INNOVATIVE ENERGY TECHNOLOGY SYSTEMS AND ENVIRONMENTAL CONCERNS: A SUSTAINABLE APPROACH
ISBN: 978-93-84144-81-4

Assessment of the Water and Energy Footprint of Organic Potato Production in the Boriavi District of Anand, Gujarat

[1]Saurabh Kumar Patel and [2]Ravi N. Parmar

[1]M.Tech Student and Researcher, CEPT University K.L. Campus, University Road Ahmedabad, Gujarat
[2]M.Tech Student and Researcher, CEPT University K.L. Campus, University Road Ahmedabad, Gujarat

Abstract

The Potato is the world's most important root and tuber crop with recorded cultivation in more than 125 countries and daily consumption by more than a billion people worldwide. Organic potato cultivation is gaining more and more importance due to its ease of cultivation, nutritional content, environmental friendliness, increasing consumer awareness, and the market value. It has been observed that the choice of appropriate potato seed, irrigation methodology, water cycle regime, land preparation, maintenance of standard edaphic conditions helps to minimize the energy & water footprint of the potato production. Use of locally available Liquid Bio-Fertilizer (LBF) can optimize the potato yield and the tuber quality and minimize the need of water in the actual field conditions. Extensively used Flood and Drip Irrigation methods of organic potato cultivation has been compared here to evaluate its production potential and calculation of the water and energy footprint respectively. The average organic potato production in the Flood Method is found to be 10,500Kg/Acre whereas it is about 14,000Kg/Acre in the Drip Irrigation method. Hence, an appropriate selection of the irrigation method coupled with the use of green manure like LBF can enhance the organic potato production by 33 % per acre. The water footprint for the Flood Irrigation Method is found to be 29.17 L/Kg whereas that for the Drip Irrigation Method is 16.07 L/Kg. Similarly, the energy foot print for the Flood Irrigation Method is found to be 249 BTU / Kg and that for the Drip Irrigation Method is found to be 167 BTU/Kg respectively.

Keywords: Organic Potato, Water Footprint, Energy Footprint, Green Manure, Flood Irrigation Method, and Drip Irrigation Method.

1. Introduction

Water is not just critical to the potato yield but a range of other quality measures in the field like soil pH, moisture level, organic & inorganic matter, porosity, etc.

The water and energy footprint makes a link between consumption of resources in one place and impacts on water systems and supply of energy elsewhere. It has a wide range of research and policy applications as it can be applied from single to multiple products, processes, sectors, up to individuals, cities, nations, and at the global level.

ISBN: 978-93-84144-81-4

The concept of 'water footprint' was introduced by Hoekstra (2003) and subsequently elaborated by Hoekstra and Chapagain (2008) provides a framework to analyze the link between human consumption and the appropriation of the globe's freshwater resource. The water footprint of a product is defined as the total volume of freshwater that is used to produce the product (Hoekstra et al., 2009). The water footprint of a product breaks down into a green, blue and grey component over the temporal and spatial scale. Here, we have considered the Blue water consumed in the potato crop cycle. Irrigation water requirement is the water feed to the field artificially. Scope of this primary work is limited to virtual/embodied water. Virtual water is the water required to grow the product and not the water stored within the product.

Energy Footprint is the energy used during a product's entire life cycle in order to manufacture, transport, use, and dispose of the product. In this case, acre based water and energy usage pattern is calculated over the time considering the multiple steps involved in the water and energy cycle of the organic potato production. Both the methods are considered resource efficient with higher productivity as compared to the other conventional field methods. This research primarily aims to find out which method amongst the two is more resource efficient with respect to the consumption of water and energy use.

2. Study Area Profile

Boriavi is a Municipal Corporation, Industrial and Residential agglomeration of the Anand city located in the Anand District of Gujarat. The land of Boriavi is one of the highly valued "Vegetable Belt of India" and is one of the most prosperous town of Gujarat with centrally supplied Reverse Osmosis water supply facility to each of the city's households. Every summer, the locals come together to celebrate the 'Annual Batata or Potato Festival' using various rituals to symbolize fertility and prosperity of the region. Anand Agricultural University has newly developed Liquid Bio-Fertilizer (LBF) using locally available derivatives of plants, animal body wastes, and other related organic materials. It is notable to mention that the chemical fertilizers cost up to Rs 28,000 per hectare for growing crops such as Potato and Ginger whereas the use of LBF can cut down the cost to below Rs 4,000/hectare leading to substantial low cost of the crop production.

