other hand it characterizes the impact of livestock activity on the productivity in semi-arid regions. A large variation between the stables was recorded in the amount of irrigation applied according to the forage calendars practiced; this indicates that the water footprint within the farms is less effective. Other factors of variation were determined indicating a great weakness in the management of cultivated fodder and the insufficient rationing of the herds. The results reflect variability in the use of total water, whatever its origin. The activity of dairy farming in the study region depends mainly on rainfall, but supported by irrigation water whose pressure is less on groundwater compared to fodder crops. Consequently, the prospects for the resilience of dairy production systems for cows in semi-arid conditions vary from medium to good, but the improvement in water productivity remains insufficient and requires further research on the interactions between fodder crops, irrigation water and agronomic factors.

Potrošnja vode u okviru sistema za proizvodnju mleka u polusušnim ravnicama severne Afrike

Houari Yerou, Benamar Belguerbi, Abdelkader Homrani, Kheloufi Benabdeli

Rezime

Vodni resursi postaju oskudni i moraju se sačuvati. Značajna upotreba vode povezana je sa poljoprivredom uopšte, a posebno sa stočarstvom. Vrlo malo istraživanja u polusušnim regionima je bilo posvećeno proceni doprinosa preživara u nedostatku vode. Ovaj rad ispituje veze između uzgoja krava za proizvodnju mleka i različitih vodenih resursa dostupnih u ekosistemu sa klimatskim ograničenjima. Da bi zadovoljili buduću potražnju za hranom, uz održivo upravljanje raspoloživim zemljišnim i vodnim resursima, farme za proizvodnju mleka u polusušnim regionima moraju se prilagoditi na klimatske i socijalno-ekonomske promene. U ovom istraživanju fokusiramo se na region južnog Mediterana kako bismo analizirali ključne faktore koji utiču na produktivnost vode u mlekarstvu, posebno u kontekstu koji karakteriše nestašica vode. Da bi se okarakterisao odnos između uzgoja mlečnih goveda i vodenih resursa, sproveden je monitoring 40 objekata za držanje krava za proizvodnju mleka, u polusušnom regionu. Procenjeni su tehnički i ekonomski parametri svake farme: upotreba vode prema njihovom poreklu u proizvodnji stočne hrane po izvorima, količina sveže vode koja se koristi za proizvodnju proizvoda, mereno na farmi, ukupna krmna biomasa, sistem hranjenja na farmama i postignute proizvodne performanse. Analiza podataka pokazuje da se produktivnost krme u suvoj materiji razlikuje između ova dva sistema sa vrednostima reda od 12520 do 17188 kg/ha ($p<0,05$), respektivno za ekstenzivne i intenzivne sisteme. Prinos mleka po kravi nije premašio prosečnu vrednost od 3680 kg (od 3240 do 4120 kg). Srednja bruto marža po kilogramu mleka bila je niska, ne prelazeći 0,13 €. Značajan uticaj ($p<0,05$) vrednosti upotrebe/potrošnje vode između dva sistema na farmama za proizodnju mleka - prosečna vrednost od oko 2,05 m3/kg mleka (raspon od 1,96 do 2, 15 za intenzivna i ekstenzivna gazdinstva). Doprinos kiša procenjuje se na 57%, a ostatak predstavlja učešće navodnjavanja i virtuelne vode (količina sveže vode koja se koristi za proizvodnju proizvoda, mereno na mestu gde je proizvod stvarno proizveden) sa 18%, odnosno 25%. Potrebno je preduzeti neophodne korake tokom procesa proizvodnje mleka kako bi se poboljšala produktivnost vode za proizvodnju krme i mleka koja u velikoj meri zavisi od godišnjih padavina i u manjoj meri, od podzemnih voda.

Ključne reči: farme za proizvodnju mleka, prinos mleka, produktivnost vode, potrošnja vode, polu-sušno zemljište

Acknowledgments

This study was carried out by the participation of members of the research team of Geo-sciences and sustainable development laboratory (*LGDE*) of University Mustapha Stambouli of Mascara. The authors particularly thank the dairy cattle breeders of the Mascara region for their kind participation in the monitoring protocol implemented and the local agricultural authorities directing the agricultural services and the chamber of agriculture for their support.

