VIRTUAL WATER CONTENT OF CATTLE FARMS: A CASE STUDY FOR CAMEL PRODUCTION IN SAUDI ARABIA

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ABSTRACT

Lack of freshwater is becoming an issue worldwide. The best management of water resources requires understanding of sector wise water consumptions. Assessment of virtual water content (VWC) for the cattle farms can assist in better understanding of water consumption in this sector. In this paper, VWC was estimated for producing camel in the cattle farms in different regions of Saudi Arabia. VWC were compared and their trends were analyzed for the period of 2006-2010. Productions of camel showed decreasing trend between 2006 and 2010, with the head counts of 0.284 and 0.213 million respectively. The unit VWC for producing camel has been estimated to be 23211 m^3/ton. In the entire country, VWC for camel were predicted to be 4406 and 3336 million cubic meter (MCM) in 2006 and 2010 respectively (24.3% decrease). Riyadh had the highest VWC (1416-1888 MCM/yr), representing approximately 42.2-43.5% of total VWC for camel in the country. The VWC for camel showed decreasing trends in Riyadh, Qaseem, Eastern region, Asir, Tabouk, Hail and Makkah, and increasing trends in Madinah, Jazan and Al-Baha. This study is likely to fill the gap in the literature, as the information on VWC for camel is seldom available, while camel is a significant meat contributory cattle in many Middle Eastern countries. This study may be useful in predicting water footprint for cattle production to better plan for water resources management.

Keywords: Virtual water content, water conservation, cattle farms, shift in dietary consumption

1. Introduction

Water footprint (WFP) has been increasingly used as an indicator of water consumption (Hoekstra, 2003; Chapagain and Hoekstra, 2003). WFP shows the extent of water use related to consumption of populations. Past studies have reported that the major fractions of national water footprint (NWFP) in a country are due to the agricultural and industrial products while agricultural sectors consume more than 80% of the global freshwater supplies (Mekonnen and Hoekstra, 2011). The cattle farms, agricultural products are extensively used, which have an important role in the management of NWFP. The WFP concept is closely linked to the concept of virtual water. Virtual water is defined as the volume of water required to produce a commodity or service. In assessing NWFP, it is essential to quantify virtual water in the products that are produced and consumed within the country, and flow of virtual water leaving and entering the country (Hoekstra and Chapagain, 2007). Quantification of virtual water content (VWC) in the cattle produced through farming plays an important role in understanding the NWFP of a country. VWC identifies the type of cattle responsible for the larger fractions of water consumption, and thus provides an opportunity to adjust their productions to lower NWFP.

Various cattle (e.g., camel, cow and chicken) and egg are produced through in-house and open grazing farming in Saudi Arabia (SSYB, 2011). VWC for these cattle can vary depending on the climatic condition, region and approach of farming. For example, Chapagain and Hoekstra (2003) predicted the VWC for 1 ton of cow and poultry in Saudi Arabia as 11,359 and 4,146 m^3 respectively. In Egypt, these were 15752 and 2268 m^3/ton respectively, while in Germany, these were 7768 and 877 m^3/ton respectively. In Saudi Arabia, climatic conditions in different regions are variable, which can affect the VWC of a cattle. Further, farming practices and feed consumptions are tempo-spatially variable. In addition, the country produces considerable amount of camel, while camel is not typically produced in most countries, and the VWC for camel is seldom available in literature (Chapagain and Hoekstra, 2003). As a result, data on VWC in the past studies may not reflect the Saudi Arabian farming practices and cattle adequately (Chapagain and Hoekstra, 2003; Mekonnen and Hoekstra, 2010, 2011). To better explain the VWC for the cattle farms in Saudi Arabia, assessment of VWC for camel is necessary. The VWC can provide a direction to allocate camel production for maximizing water conservation in different regions. In this study, VWC for producing camel in Saudi Arabia were predicted and the trends of VWC were analyzed.

2. Methodology

2.1. Study area and data collection

Saudi Arabia is divided into 13 administrative regions. The main farming animals include camel, cow, milking cow, sheep, goat and poultry while significant quantity of egg are also produced. Data on camel productions for the period of 2006-2010 were obtained from the Saudi Statistical Yearbook (SSYB, 2011). The feeding compositions, feeding styles and water consumptions prior to reaching to the slaughtering ages were obtained from literature and field survey (Chapagain and Hoekstra, 2003). The survey was conducted in the cattle farms in Qatif, Saudi Arabia. The field data were compared and fused with the available data in the literature (Chapagain and Hoekstra, 2003).

