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RESEARCH ARTICLE

REVIEW OF METHODOLOGIES OF WATER FOOTPRINT.

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Abstract

Water resource is becoming a scarce commodity in many parts of the world necessitating its conservation and efficient use. Water footprint is used to give an idea on the amount of water different products need for their production, consumption and disposal of their waste. There is therefore some need to quantify the volumetric amount and the environmental impact of using water in producing and consuming goods and services. In this article, the different methodologies of calculating water footprint (WF) are reviewed with an aim of deciding their possible applications in everyday life. As the methodologies are evolving each day, it means they number into dozens and as such only articles from Web of Science journals published after 2010 were reviewed to reduce and narrow the scope of study. Generally, the methodologies revolved around the amount of water consumed in producing a good or service and the likely effect on the environment. The approach and the quality of data used to calculate WF determines the acceptability of the results. Therefore, methods should try to consider all the water components wherever necessary, that is, the green, blue and grey water. The recommendation drawn from the study is to consolidate the methodologies into one acceptable among the researchers, scientists and stakeholders for uniformity, easy of interpreting the results and improve its usefulness in policy making.

Introduction:-

The water footprint of an individual or community is defined as the total volume of freshwater that is used to produce goods and services consumed by the individual or community (Hoekstra and Chapagain, 2008). With this basic definition in mind, water footprint can be calculated for any activity, commodity, business etc. The need to know the water usage is growing louder each day with the growing scarcity of the commodity. The outlook of water resource availability looks gloomy as we go forward due to population increase and persistent frequent droughts. There is therefore need to sustainably and efficiently use this precious commodity through, for example, deliberate decisions to drop economic activities that require a lot of water in favour of those activities that require little water. For that to be practical, the actual water consumption in producing a commodity need to be quantified (Lamastra et al., 2014). As the water footprint concept is gaining significant momentum, there have been growing calls to standardise the calculation methodologies to make the obtained data more useful, both as a policy and as a research tool (Hoekstra, 2011). This paper reviews methodologies put forward by researchers and scientists to calculate the water footprint of goods and services in the past five years and published in the web of science journals.

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Volumetric water footprint:-
The basic method of water footprint discussion can only make more sense if it starts with Hoekstra who is one of the pioneers of the idea. The plain starting point and methodology is stated as follows;

$\mathbf{WF_{total} = WF_{green} + WF_{blue} + WF_{grey}}$ where;

WF_{total} is the total water footprint
WF_{green} is the rainwater to produce a product
WF_{blue} is surface and ground water required for the production of good or service
WF_{grey} is water for pollution assimilation depending on ambient water quality standards

This was initially introduced in calculating the water used in producing and consuming rice (Chapagain and Hoekstra, 2011). The calculation was in global context and as such the method can be used to analyse the trade impact of agricultural commodities. Su et al. (2015) used the same method to calculate the water footprint of bio-energy crops. However, in this case the amount of water in the crop product was seen to be 0.1% -1% of the total evapotranspiration and was therefore deemed insignificant and was consequently not included in the calculation of the green water. The results found were presented in form of water use efficiency in different climatic localities which makes the method useful in choosing crops to grow in different areas for maximum water use efficiency (Su et al., 2015 and Chouchane et al., 2015).

Impact-oriented water footprint:-
There are many impact-oriented water footprint calculation methodologies and some of these are summarised in the next discussion.

Stress-weighted WF:-
Chouchane et al. (2015) modified the general WF methodology by measuring the water scarcity of a country through comparing blue water consumption to renewable blue water resource to come up with a ratio that can then be used for categorisation of a country or society into water secure or stressed. Blue water consumption and not withdrawal rate (Chouchane, et al. 2015) is used in this method with the reasoning that some of the withdrawn water will be available again for reuse as it re-enters into the rivers and streams. This idea is important as it avoids 'double counting' which can give unrealistic water use amounts thereby misleading in decision making. However, the fact that the water scarcity is calculated per year can give a distorted figure given the variability of water availability and consumption in different seasons of the year.

