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ASSESSMENT OF WATER FOOTPRINT OF GRAPE INDUSTRY: A CASE STUDY

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ABSTRACT

This study quantifies the total water footprint of a grape industry, where the export of grapes occurs in large scale. The total water required by the industry and the water utilized for growing of grape crop was studied by this project. This industry lies in Mohadi village of Dindori Tehsil of Nashik district of Maharashtra state in Western India. The area lies between 19°99' N Longitude and 73°78' E Latitude. This area comes under dry zone. This is situated at an altitude of 660 m above mean sea level. The results indicated that the Green water footprint of grape crop was 496.53 m^3/ton; Blue water footprint was 132.8 m^3/ton; Grey water footprint was 51.73 m^3/ton and the total water used in the grape export process was 1.18 m^3/ton. Thus the total water footprint for grape crop was calculated and it was 682.24 m^3/ton equals to 682.24 litres/kg of grapes.

Keywords : Crop Water Use, Grape Export, Maximum Acceptable Concentration, Process Water Use, Water Footprint

I. INTRODUCTION

Water is a natural resource and a basic human need. It gives life and livelihood. It is also a basic need for any planning and development. Due to population growth, irrigation and industrialization, the demand for water has gone to a large extent and has been subjected to a variety of pressures. So appropriate management and judicious use of water is necessary and is an important part of sustainable development. There has been little attention paid to the fact that, in the end, total water consumption and pollution relate to what and how much community consumes and to the structure of the global economy that supplies the various consumer goods and services. Until the recent past, there have been few thoughts in the science and practice of water management about water consumption and pollution along whole production and supply chains.

Hoekstra and Chapagain (2008) have shown that visualizing the hidden water use behind products can help in understanding the global character of fresh water and in quantifying the effects of consumption and trade on water resources use. The improved understanding can form a basis for a better management of the globe's freshwater resources.

Water footprint is the amount of fresh water utilized in the production or supply of the goods and services used by a particular person or group. It includes the water used directly and also the water it took to produce the food you eat, the products you buy, the energy you consume and even the water saved in recycle. The water footprint

is an indicator of use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. It is the volume of freshwater used to produce the product, measured over the full supply chain.

The blue water footprint refers to consumption of blue water resources (surface and groundwater) along the supply chain of a product. 'Consumption' refers to loss of water from the available ground-surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area or the sea or is incorporated into a product. The green water footprint refers to consumption of green water resources (rainwater in so far as it does not become run-off). The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards.

The aim of the study is to estimate green, blue and grey water footprint of Grape crop and its export. We quantify the green, blue and grey water footprints included in Grape export by using different formulae. Attempt has been made to study water footprint in the project entitled as "Assessment of Water Footprint of Grape Industry: A Case Study", with the following objective: "To determine the water footprint of Grape industry at Nashik."

II. METHODS

The formulae derived by Hoekstra and Mekonnen (2008) to determine the water footprint was used for calculating the water footprint of grape industry.

2.1 Study Area

A Grape Industry Sahyadri Farmers' Producers Ltd. was selected as study area for the present project work. The SFPCL has a set up over an area of 63.5 acres and budget is near about 120 crore rupees. Plenty of the water with canal and well irrigation source, skilled and unskilled labor and required inputs are available in surrounding area.

2.2 Calculation of the water footprint of a grape

2.2.1 Calculation of Green Water Footprint

First, the green water component was calculated. Crop water requirement (CWR) was calculated by multiplying the crop coefficient (K_c) by the reference crop evapotranspiration ET_0 (mm/day).

$$: CWR = K_C \times ET_0 \quad (1)$$

When rainfall is insufficient to compensate for the water lost by evapotranspiration irrigation is required. The irrigation requirement (IR) is zero when the effective rainfall (Peff) exceeds the CWR and otherwise equal to the difference between the CWR and effective rainfall.

$$: IR = Max\left(0, CWR - P_{eff}\right) \quad (2)$$

The green water evapotranspiration is equal to the minimum of CWR and effective rainfall.

$$: ET_g = Min\left(CWR, P_{eff}\right) \quad (3)$$

The crop water use (CWU) as defined by Hoekstra (2008) consists of the green (CWU_g) component and is the accumulation of daily evapotranspiration over the complete growing period. The CWR is given in mm and is multiplied by the factor 10 to convert into m^3/ha.

