Food, Water and Energy nexus in the arena of Climate Change - Indian Perspective

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Abstract

Food, water and energy are inseparably linked and actions in one sector influence the others. Essential inputs for food production are water and energy; water extraction, treatment and redistribution need energy; and energy also requires water. Food production depends on water, land and other natural resources, in other words a range of ecosystem services. Food and agricultural practices in turn influence water and energy demand. Their demand is also influenced by dynamic nature of all the three as well by different policies. The resource stability nexus goes more troubling when considering the long-term consequences of climate change especially in developing countries like India. India is having two third of its area monsoon dependent, having diverse seasons, crops and farming system with close link between climate and water resources, nexus approach is need of the hour.

The nexus approach can enhance understanding of the inter-link of the sectors and strengthen coordination among them. But it requires a major shift in the decision-making process towards taking a holistic view for developing institutional mechanisms to coordinate the actions of diverse actors and strengthen complementarities and synergies among the three sectors.

Keywords: Agriculture, Nexus, Food, Energy, Water, Climate change.

Introduction

The food water and energy nexus is at the center of global research, development and policy. The global community is well aware of challenges hovering around food energy and water to nourish global population as they are inextricably linked. But so far, all the three components are addressed in isolation within sectoral boundaries.

Water is an input for producing agricultural goods in the field; at the same time energy is required to distribute water and to produce food. Energy source may be a water pump *vis-a-vis* electricity, power tractors, irrigation machinery or machines to process and transport agricultural goods. Agriculture is the largest consumer of water resources, which accounts for 80-90 % of all freshwater use.[7]

Growing demand for water energy and food is further compounded by climate change impacts. Extreme weather events such as intensified floods and droughts, could damage crops electrical systems and water infrastructure. All aspects of food security are potentially affected by climate change including food production, access, use and price stability.[14]

Regarding water, climate change is projected to reduce renewable surface and ground water resources in most dry subtropical regions, intensifying competition for water among sectors.[14] Water security i.e. access, safety and affordability, are affected by the energy and food sectors.

The water–energy nexus: Water and energy are critical resource inputs for economic growth. The correlation between economic growth and energy demand has been widely established.[12] In most energy production processes, water is a key input: fossil fuel production requires water for extraction, transport and processing; thermoelectric generation based on nuclear, fossil fuels or CSP requires water for cooling; hydropower can be generated only if water is readily available in rivers or reservoirs; feedstock production for bio-fuels, such as ethanol, may depend on water for irrigation and renewable energy resources such as solar require water for cooling and cleaning panels or collectors for improved efficiency.[23] Supply chain for water starts with a source, then water is extracted (e.g. pumping of groundwater), sometimes treated and conveyed – moving directly to an end-use (e.g. household, irrigation, commercial).

Once used, the water is returned back to the environment through discharge – with or without treatment – or through evaporation. In some cases, treated water may be reused.[25] There is general recognition that the starting point of any effort to address the nexus is quantifying the interlinkages and understanding the trade-offs. The International Energy Agency (IEA) included a special section on water and energy in its 2012 World Energy Outlook for the first time in the organization’s history.[11] Addressing the nexus, the World Bank established the “Thirsty Energy” initiative to help governments in developing countries tackle issues related to water resources and power services.

Additionally, in response to the growing importance of this nexus, water and energy was the theme of the World Water Day 2014.[21] India has 18% of the world's population; It has 4% of water resources of the world. annual per capita availability of water decreases from 6,042 cubic meter in the year 1947 to 1,545 cubic meter in 2011 and UN report predicts annual per capital availability of water will further reduce to 1,340 cubic meters by 2025 and to 1,140 cubic meters by the year 2050. Energy optimization exercises can be done by the water supply companies to lower their operational costs.

Although high-energy-efficient pumps may have a higher price, life-cycle analysis shows that 85% of the costs used during the lifetime of a pump are the energy costs and therefore a high-energy-efficient pump saves a huge amount of money during the lifetime of the pump as opposed to a cheap pump with low efficiency. Pumping systems when operated using frequency converters, will allow a much better pump-control and provide pumping at a variety of speed and deliverance.