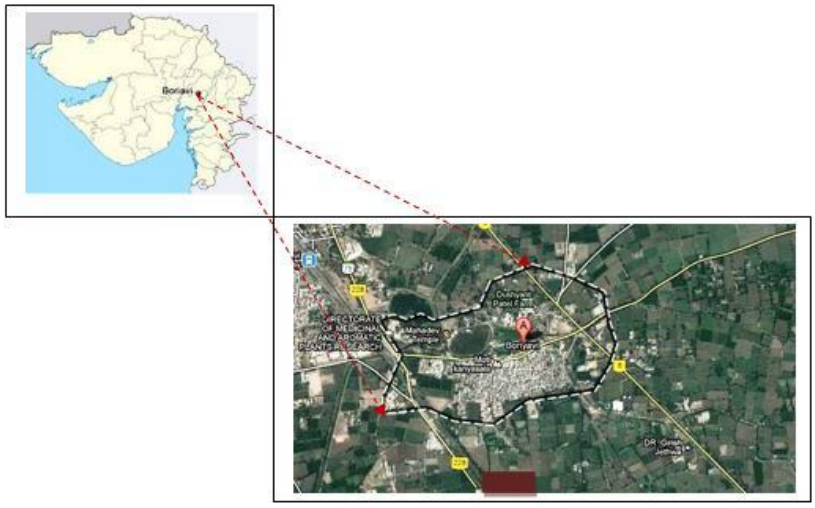

Fig. 1: Locations of the 1 Acre Land (Brown Rectangular) under the Organic Potato Cultivation in Boriavi District, Anand, Gujarat as on November, 2013.

ISBN: 978-93-84144-81-4

The cultivation of the organic Kurfi Pukhraj or C-166 variety of potato usually happens in the winter season between 15th November to 02nd February every year in the Boriavi region of Anand district under the favorable climatic and edaphic conditions. It is in high demand due to its waxy texture, mild flavor, ease to cook, and minimum discoloration after cooking. It is not suitable for the processing. Climate of the study area during the 90-110 days crop cycle for the year 2013 ranged between 16° C to 30° C. The average annual rainfall in the preceding monsoon months of 2013 was about 1100 mm. The soil type of the cultivable land was Goradu Sandy Loam which is a type of Black Soil favorable for harboring the organic potato cultivation.

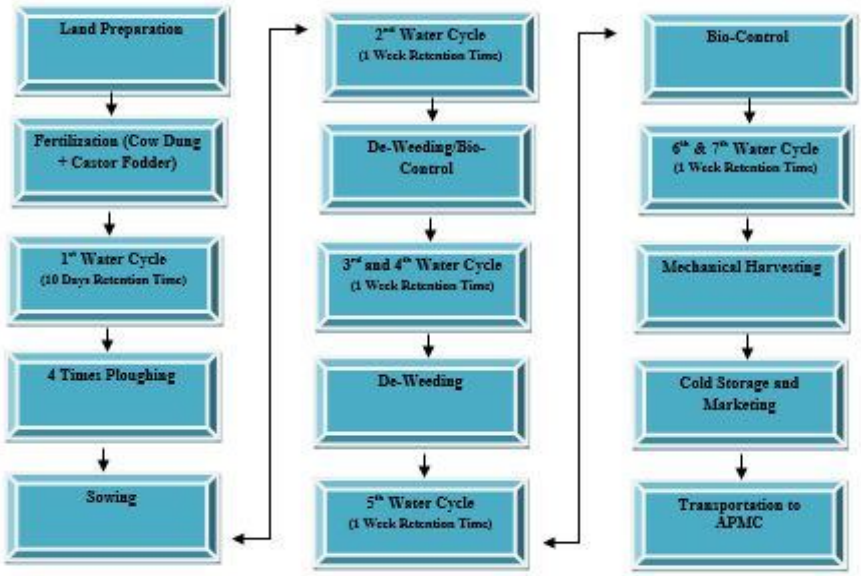

Fig. 2: Flow Diagram of the Steps Involved in the Organic Potato Crop Cultivation (Solanum tuberosum) of C-166 Variety

