Water footprint assessment of sheep and goat production in the agro-pastoral production system in the region of Sidi Bouzid in Central Tunisia

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Abstract. There is an increasing concern on the continuous and rapid decreaseof water availability across the whole territory particularly in central and southern Tunisia. This constraint is adversely affecting livestock production and the sustainability of different production systems. Agriculture is a major water-consuming sector. Small ruminants' production is the main source of income of most of households in the region of SidiBouzid (semi-arid region in Central Tunisia). However, water scarcity is threatening this sector. This study aims to determine water footprint (WF) in the community of Zoghmar in SidiBouzid and to assess water use in sheep and goat farming, using a water footprint method compliant with life cycle assessment. A distinction is made between green, blue and grey water footprint, to make a comprehensive and complete overview of freshwater consumption and pollution. Data have been generated from a survey performed on a wide range of farms in this community. Three main factors driving the WF of meat: feed conversion efficiency (feed amount per unit of meat produced), diet composition and feed origin. Sheep and goat were raised under the agro-pastoral system. This study shows that the average WF of sheep meat is 6222 liter/kg of carcass for which 94% green, 5% blue and 1% grey. However, WF of goat meat averaged 4521 liter/Kg of carcass. Proportions of water footprint categories are equal to those obtained with sheep. It is concluded that goat meat production is less water demanding than sheep confirming the common opinion that goat is better adapted to harsh conditions prevailing in arid and semi-arid region than sheep. Moreover, the water footprint of meat is determined mostly on the basis of feedsdistributed to the animals, therefore the more low WF feeds, like cactus cladodes, are included in livestock's diets the lower WF of meat would be recorded.

Keywords. Water Footprint–small ruminants–meat–agro-pastoral system–SidiBouzid.

Détermination de l'empreinte hydrique des ovins et des caprins dans le système agro-pastoral de la région de Sidi Bouzid en Tunisie

Résumé. *Il ya une préoccupation croissante quant àla diminution continue et rapide de la disponibilité des ressources hydriques constatée sur l'ensemble du territoire en particulier dans la Tunisie central et au sud. Cette contrainte est entrain d'affecternégativement le secteur d'élevage et la durabilité des systèmes de production. L'agriculture est un important consommateur d'eau. La production de petits ruminants est la principale source de revenus de nombreux petits éleveurs dans la région de Sidi Bouzid (semi-aride en Tunisie Centrale). Cependant, la pénurie d'eau menace ce secteur. L'objectif de notre étude est de déterminer l'empreinte eau (WF) dans la communauté de Zoghmar à Sidi Bouzid et d'évaluer l'utilisation de l'eau dans l'élevage ovin et caprin, en utilisant une méthode de l'empreinte eau conforme à l'évaluation du cycle de vie. Une distinction est faite entre l'eau vert, bleu et gris, pour faire un aperçu complet sur la consommation d'eau douce et la pollution. Les données ont été générées à partir d'une enquête réalisée sur un large éventail de fermes dans cette communauté. Trois principaux facteurs affectent l'empreinte hydrique de la viande: l'efficacité de conversion des aliments (quantité d'aliments par unité de viande produite), composition du régime alimentaire et le type de l'aliment incorporé dans la ration. Les ovins et les caprins sontélevésdans un système agro-pastoral. Cette étude montre que la valeur moyenne du WF de la viande de mouton est 6222 litres / kg de carcasse pour laquelle 94% d'eau verte, 5% d'eau bleue et 1% d'eau grise. Cependant, WF de la viande de chèvre est d'en moyenne 4521 litres / kg de carcasse. Les proportions des catégories d'eau sont égales à celles obtenues avec les moutons. Il est conclu que la production de viande de chèvre est moins exigeante en eau que les moutons ce qui confirme l'opinion commune que la chèvre s'adapte mieux aux conditions difficiles qui prévalent dans les régions aride et semi-aride que les moutons. En outre, l'empreinte eau de la viande est principalement déterminée en*

fonction de la nature des aliments distribués aux animaux, par conséquent plus les aliments incorporés dans la ration ont une faible WF tels que le cactus, plus le WF pour la production de la viande est faible.