References

ABDELGUERFI A., LAOUAR M., M'HAMMEDI BOUZINA M. (2008): Les productions fourragères et pastorales en Algérie: Situation et 15 Possibilités d'Amélioration. Revue Semestrielle 'Agriculture & développement'' (INVA, Alger), janvier 2008, n°6: 14-25.

ARBOUCHE F., ARBOUCHE Y., ARBOUCHE R., ARBOUCHE H.S. (2009): Effets du stade phénologique des prairies permanentes forestières du Nord Est Algérien sur leur production et leur valeur nutritive. Livestock Research for Rural Development 21, 7. www.lrrd.org/lrrd21/7/arbo21115.htm

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

ARMSTRONG D.P. (2004): Water-use efficiency and profitability on an irrigated dairy farm in Northern Victoria: a case study. Australian Journal of Experimental Agriculture 44, 137–144.

BELHADIA M.A. (2016): Stratégie des producteurs laitiers et redéploiement de la filière lait, dans les plaines du Haut Cheliff. Formaliser l'informel. Thèse Doctorat Es- Sciences Agronomiques. ENSA- Algeria.

BOUAZZAMA B., XANTHOULIS D., BOUAZIZ A., RUELLE P., MAILHOL J.C. (2012): Effect of water stress on growth, water consumption and yield of silage maize under flood irrigation in a semi-arid climate of Tadla (Morocco). Biotechnologie, Agronomie, Société et Agronomie 16, 468–477.

CARDOT V., LE ROUX Y., JURJANZ S. (2008): Drinking Behavior of Lactating Dairy Cows and Prediction of Their Water Intake. Journal of Dairy Science, 91, 2257–2264.

DACCACHE A., CIURANA J.S., RODRIGUEZ DIAZ J.A., KNOX J.W. (2014): Water and energy footprint of irrigated agriculture in the Mediterranean region. Environmental Research Letter, 9, 12, 124014. https://doi.org/10.1088/1748-9326

DEUTSCH L., FALKENMARK M., GORDON L., ROCKSTRÖM J., FOLKE C. (2010): Water mediated ecological consequences of intensification and expansion of livestock production. In: Steinfeld, H., Mooney, H.A., Schneider, F., Neville, L. (Eds.), E Livestock in a changing landscape. Washington DC, USA, pp 97–111.

DOREAU M., CORSON M., WIEDEMANN S.G. (2012): Water use by livestock: a global perspective for a regional issue? Animal Frontiers 2, 9–16.
ERCIN A.E., ALDAYA M.M., HOEKSTRA A.Y. (2012): The water footprint of soy milk and soy burger and equivalent animal products. Ecological Indicators, 18, 392–402. doi:10.1016/j.ecolind.2011.12.009
FAO. (2016): Area equipped for irrigation and percentage of cultivated land. http://www.fao.org/nr/water_ World Data-Irrigation/eng.pdf.
FADER M., SHI S., VON BLOH W., BONDEAU A., CRAMER W. (2016): Mediterranean irrigation under climate change: more efficient irrigation needed to compensate for increases in irrigation water requirements. Hydrology and Earth System Sciences 20, 2, 953–973. https://doi.org/10.5194/hess-20-953-2016
GAULY M., BOLLWEIN H., BREVES G., BRÜGEMANN K., DÄNICKE S., DEMELER J.G., HANSEN H., ISSELSTEIN J., KÖNIG S., LOHÖLTER M., MARTINSOHN M., MEYER U., POTTHOFF M., SANKER C., SCHRÖDER B., WRAGE N., MEIBAUM B., VON SAMSON-HIMMELSTJERNA G., STINSHOFF H., WRENZYCKI C. (2013): Future consequences and challenges for dairy cow production systems arising from climate change in Central Europe A review. Animal, 7, 843-859.
GAUDINO S., GOIA I., GRIGNANI C., MONACO S., SACCO D. (2014): Assessing agro-environmental performance of dairy farms in northwest Italy based on aggregated results from indicators. Journal of Environmental Management 140, 120–134.
GIORGI F., LIONELLO P. (2008): Climate change projections for the Mediterranean region. Globe planet Chang 63, 2–3, 90–104. https://doi.org/10.1016/J.GLOPLACHA.2007.09.005
GHOZLANE F., BOUSBIA A., BENYOUCEF M.T., YAKHLEF H. (2009): Impact technico-économique du rapport concentré/fourrage sur la production laitière bovine: cas des exploitations de Constantine. Livestock Research for Rural Development 21, 6.
HOEKSTRA A.Y. (2012): The hidden water resource use behind meat and dairy. Animal Frontiers 2, 3–8.
HOEKSTRA A.Y., CHAPAGAIN A.K. (2007): Water footprints of nations: water use by people as a function of their consumption pattern. Water Resources Management 21, 35–48.
HOEKSTRA A.Y. (2012): The hidden water resource use behind meat and dairy. Animal Frontiers 2,2:3–8. doi:10.2527/af.2012-0038
HOEKSTRA A.Y., HUNG P.Q. (2002): Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade. Value of water research report Series. vol11. UNESCO-IHE, Delft, Netherlands.
HOLTER J.B., URBAN W.E.J.R. (1992): Water partitioning and intake prediction in dry and lactating Holstein cows. Journal of Dairy Science, 75, 1472–1479.

