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9. Carbon and Water Footprint for Eco-Friendly Agriculture Practices

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Abstract:

Around the world, 5% of all energy is utilized in agriculture. Agriculture consumes 5% of global energy, primarily for irrigation, machinery, and food processing. To reduce environmental impact and ensure long-term food security, sustainable practices and energy-efficient technologies are crucial. Thus, there must be a significant change in the agricultural production process. Currently, any agricultural growth must prioritize the sustainable use of water. Agricultural production effects freshwater wetlands and water quality and quantity. For agricultural production to be sustainable, it is essential to consider the carbon, and water footprints. In order to have the least possible impact on climate change, agricultural systems are crucial for lowering large inputs of greenhouse gas emissions, as well as for improving water use. Carbon emissions and water footprint can be used to analyze the production of agricultural systems.

Keywords:

Agriculture, Carbon footprint, Greenhouse gas, Water, Sustainable

9.1 Introduction:

The consumption of freshwater and global warming, both are severely affected by the food industry. The food industry has a significant impact on both freshwater consumption and global warming. The extensive use of water by the food industry for livestock production, processing, irrigation, and other purposes adds significantly to the use of freshwater resources. Additionally, the practices used in the food industry, such as methane emissions from livestock and deforestation for agricultural purposes, add to global warming. The urgent need for sustainable practices in the food industry to lessen its negative effects on freshwater resources and climate change is highlighted by these interconnected effects.

The sizeable contribution of AFOLU activities to greenhouse gas emissions worldwide. Deforestation, the raising of livestock, and agricultural soil management techniques are the main causes of these emissions. Water is crucial for crop growth and productivity in irrigation practices, which account for a large portion of agriculture's high water demand. Although it highlights the need for effective irrigation methods and conservation measures, this heavy reliance on freshwater resources poses significant challenges for sustainable water management.

India's population growth presents the country with the dual problem of boosting food production while reducing accompanying GHG emissions and giving the country's limited water resources.

Studies reveal the impact of India's crop production on greenhouse gas emissions. Accurate and trustworthy estimates require gathering primary data from the field and identifying regional variations and farming methods influencing emissions. Residue burning is a significant research gap in India, contributing to air pollution and greenhouse gas emissions.

Conducting an LCA-based study on CF accounting and assessing the environmental impact of residue burning could provide valuable insights for sustainable agricultural management. Agroclimatic zones and farm sizes significantly impact crop yields and agricultural practices. Understanding variations in CF across these factors is crucial for policymakers, farm can greatly and res to develop targeted interventions and strategies for sustainable agriculture in India.

Studies emphasize the need for specialized environmental interventions and policies considering regional farming methods and cultural contexts, emphasizing the importance of understanding these factors for effective environmental impact. Scallop crops like rice and wheat are grown in large quantities, significantly impacting global food security and livelihoods. This farming raises concerns about environmental sustainability and resource depletion, posing a significant threat to global food security.

Rice and wheat are the two crops with the largest blue water footprints (Mekonnen and Hoekstra, 2011). Rice is water-intensive due to its preference for flooded fields, while wheat requires significant irrigation in low-rainfall areas. Both crops contribute significantly to the ocean's water resources. Promoting effective irrigation methods and sustainable water management techniques like rainwater collection and recycling can reduce water use and GHG emissions.

Rice farming has expanded into porous and coarse soils, increasing food production and food security in areas with common soils. Irrigation enables farmers to grow rice year-round, even in regions with limited rainfall, enabling them to grow this crucial crop year-round.

As a result, CF and WF assessment based on farmer inputs can simultaneously provide significant insights like the discrepancy between theoretical and actual water use. This can aid in locating opportunities to increase water use efficiency and serve as a decision-making framework for sustainable water management techniques. Additionally, CF and WF assessments can offer insightful data on how agricultural activities generally affect the environment, enabling targeted interventions to lower carbon emissions and water pollution. Research on tomato and pumpkin yielded crucial information on the CF and WF of crop production. Expanding the analysis to other crops is essential for a comprehensive understanding of environmental impact.