Mots-clés. *Empreinte hydrique–petits ruminants–viande–système agro-pastoral–Sidi Bouzid.*

I – Introduction

Global demand for food is expected to increase by 70% in 2050 as a result of population growth, which is expected to peak at 9.2 billion by 2075 (FAO, 2013). To meet this demand, the worldwide production of agricultural and food products should be at least doubled. This important demand foragri-food products will put further pressure on natural resources mainly freshwater resources. Furthermore, threatening food security in both the developed and developing countries. Livestock production has been identified as an important source of humanity's burden on freshwater resources (Mekonnen and Hoekstra, 2012) that are overexploited in many parts of the world (UNESCO-WWAP, 2009). The accumulation of human pressure is the main cause of many environmental issues and world leaders face the challenge of developing appropriate policies and investments to prevent further detrimental effects (Galli et al., 2013). Therefore, in order to monitor the pressures on fresh water resources induced by human activities, water footprint indicator was performed to measure the pressure on water resources (Fang et al., 2014). The water footprint (WF) of consumption of a system, process, or geographic area is the freshwater required to produce goods or services (Hoekstra and Chapagain 2007; Hoekstra, 2009; Hoekstra et al., 2011). Additionally, with the expected increase of livestock production in developing countries, these problems are likely to become even more serious. Tunisia is one of the driest countries in the Mediterranean area with very limited water resources. The country is currently experiencing extreme summer temperatures, decreasing precipitation and more frequent periods of extreme drought and wetness. Water resources in Tunisia are already overexploited. Small ruminants' production is the main source of income of many households in the region of SidiBouzid (Central Tunisia). Water scarcity is threatening this sector.This study aimedto assess water footprint of sheep and goat meat produced in the community of Zoghmar in SidiBouzid. This indicator could help reducing water use in this semi arid region. Additionally, this study compares WF of sheep and goat meat to assess the profitability from raising either sheep of goat in this region.

II – Methods and data

1. Area of study and farming systems description

The study was conducted in Zoghmar community in SidiBouzid located in Central Tunisia (Figure.1).It is characterized by less than 350 mm rainfall per year and periodic droughts. Agro-pastoral system is the dominant production system, and people get their incomes from both small ruminants and crop production. The majority of farm households in this region are on small agro-pastoral farms. Surveys were conducted in 50 farms from this community where sheep and goat production is an important activity. This survey was also performed to determine diet composition among season, animal watering, fodder crops types and herd management.

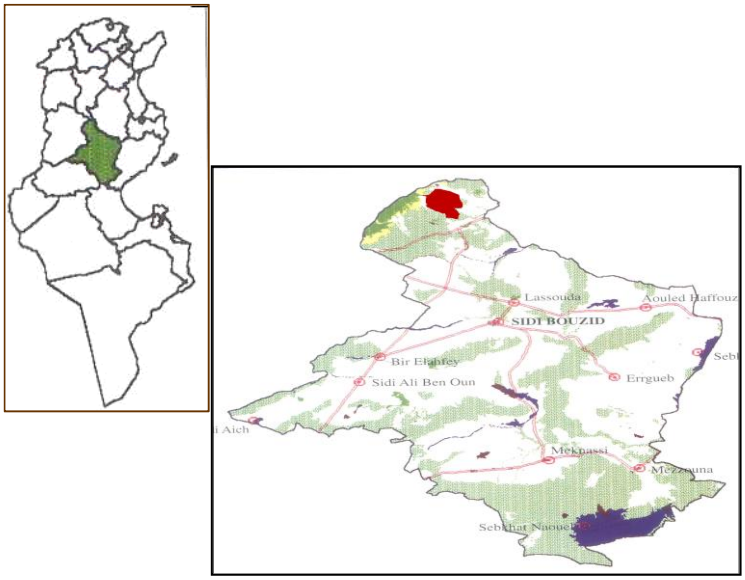

Fig. 1. Localization of the governorate of SidiBouzid and Zoghmar Community (Tunisia).