Table 1: Geographical, Demographic, and Agricultural Profile of the Boriavi District, Anand

Head	Distribution
Village	Boriavi
District	Anand
GPS-Coordinates	22.6276°N, 72.9347 °E
Population (2011)	19,853
Males	10,281
Females	9,572
Literacy Rate Males	8,622
Literacy Rate Females	6,604
Total Agricultural Land Area	1,460 Acres
Total Potato Growing Area	1,000 Acres
Soil Type	Black Soil
Major Crops	Ginger, Potato, Turmeric
Crop Market	Anand/Baroda APMC

Source: Boriavi Nagarpalika, Boriavi, Anand
Note: APMC- Agricultural Produce Market Committee

ISBN: 978-93-84144-81-4

3. Methodology

In this study, we have evaluated two cases of Organic Potato Production in one acre land area of Anand, Gujarat to perform the calculations of the Water and Energy Footprints respectively. For the Calculation of the Water Footprint, we have adopted a well-established method known as Volumetric Method (Hoekstrea and Copengain, 2008). Extensively used Flood and Drip Irrigation Method was used to calculate the water and energy consumption for both the methods in the actual field conditions. Key parameters which were considered during the calculation are the site conditions, total irrigated land area, seed quantity requirements, volume of water used, and total time required for the irrigation. The field based experiment also takes into account the energy consumed through the combustion of diesel in the various operation of potato cultivation like land preparation, ploughing, sowing, harvesting, and transportation of the crop to the cold storage facility and later to the market.

Formulae used for the calculation of the Footprints are:

Water Footprint (WFK)=Total Water Consumed (Liters) / Total Quantity Produced (Kgs)

$$WFk = WC/QT$$

Energy Footprint (EFK)=Total Electricity Consumed (kWh) / Total Quantity Produced (Kgs)

$$EFk = EC/QT$$

4. Data Analysis and Calculations

The present study is on Acre based calculation of potato crop production. Data analyzed is purely based on actual farm practice at the experimental site and the raw numeric data with respective applicable method.

4.1 Water Footprint

The given analyses consider only blue or surface water for the calculations of the footprint in:

Flood Irrigation. Flood irrigation is most common method of irrigation in India however it tends to consume more water as per the actual trials in the agricultural land. During whole crop cycle water consumption had been calculated through digitized meter at the farm bore well with the live time recording frame.

Drip Irrigation. It is a moderately expensive irrigation method, but consume lesser water than the flood irrigation method. Drip Irrigation is equipped with the water meter with the live time frame. Metered unit is pre calibrated as per the standards.

Table 2: Water Footprint Calculation For Per Acre Potato Grown in the Flood Irrigation Method.

Sr. No.	Subsequent Site Preparation	Time Required in Hours	Amount of Water Required in Liters
1	Initial Land Preparation	4 Hours	75,150
2	1st Water Cycle	1 Hours and 45 Minutes	31,500
3	2nd Water Cycle	1 Hours and 45 Minutes	31,500
4	3rd Water Cycle	1 Hours and 45 Minutes	31,500
5	4th Water Cycle	1 Hours and 45 Minutes	31,500
6	5th Water Cycle	1 Hours and 45 Minutes	31,500

ISBN: 978-93-84144-81-4

7	6th Water Cycle	2 Hours	36,000
8	7th Water Cycle	1 Hours and 10 Minutes	37,800
	Total	**14 Hours and 35 Minutes**	**3,06,450**

***Note*:** 7.5 hp water motor pump discharges about 18,000 liters of water /hour.

Table 3: Water Footprint Calculation For Per Acre Potato Grown in the Drip Irrigation Method.