Policymakers can develop targeted strategies to reduce GHG emissions and water use in agriculture by understanding CF variations across agroclimatic zones and farm sizes. Evaluating inputs and identifying successful mitigation strategies can help reduce environmental effects and support a more environmentally friendly and sustainable agricultural sector.

9.2 Environmental Footprint Indicators:

Relevant indicators of the environmental effects of agriculture and FSs are variables that depict both direct and indirect measurements of resource use as well as unfavourable changes in the quality and functionality of limited, important, and vulnerable natural resources.

The quality of the soil, water, air, and atmosphere are some of the crucial ecological indicators. Natural resources might be viewed as limited, fragile, and non-renewable instead of as a factor of production. Wiek and Tkacz (2013), proposed the term "ecological indicator" or EFP to denote ecological assets that a community requires, as well as the natural resources it uses to produce the necessary goods and services, and also to absorb or dispose of the waste or byproduct. This concept was based on life cycle analyses for a variety of products and services.

Therefore, EFP, which includes all components, including water and biodiversity, is a measure of GHG emissions during the production of products or services in relation to global warming and anthropogenic emissions.

The term "carbon footprint" or CFP refers to this indication, which is transformed to a carbon (C) equivalent for goods and services over their full life cycle, from conception to final disposition. The latter is frequently employed among the general public to highlight the danger posed by human-caused climate change (Chen et al., 2021).

As the primary element of EFP, CFP may account for more than half of the EFP of an agricultural commodity (Balogh, 2019). The EFP, however, consists of a variety of elements, including resources (RFP), food (FFP), nitrogen (NFP), biodiversity (BFP), and land (LFP) (Figure 9.1). The word CFP refers to a total numerical value expressed in terms of carbon dioxide equivalent for all EFP components (e.g., LFP, WFP, BFP, RFP, FFP, etc.). CFP is so commonly utilised in the context of identifying strategies for mitigating and coping with global climate change.

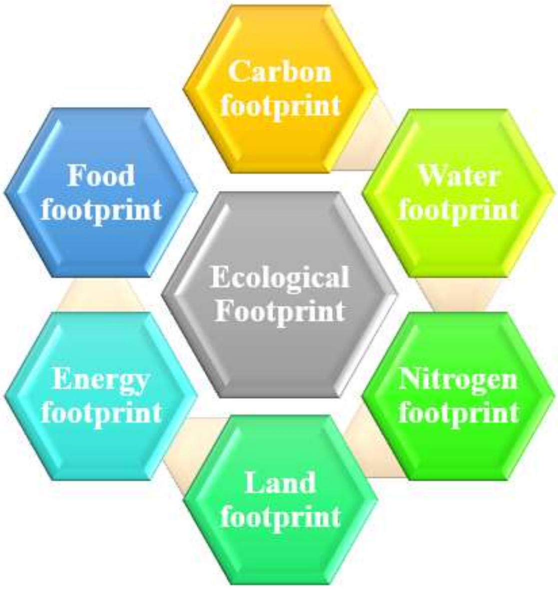

Figure 9.1: Environmental footprint indicators

9.3 Concept of Carbon and Water Footprint:

Farmers can optimize water use by implementing Conservation Farming (CF) techniques like crop rotation and cover cropping. Water Footprint Management (WF) focuses on analyzing and reducing water usage during production stages, including supply chain operations and irrigation systems. These methods enhance resource efficiency and promote sustainable water management in agricultural practices.

CF and WF are essential metrics for evaluating a product's environmental impact, with WF focusing on the water footprint and CF on greenhouse gas emissions. These metrics aid in making environmentally friendly decisions and understanding product sustainability. WF consists of green, blue, and grey footprints, with green referring to water stored in soil moisture and blue referring to surface or subsurface water used during manufacturing. Grey represents contamination of water during agricultural operations, as highlighted by Hoekstra (2017). This is a sign that agricultural practices have caused pollutants or other impurities to enter the water supply.