2. The water footprint concept

The Water Footprint concept (WF) was introduced in response to the need for a consumption-based indicator of freshwater use (Hoekstra, 2003). The WF is an indicator that looks at both direct and indirect water use of a consumer or producer. The WF of an individual, community or business is defined as the total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in terms of water volumes consumed (evaporated or incorporated into a product) and/or polluted per unit of time.

A water footprint can be calculated for a specific product,e.g. WF for meat or milk, for any well-defined group of consumers (for example, an individual, family, village, city, province, state or nation) or producers (for example, a public organization, private enterprise or economic sector). The WF is a geographically explicit indicator, showing not only volumes of water use and pollution, but also the locations (Hoekstra and Chapagain, 2008). Three key water components are tracked in its calculation: The green water footprint refers to consumption of green water resources (rainwater in so far as it does not become run-off).The blue water footprint refers to consumption of blue water resources (surface and groundwater).The grey WF of a product refers to the volume of freshwater required to assimilate the load of pollutants based on existing ambient water quality standards (Hoekstra, 2009).

Water footprint of animal and animal products

The water footprint of sheep and goat consists of different components: the indirect water footprint of the feed and the direct water footprint related to the drinking water and service water

consumed on-farm and slaughterhouse activities (Chapagain and Hoekstra, 2003, 2004). The water footprint is expressed as:

$WF_{sheep, goat} = WF_{feed}[a, c, s] + WF_{drink}[a, c, s] + WF_{service}[a, c, s]$

Where WF feed [a, c, s], WF drink [a, c, s] and WF service [a, c, s] represent the water footprint of an animal for animal category a in country c in production systems s related to feed, drinking water and service water consumption, respectively. Service water refers to the water used to clean the farmyard, wash the animal and carry out other services necessary to maintain the environment. The WF of an animal and its three components can be expressed in terms of m3/yr/animal, or, when summed over the lifetime of the animal, in terms of m^3 /animal.

The WF of meat will be calculated based on the WF of the animal at the end of its lifetime, the water consumed for processing the slaughtered animal into meat, the amount of meat derived from one animal, and the relative value of meat compared to the value of other products derived from the animal. The WF of meat expressed on liter/kg of carcass weight.

The water footprint of animal feed

The water footprints of animal feeds (crops, roughages and crop by-products) were estimated using a crop water use model that estimates crop water footprints at a 5 by 5 arc minute spatial resolution globally. Grey water footprints were estimated by looking at leaching and runoff of nitrogenfertilisers only, following Mekonnen and Hoekstra (2010a,b).

III – Results and discussion

This study showed that the typical diet used for both sheep and goat in the community of Zoghmar across seasons includes 30 to 50% of concentrate feeds (barley, wheat bran orcommercial concentrate). In summer and autumn seasons, farmers rely on cactus cladodes to replace part of concentrate feeds and gross feedstuffs (stubbles, oat hay, and straw). Sheep and goat raised in thissemi-arid region are in most cases grazing on degraded rangelands.

Figure 2 shows that chopped cactus cladodes, olives leaves, stubbles and range vegetation have lower total WF than the other livestock feeds used by farmers. Feeds originating from cereals (e.g. barley grains and wheat bran) havethe highest WF in the targetregion. The green WF has the biggest share of the total WF of feed products. For the blue WF, commercial concentrate has the highest blue WF, while range vegetation, stubbles and chopped cactus were mainly rainfed. Goat meat has the lowest WF (4521 liter /Kg of carcass) compared to sheep meat which has a WF averaging6222liter /Kg of carcass (Figure 3). Similar results were obtained by Mekonnen and Hoesktra (2010b). This difference couldbe ascribed to the higher feed conversion efficiency in goat than in sheep. Difference in foraging and selecting behaviour of these two species could be also another reason. Since concentrates have higher WF than roughages, the ratio forage to concentrate affects WF of meat..