At present, energy production accounts for nearly 15% of global freshwater withdrawals – or 580 billion cubic meters (m3) of water – every year.[11] The share of water withdrawn and consumed for energy significantly varies at the national level. Water, in many ways, fuels economic growth and progress. It grows our food, generates power and cools our energy-generating plants. Just as the reliable supply of safe water is vital for individual households, water is essential for industry, agriculture, energy production and other human development related areas. In short, national economies are more secure when the key economic sectors are water-secure.

Nearly 16% of global electricity production is hydro-based and hydropower is a major source of electricity in many countries, accounting for nearly 88% of total electricity generation in India. As easily accessible freshwater resources are depleted, the use of energy-intensive technologies such as desalination or more powerful groundwater pumps is expected to expand rapidly.[7,23,24] The intensity of the water–energy nexus is a regional, national or sub-national characteristic, which depends on the energy mix, demand characteristics, resource availability and accessibility. For power production, for example, the choice of fuel and technologies holds significant impacts for the quantity of water required.[11,16,23] Renewable energy technologies such as solar photovoltaics (PV) and wind consume little-to-no water during operation compared to fossil fuel-based plants that require large amounts of water during the different stages of energy production.[9]

Climate change aggravates these risks greatly, as it can lead to unanticipated disruptions in water availability and cause a gradual, yet significant, change in the quality of water available for cooling and extraction. There is ample evidence suggesting that one of the key impacts of climate change on the energy sector will be an increase in ambient temperatures, which can lead to reduced power operations or even temporary shutdown of power plants. Making water available for a variety of end-uses requires different levels of treatment, depending on the water source. This also has implications for how much and where energy is required. Pumping groundwater for irrigation purposes, for example, requires no treatment; energy needs therefore are lower compared to, say, desalination, which uses substantial amounts of energy to pump and treat seawater or brackish water. Climate change is projected to decrease water availability in many semi-arid and arid regions,[10] with shifting rainfall patterns and intensified droughts threatening water resources necessary for different inputs of energy supply. Thermoelectric power generation, oil and gas production and renewables such as hydropower and bioenergy are vulnerable to reduced production due to water dependent processes.[3]

In India, 79% of new energy capacity is expected to be built in areas that already face water scarcity or water stress. Coal will remain a key energy source to meet rapidly expanding power needs despite the apparent water conflicts.[22] For example, the country plans to build a cluster of 71 coal plants in the Vidarbha region of Central Maharashtra, a highly water-stressed area where lack of water for irrigation has been documented in the last decade.[6] Globally, over 3800 km^3 groundwater is withdrawn annually, in which the share of agricultural sector is 70%. India is among the top abstractors of groundwater with 646 km^3 withdrawn annually followed by China (550 km^3) and the US (477 km^3).[19]

Source: World bank[23]

Fig. 1: Illustrations of water energy nexus

The water–food nexus: The relationship between water and food systems is among the most widely covered elements of the nexus. Historically, the accessibility and availability of water resources has greatly influenced the evolution of agricultural practices globally. The type of crops grown, the crop cycles and the irrigation method adopted all vary from arid to wet parts of the world. Today, the water–food nexus is symbolic of vulnerabilities on two fronts: changing patterns of water supply that is influencing the reliability of water-intensive sectors including agriculture and growing competition for limited water resources in meeting the projected increase in food demand.

Moreover, the use of fertilizers and agro-chemicals has grown considerably under usual agricultural practices. Such inputs release chemical compounds that percolate to the groundwater. By 2050, a projected 60% increase in agricultural production, will cause water consumption for irrigation to rise by 11% and withdrawal by 6%, despite accounting for modest gains in water efficiency and crop yields.[4] In the face of these competing demands, increasing allocation of water for irrigation will be challenging.[17] Irrigation will have to play an important role in increasing food production. Water is necessary, of adequate quantity and quality, to produce food and further downstream, during the preparation and consumption of food.