Sr. No.	Subsequent Site Preparation	Time Required in Hours	Amount of Water Required in Litres(*)
1	Initial Land Preparation (By flooding)	4 Hours	75,000
2	Alternate day Water Cycle	25 min of water cycle on daily basis for an acre of land as per the design of Pump for 60 days.	150000
	Total		**2,25,000**

***Note*:** 2 hp water motor pump discharges about 6,000 liters of water /hour.

4.2 Energy Footprint

The given analyses consider both the mechanical energy and electrical energy used in potato production for the calculations of the footprint:

Mechanical Energy. Here the energy of the diesel used in land preparation, sowing, harvesting, etc. is calculated as a part of energy footprint using the diesel conversion factor to the total diesel consumption in MJ/L.

Electrical Energy. Here the energy utilized in the irrigation and the cold storage facility of the entire single crop life cycle of potato is calculated as per the standard agronomic field practice.

Table 4: Fuel Requirements for the Ploughing, Seed Cultivation, Sowing, Harvesting, and Transportation of Crop to the Market.

Sr. No.	Agricultural Activity	Diesel Required in Litres	Energy Equivalent MJ	Energy Used In form of KWH
1	Land Preparation (Ploughing)	9	314.28	87.3
2	Sowing	5	174.6	48.5
3	Harvesting	4	139.68	38.8
4	Transportation to Cold Storage	4	139.68	38.8
5	Transportation to APMC (To & Fro)	34	1187.28	329.8
	Total	**56**	**1955.52**	**543.2**

Note: We have considered Zitell Wemer & Reinhold Conversion Factor as:
1L Disel=34.92 MJ/L
1 Mega Joule (1 MJ)=0.277778 kilowatt-hour

ISBN: 978-93-84144-81-4

Table 5: Energy Required for the Cold Storage of Seeds for about 8 Months Period.

Sr. No.	Cold Storage Capacity	Electrical Unit/ Month
1	80,000 Bags	20,000 Units
2	1 Bags	0.25 Units
3	22 Bags	5.5 Units
	For 8 months storage **	**48.4 units**

Note: 1 Bag=20 Kgs of Potato
1 Unit=1 KWh~3600K Joules
**Energy Consumption including 10 % Loss is Considered

Table 6: Energy Required for the Irrigation and Mechanical Land Preparation in the Field

Potato Cultivation Process	Total Energy used in Flood Irrigation Method Electrical Unit (KWH)	Total Energy used for Drip Irrigation Method Electrical Unit (KWH)
For Irrigation	227	147.6
For Mechanical Land Preparation and Transportation	543	543
Total Used Energy	**770**	**690**

4.3 Final Footprint Calculations

For per Kg calculation of the Organic Potato Production:

EF=EC/Qt

Where, EC=Total Energy Unit Consumed for a Crop; Qt =Total Produce)

For Flood Irrigation Method: 770/10,500=0.073 KWH=249.08 BTU/ Kg

For Drip Irrigation Method: 690/14,000 =0.049KWH=167.19 BTU/Kg

EC=Total Energy Unit Consumed a Crop; Qt=Total Produce $\{E_{(BTU)}=3412.14163312794 \times E_{(kWh)}\}$

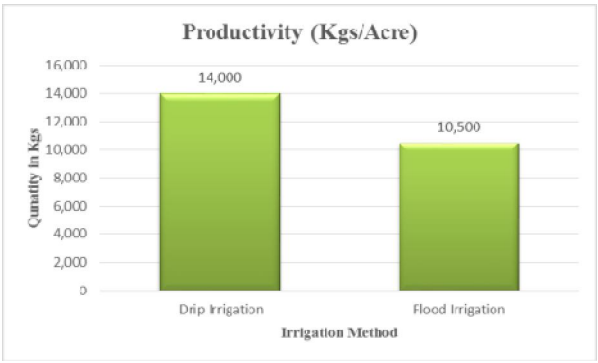

Fig. 3: Potato Production in Kgs/Acre

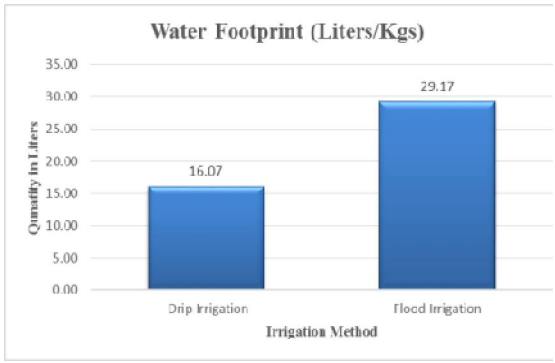

Fig. 4: Water Footprint in Liters/Kg.