These findings confirm that goat is better adapted to harsh conditions than sheep. In term of water saving, it is recommended for Zoghmar community to produce goat meat instead of sheep which is less sustainable in terms of water use. In order to reduce the WF of meat it is suggested to use feeds having high water productivity such as cactus (Ben Salem and Abidi, 2009). Therefore, cactusholds promise to increase farmers' income by increasing the economic water productivity.

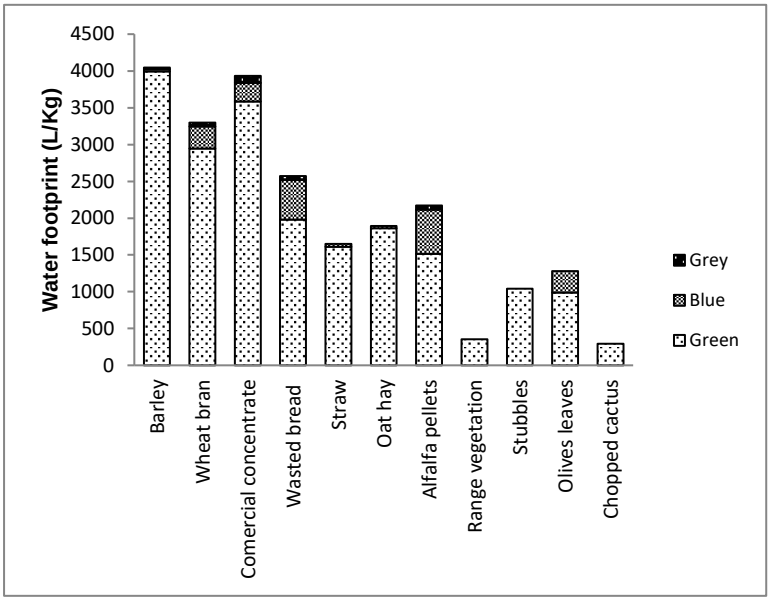

Fig. 2.Average water footprint of animal feed (liter /kg).

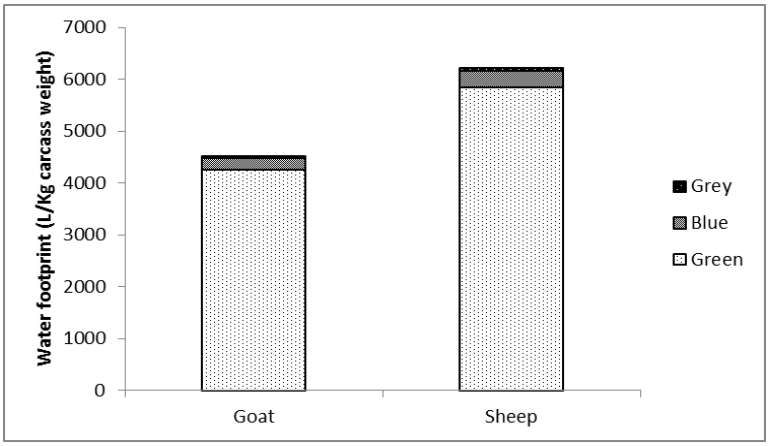

Fig.3. Average water footprint of sheep and goat meat produced in Zoghmar community.

IV – Conclusions

Our study shows that water footprint is an important indicator for the assessment of water use and its allocation. It helps analyzing the sustainability of livestock systems in terms of water use efficiency for each animal category. In addition, there are many options to improve water use efficiency for livestock production in the arid and semi-arid areas. Interventions such as rangeland rehabilitation to improve biomass availability, expanding the plantation of some shrub species and cactus, and diet manipulation to increase growth rates and carcass yields of animals. This would enhance the feed conversion efficiency, thus optimizes the profitability from water use. Lower water requirements by goat raised for meat production in Zoghmar community supports the conclusion that goat production should be developed in the region of SidiBouzidalthough this region in central Tunisia is reputed by sheep production.

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