Similarly, the intensification of certain food production practices – for example, a more aggressive use of soil-enriching nutrients or evolving diets (e.g. growing demand for protein-rich diets involving meat) – has significant implications for water security. The risks posed by the water-food nexus are summarized in table 1.

The energy–food nexus: Discussion surrounding the energy–food nexus relates mainly to energy use within the food supply chain. Depending on the extent of mechanization, agricultural production consumes energy directly in the form of fuels for land preparation and tillage, crop and pasture management and transportation or electricity supply and indirectly through the use of energy-intensive inputs such as fertilizers and pesticides, or energy for manufacturing agricultural machinery. The food chain requires significant amounts of energy, with variations in where that energy is consumed.

The food sector currently accounts for some 30% of global energy consumption, met largely with fossil fuels. A large amount of food, with a significant energy footprint, ends up as waste. Approximately a third of all food produced is lost or wasted each year, resulting in a waste of 1 to 1.5% of total global energy use.[1]

In developing countries, 40% of losses occur during post-harvest and processing, whereas in industrialized countries more than 40% of losses happen at the retail and consumer levels.[5] This wastage represents a loss of valuable water, land, energy and labour inputs that have gone into producing the food, while at the same time contributing to greenhouse gas emissions. Agriculture pumping consumes 18 % of electricity in India. Fossil fuels continue to provide the majority of the energy inputs for conventional development of the agri-food sector, ranging from electricity and/or diesel for pumping, food processing and storage, to fuel for agro-machinery.

Population growth and changing diets in emerging economies will place increased burdens on energy and food production systems due to higher demand for fertilizers and agrochemicals, higher levels of livestock production and demand for more sophisticated retail, distribution, processing, cooking and food preparation. Livestock production is projected to increase from 218 million tons in 1997-99 to 378 million tons by 2030. Producing 1 kilogram of meat requires 2-10 kilograms of fodder. Increasing meat production and other dietary changes therefore will have significant impacts on land and energy use. This will take its toll on the energy system, which will have to provide additional supplies to produce feed, process meat, distribute retail and cook the food.[17]

Identifying integrated solutions to manage the water–energy–food nexus: It is clear that each of the three sectors has impacts on the security of supply in the other sectors in a variety of ways. Measures are also being taken to adopt more sustainable and efficient agricultural practices such as shifts towards integrated "agro-ecosystems".[7] Yet despite overall progress, challenges remain. There are many synergies and trade-offs between water and energy use and food production. Using water to irrigate crops might promote food production but it can also reduce river flows and hydropower potential. Growing bioenergy crops under irrigated agriculture can increase overall water withdrawals and jeopardize food security. Converting surface irrigation into high efficiency pressurized irrigation may save water but may also result in higher energy use.

Recognizing these synergies and balancing these trade-offs is central to jointly ensuring water, energy and food security. The consultations that took place around the landmark Bonn 2011 Nexus Conference clearly highlighted the importance of integrated solutions for a green economy – a paradigm wherein economic growth is decoupled from resource depletion. The conference laid out a set of "Nexus Opportunity Areas", highlighted below, intended to "support sustainable growth and achievement of water, energy and food security by cutting across interlinked decision spaces and identifying win-win solutions".[2]

- Increase policy coherence
- Accelerate access
- Create more with less
- End waste and minimize losses
- Value natural infrastructure
- Mobilize consumer influence

Renewable energy technologies now represent a mainstream energy source. Their distributed, environmentally friendly and less-resource intensive nature means that they are compatible with the broader green growth objectives towards sustainable development. The benefits brought by renewable energy range widely and include enhancing energy security, mitigating climate change, increasing energy access and stimulating socio-economic development.