The issue of water scarcity was also central in Ridoutt and Pfister (2010) who introduced water footprint method that is stress-weighted and conservative, incorporating life cycle assessment (LCA) in water footprint. The stress weight shows the impact associated with water appropriated into the product life cycle. Land use has an impact on the availability of blue water and should therefore be included in calculation of LCA WF. The component of water scarcity is central to this method and as such, green water which is considered negligible contributor is left out in the computation of this WF. Interestingly, a water stress characterisation factor is incorporated in this method (Ridoutt and Pfister, 2010 and Jefferies et al., 2012). Water scarcity is of importance especially to dry regions of the world and as droughts are becoming frequent and persistent possibly due to climate change, water footprint focusing on scarcity will become even more important as we go forward into the future. However, the usefulness of Ridoutt and Pfister (2010) method in estimating the local, regional and global water stress will be limited due to its conservative approach as it leaves out the green water aspect. This has a negative effect as the current methods being advocated for should be comprehensive and holistic in approach. A clear picture for an informed decision is obtained when all the water components are included in the calculation.

Another stress-weighted WF method is the VIVA method that was developed in Italy and is used to assess water footprint for wines and winery products. This method incorporates the Tier III approach of calculating the grey water consumption. Tier III approach utilises contaminant flow models and real data collected at farm level. The contaminants associated with winery are fertilisers and pesticides. These can be pollutants in three different ways, namely leaching, runoff and drift. These are calculated separately and only the highest figure is used as it will represent the minimum amount of grey water to dilute contaminants to acceptable regulated levels (Lamastra et al, 2014). This method can be of use in winery industry and indeed other agricultural products that are input intensive, that is, those that require application of a lot of fertilisers and pesticides. Due to its real data usage, it provides an accurate grey water use which lacks in other methods. Herath et al. (2013) had an almost same method of accounting for the water use in viticulture.

Life Cycle Assessment WF:-

The life cycle assessment water footprint measurement was done by Jefferies, et al. (2012) who was concerned with the impact of water use throughout the life cycle of a product. At impact level assessment, the LCA and WF address the same issue hence the combining of the methodologies. Impact on water resources across the life cycle of tea and margarine was assessed by adding the production WF and consumption which is basically the WF as described by Hoekstra et al. (2011), Supply chain WF which is amount of water at a specific business unit to prepare commodity for marketing, Operational WF which comprises freshwater needed to produce a commodity at a specific business unit and the Consumer WF which is the direct and indirect water needed to use the commodity (Jefferies et al., 2012). It can be noticed that though the method tries to trace the impact of a commodity from production to final consumption, the leaving out of grey water in calculating the WF is the weakest link of an otherwise comprehensive assessment. Francke and Castro (2013) however, encompass the grey water component making the method more comprehensive and reliable (Francke and Castro, 2010). The method of LCA water footprint is useful for business entities to assess corporate risk that may be associated with their product in relation to water use.

'Opportunity Cost' WF:-

There is replacement pressure exerted on water resources put by people as they seek to find alternative source of fresh water if their water source is disturbed, diverted or destroyed. Pressure can even be on land as there may be need to replace such resources as fish with livestock or crops (Orr et al., 2012; Herath, et al., 2011). Example is the result of the construction of the Mekong dam along Mekong River. Countries downstream like Myanmar who used to get fish from the river may need to increase livestock production to replace the lost food and income from fish. Herath et al. (2011) looks at the change in the land use due to the hydroelectricity generation infrastructure development. Such replacement water footprint can be used to analyse the cost-benefit analysis of newly suggested projects that are water intensive. 'Opportunity cost' of water footprint can be applied and be useful in a wide array of industries and commodities to assess the impact of any decision on the water resources.