The CO2-equivalent is a crucial metric for comparing greenhouse gases and their impact on climate change. It accounts for gases like methane and nitrous oxide, as well as CO2's warming potential. This standardized unit helps researchers understand the impact of emissions and develop effective mitigation plans. Crop yield, demand, quality, and meteorological conditions are the main factors determining the cost of production (CF) and weight loss (WF) of agricultural products. These factors help farmers allocate resources effectively and minimize their environmental impact. Considering inputs like fertilizer and pesticides and meteorological factors like temperature and rainfall helps farmers understand crop production variability and adjust farming practices accordingly. The CF and WF evaluation of a product provides context for inputs and water usage.

Consumers, dealers, and the food industry can contribute to the logical management of inputs, resulting in more environmentally friendly production techniques and a smaller negative impact. This knowledge helps consumers make informed decisions, selecting goods that align with their values and support water conservation efforts. The environmental impact of a product is significantly impacted by its water and carbon footprints. Sustainable cultivation methods like organic farming and precision agriculture can reduce these footprints. Efficient transportation strategies and improved distribution networks can also reduce energy usage and environmental impacts. Businesses must consider these factors to maximize input management and minimize product environmental impact.

9.3.1 Agriculture and Carbon Footprint:

Greenhouse gas emissions are crucial metrics for evaluating agricultural sustainability, as they significantly impact ecosystems and contribute to climate change. Monitoring and reducing greenhouse gas emissions is essential for achieving global sustainability goals and minimizing the negative impact of agriculture on the environment. The term "carbon footprint" is defined and used in their analysis based on two methods for calculating the effects.: (a) the total greenhouse gas emissions per unit of farmland, measuring the overall emissions from crop production with an emphasis on environmental health, and (b) the amount of greenhouse gas emissions associated with each kilogram of grain produced, emphasizing both the products (i.e., grain yield) associated with each unit of emission as well as emissions during crop production. The latter strategy focuses on increasing crop production while reducing greenhouse gas emissions using sustainable farming techniques like organic and precision agriculture. It maximizes resource use and reduces chemical inputs, preserving the environment.

It is commonly acknowledged that humanity's current EFP cannot last. Humanity has significantly changed the earth's landscape, dramatically increased resource use, and produced a significant amount of garbage as a result of land conversion for agriculture and other anthropogenic activities. According to Hoekstra and Wiedmann (2014), the actual vs sustainable EFP of humanity was 10.5 vs. 8.0 Mg/capita of material footprint, 1000-1700 vs. 1100-4500 B m3 of blue water, and 18.2 vs. 12 B ha of land. In addition, Hoekstra and Wiedmann noted that the WFP for humanity (measured in B m3 year) was 1400 for grey water and 6700 for green water. The foundation of civilization, which started with the introduction of agriculture around 8000 BC, is food and agriculture. The majority of cultures and religion’s view soil and agriculture as integral to their legacy. In fact, establishing global peace and stability depends on sustainable soil and agricultural management (Lal, 2015). Natural resources are also heavily consumed by agriculture and FSs. Currently, 3.75 billion hectares (3.75 billion acres) of the ice-free area are used for agriculture, of which 1.5 billion hectares (3.50 billion acres) are used for crop cultivation.

Furthermore, irrigation uses 70% of all fresh water withdrawals. Despite being a problem that, according to a wide range of religions and cultures hunger and malnutrition are the unattractive sides of both agriculture and FSs that need to be addressed. The latter includes the effects of agriculture and FSs on the environment (such as soil, water, air, and biodiversity) as well as the maintenance of famine and hidden hunger. Agriculture and FSs account for a sizable portion of the total CFP, particularly in emerging nations.