2.2. Calculation of virtual water content

The VWC for camel can be estimated following Chapagain and Hoekstra (2003) as:

$$VWC = VWC_{feed} + VWC_{drink} + VWC_{service} \quad (1)$$

Where, VWC = virtual water content for camel (m^3/animal), VWC_{feed} = VWC for food consumption (m^3/animal), VWC_{drink} = VWC for drinking (m^3/animal), $VWC_{service}$ = VWC for servicing (m^3/animal). In most developing and developed countries, feed is the mixture of crops, crop residues and industrial products (Chapagain and Hoekstra, 2003). In addition to the VWC for feed, water required for feed mixing needs to be added. VWC for feed can be predicted as:

$$VWC_{feed} = (CW \times SA + WFM) \quad (2)$$

Where, CW = total VWC for crops used as feed (m^3/year), SA = slaughtering age (yr); and WFM = water for feed mixing (m^3/animal). Water for mixing is approximately 50% of the feed amount consumed by the cattle (Chapagain and Hoekstra, 2003). To assess CW, data on specific water demand (SWD) of the feed crops and average feed amount (AFV) are necessary. Abbas (2003) predicted crop water requirements (CWR) for the major crops produced in Saudi Arabia. CWR were divided by the crop yields to obtain SWD for different crops. Data on AFV were obtained through field survey and literature (Chapagain and Hoekstra, 2003; Khan *et al*. 2003; Abdallah and Faye, 2013). The SWD is multiplied by AFV to obtain the CW for a specific crop. Table 1 shows the CW for feed requirement in a year for producing a camel. Average values of slaughtering age, average daily water demands for drinking, servicing, feed intake and mixing are also shown in Table 1. Water for drinking and services for an animal depends on local weather condition (i.e. temperature, humidity, rainfall etc.) and farming approach. These can be estimated as: $VWC_{drink} = ADD_d \times SA \times 365$; and $VWC_{service} = ADD_s \times SA \times 365$. Where, ADD_d = average water consumption per animal (m^3/day), ADD_s = average water demand for service per animal (m^3/day), 365 = conversion factor from year to day.

The unit virtual water content (VWC_u) is estimated as the VWC per unit weight. By knowing the weight of an animal, VWC_u can be predicted from Equation 1. Farming practices play an important role in predicting VWC_u. Farming practices were assumed to be 'mixed' type, meaning the mixture of 'grazing' and 'industrial' feedings, which is consistent to Chapagain and Hoekstra (2003). Gerbens-Leenes *et al*. (2011) reported that the cattle produced through industrial farming had more weights than those of the 'grazing' farming. Chapagain and Hoekstra (2003) reported similar findings. In this study, average weights of the grazing and industrial farming were considered for 'mixed type' farming. Total VWC of camel can be calculated as: $VWC_t = VWC_u \times W$. Where, VWC_t = VWC for the camel (m^3/yr), W = Total weight of camel produced in a year (ton/yr). W can be obtained as: W = LW ×N, where LW = Live weight of camel (ton/animal); N = No. of camel slaughtered in a year.

Table 1: Calculation of VWC for camel

Feed crop	SWD	AFV	CW
Wheat	1321	0.53	700
Oats	2448	0.12	294
Barley	787	0.237	187
Dry peas	1377	1.2	1652
Soyabean meal	1227		
Canola meal	1098		
Mill screen	1441		
Total grain		2.087	
Non grain portion	413		
Pasture	862	1.26	1087
Total feed volume		3.347	
Total water for feed per year			3919

Slaughtering age (years)	4
ADD_d (L/day)	30
ADD_s (L/day)	6.5
VWC_{drink} (m^3/camel)	43.8
$VWC_{service}$ (m^3/camel)	9.49
Water for feed (m^3/camel)	15676
Water for feed mixing (m^3/camel)	6.694
Total VWC (m^3/camel)	15737
Weight of camel (kg/camel)	678 (630 – 726)
VWC_u (m^3/ton of meat)	23211 (21676 - 24979)

SWD: Specific water demand for crop (m^3/ton); AFV: average feed amount (ton/year); CW: crop water (m^3/year); ADD_d: Average daily demand for drinking (L/day); $ADD_{service}$: Average daily demand for servicing (L/day)