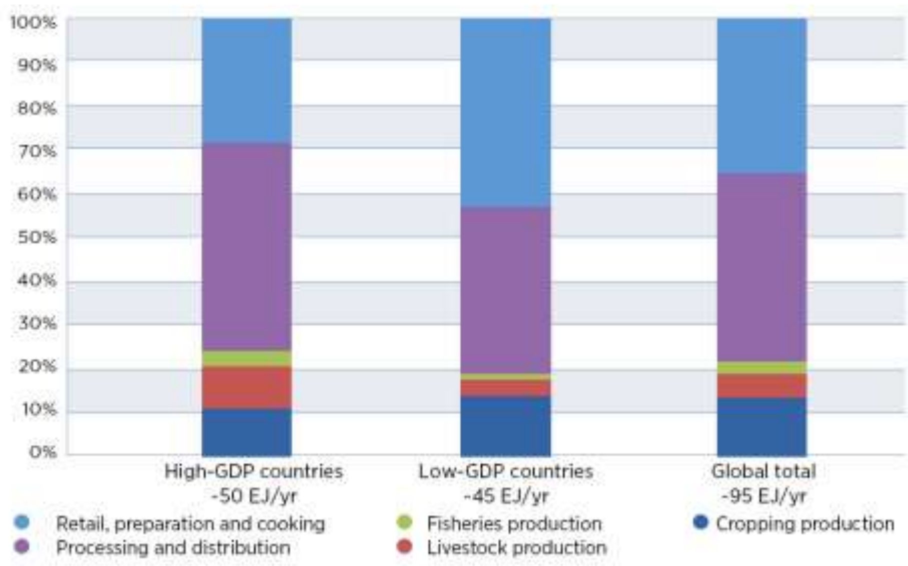
At the country level, fragmented sectoral responsibilities, lack of coordination and inconsistencies between laws and regulatory frameworks may lead to misaligned incentives. If water, energy and food security are to be simultaneously achieved, decision-makers, including those responsible for only a single sector, need to consider broader influences and cross-sectoral impacts. A nexus approach to sectoral management, through enhanced dialogue, collaboration and coordination, is needed to ensure that co-benefits and trade-offs are considered and that appropriate safeguards are put in place. Lastly, factors such as the impact of climate change on water resources and the effects of geo-politics and policies on energy sources and pricing, can hamper development goals that aim to achieve food security in the long run.

Indian Scenario: South Asian countries face mounting challenges in meeting the growing demand for food, water and energy for a rapidly growing population. Countries have provided policy support to increase cereal production including providing incentives by subsidizing water and energy and guaranteeing rice and wheat prices.[18] While such incentives have increased production of cereal which in turn increased the demand for water and energy, led to degradation of the resource base and contributed to an increase in water-related disease.

Table 1
Summary of risks and impacts within the water–food nexus

	Risks	Impacts
Water –related risks to food security	• Increased variability in water availability. Particularly due to climate change • Regional concentration of food production and consumption Impact of water quality on food production and consumption	Changes in supply of food products. Leading to higher price volatility. Further compounded by regional concentration of food production activities. Utilization of poor-quality water along differ stages of the food supply chain can have negative impacts. Including soil degradation and accumulation of Contaminants within the food chain
Food –related risks to water security	Impact of agricultural activities on water resources Poorly regulated agricultural foreign direct investments (e. g. international land leasing Water resource over- utilization due to food security ambitions	Use of external inputs for agriculture and food production can to water pollution affecting downstream activities and aquatic life Increased agricultural land leasing. When poorly regulated. Could lead to expanded use of local water resources. With negative local socio-economic impacts Pursuit of food security ambitions can strain water resources, often leading to substantial depletion in freshwater reserves

Source: IRENA



Source: FAO[5]

Fig. 2: Direct and indirect energy inputs at different stages of the food sector

Despite the inherent interconnections between food, water and energy production, agencies often work in a fragmented and isolated way. Free water and subsidized electricity have not only encouraged overexploitation of resources, they have also led to under-investment in water and energy-saving technologies and approaches and hindered crop diversification and broad-based agricultural growth in line with the comparative advantages. Access to electricity, energy subsidies and affordable pumps allowed farmers to shift their dependence from surface irrigation (via canals) to groundwater (via wells and tube-wells).