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.
IGLESIAS A., GARROTE L. (2015): Adaptation strategies for agricultural water management under climate change in Europe. Agricultural Water Manage, 155, 113–124. https://doi.org/10.1016/J.AGWAT.2015.
IGLESIAS A., GARROTE L., DIZ A., SCHLICKENRIEDER J., MARTIN-CARRASCO F. (2011): Re-thinking water policy priorities in the Mediterranean region in view of climate change. Environmental Science & Policy 14, 7, 744–757.https://doi.org/10.1016/j.envsci.2011.02.007
IGLESIAS A., MOUGOU R., MONEOM QUIROGA S. (2011): Towards adaptation of agriculture to climate change in the Mediterranean. Regional Environmental Change 11(S1), 159–166. https://doi.org/10.1007/s10113-010-0187-4
INRA (2007): Alimentation des bovins, ovins et caprins. Besoins des animaux. Valeurs des aliments. Tables INRA, Editions Quae, Paris, France, 307p.
IPCC (2014): Intergovernmental Panel on Climate Change. Summary for policy makers. University Press Cambridge, United Kingdom, New York USA.
IPCC (2007): Mitigation Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, Meyer, L.A. eds. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
KADI S.A., DJELLAL F., BERCHICHE M. (2007): Caractérisation de la conduite alimentaire des vaches laitières dans la région de Tizi-Ouzou, Algérie. LRRD.Volume 19. Article. www.lrrd.org/lrrd27/7/taye27128
KHELIL ARFA H., BOUDON A., MAXIN G., FAVERDIN P. (2012): Prediction of water intake and excretion flows in Holstein dairy cows under thermo neutral conditions. Anime Consortium. http://dx.doi.org/10.1017/S175173111200047x.
KINA STIENTJE H., ŽIGA M. (2019): Adaptations in irrigated agriculture in the Mediterranean region: an overview and spatial analysis of implemented strategies. Regional Environmental Change, 19, 1401–1416 https://doi.org/10.1007/s10113
KUPER M., FAYSSE N., HAMMANI A., HARTANI T., HAMAMOUCHE M.F., AMEUR F. (2015): Liberation or anarchy? The Janus nature of groundwater use on North Africa’s new irrigation frontiers. In Integrated groundwater management (ed. Jakeman T, Barreteau O, Hunt R, Rinaudo J-D and Ross A), Chapter 19. Springer Publishers, Dordrecht, The Netherlands (in press).
LEBACQ T., BARET P.V., STILMANT D. (2013): Sustainability indicators for livestock farming. A review. Agronomy for Sustainable Development 33, 311–327.
LE GAL P.Y., KUPER M., MOULIN C.H., SRAÏRI M.T., RHOUMA M. (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., FREDEEN A.H. (2005): A comparison of methods used to determine biomass on naturalized swards. Journal of Agronomy and Crop Science 191, 152–160.
MEKONNEN M.M., HOEKSTRA A.Y. (2012): A global assessment of the water footprint of farm animal products. Ecosystems 15, 3, 401–415. doi:10.1007/s10021-011-9517-8
MEKONNEN M.M., HOEKSTRA A.Y. (2016): Four billion people facing severe water scarcity. Science Advances, 2(2):e1500323. doi:10.1126/sciadv.1500323
MEYER U., EVERINGHOFF M., GÄDEKEN D., FLACHOWSKY G. (2004): Investigations on the water intake of lactating dairy cows. Livestock Production Science, 90, 117–121.
MURPHY M.R., DAVIS C.L., MCCOY G.C. (1983): Factors affecting water consumption by Holstein cows in early lactation. Journal of Dairy Science, 66, 35–38.
MEUL M., VAN PASSEL S., FREMAUT D., HAESAERT G. (2012): Higher sustainability performance of intensive grazing versus zero-grazing dairy systems. Agronomy for Sustainable Development 32, 629–638.
MONTAZAR A., SADEGHI M. (2008): Effects of applied water and sprinkler irrigation uniformity on alfalfa and hay yield. Agricultural Water Management 95, 1279–1285 Moran.
ROCKSTRÖM J., FALKENMARK M., KARLBERG L., HOFF H., ROST S., GERTEN D. (2009): Future water availability for global food production: the potential of green water for increasing resilience to global change. Water Resources Research 45, W00A12.
SCHLINK A.C., NGUYEN M.L., VILIJOEN G.J. (2010): Water requirements for livestock production: a global perspective. Revue des Sciences et Techniques de l’OIE 29, 603–619.
SCHILLING J., KORBINIAN P.F., HERTIG E., SCHEFFRAN J. (2012): Climate change, vulnerability and adaptation in North Africa, with focus on Morocco. Agricultural Ecosystems and Environment 156, 12–26.
SCHLINK A.C., NGUYEN M.L., VILIJOEN G.J. (2010): Water requirements for livestock production: a global perspective. Revue des Sciences et Techniques de l’O.I.E, 29, 603–619.
UNITED NATIONS. (2017): The United Nations world water development report 2017: wastewater: the untapped resource; facts and figures; 2017. Retrieved from http://unesdoc.unesco.org/images/0024/ 002475/247553e.pdf. Accessed 12 March 2018
SHARMA B., MOLDEN D., COOK S. (2015): Water use efficiency in agriculture: Measurement, current situation and trends. In: P. Drechsel, P. Heffer, H. Magen, R. Mikkelsen, and D. Wichelns, editors, Managing water and fertilizer for sustainable agricultural intensification. International Fertilizer Industry Association, Paris, France; International Water Management Institute, Colombo, Sri Lanka;