3. Results

Approximately 0.284 and 0.213 million of camel were produced in Saudi Arabia in 2006 and 2010 respectively, indicating a decrease of 25% (SSYB, 2011). Production of camel was highest in Riyadh, contributing 41.5–43.7% of total camel in the country. The other major regions producing camel are Qaseem, Eastern region and Makkah, contributing 9.4 – 14.1%, 8.0 – 12.0% and 7.2 – 9.4% respectively. Camel production shows decreasing trends in most regions (4.8-66.7% reduction) except Madinah, Jazan and Al-Baha (33.3-100% increase). On average, one camel consumes 3.35 tons of feed annually, in which 2.1 tons are grain/grain products (wheat, dry peas, etc.). This feed is equivalent to the feed for 1.5 meat producing cows or 192 chickens (Chapagain and Hoekstra, 2003; Khan *et al*. 2003; Abdallah and Faye, 2013). The live weight of a camel produced through grazing, mixed and industrial farming are 630, 678 and 726 kg respectively (Chapagain and Hoekstra, 2003). For mixed farming, which is followed in Saudi Arabia, VWC for 1 ton of camel meat has been predicted to be 23211 m^3, while the VWC for the industrial and grazing farm grown camel were 21676 and 24979 m^3 per ton respectively. VWC for camel are shown in Table 2. In Riyadh, VWC were 1416 – 1888 million cubic meter (MCM) per year during 2006 – 2010, contributing 42.2 – 43.5% of total VWC for camel in the country. The other major regions for VWC are Qaseem, Eastern region and Makkah contributing 9.4 – 14.1%, 8.0 – 12.1% and 7.2 – 9.4% of total VWC respectively.

The VWC in 2006 were 1888, 535, 535, 346 and 330 MCM in Riyadh, Qaseem, Eastern region, Hail and Makkah respectively. In 2010, these values were 1416, 315, 268, 283 and 315 MCM respectively, representing the decrease of 25, 41.2, 50, 18.2 and 4.8% respectively. Conversely, VWC in Madinah, Jazan and Al-Baha were 94.4, 47.2 and 63 MCM in 2006, which were increased by 100, 33.3 and 75% in 2010 respectively. Northern borders do not produce notable amount of camel (Table 2). VWC for camel in the entire country for 2006 through 2010 are shown in Figure 1. In 2006 and 2010, VWC were 4406 and 3336 MCM respectively (24.3% decrease). The overall VWC showed a decreasing trend. The rate of VWC decrease was estimated to be 291 MCM per year.

Table 2: VWC for producing camel in different region of Saudi Arabia

Region	2006	2007	2008	2009	2010	Change (%)
Riyadh	1888	1888	1574	1574	1416	-25.0
Makkah	330	315	283	299	315	-4.8
Madinah	94	110	126	157	189	100.0
Qaseem	535	504	535	362	315	-41.2
Eastern Region	535	504	378	330	268	-50.0
Aseer	205	220	157	142	110	-46.2
Tabouk	47	63	31	31	16	-66.7
Hail	346	362	299	315	283	-18.2
Jazan	47	47	63	63	63	33.3
Nazran	157	173	126	157	157	0.0
Al-Baha	63	63	47	79	110	75.0
Al-Jouf	157	142	110	110	94	-40.0

4. Conclusions

This study predicted VWC for camel through farming in different regions of Saudi Arabia. To date, not many studies are available to predict water consumptions for these farms. Despite many studies are available globally on the assessment of VWC of many animals, availability of VWC for camel is rare. To my knowledge, this is the first initiative to assess the VWC for camel, while camel contributes significant fractions of meat in the Middle Eastern region. Past studies have predicted VWC for the farm animals using gross national income (GNI), where farming practices were assumed as grazing, mixed and industrial for GNI < 1200, 1200 < GNI < 17000 and > 17000 US$/yr/capita respectively. However, this classification have ignored the effects of local food ingestion patterns and farming practices. There is a need to better understand the VWC for the other animals produced through framing in the country. Future study need to include the effects of climate change on the VWC for different animals produced through farming.

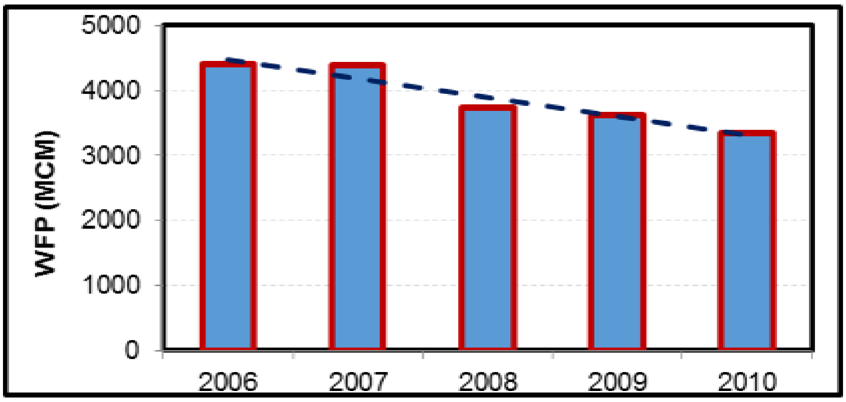

Figure 1: Trend of VWC for producing camel in Saudi Arabia

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