$$: CWU_{green} = 10 \times \sum_{d=1}^{n} ET_{green} \quad (4)$$

To calculate the green component of the water footprint of a product (WF_g, m^3/ton), the crop water use divided by the yield (Y, ton/ha).

$$: WF_{proc,green} = \frac{CWU_{green}}{Y} \quad (5)$$

2.2.2 Calculation of Blue Water Footprint

In case no irrigation is applied blue water evapotranspiration is zero. Otherwise the blue water evapotranspiration is the minimum of the irrigation requirement and the amount of irrigation water that is available for plant uptake (I_{eff}).

$$: ET_b = Min(IR, I_{eff}) \quad (6)$$

The CWR is given in mm and is multiplied by the factor 10 to convert into m^3/ha. And the crop water use component of blue water footprint is calculated.

$$: CWU_{blue} = 10 \times \sum_{d=1}^{n} ET_{blue} \quad (7)$$

The blue component of the WF (WF_b, m^3/ton) was calculated by dividing the blue crop water use by the yield (Y, ton/ha).

$$: WF_{proc,blue} = \frac{CWU_{blue}}{Y} \quad (8)$$

2.2.3 Calculation of Grey Water Footprint

The third component of the WF is grey water (WF_{grey}, m^3/ton). That is calculated as the load of pollutant that enters the water system (L, kg/ha) divided by the maximum acceptable concentration for the pollutant considered (C_{max}, kg/m^3) and the crop yield for one cropping season (Y, ton/ha).

$$: WF_{grey} = \frac{L/C_{max}}{Y} \quad (9)$$

2.2.4 Calculation of total water footprint

The total WF can now be calculated by accumulating the three components:

$$: WF_{total} = WF_{green} + WF_{blue} + WF_{grey} \quad (10)$$

2.2.5 Calculation of Process Water Use

The water consumed in procedure of grape export is calculated in this step. From all these processes, the major processes during grape export, where water is used in large quantity are **Pre-cooling** and **Cooling**.

2.2.6 Calculation of total water footprint for grape

Total water footprint for exportation of 1 kg grapes is equal to the water footprint of growing season of grape plus the process water used in industry.

III. RESULTS AND DISCUSSIONS

3.1 Green Water Footprint

3.1.1 Crop Water Requirement (CWR)

The Reference crop evapotranspiration ET0 for grape crop is considered as 8mm/day. The crop coefficients for different stages of grape are- initial stage (0.7), development stage (0.9), mid stage (1.15), late stage (0.8). These values are provided by FAO-56. The CWR was calculated from the constant value of ET0 grape crop and the Kc values for each successive stage of grape growing. Crop water requirement of grape crop was **1888 mm/day**.

3.1.2 Irrigation Requirement (IR)

For Nashik, the effective rainfall (Peff) was 1489.6 mm considering the fixed percentage i.e. 80%. The irrigation requirement is calculated by subtracting the effective rainfall from the CWR. The irrigation requirement (IR) is therefore equals to **398.4 mm**.

3.1.3 Green Water Evapotranspiration (ETg)

Green water evapotranspiration ETg of grape crop was **1489.6 mm**.

3.1.4 Crop water use component of green water footprint (CWUgreen)

By multiplying it with 10; the crop water use component of green water footprint (CWUg) was **14896 m^3/ha**.

3.1.5 Green water footprint (WFgreen)

For grape, the on an average yield is 30 tons/ha/yr. Hence, green water footprint (WFgreen) of grape crop was **496.53 m^3/ton**.

3.2 Blue Water Footprint

3.2.1 Plant Water Uptake (Ieff)

The irrigation efficiency considering the drip irrigation was 90% and the plant water uptake (Ieff) was **2076.8 mm**. Therefore, the blue water evapotranspiration is assumed equal to the irrigation requirement.

3.2.2 Blue water evapotranspiration (ETblue)

Blue water evapotranspiration (ETb) of grape crop was **398.4 mm**.

3.2.3 Crop water use component of blue water footprint (CWUblue)

The crop water use (CWU) for blue water footprint is CWUblue and it is also calculated in similar way as CWUgreen. The CWUb was **3984 m^3/ha**.