Energy WF:-

Energy-water-nexus has been identified as an inseparable connection as most energy sources are water intensive in their cycle generation and use. Fulton and Cooley (2015) had the energy water footprint study where they used real time data estimates of blue and green WF of energy production, trade and consumption. Their method did not factor in the grey water component, a weakness that was rectified in Okadero et al. (2014) in a study to ascertain the water footprint of energy sector. They used a method based on bottom-up approach which combines water use in detailed descriptions of individual production process and in consumption. Since energy comes from domestic and external sources, both sources are factored into the computation (Okadero et al., 2014; Feng et al., 2011). Energy sector by its very nature is water intensive and this can be used by countries whose water resources are poor to decide on the energy production method to adopt which will not severely affect water availability for other economic and domestic uses. This same method has its practical use in the estimation of energy agricultural crop water footprint like sugarcane that produces ethanol. The weakness of this approach is its simplistic approach which can often results in double counting. However, the usefulness of the energy water footprint cannot be over-emphasised now and going forward as policies are being framed that try to replace the 'dirty' fossil fuel energy with cleaner renewable sources which are however water intensive most of them. For this reason, a detailed methodology can be devised especially on the bases of the opportunity cost water footprint already discussed above.

Remote sensing WF:-

Remote sensing WF method has been of use when spatial study is at a large scale. Water footprint for benchmarking as done by Mekonnen and Hoekstra (2014; 2010) using remote sensing at spatial resolution of 5 by 5' with a dynamic water balance and crop yield model, produced data for 124 different crops. Green, blue and grey water for nitrogen application rates only were used in calculating the crop WF benchmarks (Mekonnen and Hoekstra, 2014; 2010). The benchmarks can be useful as set targets in water conservation and water use efficiency along the supply chain of a commodity. The grey water footprint is calculated using the nitrogen nutrient only which is right for most crops that require the nutrient in larger amounts compared to other nutrients. However, this is not always true as there are other crops that require more phosphorus than nitrogen like Irish potatoes. So it is important to group crops into categories of nitrogen requiring or phosphorus requiring. Generally, phosphorus is immobile in soil and so would require large amounts of water to leach than nitrogen and therefore the recommendation of using it when doing benchmark studies if resources and time do not allow using both.

Forecasting WF:-

Forecasting WF employs statistical analysis as its integral calculation methodology. Vanham et al. (2013) calculated the WF of consuming different diets focusing at three categories of diets, that is, a healthy (whatever this means), a vegetarian and a combined diet in EU countries. The results are useful in making dietary reforms as vegetarian diet was found to have the lowest WF. However, the method has a weakness of using secondary data from other sources making the results too dependent on the quality of the data used. Another closely linked WF method to the statistical WF is the one that is calculated using scenarios which is the likely situation of water use, availability and scarcity thereof in the future. Historic data can be used to make extrapolations of the future (Gerbens-Leenes et al., 2012; Ercin and Hoekstra, 2014). This has been done to get the water requirements for biofuel crop production as the world is gripped with the climate change mitigation fever. This is important as most countries are forgetting the water resource management in their transition from fossil non-renewable to biofuel renewable energy. Forecasting the future requirements of energy and water for example, can assist countries, regions and the globe to plan mitigatory action. Scenario WF can also give a picture of possible changes to global water supply and demand giving the same effect of planning beforehand. Besides being a useful planning tool in many water-related industries, scenarios by their nature are dependent on decisions still to be made which can change due to unforeseen circumstances making the method unreliable, to say the least.

Conclusion and Recommendations:-

There is 'confusion' in the best method of water footprint calculation among researchers which means even the communication of results becomes a problem. There is therefore need to collaborate and unify the water footprint work (Tillotson, M.R. et al., 2014). After reviewing a number of methodologies using a case study for comparison, results obtained are different demonstrating the need for standardisation of WF approaches (Jeswani, H.K. and Azapagic, A., 2011). A method that is holistic in approach is considered superior as it produces results that are representative of the water situation. It therefore means that methods that often leave out other water components as being negligible often mislead as a small change over time can result in a great amount of water over a period of time and space.