International Plant Nutrition Institute, Norcross, Georgia; and International Potash Institute, Horgen, Switzerland. p. 39–64.
SRAÏRI M.T., RJAFALLAH M., KUPER M., LE GAL P.Y. (2009): Water productivity of dual purpose herds (milk and meat) production in a Moroccan large-scale irrigated scheme. Irrigation and Drainage 58, S334–S345.
SRAÏRI M.T., SANNITO Y., TOURRAND J.F. (2015): Investigating the setbacks in conventional dairy farms by the follow-up of their potential and effective milk yields. Iranian Journal of Applied Animal Science 5, 255–264.
SRAÏRI M.T., BENJELLOUN1 R., KARROU M., ATES S., KUPER M. (2016): Biophysical and economic water productivity of dual-purpose cattle farming. Animal, 10, 2, 283–291doi: 10.1017/S1751731115002360
SULTANA M.N., UDDIN M.M., RIDOUTT B.G., PETERS K.J. (2014): Comparison of water use in global milk production for different typical farms. Agricultural Systems 129, 9–21**.**
VAL ARREOLA D., KEBREAB E., FRANCE J. (2006): Modeling small-scale dairy farms in Central Mexico using multi-criteria programming. Journal of Dairy Science 89, 1662–1672.
WADA Y., VAN BEEK L.P.H., BIERKENS M.F.P. (2012): Non sustainable groundwater sustaining irrigation: a global assessment. Water Resources Research 48, W00L06, 18pp
YEROU H., HOMRANI A., BENHANASSALI A., BOUSSEDRA D. (2019): Typological assessment of dairy farms systems in semi-arid Mediterranean region of western Algeria. Biotechnology in Animal Husbandry, 35, 4, 335-346. https://doi.org/10.2298/ BAH1903209

Received 11 June 2020; accepted for publication 10 December 2020