In principle, these developments empowered farmers by diversifying their irrigation options and insuring them against the rain shocks. However, the absence of a robust water management policy left the groundwater resources vulnerable to over-exploitation. Today, more than 70% of the groundwater has already been utilized and the available groundwater resources are under great stress.

The resource stability nexus goes more troubling when considering the long-term consequences of climate change especially in developing countries like India. India having two third of its area rain dependent i.e. high monsoon dependency is having diverse seasons, crops and farming system with close link between climate and water resources. Climate change brings shift in rainfall pattern, variation in temperature, extreme weather events and wet and dry spell, cause significant impact on choice and duration of crops, which in turn disturb the water – food- energy nexus's stability.

Because of uncertain and non-uniformly distributed rainfall in spite of rethinking on the choice of crops suitable for the changed climate, farmers started exploiting groundwater more to suffice their crop water requirement and balancing production of crops. Pumping more groundwater increased pressure on energy availability and thus continues the vicious circle.

In Andhra Pradesh/ Telangana, groundwater use is, in turn, explained in part by cropping patterns in the area. Although dry rice varieties and semi-arid agricultural crops are viable in the area, water-intensive paddy cultivations are preferred by farmers due to the higher prices and government support.[15] The genesis of this crisis can be traced back to the Green Revolution of the 1960s when the country's policy and epistemic communities, in order to raise agricultural yields multi-fold and make India food secure, as well as to support rural and low-income farmers, took to massive cultivation of high-yielding crops (mainly cereals), mostly employing flood irrigation (that uses relatively low levels of technology and labour).

Flood irrigation has been criticized heavily for its contribution to water wastage through evaporation, run-off, soil erosion, leaching of fertilizers and so on. Maharashtra is a leading sugarcane producer, one of the most water-intensive crops and its cultivation is primarily rain-fed, unlike in Uttar Pradesh (another major producer) where it is irrigated. The state has been reeling under severe drought for the past few years due to inadequate rainfall. The farmers have been forced to depend to a great extent on groundwater (using tube wells and borewells that pump water to the surface) to sustain yields, even at a time when drinking water is scarce. Karnataka's (not far behind Maharashtra in terms of sugarcane production) story remains the same.

Ironically, the government policy of promoting the cane industry (by reducing duties in comparison to other crops and by providing incentives for exports, free/subsidized water and electricity) so far has led to its cultivation replacing other crops such as ragi and jowar with more and more farmers opting to plant it. Similarly, rice – another water-intensive crop but one of the staple crops of India – is being grown in regions (the Punjab-Haryana belt) that have depleting water tables. This brings to light the inherent irony in the farming practices followed in the country, especially in terms of cropping patterns, wherein water-intensive crops are grown and promoted in regions (to this day) that have historically been drought-prone.

The nexus approach can enhance understanding of the interconnectedness of the sectors and strengthen coordination among them. But it requires a major shift in the decision-making process towards taking a holistic view and developing institutional mechanisms to coordinate the actions of diverse actors and strengthen complementarities and synergies among the three sectors. Similarly, the ability to achieve the goal of water and energy security will largely depend on the ways in which food is produced, processed, transported and consumed.[8] By ignoring the underlying interdependence of the three sectors, policies sometimes have the unintended consequence of shifting a crisis from one sector to another.[20]

Conclusion

Greater policy coherence among the three sectors is critical for decoupling increased food production from water and energy intensity and moving to a sustainable and efficient use of resources. Eventually, water resources are over-exploited and wasted as yields do not increase proportionately to water usage. In the subsequent years, flood irrigation has given way to drip and micro irrigation in many parts of the country but in the drought-hit areas, the former practice has not been completely abandoned.

There is an immediate need to regulate unsustainable practices and promote technological and institutional innovations to all the three strong sector of food, energy water as the goals are interlinked in different ways. Achieving the goal of food security and ending hunger, for example, depends strongly on achieving the goal of water and energy security which is needed to ensure water and energy is available for food production.

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