References:-

1. Bayart, J.B., Deschenes, L., Margni, M., Vince. & Koehler, A. (2010).A framework for assessing off-stream freshwater in LCA. *International Journal of Life Cycle Assessment*, 15, 439 – 453.
2. Chapagain, A.K. & Hoekstra, A.Y. (2011).The blue, green and grey water footprint of rice from production and consumption perspectives. *Ecological Economics*, 70, 749-758.
3. Chouchane, H., Hoerkstra, A.Y., Krol, M.S. &Mekonnen, M.M. (2015).The water footprint of Tunisia from an economic perspective. *Ecological Indicators*, 52, 311-319.
4. Ercin, A.E. & Hoekstra, A.Y., (2014). Water footprint scenarios for 2050: A global analysis. *Environment International*, 64, 71 – 82.
5. Feng, K., Hubacek, K., Minx, J., Siu, Y.L., Chapagain, A.K. & Yu, Y. (2011).Spatially explicit analysis of water footprints in the UK. *Water*. 3, pp. 47 – 63
6. Francke, I.C.M. & Castro, J.F.W., (2012). Carbon and Water footprint analysis of a soap bar produced in Brazil by Natural Cosmetics. *Water Resources and Industry*, 1-2, 37 – 48.
7. Fulton, J. & Cooley, H. (2015). The Water Footprint of California's Energy System, 1990 – 2012. *Environmental Science and Technology*. 49(6), 3314 – 3321.
8. Gerbens-Leenes, P.W., Lienden, A.R., Hoekstra, A.Y. & Meer, Th.H. (2012) Biofuel scenarios in water perspective: The global blue and green water footprint of road transport in 2030. *Global Environmental Change*, 22, 764-775.
9. Herath, I., Deurer, M., Horne, D., Singh, R. & Clothier, B. (2011). The Water Footprint of Hydroelectricity: a methodological comparison from a case study in New Zealand. *Journal of Cleaner Production*, 19, 1582-1589.
10. Herath, I., Green, S., Singh, R., Zijpp, S. & Clothier, B. (2013). Water foot-printing of agricultural products: a hydrological assessment for the water footprint of New Zealand's wines. *Journal of Cleaner Production*, 41, 232-243.

11. Hoekstra, A. D. & Chapagain, A. K. (2008). Globalisation of water: Sharing the Planet's Freshwater Resources. *Blackwell Publishing*. UK.
12. Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. & Mekonnen, M.M. (2011). The Water Footprint Manual.http://www.waterfootprint.org/?page=files/WaterFootPrintAssessmentManual.
13. Jefferies, D., Munoz, I., Hodges, J., King, V.J., Aldaya, M., Ercin, A.E., Canals, L.M. & Hoerkstra, A.Y. (2012.) Water Footprint and Life Cycle Assessment as approaches to assess potential impacts of products of water consumption. Key learning points from pilot studies on tea and margarine. *Journal of Cleaner Production*, 33, 155-166.
14. Jeswani, H.K. &Azapagic, A., (2011). Water footprint: methodologies and a case study for assessing the impacts of water use. *Journal on Cleaner Production*, 19(12), 1288-1299.
15. Lamastra, L., Suciu, N.A., Novelli, E. & Trevisan, M. (2014). A new approach to assessing the water footprint of wine: An Italian case study. *Science of the Total Environment*, 490, 748-756.
16. Mekonnen, M.M. & Hoekstra, A.Y (2014) Water footprint benchmarks for crop production: A first global assessment. *Ecological Indicators*, 14, 214-223.
17. Okadero, T., Chontanawat J. & Gheewala, H.S. (2014). Water footprint for energy production and supply in Thailand. *Energy*, 77, 49-56.
18. Orr, S., Pittock, J., Chapagain, A. & Dumaresq, D. (2012). Dams on the Mekong River: Lost fish protein and the implications for land and water resources. *Global Environmental Change*. 22(4), 925 – 932.
19. Ridoutt, B.G. &Pfister, S. (2010). A revised approach to water foot-printing to make transparent the impacts of consumption and production on global freshwater scarcity. *Global Environmental Change*, 20, 113-120.
20. Su, M.H., Huang, C.H., Li W.Y., Tso, C.T & Lur, H.S. (2015). Water footprint analysis of bioethanol energy crops in Taiwan. *Journal of Cleaner Production*, 88, 132-138.
21. Tillotson, M.R., Liu, J., Guan, D., Wu, P., Zhao, X., Zhang, G., Pfister, S. & Pahlow, M. (2014) Water footprint symposiums: Where next for water footprint and water assessment methodology? *International Journal Life Cycle Assessment,* 19, 1561-1565.
22. Vanham, D., Mekonnen, M.M. & Hoekstra, A.Y. (2013). The water footprint of the EU for different diets. *Ecological Indicators,* 32, 1-8.