3.2.4 Blue water footprint (WFblue)

Therefore blue water footprint (WFblue) of grape was **132.8 m^3/ton**.

3.3 Grey water footprint

The pollutants such as nitrogen, phosphorus, potassium and sulphur were considered and the load values were 172.97 kg/ha, 222.39 kg/ha, 271.81 kg/ha and 108.91 kg/ha respectively. The maximum acceptable

concentration for these pollutants was 0.5. Therefore, the grey water footprint (WFgrey) of grape crop was **51.73 m^3/ton**.

3.4 Total water footprint of grape crop for growing season

Hence, the total water footprint of grape crop is the sum of green, blue and grey water footprints and it was **681.06 m^3/ton**.

Table No. 3.1 Water Footprint for growing of Grape Crop

Crop water requirement	1888 mm
Green water evapotranspiration	1489.6 mm
Blue water evapotranspiration	398.4 mm
Green water use	14896 m^3/ha
Blue water use	3984 m^3/ha
Green water footprint	496.53 m^3/ton
Blue water footprint	132.8 m^3/ton
Grey water footprint	51.73 m^3/ton
Total water footprint	**681.06 m^3/ton**

3.5 Process water use

3.5.1 Water used in Pre-cooling

The capacity of pre-cooling chamber is 30 tons/day and 8000 lit/day water is required. Hence, the water required for pre-cooling of 1 ton of grape is 266 lit/ton i.e. **0.266 m^3/ton**.

3.5.2 Water used in Cooling

The capacity of cooling chamber is 50 tons/day and 10000 lit/day water is required. Hence, the water required for cooling of 1 ton of grape is 200 lit/ton i.e. **0.200 m^3/ton**.

3.5.3 Water used by labors

There are 244 labors handling 200 tons grapes. The water required for labors for drinking, washing etc. is around 7 litres/worker. Therefore total water used by workers is 1708 litres/200 tons. For 1 ton of grape handling, the water used by labors is 8.54 lit/ton i.e. **0.00854 m^3/ton**.

3.5.4 Water used in Transportation

The capacity of a vehicle is 14 tons. The distance is around 50 km. Total amount of diesel is 140 litres for 200 tons handling. Hence, 0.7 litre diesel is required for 1 ton of grapes handling. From standard values, 1 litre diesel is equivalent to 10 kWh electricity and thus, 0.7 litres diesel is equivalent to 7 kWh electricity. And for 1 kWh electricity, 72.75 litres of water is required. Therefore, for producing 14 kWh electricity, 512.5 litres of water is required. i.e. **0.51 m^3/ton**.

3.5.5 Water used for Electricity

In industry, around 544.58 kWh electricity is used for mainly pre-cooling and cooling. Therefore converting it into water used as above; the total water required for 1 ton of grapes is **0.198 m^3/ton**.

3.5.6 Total process water use

From above calculations, the total process water used is the sum of water used in pre-cooling, cooling, by labors, in transportation and for electricity. And the total process water used is (0.266+0.200+0.00854+0.51+0.198) = **1.18 m^3/ton**.

Table No.3.2 Water use in industry (Grape export process)

Process	**Water use (m^3/ton)**
Pre-cooling	0.266
Cooling	0.200
Electricity	0.198
Other (Labors)	0.00854
Transportation	0.51
Total Water Use	**1.18**

3.6 Calculation of total water footprint of grape

Total water footprint for production of 1 kg grapes is equal to the water footprint of growing season of grape plus the process water used in industry.

Total WF = 681.06 + 1.18

= **682.24 m^3/ton**

= **682.24 litres/kg**

IV. CONCLUSIONS

Following conclusions are made from the project work:

1) The Green water footprint of Grape was 496.53 m^3/ton, blue water footprint was 132.8 m^3/ton and grey water footprint was 51.73 m^3/ton.

2) The Green water footprint for grape crop is higher than blue and grey water footprint. Hence, it can be concluded that the major water consumed due to evapotranspiration in green water use.

3) The total water footprint for growing of Grape crop was 681.06 m3/ton and the total process water use was 1.18 m^3/ton. Thus, the total water footprint for exportation of 1 kg of grapes is 682.24 m^3/ton. i.e. 682.24 litres/kg.

4) The water required to grow the Grape crop is higher than the water required for Grape export.

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