For instance, five pillars for reducing CFP were identified at COP-26 in Glasgow (2021): (1) eliminate waste; (2) intelligently use power; (3) use bioenergy for circular economy; (4) employ hydrogen; and (5) sequester carbon (C). Agriculture, the majority of which have significantly depleted terrestrial carbon stores (Lal, 2018), rely on the final pillar of carbon sequestration since they have a high ability to store atmospheric CO_2 in biomass. The CFP of agricultural production is influenced by a variety of agricultural factors.

According to Balogh (2019), agricultural output factors including arable land, agricultural machinery, fertiliser use, irrigation, and other inputs which are dependent on economic growth. In order to reduce CFP of FSs, it is therefore necessary to identify factors affecting agricultural productivity and use-efficiency as well as site-specific technological options based on advised and scientifically supported best practises that can lower CFP of food products and other related commodities.

9.3.2 Agriculture's Water and Carbon Footprint:

Determining Crop Footprint (CF) and Water Footprint (WF) involves analyzing each crop species' life cycle within a region. This helps estimate the resources needed for growth and production, such as water and carbon. This analysis helps in determining CF and WF, aiding in sustainable agricultural practices, and reducing the environmental impacts of crops. Lower carbon and water footprint (CF) and water footprint (WF) products offer numerous advantages for consumers and the manufacturing process. These products reduce environmental impact, reduce climate change, and promote sustainable resource management. Traditional systems lack water efficiency compared to organic and integrated production methods, which prioritize effective irrigation and water conservation techniques. These methods, like rainwater collection and drip irrigation systems, aim to reduce water waste.

A combination of production system and farm site can reduce in and production costs, resulting in energy savproductivity. Strategically planning these elements maximizes resource utilization and minimizes waste, leading to higher profits and enterprise sustainability. Combination promotes nutritious food production, enabling consumers to measure and record the CF and WF of food.: (a) Choose items that genuinely fight climate change (b) Identify the product's competitive advantage versus other products and (c) By highlighting the use of products with lower CF and WF, promote the overall environmental advantages.

Producers should reduce inputs like fertilizers, gasoline, and irrigation equipment to reduce their carbon footprint. These compounds limit both N_2O emissions into the environment and leaching into deeper soil layers (Akiyama et al., 2010). Reduced input losses and sensible water management in cultivation procedures may make crops more tolerant of dry regions. In conclusion, agricultural production must employ environmentally friendly farming techniques that lower CF and WF.

Agricultural products' enhanced flavour, nutritional value, and desirability provide added value, giving farmers a competitive advantage and enabling higher market prices.

9.4 Conclusion:

Environmental indicators assess agricultural systems based on yield and water use, providing crucial information on their effectiveness and sustainability. These indicators enable informed decisions to support sustainable farming practices by considering both yield and water consumption. Implementing environmentally friendly farming methods like organic farming, crop rotation, and integrated pest management can reduce soil erosion, increase biodiversity, and reduce the use of synthetic fertilizers and pesticides in agriculture.

A sufficient number of farms can enable comparisons between farming methods, species, and environments, providing insights into efficiency and sustainability. Considering factors like soil quality, climatic conditions, and economic viability enhances the precision and applicability of these comparisons.

This strategy improves input rationalization by offering lower carbon footprint (CF) and water footprint (WF) products, meeting consumer preferences while using less energy. It encourages producers to innovate and create environmentally friendly production techniques, reducing waste and resource utilization. This not only benefits the environment but also encourages responsible energy use in the supply chain.

To stabilize agricultural production's resilience to climate change, farmers can adopt less intensive farming methods like crop rotation, agroforestry, and integrated pest management. These practices promote biodiversity and reduce chemical inputs. Precision agriculture methods like soil mapping and remote sensing maximize resource use and reduce environmental effects.

Agro-environmental indices are valuable for decision-makers seeking to balance agricultural productivity and climate change. These indices provide insights into the impact of agricultural practices on the environment, enabling sustainable farming practices. By considering these indices, decision-makers can make informed decisions that support productivity and environmental preservation in the face of climate change challenges.

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