ISBN: 978-93-84144-81-4

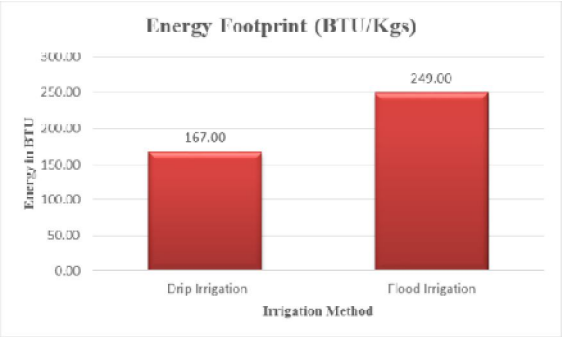

Fig. 5: Energy Footprint in BTU/Kg.

5. Recommendations

1. Water consumption and pollution related to consumption and usage should be factored into the price of the traded commodities.
2. There is need for the National Water Footprint reduction targets and a National Water Pricing Protocols in India.
3. Coherent Energy-Water Management Strategies can foster the Climate Smart Agriculture Practices in India.
4. Drip Irrigation method in combination with the organic bio-fertilizers should be promoted for the sustainable agriculture.
5. In favor of the National Agricultural Policy, there is need to subsidize the Drip Irrigation method so as facilitate its adequate penetration into the agricultural fields and facilitate sustainable growth of agriculture at the rate of 4 % per annum.

6. Conclusion

As per the study, the Organic Potato Production in the Flood Irrigation Method is found to be about 10,500 Kgs/Acre (525Mann/Acre) whereas in the Drip Irrigation Method it is about 14,000 Kgs/Acre (700Mann/Acre). Also, according to our calculations the Water Footprint for Flood Irrigation Method is about 29.17 L/Kg whereas that for the Drip Irrigation Method is 16.07 L/Kg. Also, the Energy Foot Print for the Flood Irrigation Method is found to be 249 BTU / Kg and that for the Drip Irrigation Method is found to be 167 BTU/Kg. Hence, Drip Irrigation method is 44.90 % more efficient with respect to its water footprint and 32.93 % in its energy footprint than the Flood Irrigation Method.

7. Acknowledgements

This research forms an independent part of the M.Tech course curriculum on Sustainable Processes and Systems. The authors takes the opportunity to acknowledge the invaluable contributions made by their Prof. Urvi Desai and Prof. Jigna Desai, Assistant Professor (Architecture), CEPT University, Ahmedabad for their constant and sincere efforts on improving the quality of the work. The library facility of CEPT University, friends, and associated staff were immensely helpful during the period. Lastly, we thank almighty for having given us the endeavor and longevity to see the completion of this academic research work.

References

[1] Allan, J. A. (2003) 'Virtual water–the water, food, and trade nexus: Useful concept or misleading metaphor?' Water International, Vol 28, No 1, pp 106–113.
[2] Hoekstra, A. Y. (2008) 'The water footprint of food', in J. Forare (ed) Water For Food, The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Stockholm, pp 49–60.
[3] Hoekstra, A. Y. (2009) 'Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis', Ecological Economics, Vol 68, no 7, pp1963–1974.
[4] Hoekstra, A. Y. and Chapagain, A. K. (2007) 'Water footprints of nations: Water use by people as a function of their consumption pattern', Water Resources Management, Vol 21, No 1, pp 35–48.
[5] Rockstrom, J. (2001) 'Green water security for the food makers of tomorrow: Windows of opportunity in drought-prone savannahs', Water Science and Technology, Vol 43, No 4, pp 71–78.
[6] Smakhtin, V., Revenga, C. and Doll, P. (2004) 'A pilot global assessment of environmental water requirements and scarcity', Water International, Vol 29, No 3, pp 307–317.
[7] http://www.waterfootprint.org, as viewed on 15th August, 2014.
[8] http://www.ecologicalfootprint.com, as viewed on 15th August, 2014.
[9] http://www.footprintnetwork.org, as viewed on 15th August, 2014.

****